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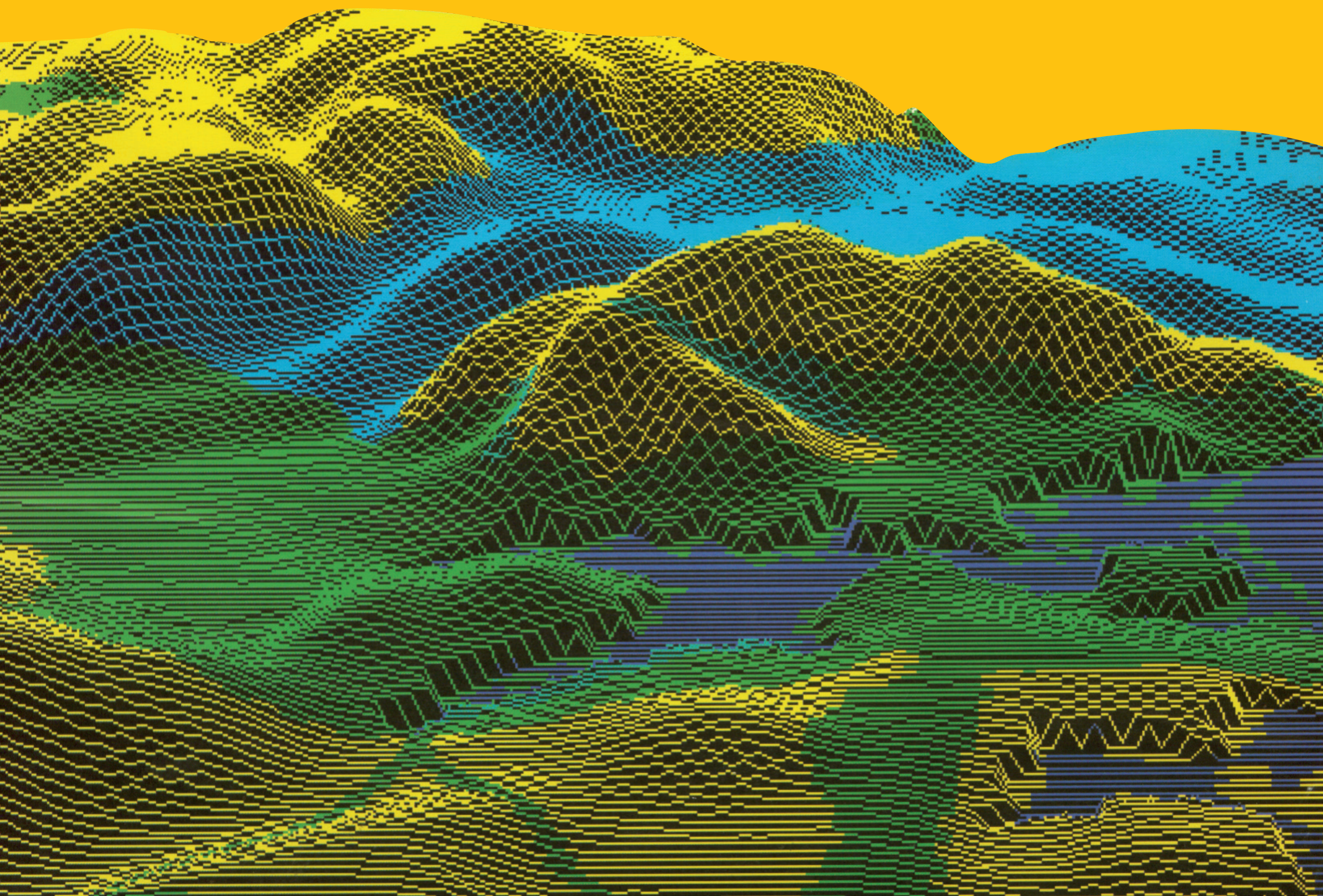

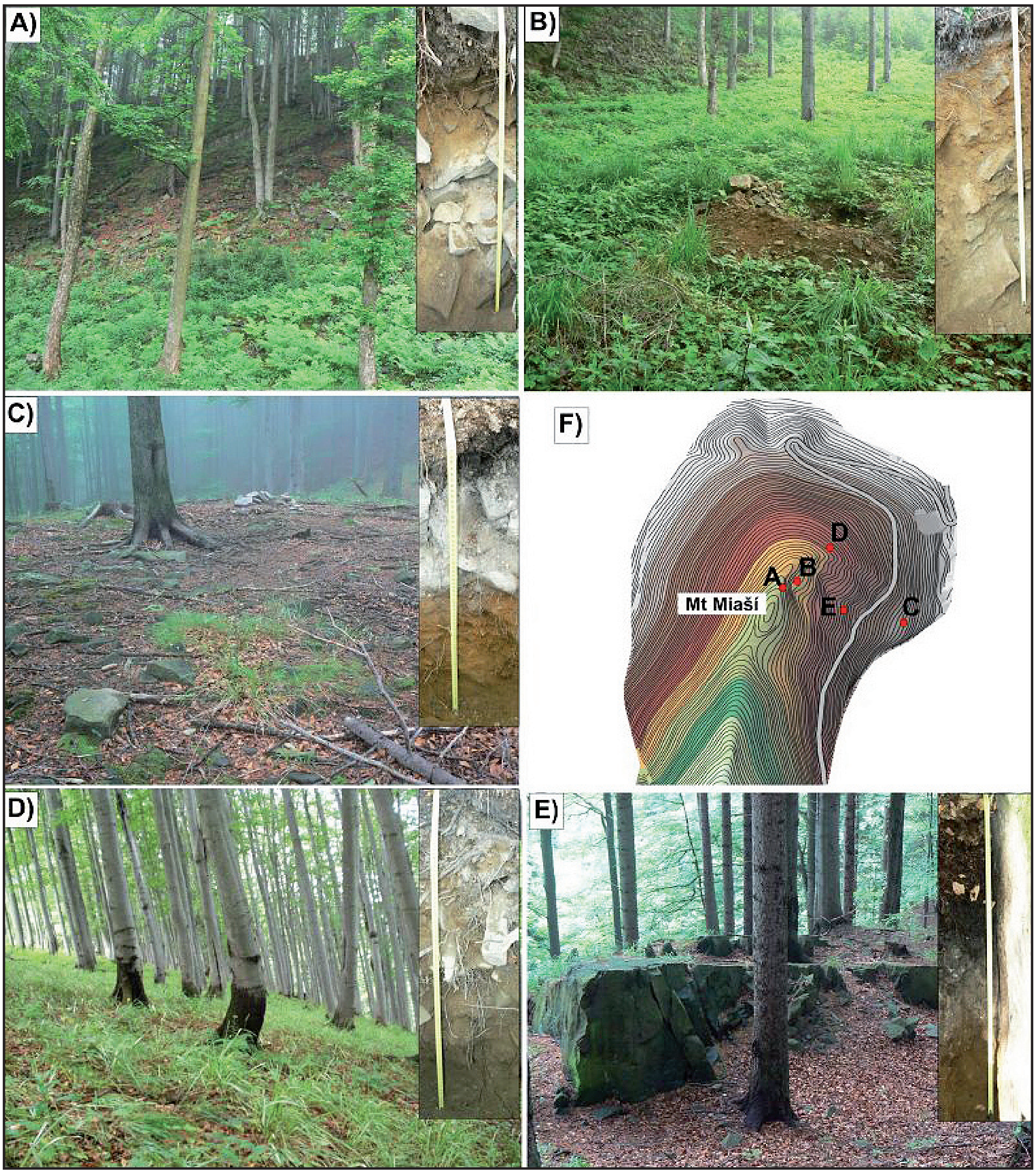

Fig. 2: Soil and vegetation variability of the Miaší Mt slope deformation (used soil taxonomy after Němeček et al., 2001; taxonomy of potential natural vegetation sensu Buček, Lacina, 1999): A) headscarp with Umbric Ranker (signs of podzolization), vegetation of Fagi-acereta inferiora; B) rotated block near the headscarp with developed Cryptopodzol with very high content of debris, vegetation of Abieti-fageta aceris inferiora; C) accumulation zone with developed Podzol, vegetation of Abieti-fageta aceris inferiora; D) non-affected slope by landsliding, Cambisol with Abieti-fageta typica; E) fallen rock block, near the block there is developed Umbric Podzol with a high content of debris, vegetation of Abieti-fageta; F) localization of sampled areas

Illustration related to the paper by Jan HRADECKÝ, Tomáš PÁNEK and Jiří ŠVARC

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SELECTED ASPECTS OF RAW MATERIALS EXTRACTION IN THE CZECH REPUBLIC IN 1990 – 2006, IMPACTS OF ECONOMIC TRANSFORMATION AND ENVIRONMENTAL CONSEQUENCES

Irena SMOLOVÁ

Abstract

Transformation processes in the Czech economy resulted in significant changes in raw materials extraction. In this paper, such changes concern the volume of extracted materials, as well as employment in mining industries. The area and structure of mining spaces are also reflected in such changes. This report describes an assessment of changes in raw materials extraction and development from 1990 to 2006: selected aspects assessed here include changes in the spatial distribution of mining localities, the economic effects of mining for municipalities, the globalisation of extraction activities, some specifics of mining in specially protected areas, and the possible further use of abandoned mining spaces.

Shrnutí

Vybrané aspekty těžby nerostných surovin v České republice v letech 1990–2006, vlivy ekonomické transformace a environmentální důsledky

Proces transformace české ekonomiky s sebou přinesl i výrazné změny v oblasti těžby nerostných surovin. Změna nastala, jak co do objemů těžených nerostných surovin, tak v oblasti zaměstnanosti v těžebním průmyslu. To se odrazilo i ve změně rozlohy i struktury dobývacích prostorů. Příspěvek se zabývá hodnocením změn vývoje těžby nerostných surovin v období let 1990 až 2006 a mezi vybrané hodnocené aspekty patří změny prostorového rozložení lokalit těžby, ekonomický efekt těžby pro obce, proces globalizace v těžebním průmyslu, specifika těžby ve zvláště chráněných územích a možné další využití opuštěných dobývacích prostorů.

Key words: *mining spaces, mineral resources, building minerals, globalisation of quarrying activities, Czech Republic.*

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1. Introduction

The Czech Republic belongs among European countries with a relatively high natural potential comprising both energy resources, ores to the limited extent, and sufficient volumes of most building materials. The Czech Republic is currently one of the Top 10 world producers of diatomite, kaolin, feldspar materials, brown coal (including lignite) and bentonite. World importance possesses namely the extraction of uranium ore as a strategic resource. The share of the Czech Republic in total world production is over 5% for brown coal, more than 3 % for kaolin and feldspar materials, almost 3% for diatomite, nearly 2% for bentonite and nearly 1% for uranium ore.

2. Mining areas in the Czech Republic

As of December 31, 2006, there were 994 claimed mining areas with a total area of 1,438 sq km in the Czech Republic (2% of the country's territory, see Tab. 1). Mining area demarcation is an initial step in the procedure leading to extraction permit, entailing the beginning of anthropogenic relief transformation. In accordance with Act No. 44/1988 Coll. on Protection and Utilization of Mineral Wealth (the Mining Act) as amended by Act of the Czech National Council No. 541/1991 Coll., mineral resources in the Czech Republic are property of the state. They consist of the deposits of selected minerals claimed as "exclusive deposits". Additionally, a "protected deposit territory" is established for exclusive deposits of mineral resources in order to prevent any construction activities unrelated to extraction of the exclusive deposit. Considering the fact that nearly 90% of mineral resources in the Czech Republic are extracted from opencast mines, the extent of anthropogenic influence on the landscape is evident. The extraction itself is controlled by the Czech Bureau of Mines.

The process of economic transformation brought about significant changes in the size and structure of mining spaces in the Czech Republic. Compared with 1992, the total number and size of mining spaces dropped, differently according to the types of raw materials. The number of mining spaces dropped by one sixth and the total area by one third (see Tab. 1). However, the abandoned mining spaces were more numerous and were partly compensated for by approved new mining spaces since the mid-1990s.

In comparison to 1992, the largest drop was experienced by mining spaces for ores. While in 1992 there were 52 of them with a total area of 181.8 km^2, there are currently only 16 with an area of 71.2 km^2. Deposits of polymetalic ores were most responsible for the drop, particularly in connection with the slump programme in ore mining. Drop by approximately one half was experienced by uranium ore deposits.

The number and total area of mining spaces dropped also in the case of hard coal and brown coal, including lignite. While in 1992 the total of 112 mining spaces with an area of almost 1,400 km^2 were determined for coal mining, by the end of 2006, there were only 55 of them with an area of 633 km^2. The largest drop was caused by closing down the mines in hard coal fields (regions of Kladno, Rosice-Oslavany, Žacléř-Svatoňovice) at the beginning of the transformation period, i.e. in 1992–1993.

Raw material	Number of mining areas				Total area of mining areas (sq km)			
	1992	1993	2006	Index 2006/1992 (%)	1992	1993	2006	Index 2006/1992 (%)
Hard coal	50	38	22	44.0	858.7	524.4	336.5	39.2
Brown coal and lignite	62	54	33	53.2	531.3	458.4	297.0	55.9
Crude oil and natural gas	25	27	95	380.0	267.8	253.9	434.2	162.1
Ores	31	18	5	16.1	45.3	29.6	5.6	12.4
Radioactive raw materials	21	16	11	52.4	136.5	99.7	65.6	48.1
Kaolin	13	25	29	223.1	10.1	9.6	11.9	132.2
Building stone	354	351	381	107.6	23.0	60.5	65.7	285.7
Gravel sand, sands	237	165	175	104.8	146.0	109.2	117.3	80.3
Limestones and dolomites	30	63	50	166.7	19.2	28.6	26.2	136.5
Brick clays	176	175	106	60.2	37.0	36.7	24.6	60.7
Other minerals	134	184	87	53.7	86.1	77.1	53.3	55.1
Total	1,148	1,091	994	86.6	2,161	1,678.1	1,437.8	66.5

Tab. 1: Mining areas in the Czech Republic (1992-2006)
Source: Makarius, R. [ed.] (1993, 1995, 2007); Kavina P. [ed.] (2004); Czech Bureau of Mines database

In 1992–2003, hard coal mining spaces in the Ostrava-Karviná coalfield had been gradually closed down. As recently as at the beginning of the 1990s, practically whole area of the Ostrava-City and Karviná districts was taken up by mining spaces made up of contiguous polygons. At the same time, a greater part of hard coal mining spaces was determined already in the 1960s and 1970s. In accord with the slump programme the mines were closed but also the stock written off and the mining spaces abandoned. Figures 1a to 1d document the development in the Ostrava-Karviná coalfield in years 1990, 1995, 2000 and 2006, when the hard coal extraction was moved from the Ostrava part to the Karviná part and determined hard coal mining spaces were abandoned and in the same borders there were set up new natural gas mining spaces.

Currently there are hard coal mining spaces in the Ostrava Region only in the Karviná part and in the Frýdek-Místek district. Out of them, the mining spaces Louky and Stařίč are determined both for hard coal and natural gas extraction.

Brown coal mining spaces had been gradually abandoned in 1992–2001. Most of them were abandoned in connection with governmental territorial limits. In the case of lignite extraction, there is now only one mining space (Hodonín). Besides the significant drop in the number and size of coal (hard and brown) and ores mining spaces, in comparison to 1992 significantly increased the number and area of mining spaces for crude oil and natural gas in newly discovered deposits (the Dolnomoravský úval Graben, Žďánický les Forest, and the southeastern rim of the Bohemian Massif).

The process of transformation of the Czech economy brought about significant changes in the spatial structure of mining spaces. The largest mining spaces in the Czech Republic are currently approved for the extraction of energetic materials and for the subsurface storage of natural gas (70 largest mining spaces according to size), out of which 40 mining spaces are larger than 10 km^2. The largest mining space in the Czech Republic is in Trojanovice (63.5 km^2) in the Frenštát district, which is also one of the most discussed.

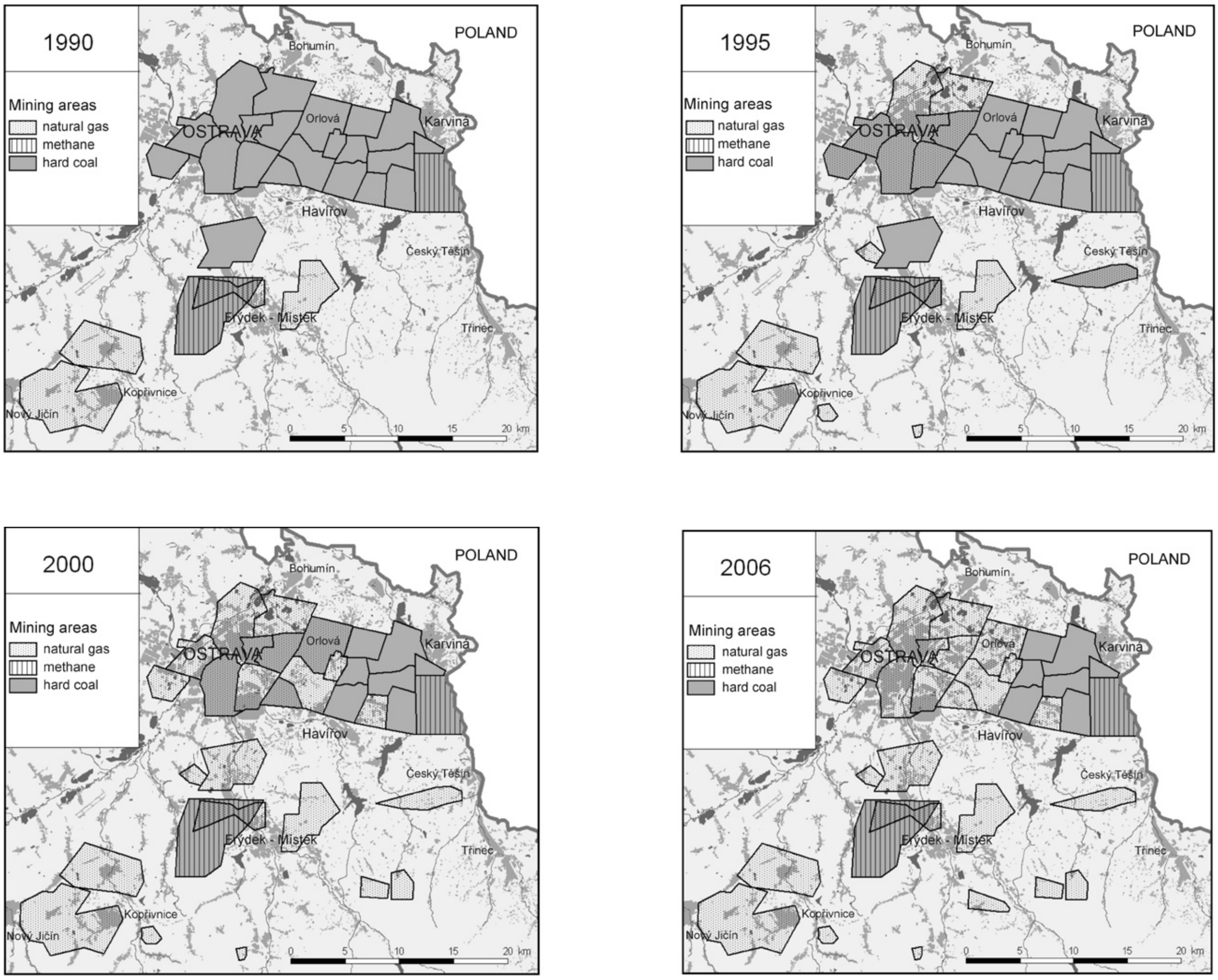

Fig. 1: Development of size and structure of mining spaces in the Ostrava Region in 1990 – 2006
a) situation by December 31, 1990, b) situation by December 31, 1995, c) situation by December 31, 2000, d) situation by December 31, 2006

Mining spaces in the Czech Republic are now largely approved for extraction of building materials, i.e. building stone, brick clays and gravel sands and sands and their number had increased during the last 5 years. New mining spaces are subject to the EIA process (Environmental Impact Assesment). In 1990-2006, a total of 238 mining spaces was approved, out of which one third were mining spaces for crude oil and natural gas extraction, almost one fourth for gravel sand extraction and one fifth for building stone extraction. Regionally, a greater part of newly approved mining spaces are located in the Hodonín, Břeclav and Vyškov districts (see Figs. 2 and 3).

At present, the importance of mineral resources extraction has been shifted from public interest to the interest of private mining companies that intend to economically profit from mineral resources of the territory. This leads to a variety of conflicts of interests between municipalities along with citizen associations and mining companies. Nevertheless, the "mining lobby" plays an important role in the regional development, especially in areas with underdeveloped economies where the presence of mining companies is approached as mostly positive. Mining companies represent an important source of income for the municipal budget and often contribute to off-budgetary incomes despite the landscape risks and environmental impacts resulting from mining activities. Municipalities whose territories are affected by mining receive remunerations for the allotments and compensations from the extracted minerals in accordance with §32a of the Mining Act (No. 44/1988 Coll.). The remunerations are paid to accounts kept by regional branches of the Bureau of Mines and are subsequently distributed to authorised beneficiaries, i.e. to municipalities and to state budget. Annual payment per mining area larger than 2 hectares is CZK 10,000 plus additional fee per each extra sq km. Annual payment for mining areas smaller than 2 hectares is CZK 2,000.

According to the Mining Act, the annual compensation for extracted minerals is calculated as a percentage of total revenues for extracted mineral at an actual market price (the maximum compensation is 10%). Twenty five per cent of the amount paid to the Bureau of Mines is transferred to the state budget of the Czech Republic.

This money is used for the reparation of damages to the environment caused by the extraction of exclusive and non-exclusive deposits. The remaining 75% are transferred to the budget of the municipality (see Fig. 4). Remuneration is paid in accordance with the kind of extracted mineral. The actual rate depends on the kind of mineral resource and is set by Decree No. 617/1992 Coll. of the Ministry of Economics, with e.g. 5% for oil and natural gas, 0.5% for underground mined coal, 1.5% for opencast mined coal, 8% for kaolin, 10% for high-quality limestones, 3% for other types of limestone and other cement mineral resources, etc.

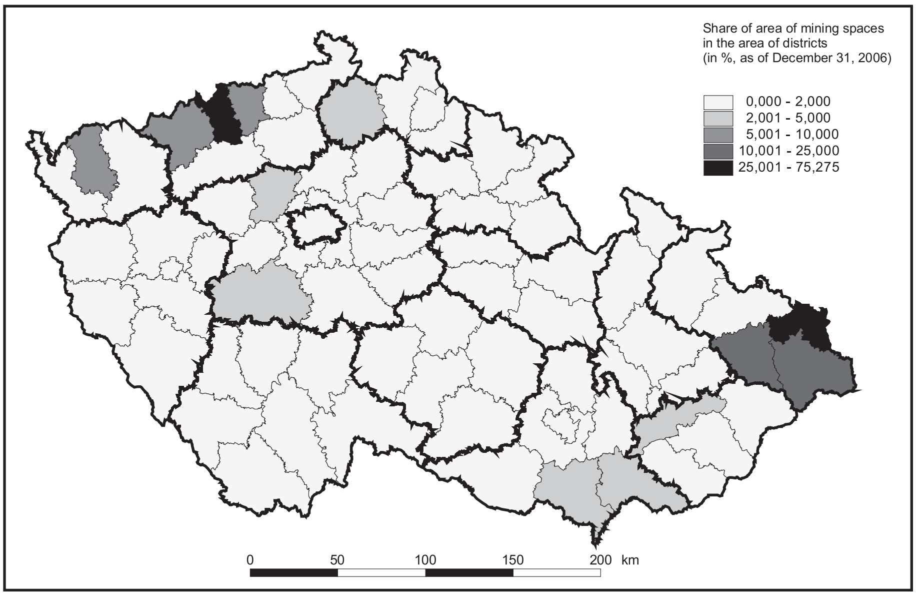

Fig. 2: The share of mining spaces in the area of districts (as of December 31, 2006)

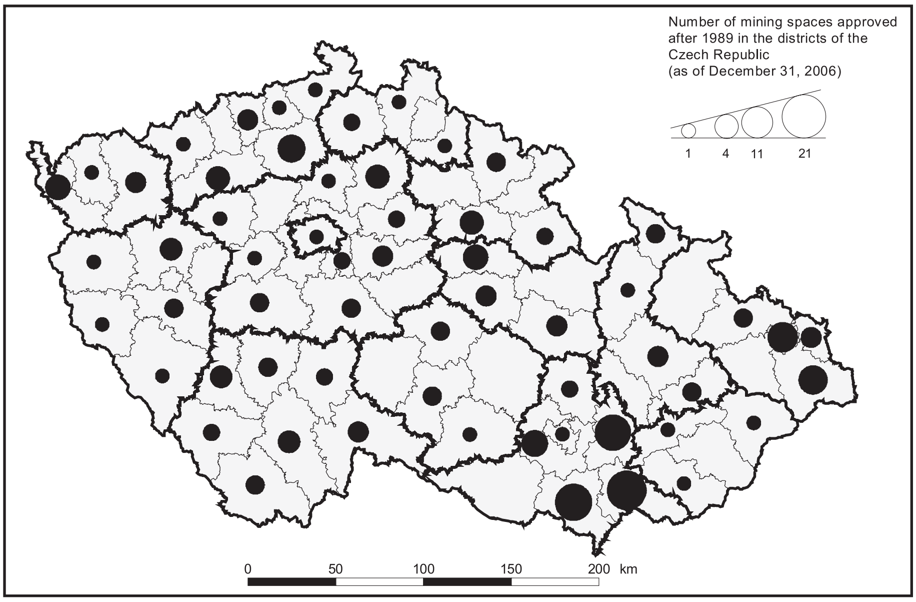

Fig. 3: The number of mining spaces approved after 1989 in districts of the Czech Republic (as of December 31, 2006)

3. Extraction of mineral resources in the Czech Republic in 1990–2006

Development of raw materials extraction in 1990–2006 can be characterised as a period of crucial restructuring and transformation that manifested itself as slump and total decrease in the volume of extracted materials. The development proceeded differently according to groups of raw materials and was significantly influenced by both state policy in the field of raw materials and by the entrance of international mining companies onto the Czech market and by general development of the Czech economy.

The first basic change in structure and volume of extracted materials came about in 1994, i.e. at the very beginning of transformation period, when the extraction of ore, excluding the uranium ore, was finished in the Czech Republic. It topped the process commenced before November 1989. While in 1989, the extraction

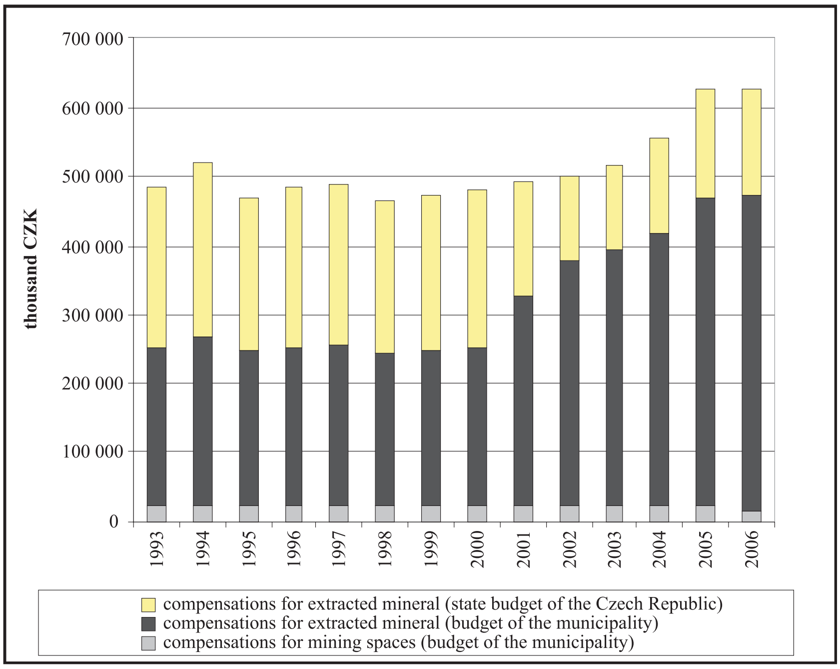

Fig. 4: Development of compensations for mining spaces and extracted mineral in the Czech Republic in 1993–2006

Raw material	Extraction			Index number 2006/1990 (%)	Index number 2006/1993 (%)
	1990	1993	2006		
metalic ores without uranium ore (10^3 t)	1,025	131	0	0	0
uranium ore (10^3 t)	2,400	437	121	6.7	27.7
hard coal (10^3 t)	23,385	18,296	14,292	61.1	78.1
brown coal and lignite (10^3 t)	77,736	63,335	44,849	54.7	70.8
crude oil (10^3 t)	50	111	267	534.0	240.5
natural gas (10^3 m^3)	230	244	222	96.5	91.0
kaolin (10^3 t)	3,378	2,326	4,018	118.9	172.7
building stone (10^3 m^3)	23,396	9,677	15,416	65.2	159.3
gravel sand, sands (10^3 t)	20,359	12,305	17,938	88.1	145.8
limestones (10^3 t)	12,909	10,071	11,507	89.1	114.3
brick clays (10^3 m^3)	3,101	1,354	1,575	50.8	123.8

Tab. 2: Extraction of mineral resources in the Czech Republic (1990, 1993 and 2006)
Source: Makarius, R. [ed.] (1993, 1995, 2005); Czech Bureau of Mines database

Localities		Extraction (10^3 t)			Number of workers*		
		1990	2006	Index 2006/1990	1990	2006	Index 2006/1990
Hard coal							
1	Ostrava-Karviná district	21,042	14,280	62.9%	63,170	20,720	32.8%
2	Rosice-Oslavany district	137	0	0	1,660	0	0
3	Žacléř-Svatoňovice district	575	12	2.1%	822	10	1.2%
4	Kladno district	1,322	0	0	4,862	0	0
5	Plzeň district	309	0	0	1,152	0	0
Hard coal – Total		***23,385***	***14,292***	***61.1%***	***71,666***	***20,730***	***28.9%***
Lignite							
6	Hodonín district	1,814	467	25.7%	2,761	431	15,6%
Brown coal							
7	Litvínov district	8,400	430	5.1%	8,919	398	4.5%
8	Ústí nad Labem district	4,126	0	0	842	0	0
9	Most district	26,633	15,641	58.7%	9,717	4,576	47.1%
10	Bílina district	7,816	8,968	114.7%	6,044	1,931	31.9%
11	Chomutov district	18,911	13,188	69.7%	4,383	1,578	36.0%
12	Sokolovská pánev Basin	11,850	6,153	51.9%	8,711	2,478	28.4%
Brown coal – Total		***77,736***	***44,380***	***57.1%***	***38,616***	***10,961***	***28.4%***

Tab. 3: Coal extraction in the Czech Republic in 1990 - 2006 by mining districts
Source: Makarius, R. [ed.] (1993, 1995, 2005, 2006); Czech Bureau of Mines database; Kavina P. [ed.] (2004)
*Note: * number of workers involved in extraction of coal*

ran in deposits occurring in the Jeseníky (Zlaté Hory) Region, Nízký Jeseník Mts. (Horní Benešov, Horní Město, Medlov), Železné hory Mts. (Staré Ransko), Krušné hory Mts. (Cínovec, Měděnec), Slavkovský les Forest (Horní Slavkov) or near the town of Kutná Hora, after 1989 there has been a gradual slump of ore extraction and finally its definite closing down at the last active polymetalic deposit in the Czech Republic in the Zlatohorský ore field (town of Zlaté Hory in the Jeseník district) in 1994. Currently there is redevelopment and recultivation being carried out at most localities of the former ore extraction.

Termination of extraction was caused mainly by economic reasons, when the extraction brought minimal profit or suffered a loss. In case of uranium ore, the extraction was concentrated into one deep mine in the village of Dolní Rožínka. According to the approved slump programme it should have been finished by the end of 2008 but in spring 2007 it was decided that the extraction would continue as long as it were economically profitable until 2012.

As to extraction of other energetic materials, the volume decreased as well. Hard coal extraction dropped by more than one third in comparison with 1990, from 23.2 million of tons in 1990 to 14.3 million of tons in 2006 (61.6% of 1990 numbers). Similarly, the extraction of brown coal and lignite decreased as well. This trend is common for most European countries, particularly EU countries (e.g. in Belgium and the Netherlands the extraction has already been terminated), where coal industry finds itself in different phases of slump programme. The Czech Republic despite the decrease in extracted volumes maintains its position among the largest European producers.

A different trend is recorded in the extraction of building materials, kaolin and limestone, when after sharp drop of extraction volumes at the beginning of the 1990s the extraction stagnated during 1993–2000 and increased as recently as during the last three years. As shown in Tab. 2 in comparison with the situation in 1990, the extraction (excluding kaolin, clay and bentonite) decreased by half in brick clays, by a third in the building stone and approaximately by one tenth in limestone and gravel sand. On the contrary, it considerably increased in clay and bentonite (double) and kaolin (almost by one fifth). The Czech Republic currently disposes of a solid material basis of non-ore materials and building materials. In case of so called industrial minerals, the Czech Republic belongs among important European and world producers (kaolin, feldspar, bentonite). Its position in feldspar extraction is of world importance since 2000 and presently the Czech Republic extracts more than 3% of the world's feldspar production. The Czech Republic is an important European producer occupying the 5th place after Italy, Turkey, France and Spain. Comparable extraction is in Poland, where the extraction volume increased during the last five years.

In general, the trend in building materials extraction (building stone, brick clay, gravel sand and decoration stone) can be during 1990–2006 characterised as sharply dropping at the beginning of the 1990s, then stagnating and following 2002 as slightly increasing. The whole transformation period is characteristic of the concentration of building materials extraction accompanied by the end of mining and closedown of a number of small mining spaces. The increased extraction of building materials and the economic growth are connected with the growing housing and investment construction and with the increasing share of international companies, which in global environment export larger part of production. Surface extraction however considerably changes the landforms.

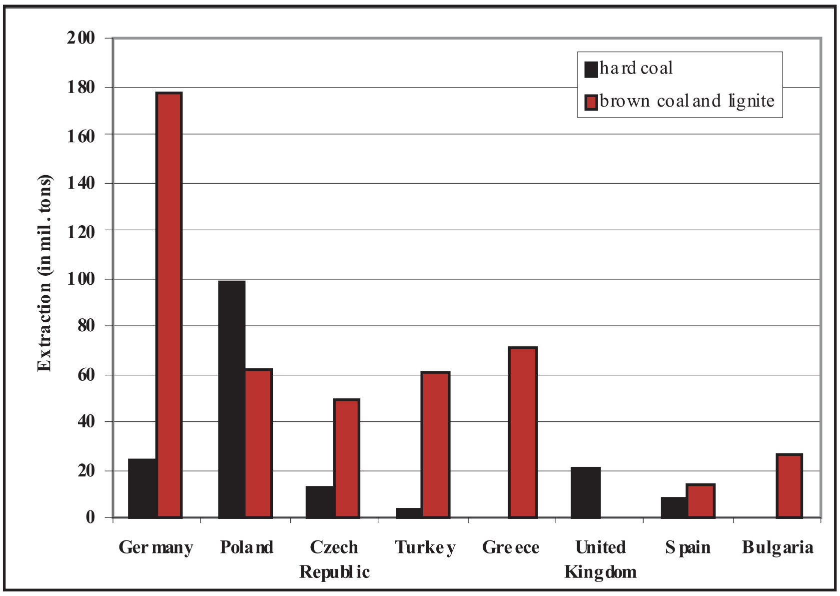

Fig. 5: Position of the Czech Republic among the most important European coal producers (2006)
Source: European Mineral Statistics 2001 – 2005, British Geological Survey, 2007

4. Globalisation of quarrying activities

The transformation process of Czech economy introduced the participation of foreign quarrying companies into exploitation of raw materials in the Czech Republic. Among the most significant ranks the participation of transnational companies in quarrying construction raw materials. This participation links to the issue of growing export volumes of limestone, gravel sands, kaolin, and brick clays.

The largest shares in the quarrying of construction raw materials belong to German, Austrian and Swiss companies (Tab. 4). ***Lasselsberger a.s.***, a subsidiary of an Austrian transnational company Lasselsberger, dominates in kaolin quarrying (almost 80% of amount extracted in the Czech Republic). This Czech subsidiary with headquarters located in the town of Plzeň (Pilsen) quarries also clays in the Plzeň region, besides kaolin. The company has extended its activities into the region of Chodsko (feldspars, kaolin, clays, gravel sands), into the Třeboň region (feldspars, kaolin, clays, gravel sands), and into the Brno region (feldspars and gravel sands). In 2005, Lasselsberger a.s. became the successor of companies Kemat s.r.o. and LB Cemix s.r.o., this way extending its quarrying areas to the Cheb region (clays and gravel sands).

A significant participation of foreign companies also relates to the mining of carbonate rocks (limestone, dolomite). Companies producing more than one tenth of total quarrying amounts are: ***Lafarge Cement a.s.*** (12.2% of all limestone quarried in the Czech Republic) and Českomoravský cement a.s. (11.4%), member of the German concern ***Heidelberg Cement Group***. Other important foreign quarrying companies are ***Holcim (Česko) a.s.*** (9.8% of all limestones quarried in the Czech Republic), Cement Hranice a.s. (8.6%), since 1997 with a major share owned by the German concern ***Dyckerhoff***, and also Lasselsberger a.s., holding a 75% share in the Kotouč Quarry in the town of Štramberk since 2006. The Austrian corporation ***Omya a.s.*** quarries high quality limestone in the Jeseník region: in Vápenná (company headquarters) and Horní Lipová (municipality of Lipová-lázně).

Dominating in brick clay quarrying is the Austrian company ***Wienerberger sklářský průmysl, a.s.***, active in the Czech Republic since 1992. It holds 12 industrial plants, including the newly opened Jezernice brickworks near the town of Lipník nad Bečvou (since the beginning of 2005).

Raw material	Company's share in total amount extracted in the Czech Republic			
	Lasselsberger, a.s.	Holcim (Česko), a.s.	Heidelberg Cement Group	Wienerberger CP, a.s
kaolin	79.7 %	0	0	0
gravel sands and sands	6.0 %	4.3 %	9.1 %	0
limestone	6.3 %	9.8 %	11.4 %	0
brick clays	0.2 %	0	0	43.4 %
clays and bentonites	46.1 %	0	0	0

Tab. 4: The share of foreign companies in overall quarrying amounts of selected raw materials in the Czech Republic (2006)
Note: 0 = no share in quarrying of the material
Source: Czech Bureau of Mines database, Makarius, R. [ed.] (2006), own calculations

5. Environmental consequences of the extraction of selected mineral resources in the Czech Republic

Extraction of mineral resources in the Czech territory dwells on the Mining Act (No. 44/1988 Coll.), which newly established the status of "protected deposit territory", where it is forbidden to establish constructions and equipment not related to the extraction of the deposit. For the sake of the protection of nature and landscape there are further limitations stipulated for the extraction of mineral resources, especially those resulting from Act No. 114/1992 Coll. on the Protection of Nature and Landscape, as amended by Act No. 218/2004 Coll., which states that on the whole territory of National Parks (NP) it is forbidden to extract minerals, rock and humolites, except for the building stone for structures in the territory of NP, and that in the territory of Protected Landscape Areas (PLA) it is forbidden to "transform the preserved natural environment". However, explicit restriction of extraction applies only to the 1st PLA zones only. Moreover, there are further restrictions in the protective zones of water resources, protected areas of the accumulation of underground and surface waters, in the protected area of spas, etc. As of 1992, new intentions to extract raw materials were subject to consideration of their impact on the environment by application of Act No. 244/1992 Coll. In 2002, in accordance with the law of the European Communities, a new legislative tool came into force with Act No. 100/2001 Coll. on the Consideration of Environmental Impact (latest amendment in 2004 by Act No. 93/2004 Coll.). In this law, consideration of environmental impact by the EIA (Environmental Impact Assessment) procedure applies to determined intentions and concepts, the realization of which should have significant impact on the environment. The intentions and concepts are listed in two categories. One category comprises intentions subjected to consideration at all times (e.g. establishment of a new mining area or modification of an existing one, underground mining of coal exceeding 100,000 tons/year, increase of opencast mining exceeding 1 million tons/year, or extraction of mineral resources between 10,000 and 1 million tons/year). The other category comprises intentions requiring declaratory proceedings. This is required for example for underground mining exceeding 100,000 tons/year, extraction of other raw materials exceeding 10,000 tons/year, or increase of existing extraction to 1 million tons/year.

The most extensive conflicts of interests happen in the cases of extraction of limestone and other carbonates. With respect to the exceptional nature of karst areas, most karst localities are protected by law and extraction on their territory must be permitted by exception granted by the Ministry of Environment. In the last few years, the extraction of limestone in strictly protected areas is of opposite trend than in the case of other raw materials. Despite the fact that the total volume of materials extracted in strictly protected areas has decreased in the period from 1990 until present, in case of limestone, the volume of extraction increased in the last few years after a decrease in the early 1990s. Whereas in 1995 the extraction of limestone in the protected landscape areas amounted to 2,327,000 tons, i.e. 21.6% of their total extracted volume in the Czech Republic, the figure increased to 3,381,000 tons by 2003, which is over a third of the total extraction of limestone in the Czech Republic. Therefore, the growth index rate for the period 1995–2003 reached 145%. Moreover, there are several other mining areas localized in the close vicinity of strictly protected areas. Right off the boundary of the Železné hory Mts. PLA, there is extraction in progress the volume of which exceeds 1 million tons/year in the mining area of Prachovice (Holcim (Česko) a.s. Prachovice) as well as in the close vicinity of the Moravian Karst PLA in the mining area of Mokrá (Heidelberg Cement).

Extraction of limestone is a serious stress to protected landscape areas, which can be expressed by the volume of extraction per sq km. Among all PLAs in the Czech Republic, the most extreme stress occurs in the PLA of Bohemian Karst where the load exceeds 26,000 tons of raw material produced per sq km and in the last few years a slightly increasing trend continued, in spite of the fact that stress exceeding 10,000 tons per sq km is considered unbearable (see Figs. 6 and 7). High stress due to extraction of limestone occurs also in the PLA of Moravian Karst (2,000 tons of raw material produced per sq km) or in the PLA of Pálavské vrchy Hills, one of the six UNESCO Biosphere Reserves in the Czech Republic (800 tons of raw material produced per sq km). Despite the effort of primarily ecological associations to reduce extraction in strictly protected areas, it is very difficult to reduce the extraction in most localities. The only outcome is that the construction of new cement works was not realized (e.g. Tmáň in Bohemian Karst). A unique project, for the time being, is the "Extraction of Limestone: Example of Involvement of the Public in the EIA Process", which was supported by the Ministry of Environment and which brought, for example, preclusion of a further expansion of the mine Čertovy schody in the Bohemian Karst. Apart from that, new areas for extraction are being approved, which is always subject of consideration. Since 2001, the following limestone extraction sites have been approved: the Chotěšov mining site near Litoměřice (in 2002) and the Líšeň II mining site in Brno. The mining site of Hvozdečko near Olomouc, with an expected extraction of 40,000 tons/year, is currently being approved.

6. Possibities of using abandoned mining spaces

After termination of mining activity, mining and quarry works offer very wide spectrum of possible further use. Apart from the exhaustion of deposits, the closures occur due to other reasons, too: e.g. variation in prices on the world market, loss of consumers, economic reasons, geological and geotechnical reasons (shock bumps or clumps), security and health reasons (injuries, fatal accidents), state policy, environmental reasons or conflicts of interests (local population, local communities, land owners vs. mining companies). Discussions are led on further use, and successful closure of a mine is often more problematic and economically demanding than its development in the past. Experience from western of northern European countries, the U.S.A., Australia or

Fig. 8: Extraction in the Broumovsko PLA – NNR Broumovské stěny (Locality Božanov) (Photo: I. Smolová, 2007)

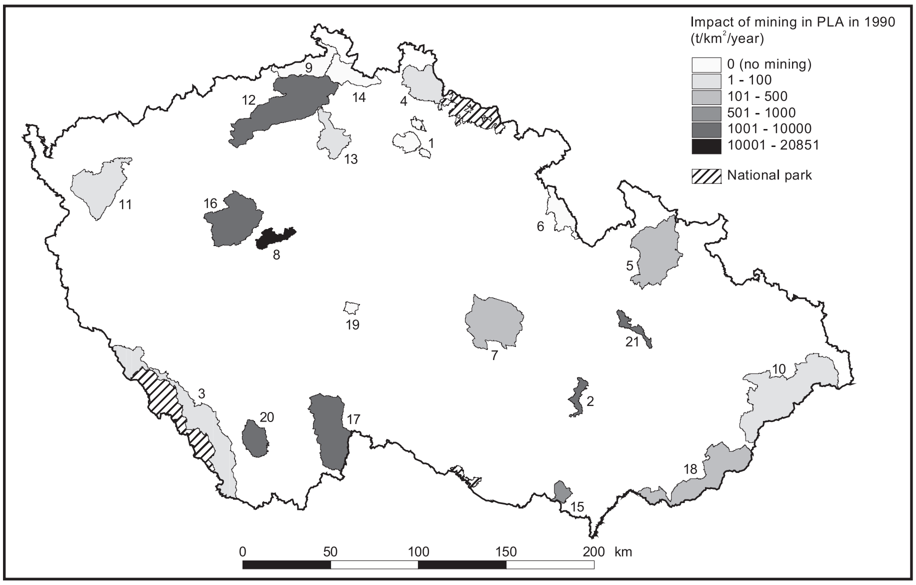

Fig. 6: The load of Protected landscape areas with raw materials extraction in 1990
1 – Český ráj (The Bohemian Paradise) PLA, 2 – Moravský kras (The Moravian Karst) PLA, 3 – The Šumava Mts. PLA, 4 – The Jizerské hory Mts. PLA, 5 – The Jeseníky Mts. PLA, 6 – The Orlické hory Mts. PLA, 7 – The Žďárské vrchy Hills PLA, 8 – Český kras (The Bohemian Karst) PLA, 9 – Labské pískovce (The Elbe Sandstones PLA), 10 – The Beskydy PLA, 11 – The Slavkovský les Forest PLA, 12 – České středohoří (The Bohemian Middle Mountains PLA), 13 – The Kokořínsko PLA, 14 – The Lužické hory Mts. PLA, 15 – The Pálava (Pálava Hills) PLA, 16 – The Křivoklátsko PLA, 17 – The Třeboňsko PLA, 18 – Bílé Karpaty (The White Carpathians PLA), 19 – The Blaník PLA, 20 – The Blanský les Forest PLA, 21 – The Litovelské Pomoraví PLA, 22 – The Broumovsko PLA, 23 – The Poodří PLA, 24 – The Železné hory Mts. PLA, 25 – Český les Forest (The Bohemian Forest) PLA

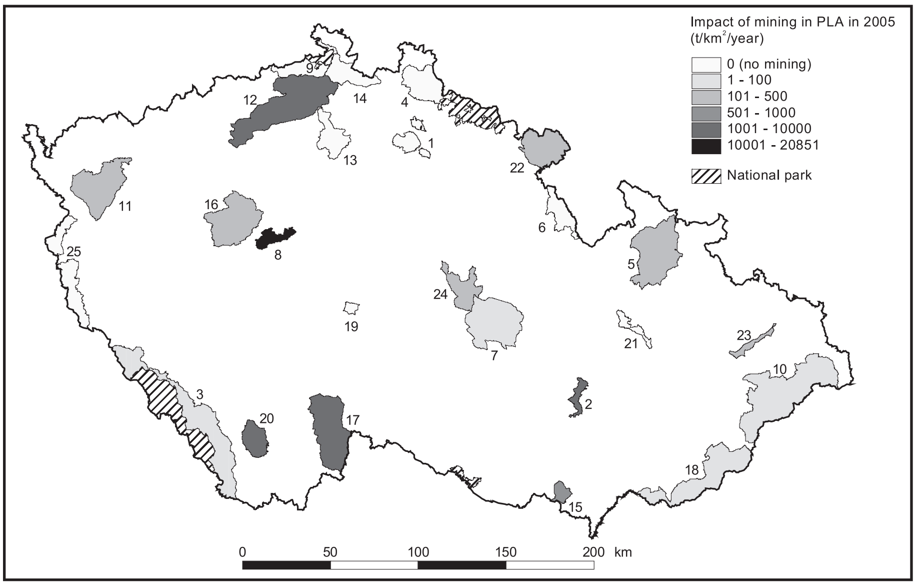

Fig. 7: The load of Protected landscape areas by raw materials extraction in 2005
Explanatory note: see Fig. 6

Canada show possibilities well-proven by the long-term operation of mines and quarries.

In the localities of abandoned mining sites, there can be sport complexes or recreational centres. Geotourism becomes one of new directions in the developing tourism during the last 10 years (e.g. Hose, 2005; Macadam, 2001; Newsome, Dowling, 2005) and valued localities of attraction for tourism are not only geomorphological landforms such as rock towns, karst areas or canyons, but also quarries, which contribute to geological and geomorphological literacy and in case of their suitable use, they can become very attractive localities. One of examples is the ski area in Bottrop in the west of Germany in North Westphalia, where in places of abandoned coal mines there is ski area (Alpincenter) with in Europe longest indoor ski slope (length 640 m and width 30 m). In Portugal in Braga in the locality of large quarry (granite extraction), a football stadium was constructed for the European 2004 Cup (finished in 2003) with a capacity over 30 thousand viewers. In central Sweden (7 km south of Rättvik), a theatre was built in the place of abandoned limestone quarry[1] (Dalhalla). The theatre was open in 1995 and has a capacity of 4 thousand seats. Thanks to exquisite acoustics it gradually became one of the most sought cultural places in Europe.

Relatively frequent is the use of subsurface mines for foodstuffs storage (cheese, beer, wine). The example can be the Fontina cheese storage in Aosta Valley in Italy. Recultivated sites are also used to grow plants (e.g. vine or medicinal herbs). One of interesting projects is the currently realised project Eden[2] in Great Britain. The originally surface kaolin quarry in British Cornwall was changed into a complex simulating the condition of tropic ecosystem and Mediterranean climate (Macadam, 2001). The first part was open to public in 2001, an education centre was open in 2005 and a third ecosystem is planned in future that would be simulating arid climate. The facility quickly became one of very popular tourist attractions of Great Britain (since 2001 it was visited by more than 8 million people). Important is also the question of employment, when in locality, where miners lost their jobs, the complex brought 500 new jobs. A similar great project is currently realised in British Columbia (Britannia Project) in Canada.

Experience shows that indispensable part of such realisations is cooperation of all subjects interested in the region, preferably on the basis of win-win situation. In case of mining companies, the geotourism is advantageous even for the enhancement of public awareness about mining consequences. In the Czech Republic, Mining Unions are examples of successful activity. In this field the Czech Republic has still unused potential, particularly with regard to rich and varied mining history. For the present, the localities are only sparsely used so far (Figs. 9a,b – see cover p. 4). The potential is used neither by municipalities, rare are projects of opening up the mining underground and in recent years some interesting nature trails are being realised. At the local level, there are rarely developed interesting projects initiated by local patriots (e.g. in the Zlaté Hory Mts., the Příbramsko region, the Bohemian Karst or in the Ostrava region).

Incorporating quarries into the landscape by transforming them into landscape parks, botanical gardens or arboreta are all possible ways of utilizing abandoned quarries. One of these projects was already realized in the former limestone quarry in the town of Štramberk (Figs. 10a,b – see cover p. 3), where a botanical garden and an arboretum started to grow in 1996 and its close surroundings. The site is almost 10 ha in size. Except for the quarry itself, the area also includes the adjacent meadows and scree forests, in the surroundings of which the arboretum is emerging. Nowadays, the Botanical Garden and the Arboretum cover almost 10 ha, the 2.76 ha of which are covered by botanical gardens, 4.79 ha by the arboretum and the rest is covered by the adjacent meadows and forest stands. The author of the project of the Štramberk Botanical Garden and Arboretum was Prof. Ivan Otruba, MSc, who except for the technical and biological reclamation designed the architectonic solutions and the placement of vegetation, paths and fencing. A nature trail was also created and is divided into three basic parts: geological, botanical and zoological. The implementation of the project started in 1996. Under the decree of the Ministry of Environment, the area received the status of Botanical Garden and Arboretum in 1998.

Expositions of wetland and xerophilous vegetation in the botanical garden are gradually increasing in size, which mainly include plant species occurring in the Štramberk region and its near neighbourhood. The site also serves as a refuge for plants accumulated during the removal of the wetland in the area of the Kotouč quarry, which is still in operation. Among these, there are also many protected species such as *Hippochaete variegata*, *Typha laxmannii*, *Epipactis palustris*, *Pinguicula vulgaris* and the critically endangered *Myricaria germanica*. The indented terrain of the quarry bottom, in which you can find shaded wetland with lakes and sunny rock faces, enables coexistence of the wetland and xerophilous vegetation in a relatively small area. In the present time, the botanical gardens exhibit more than 1,400 plant species. In the arboretum part, about 20 thousand trees and bushes have been planted. Nevertheless, this part of the botanical garden will be interesting for visitors only after several years when the trees will grow up. Newly formed biotopes on the stony floor of the former quarry have created a refuge for snímal species populations. The wetland has become a place sought mainly by amphibians. Rock outcrops, talus fields and meadows, provide habitats for species such as *Oedipoda coerulescens*, *Cicindela campestris*, *Crocidura suaveolens* and *Dryomys nitedula*. The rocky steppe is incredibly rich in invertebrate species, the number of which reached 1,000 during the first investigations. Another area of interest is represented by the block accumulations of the Štramberk limestone uncovered by mining that are rich in various fossil species of organisms. The most numerous fossils can be found at the entrance of the Pouťová Cave.

Altogether, there were about 600 species of the fossil organisms described. The steep walls of the former limestone quarry are a popular climbing area. You can find more then 40 marked climbing trails of different exigence levels there.

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[1] Pit quarry is 60 m deep, 400 m long and 175 m wide (www.dalhalla.se).

[2] The author of the project is architect Nicholas Grimashaw.

Mining activity can have also other than economic positives in the landscape, when suitable conditions for life of selected plant and animal species may appear there after the end of extraction in place of a mining space after some time when the quarries are left to natural succession. Quarries can paradoxically become valuable localities increasing the landscape diversity and can contribute to ecological stability of an area. Especially the exposure of rock bed and stone steps creates specific stand conditions that give rise to endangered plant and animal species. The examples are some abandoned quarries enhancing the landscape diversity, which have become important biotopes of aesthetic importance and which include exquisite landscape elements.

Conclusion

The Czech Republic is one of European states with a relatively high natural potential comprising both energetic resources, ores to the limited extent, and sufficient volumes of most of building materials. The Czech Republic currently belongs to a group of Top 10 world producers of diatomite, kaolin, feldspar materials, brown coal (including lignite) and bentonite. World importance possesses namely the extraction of uranium ore as a strategic resource. The share of the Czech Republic in total world's production is more than 5% for brown coal, more than 3% for kaolin and feldspar materials, almost 3% for diatomite, almost 2% for bentonite and almost 1% for the uranium ore.

Although in modern history the Czech Republic and its previous state formations within its territory did not rank among leading mining countries, the utilisation of domestic raw deposits was high in the past. Over the course of each individual historical period, priorities in terms of extraction of minerals changed, and this reflected in the varied intensity of extraction with a number of consequences including noticeable changes in the relief. At present, there are 994 mining spaces with a total area of 1,438 sq km in the Czech Republic. The process of economic transformation brought about significant changes in the size and structure of mining spaces in the Czech Republic. As compared with 1992, the total number and area of mining spaces dropped, differently according to the types of raw materials. At present, the importance of the extraction of mineral resources has been shifted from the area of public interest to the interest of private mining companies, which intend to make profit from mineral resources in the territory. In the last few years, structural changes in the Czech economy, especially in industry, influenced both the role and the importance of extracting and processing of minerals and materials of mineral origin. Index of mineral production share in GDP reflects the changes, as it decreased from 3.7% in 1993 to 1.3% in 2005.

Development of raw materials extraction in 1990–2006 can be characterised as a period of crucial restructuring and transformation that manifested itself in slump and total decrease in volume of extracted materials. The development proceeded differently according to groups of raw materials and was significantly influenced by both state policy in the field of raw materials and by entrance of international mining companies onto the Czech market and by general development of the Czech economy.

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UNDERGROUND COAL MINING IN THE KARVINÁ REGION AND ITS IMPACT ON THE HUMAN ENVIRONMENT (CZECH REPUBLIC)

Hana DOLEŽALOVÁ, Karel HOLUB, Zdeněk KALÁB

Abstract

The objective of the project discussed in this article is to suggest that mining activity in the Ostrava-Karviná Coal Basin has a long-term negative impact on the human environment. This assertion is based on the results of long-term seismic monitoring in coal mines, which are, in principle, dealing with the investigation of locally-induced seismicity regimes. A 'seismic regime' is defined as a complex of studies aimed at the determination of various time dependent parameters, e.g. the spatial and temporal distribution of seismic event foci, release of seismic energy (displayed usually by Benioff graphs), and regularities of frequency-energy relationships. A special area of interest represents a detailed study of manifestations of individual seismic mining shocks observed on the surface, and their influence on structures, buildings and inhabitants. All of these effects are most often denoted as seismic load, and their displays are represented as so-called "maps of clash of interests", which enable the definition of values of seismic loading for predetermined localities, and to estimate the risk for selected buildings and structures. Sinking and other deformations of the surface represent another negative impact on landscape caused by long-term mining activity. Geodetic measurements are applied in the process of observations aimed primarily at determination of the surface elevation and / or changes of the surface of the undermined area. Several methods are used in this respect, e.g. geometric levelling, site surveying, GPS, ground and aerial photogrammetry.

Shrnutí

Hlubinné dobývání uhlí na Karvinsku a jeho dopad na životní prostředí (Česká republika)

Hlubinné dobývání v ostravsko-karvinském uhelném revíru má dlouhodobě negativní dopad na životní prostředí celé oblasti. Seismický monitoring na uhelných dolech, který sleduje seismický režim indukovaných otřesů, zahrnuje: sledování časoprostorové rozložení ohnisek otřesů, uvolňování seismické energie, zobrazované Benioffovými grafy, a zákonitosti energeticko-četnostního rozdělení těchto jevů. Kromě toho jsou detailně studovány projevy otřesů na povrchu a jejich vliv na stavby, budovy a na obyvatelstvo. Všechny tyto účinky jsou označovány jako seismické zatížení a jejich zobrazení představují tzv."mapy střetu zájmů", na základě kterých lze ocenit ohrožení vybraných staveb a budov. Sedání a jiné deformace povrchu jsou dalším negativním dopadem na krajinu na poddolovaném území. Na základě geodetických měření je zjišťován průběh reliéfu povrchu a jeho změny v čase.

Key words: *Czech Republic, Ostrava-Karviná Coal Basin, induced seismicity, surface subsidence*

1. Introduction

Long-term negative impact on the environment is one of the effects of underground mining. Factor responsible for damages to surface and surface structures in the area under study can be the impact of mining, both in the form of surface deformation and in the form of seismicity induced by intense mining (e.g. Kwiatek et al., 1998; Kaláb, 2004).

The concerned area is the region of Karviná as a part of the Upper Silesian Coal Basin – (hereafter USCB) (see Fig. 1), North Moravia, in which events induced by intensive mining are documented to have occurred for a long time (Holub, 1995; Kaláb, Knejzlík, 2002). Underground exploitation of hard coal in this region is implicating changes in the configuration of stress-strain conditions in the rock massif. Consequently, the overrun of the limiting state of elastic parameters can evoke brittle fractures and radiation of seismic energy (mining induced seismic event). These events are of a similar character as weak natural earthquakes and they closely relate in space and time to the current mining activities. The origin of seismic events that are induced by mining activity, however, may be seen also after a longer period when the underground works were closed, because the stress-strain state in rock massif must reach entirely stable equilibrium. Responses of the rock massif to mining activities greatly differ in individual localities in dependence on the rock composition and physico-technological parameters.

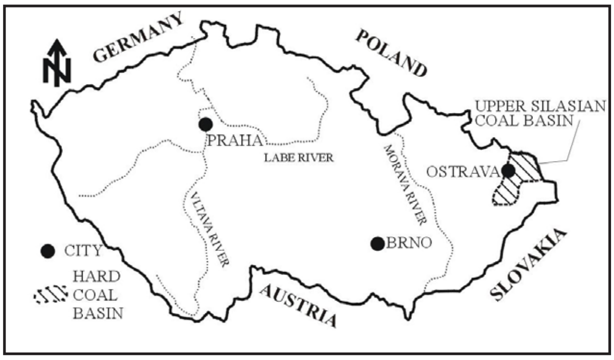

Fig. 1: Geographic location of a part of the Upper Silesian Coal Basin situated in the territory of the Czech Republic (Takla et al., 2005)

The Ostrava-Karviná Coal Basin (Czech part of the USCB) has a complicated geological structure primarily due to its position on a contact of the Variscan Bohemian Massif and the Outer Western Carpathians (for details see e.g. Dopita et al., 1997; Takla et al., 2005).

Although the coal extraction in the Ostrava region began in the 18th century as opencast mining and later was substituted by coal extraction at a greater depth, the first rockburst occurred in 1912. Other rockbursts had been observed after a lag of seismic silence until 1930. A significant increase in the number of induced seismic events was reported before World War II and another growth followed at the beginning of the 1950´s. In the period from 1955 to 1970, the seismic activity was very low and coincided with the termination of mining in the Ostrava basin. On the other hand, some strong induced seismic events occurred within the years 1970-1976 in the mines situated in the Petřvald basin. At the same time, since 1970, strong induced seismic events were observed in the Karviná basin, where intensive coal extraction in the seam No. 33 was in progress. The depth of –300 m was roughly considered a general limit where rockbursts had been not observed. The situation of individual coalmine basins and mines in the eastern part of the Ostrava-Karviná Coal Basin (OKCB) is shown in Fig. 2.

2. Seismological observations

All these seismic events mentioned before were reported on the basis of macroseismic observations underground, e.g. disturbance of the rock massif or devastation of mine workings; some of them were also felt on the surface. The first seismic station situated on the surface was erected in this region at the end of 1977. The number of stations gradually increased and in 1983, five underground stations and five stations on the surface were in operation (Holub, 1983). The most severe seismic event induced by mining occurred in the ČSA Mine in April, 1983. Its seismic effect reached the level of a weak earthquake – having a local magnitude of 3.75 (Trávníček et al., 1987).

This strong rockburst documented that analogue instruments installed at the seismic stations of the local seismic network had been unable to record stronger seismic events with reliable quality. The first step to improve the quality of records was the replacement of analogue instruments with digital ones. Moreover, the construction of a regional seismological network, consisting of 15 stations situated in shallow boreholes was anticipated, too. The regional monitoring network was during its building divided into two parts (10+5 stations). Ten stations were distributed around the eastern part of the coalmine district, while five stations were placed in the southern part of the coal deposit, i.e. in an area adjacent to the Frenštát Mine. The regional network was put into permanent operation at the beginning of 1992 (Trávníček et al., 1995; Knejzlík, Zamazal, 1992). Meanwhile the number of stations constituting the local seismological network had been

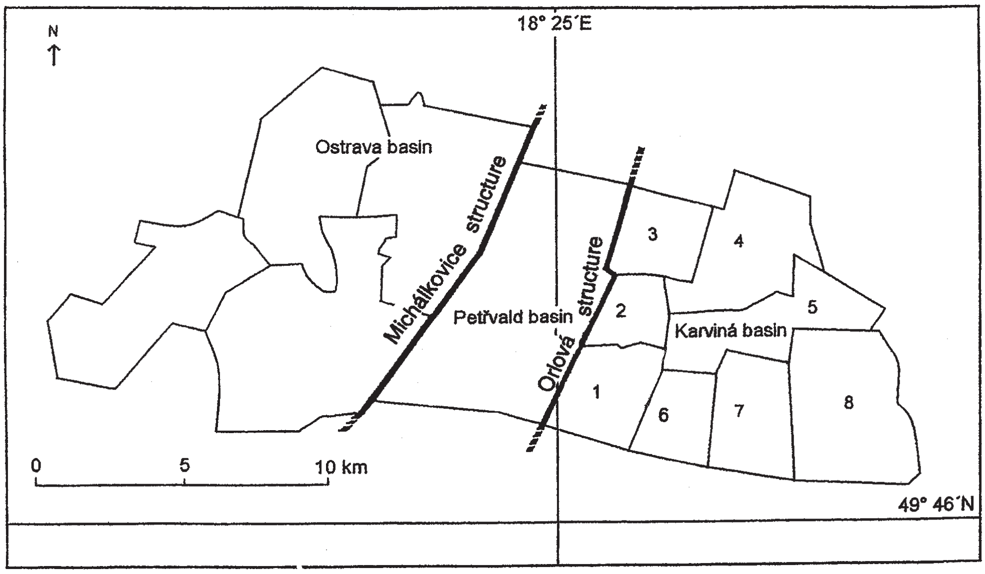

Fig. 2: Map of boundaries of coal basins (——) and demarcation of mines (——) combined to the Ostrava-Karviná Coal Mine District. Mine: 1 - Dukla (closed), 2 - Lazy, 3 - Doubrava, 4 - ČSA, 5 - Darkov, 6 - František (closed), 7 - 9. květen, 8 - ČSM (acc. to Dopita et al., 1997) and location of the OKCB

gradually extended and apparently in 2000, more than 40 seismic stations were in operation there (Kalenda, Holub, 2000). The number of stations was later slowly lowering due to limited coal extraction and termination of coal mining in mines Dukla and František. The construction and operation of the two monitoring systems prepared conditions for continuous observation and objective estimation of the induced seismicity development recorded in the OKCB.

The automation of procedures for detection and recording of seismic events and digital data processing provided by both monitoring networks enabled to determine the locations of foci and to quantify the seismic energy released by individual events within a broad-band energy scale. The data resulting from the final interpretation are stored in a geophysical database, which enabled to establish automatically various data sets considering special point of views, e.g. construction of foci plot, frequency-energy distribution, Benioff diagram, different statistical files. All these data files are chosen and arranged by the energy range of seismic events, time interval and position of the area under investigation.

Many induced seismic events are recorded at the seismic station in Ostrava-Krásné Pole (OKC), which is situated in the outskirts of Ostrava, roughly 25 km westwards from the centre of coalmines. Considering that this station is included into the Czech regional seismological network, its position close to the focal region of induced seismic events ensures reliable data for the foci localization of mining induced seismic events within the regional network. Fig. 3 represents the illustration of an induced seismic events recorded at the seismic station OKC.

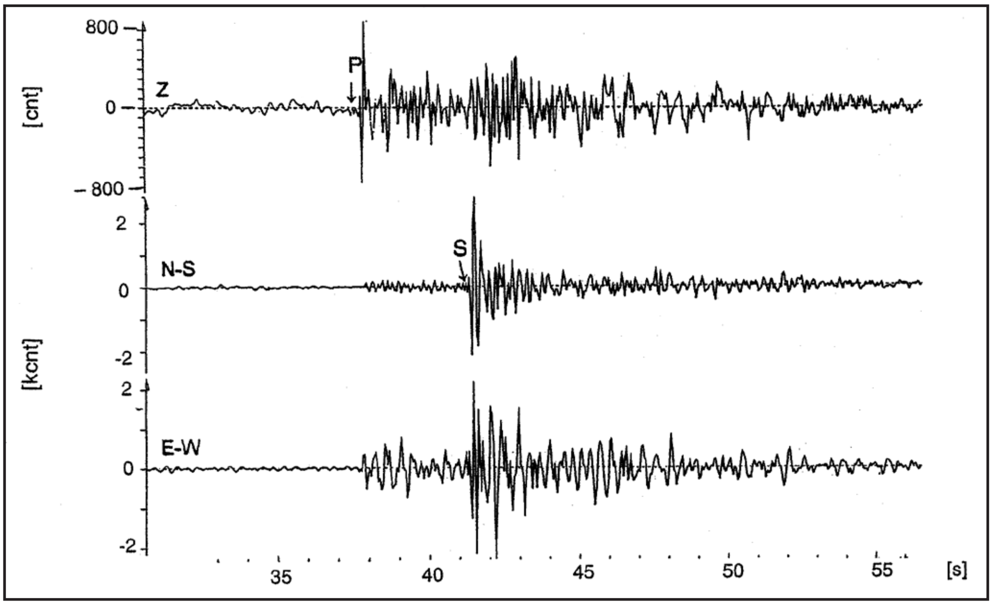

Fig. 3: Three-component seismogram of the event, which occurred in the ČSA Mine on January 2, 2008; epicentral distance r = 24.7 km and released seismic energy estimated as E = 2 x 10^4 J

3. Regime of the induced seismicity

Under the term of seismic regime we understand a complex of all earthquakes observed in the concerned area within a time interval. Since the seismic regime of induced seismic events observed in the OKCB is almost identical with the regime of earthquakes, methodological approaches applied are very similar to those used in the investigation of regularities of the earthquake regime. These approaches are, in principle, based on the statistical methods and their application anticipates that a sufficient amount of homogeneous observatory data is gathered. The necessity of input data quantity follows out from the complexity and spatio-temporal ambiguity of relations among the induced seismic events and geological structure of the deposit, underground-technical and geomechanical situations. However, the extent of preventative measures applied has to be taken into account, too, because these measures exactly complicate deriving of empirical relations in the course of investigation of seismic regime of the induced seismicity in regions with mining activities. On the other hand, this negative impact is compensated by a relatively high number of induced seismic events recorded within the broad span of their energies. Nevertheless, in the process of the seismic regime investigation, two viewpoints are usually used, namely the study of long-term characteristics of seismicity and the temporal development of the seismic regime.

3.1 Spatial and temporal distribution of rockburst foci

One of the main goals for establishment both monitoring networks was to obtain complete information about the evolution of seismic activity in the eastern part of the USCB. As opposed to foci of earthquakes, which are usually concentrated to shear zones, the foci of induced seismic events, including the rockbursts, are concentrated first of all to regions where coal extraction is carried out at present. Specific conditions were frequently created for foci origin during mining activities in the past as a consequence of the equilibrium failure of the original stability of rock mass. Beside the foci concentration either in the zone in front of the face, roof caving in the opposite side of advancing face or in goaf, some events may occur during the roads drivage. A special group of seismic events represents events origin of which is in higher roof above the mined coal seam. These are also classified as mining shocks which are very often felt by inhabitants on the surface. In addition to spatial distribution of foci also their temporal distribution supplied very important information. An example of a long-term location map in the OKCB is shown in Fig. 4.

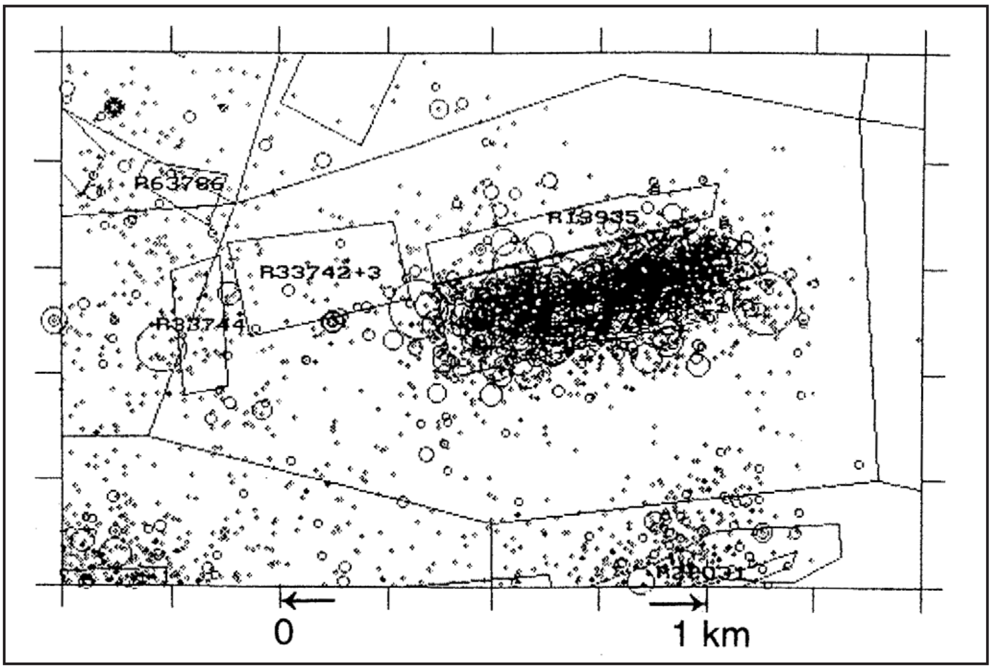

Fig. 4: Planar foci plot of seismic events ($E \geq 102$ J) located in the OKCB during 1992. Mine takes and tectonic blocks are demarcated by thick and thin lines, respectively; in the upper right corner the energy scale is given

3.2 Benioff graph and its gradient

Accumulation and release of strain energy in relation to its temporal changes is another parameter of decisive importance in the assessment of mining-induced seismicity. Benioff used diagrams to display the time progress of the earthquake seismic regime, representing the accumulation of relative deformations in the form of stepwise curves defined as $\sum E^{1/2}$ for a given time unit (Benioff, 1951). In general, such a cumulative graph gives a good overview of temporarily dependent variations of seismic activity, where medium and strong seismic events assert themselves mainly, while less intensive events are rather suppressed. When displaying Benioff graphs for a wider area, small deviations from the basic trend of temporal development are observed. As opposed to that, if a smaller area is taken into account, then more intensive local variations are obvious which depend on the distribution of active workings. These cumulative diagrams are used in the long-term investigation of trends of induced seismicity development in the region of the OKCB and they can be calculated for different areas of interest, e.g., for wider surroundings of a panel mined, for the complete tectonic (mining) block or for the entire coal mine district. Simultaneously, different time intervals can be considered. In Fig. 5 an example of Benioff graph for the eastern part of OKCB constructed for three years interval is shown, and, moreover, the strongest rockburst occurring on June 13, 2002 with an energy of $E = 5x10^8$ J is depicted.

Some practical applications based on the results of long-term seismological observations were implemented in the rockburst preventive scheme, namely in the course of the classification of different workings according to their rockburst risk or during the reclassification of the workings that have already been classified. The essential parameter used for the determination of instantaneous stress-strain status of the given area is the daily gradient of Benioff graph, which is defined as $S = \sum E^{1/2}/t$. This parameter has been regularly adopted for t = 7 and one-day moving time window (see, e.g. Holub et al., 1988; Holub et al., 1991).

3.3 The frequency-energy relationship

Seismic regime induced by underground mining can be investigated using statistical approaches similar to those used for the investigation of natural seismic events. One of these approaches is characterized by the relationship between the number N of events and their energy E which corresponds to negatively exponential

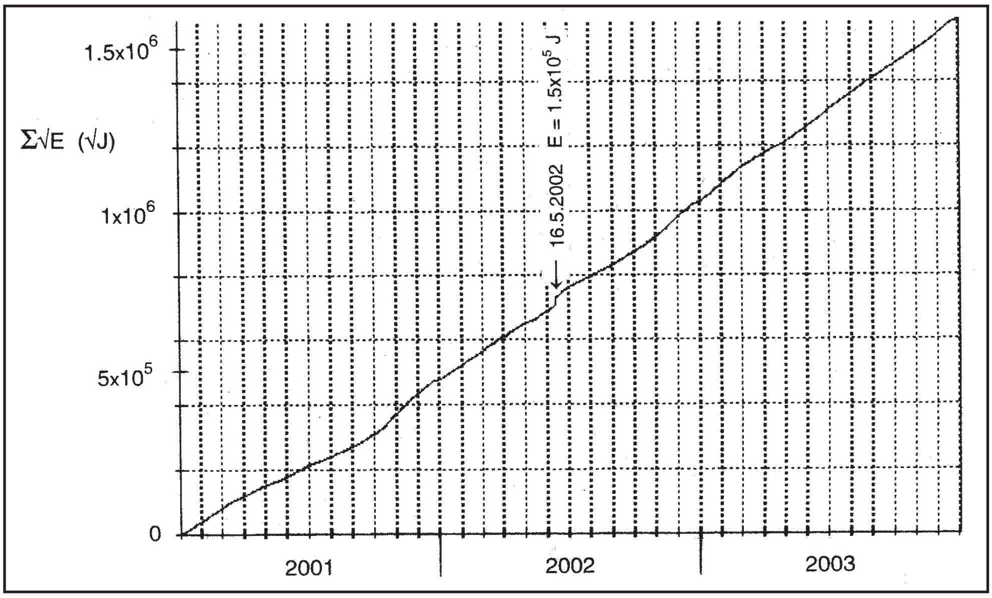

Fig. 5: Benioff graph for the evolution of seismic activity in the USCB for years 2001-2003

law (see Fig. 6) which can be approximated within the limited interval of energies on a bilogarithmic scale by the equation of a straight-line, which is expressed by the following relationship:

$$log\ N = a - b\ log\ E, \qquad (1)$$

where N is the number of seismic events observed , E *(J)* is the energy released, a and b are numerical constants. The parameter b, i.e. the slope of the straight-line in *Eq.* (1), describes, in principle, the ratio between weak and strong seismic events, and in this way it can express very well the level of endangerment by strong seismic events in coal mines. It can be applied as a criterion of stress-strain states in the rock mass. It is generally considered that the higher slope b ($b > 0.7$) observed, the more favourable situation in the mine is expected and vice versa. This assumption was documented during the mining in the coalface panel No. 13933 when the value of $b \approx 0.44 – 0.52$ was calculated and simultaneously a series of strong induced events and rockbursts was observed (Holub, 1996). On the other hand, the parameter a determinates to a certain extent the average of the seismic regime background in the investigated region. With the aim of maintaining an equal span of individual energetic classes, equation $\log E = \log E_C \pm 1/6$, where $\log E_C$ is the mean value in a given energetic interval, was introduced. As for the frequency of events, annually up to 40 thousands seismic events within broad-band energy spans are detected in the Karviná area; an overview of stronger events ($E \geq 10^4$ J) is presented in Tab. 1.

4. Effect of mining-induced seismicity on the surface

Study of mining-induced seismic activity in the Karviná region (Czech Republic) documents that vibration effect of the most intensive events and/or events with the shallow foci can be observed on the surface. These vibrations are frequently reason for discussions and disputes, especially in cases when people live in the surroundings of undermined areas. However, not always the vibrations are responsible for damages to structures

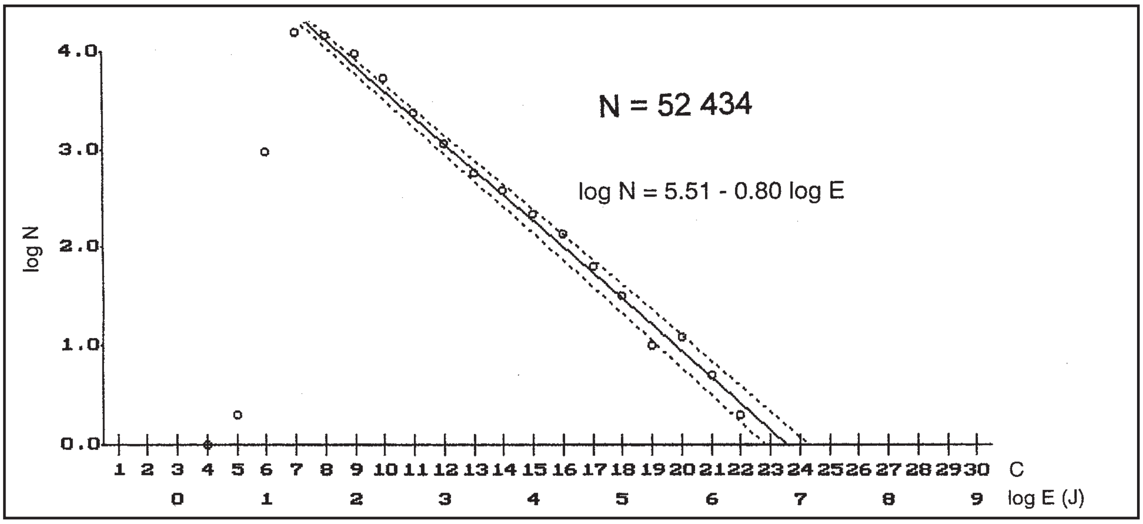

Fig. 6: Frequency-energy distribution of the seismic events recorded in 2003

		Number of seismic events						
year		2000	2001	2002	2003	2004	2005	2006
Energetic class (J)	10^4	186	178	282	294	330	312	278
	10^5	5	18	38	38	31	39	42
	10^6	3	1	4	2	2	5	6
	10^7	0	0	0	0	0	0	0
	10^8	0	0	1	0	0	0	0

Tab. 1: Number of events recorded by mining network stations during the period 2000 – 2006 (acc. to Holečko et al., 2007)

and buildings. Other effects of mining activities are often blamed, e.g. sinking and other deformations on the surface or changes of groundwater level. In addition, effects that are unrelated to mining activities must be considered sometimes, too, such as wrong building foundations, unloading or additional load on the structure after reconstruction or redistribution of heavy masses.

As mentioned above, the mining-induced seismic events can reach intensities with maximum amplitude values that can cause strong macro seismic effects on the surface. Therefore, solitary seismic stations on the surface operated by the Institute of Geonics AS CR are used to detect the macro seismic effect of seismicity on the ground surface; these stations are situated in surface objects, especially in cellars. Investigation shows that seismic velocity component of the most intensive shocks exceeds the value of 10 mm.s^{-1} (value of acceleration component reaches 500 mm.s^{-2}) – see Czech Technical Standard 73 0040. These values are of such a degree of intensity that real possibilities exist of damage to buildings. Vibrations will evoke unpleasant feeling of inhabitants.

At this time, mining induced seismic activity of the region is continuously monitored by seismic stations of the mining network (administered by the OKD, DPB, a.s.). In Tab.1, a number of events are presented in dependence on their seismic energy (energy classes) recorded in 2000-2006.

4.1 Maps of the conflict of opinions

The so-called „maps of the conflict of opinions“ provide basic information about the character of seismic load, its type and intensity in confrontation with types of buildings and objects in selected areas. Cross interference of basic input themes in the maps is used (e.g. GIS technology) to obtain the required information. Maps elaboration methodology was published in Lednická et al. (2006b). Main principle is the confrontation of three basic input themes – area of interest, seismic load and constructional objects and structures. Selected thematic layers with their characteristic parameters will be related to each of these three input themes. Object type in given area (and given time) is confronted with the expected seismic load. The Karviná region was selected for the presentation of the methodology. The thematic layers will be prepared in the form of individual map layers. Subsets, which will be determined by specific behaviours and conditions, will be selected from the basic set of input data because of the cross interference of individual thematic layers. The following thematic layers were selected (details in layers depend on the selected scale):

Thematic layers of the area of interest:
- Geology
- Tectonics
- Depth of groundwater level
- Accumulation of water on surface
- Thickness of sedimentary layers
- Deformation of surface due to underground mining
- Undermined regions
- Landslides and other dynamic events
- Rock medium behaviour (rheology).

Thematic layers of the constructional objects and structures:
- Class of resistance
- Economic and social significance
- Age of buildings and structures
- Cultural monuments
- Technology of construction – monolithic structures, framed structure buildings, towers, etc.
- Used materials – masonry, timber, steel, steel-concrete structures, etc.

Thematic layers of the seismic load:
- Intensity of natural earthquakes (MSK-64 scale)
- Proposed acceleration of foundations
- Sources of induced seismicity – undermined areas (actual or abandoned mines), reservoirs
- Isolines of maximum velocity on surface (mining-induced seismicity)
- Sources of technical seismicity – intensity, range impact.

Elaboration of the individual thematic layers will be gradual, depending on the information available, quantity and complexity of data for the various themes and on accuracy during their transformation into the form of map layers. Generally, it is possible to compile maps of the conflict of opinions on different scales. Due to complexity of the presented methodology, only maps on a regional scale will be prepared.

The issue of assessing the seismic load on buildings and structures in maps of the conflict of opinions is very complicated. It is necessary to collect and to interpret an amount of seismic data from a particular area, where seismic effects are induced by mining activity and in the given time. On the other hand, seismic loads must be uniquely determined in the discussed maps so that all information from the measurements and interpretations are taken into account. The methodology of the determination of seismic load caused by mining-induced seismicity, which is presented in Kaláb (2007) and Lednická (2007), enables to include not only the maximum value measured but also the number of recorded seismic events and the number of recorded intense seismic events in the given time period.

The maps of the conflict of opinions enable us to determine values of seismic loading for specific places and/or to detect the probability of risk for evaluated buildings and structures by the given seismic vibration. Fig. 7 presents an example of such a map, i.e. undermined area in the Karviná region with mining-induced seismicity in year 2005 and historic buildings – size of circles determined values of seismic loading of given building in given place in given year (Lednická et al., 2006a).

5. Geodetic observations in the undermined territory

Subsidence depression that originates on the surface of the undermined territory due to sinking rock layers above the exploited deposit, is developing with advancing exploitation and even after the direct ending of exploitation, the movement on the surface goes on fading. The area of the developing subsidence

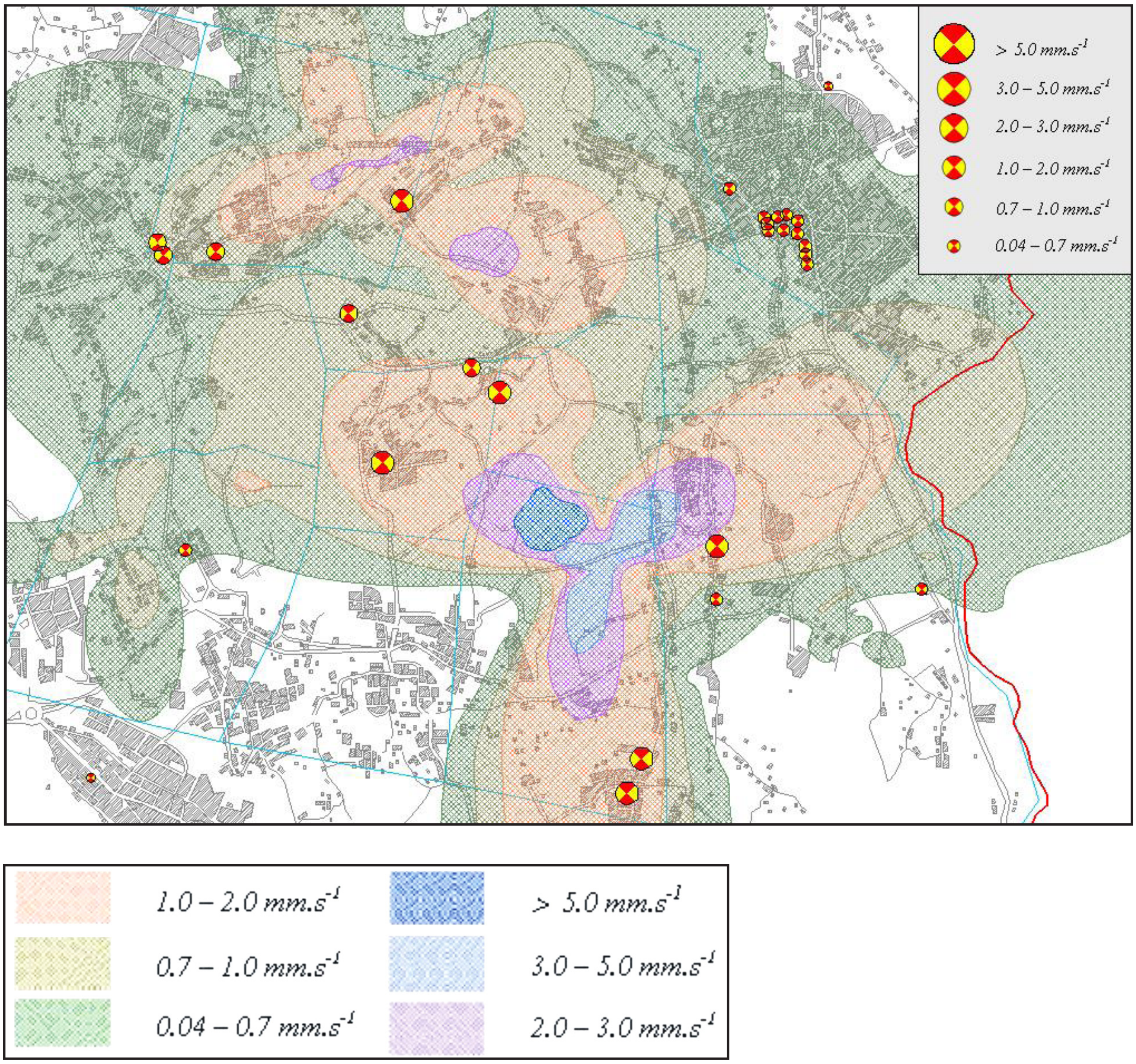

Fig. 7: Example of map of the conflict of opinions for undermined area in the Karviná region with mining-induced seismicity in 2005 and historic buildings (size of circles determined the value of seismic load in mm.s^{-1}*)*

depression exceeds the area of the exploited deposit. The most significant surface changes then happen in the direct overburden, while milder changes occur towards subsidence depression margins.

Single geodetic surveying is used to find out the condition of the surface at a given time. But what changes have actually happened cannot be stated from a single surveying. That is why it is necessary to stabilize fix points on the surface or the objects and to survey them repeatedly in order to establish surface changes in some time period.

It is usually impossible to cover the complete undermined territory with a point field. That is why the points are stabilized in profiles or chains to suitably predicate about changes in the subsidence depression (Doležalová et al., 2007). Profiles are stabilized across the subsidence depression so that the end points are on the territory that is not influenced by exploitation. Such points then enable the connection of geodetic surveying to the coordinates of stable points.

5.1. Applied geodetic methods

Geodetic methods are primarily used to observe height changes on the surface of the undermined territory. The heights are stated on selected points or profiles most often by the levelling method. To observe site changes of surface points, site geodetic methods are used. But more suitable is usually the usage of geodetic methods that enable to gain the spatial coordinates of surface points. Thanks to their repeated surveying, both height and site changes can be obtained at one time. Choosing a method for the observation of surface changes caused by undermining, especially the aim of surveying, required accuracy and field conditions are necessary to be taken into account.

Primary aim of surveying on the undermined territory is usually to observe the height condition of the surface. Vertical movement, i.e. the subsidence of the surface and its objects that is caused by sinking of overburden layers towards the exploited spaces in the underground, is probably the most visual indicator of changes in the undermined territory, as shown in Fig. 8.

An optimum method to establish the height of points is geometric levelling, in particular geometric levelling from the centre that eliminates some of systematic errors and hence increases the accuracy. According to the aim of observation and the position of exploited deposit, technical or precise levelling is chosen. As the subsidence of several tens of centimetres is usually supposed, a technical levelling is then chosen as it is simpler and its accuracy is adequate (accuracy is to about 1 cm per a kilometre of levelling run).

Thanks to its accuracy, the method of geometric levelling is also very suitable for the observation of margins of subsidence depressions, i.e. border between the territory affected by underground mining and the unaffected territory. In such places, movements are very small and so the method of precise levelling is more suitable because its accuracy is within a few millimetres. That is how even the interesting behaviour of rock massif can be detected near the margins of subsidence depressions where even some fluctuation of heights can be surveyed (e.g. Bláha et al., 2006; Doležalová et al., 2006).

There are several methods of site surveying that enable to observe the horizontal shifts of stabilized points. The most common methods include polygonal surveying, polar method and trigonometry. Angles and distances are measured and from them horizontal coordinates of points are derived. From the repeated surveying, horizontal shifts of points can be detected. But the site surveying is usually rather complementary to the height surveying. With the development of surveying equipment instead of single site surveying, spatial methods are used because they enable to establish the spatial position of points, and therefore, they offer data for the calculation

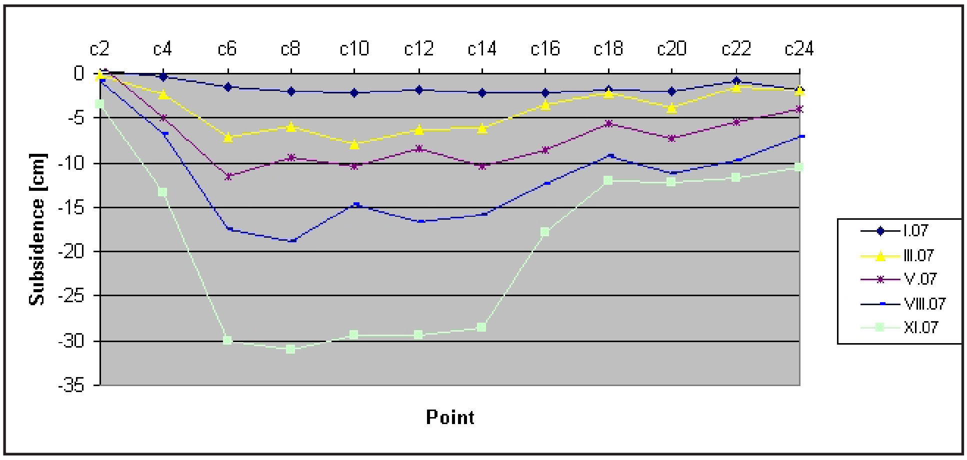

Fig. 8: Subsidence of profile points from heights by the GPS method

of both subsidence and shifts. These are the GPS method and the ground and aerial photogrammetry, but lower accuracy can be their disadvantage. That is why it is recommended to use them in areas where the changes of several tens of centimetres are expected.

The GPS method dwells on the usage of instruments that report their spatial position on the basis of receiving satellite signals. Modern instruments enable to get even immediate position. But more accurate is usually the usage of static surveying method when the GPS receiver placed on the observed point receives satellite data (in about 10 minutes) and the point's position is established not in the field but in the computer thanks to the stored data. The accuracy is then a few centimetres.

A limiting factor for the application of the GPS method can be the observed terrain itself, or more precisely trees and tall objects that may represent obstacles to signal reception or transmission towers whose electromagnetic field affects adversely the satellite signals.

The GPS method is particularly suitable for the connection of points in the undermined territory to the unaffected area, because the reference station that makes the connection can be situated as far as several tens of kilometres.

While terrestrial photogrammetry is more suitable to observe some parts of the subsidence depression or some of its objects, aerial photogrammetry offers an observation of the whole range of the subsidence depression. The principle of photogrammetry consists in scanning of the surface or its objects by photo-camera and in the subsequent processing of image overlays. Using photogrammetry, a wide area can be recorded at one time (in contrast to GPS where individual points are surveyed), but the accuracy decreases with the distance of photo-camera from the observed object and the accuracy is rather tens of centimetres (Schenk, 1999; Doležalová et al., 2003).

Optimal monitoring of undermined territory consists in the repeated GPS surveying on points stabilized in profiles or chains going through the subsidence depression (at least one longitudinal and one transversal profile), in the monitoring of the whole area by aerial photogrammetry (preferably before the beginning and after the ending of exploitation), and in the repeated precise levelling on selected parts to establish the margins of subsidence depression. Based on extensive surface surveying it is then possible to create the maps of subsidence depressions (see Fig. 9).

6. Conclusion

We list the following conclusions:

- Coal mining in OKCB is the source of induced seismic events, which are recorded by seismic stations of the local and regional monitoring networks;
- Based on the seismological observation, foci of the seismic events are localized and the increased incidence of the foci concentration is closely related to areas of mining activities underground;
- Long-term release of seismic energy is displayed in Benioff graph, the slope *b* of which predicates the increase/decrease of seismic activity. Such a course

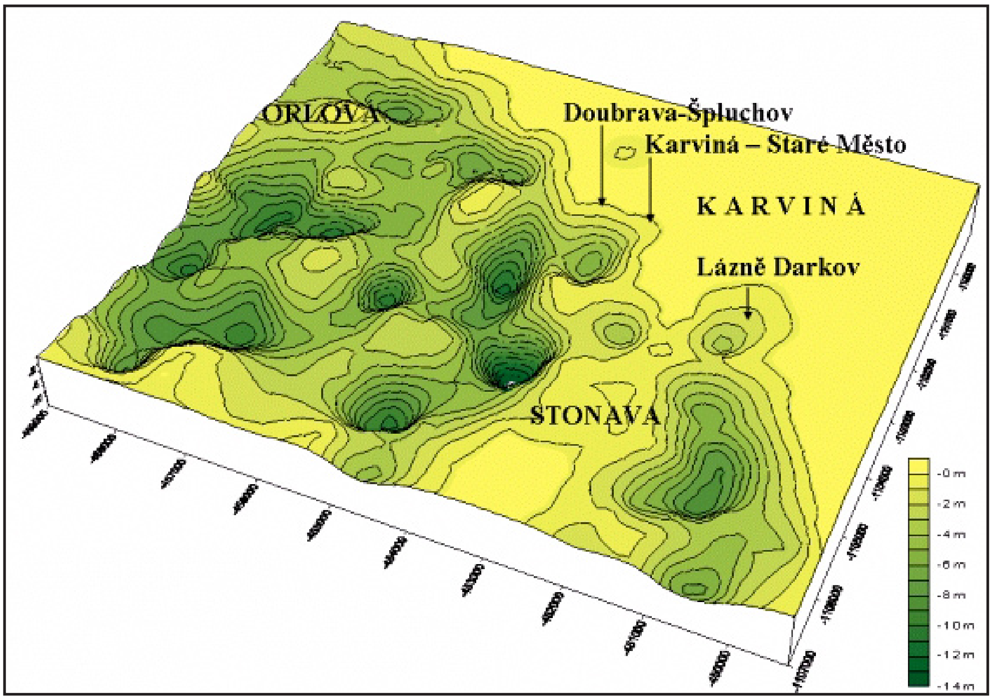

Fig. 9: Subsidence depressions in the Karviná partial basin from 1961 to 1991 (acc. to Grygar et al., 1995 in Grmela, Müllerová, 2007)

of graph with minimum slope usually represents the impact of downscaling or interruption of coal extraction and/or the end of mining activities in the area of investigation;

- Slope of the straight-line approximating the frequency-energy distribution expresses the relation between strong and weak seismic events. According to the experience, the smaller the slope ($b \leq 0.7$), the higher endangerment of workings underground is;
- Studies dealing with the effect of mining-induced seismic events on the ground surface documented that the most intense events and/or effects of the shallow foci of seismic events are observed also macroscopically on the surface. The estimation of intensity of the strongest shocks exceeds the value of about 10 mm.s^{-1}, and therefore, those events influence the stability of nearby structures and buildings
- Basic information concerning the character of seismic load, its type and intensity of seismic events related to the types of structures and buildings in the selected area of interest is represented by „maps of the conflict of opinions“
- Another phenomenon of underground mining is creation of subsidence depressions on the surface of undermined area. It is generally well known, that the most significant sinking of ground surface coincides with areas where coal extraction was closed down, while the subsidence depression towards its margins becomes smaller;
- Different methods of studying topography of the undermined area are usually applied, e.g., geometric levelling, polygonal surveying, GPS, surface and aerial photogrammetry. All these methods have special modifications the application of which depends on the subject of research.

Acknowledgement

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GEOECOLOGICAL IMPRINTS OF SLOPE DEFORMATIONS ON HABITATS – CASE STUDIES FROM THE WESTERN CARPATHIANS (CZECH REPUBLIC)

Jan HRADECKÝ, Tomáš PÁNEK, Jiří ŠVARC

Abstract

Slope deformations represent one of the dominant morphogenetic processes in the Czech part of the Western Carpathians, and they contribute significantly also to the modification of landscape evolution processes. Entirely new, and in many cases unique, habitats evolve on the bases of the differentiation of originally direct undisturbed slopes, caused by land-sliding. For the case studies of Miaší Mt. and Černá hora Mt. slope deformations, the research focussed on the imprint of land-sliding on soil variability. The evolution of specific geo-topes in the case of the extension zone of the Čertův Mlýn Mt. deep-seated slope deformation, was accompanied by the creation of a trench that was subsequently in-filled with organogenic sediments. The relatively low concentration of peat-bog biotopes in the Czech part of the Western Carpathians is often associated with landslides, as in the case of the peat-bog on the southern slopes of Groníček Mt. High dynamics of changes of geo-tope features are linked to the occurrence of flow-like landslides (as evidenced in the case study of debris flows in Smrk Mt. massif and the rock avalanche of Ropice Mt.).

Shrnutí

Geoekologická odezva svahových deformací ve stanovištích poměrech – případové studie z české části Západních Karpat (Česká republika)

Svahové deformace představují jeden z dominantních morfogenetických činitelů české části Západních Karpat a významným způsobem se podílejí na modifikaci krajinotvorných procesů. Sesuvnou diferenciací původně přímých nenarušených svahů dochází ke vzniku naprosto nových a v mnoha případech unikátních stanovišť. V prostoru blokových svahových deformací Miaší a Černá hora se studie zaměřuje na projevy sesouvání v půdní variabilitě. Vývoj specifických stanovišť v rámci extenzní zóny hluboce založené svahové deformace Čertův Mlýn byl doprovázen vznikem příkopu, který byl posléze vyplněn organogenními sedimenty. Relativně nízká koncentrace rašeliništních biotopů v české části Západních Karpat je často vázána na sesuvy, tak je tomu i v případě rašeliniště na jižních svazích Groníčku. Vysoká dynamika změn vlastností geotopů je vázána na místa s výskytem velmi rychlých typů deformací (příkladová studie blokovo-bahenních proudů v masivu Smrku a skalní laviny v prostoru Ropice).

Keywords: *slope deformations; geomorphic disturbance; geo-tope and landscape evolution; geo-ecology; Palaeoenvironmental change; Flysch Western Carpathians; Czech Republic*

1. Introduction

Nowadays, the interdisciplinary study of landscape evolution is one of common approaches both in geoscience and ecology-oriented researches (e.g. Zimmermann, Thom, 1982; Minár et al., 2001; Faľtan, 2005). Increasing interest in these types of research can be traced also in the increasing number of studies focused in this way, namely in geomorphology. Evidence of this was brought by a special issue of the Journal of Geomorphology (Vol. 89, No. 1-2, 2007) dedicated to landform/ecosystem relationship including the relation between slope failures and the landscape ecosystem (Geertsema, Pojar, 2007). This type of research dwells on the knowledge of mechanisms and triggering factors of various types of slope deformations (e.g. Dikau et al., 1996; Hungr et al., 2001).

Society generally perceives landslides as negative processes. Under favourable conditions, these typical natural hazards can represent a serious risk to human houses and land properties (Hradecký, Pánek, 2008) but also to human lives. At the same time, they represent interesting natural phenomena, namely from the geomorphological and geological point of view because -as many modern scientific studies put it- slope failures in many parts of the world have a crucial share in erosion-denudation processes (e.g. Korup, 2006) and thereby constitute one of significant morphogenetic factors, which subsequently reflects in the behaviour of landscape units – geotopes.

Areas affected by the slope movement activity of diverse mechanisms, velocity and genesis undergo transformation of the habitat conditions (e.g. Kirchner, Lacina, 2004). Every landslide activity can be considered a disturbance or stressor that changes the initial level of the given geotope via newly introduced topographic conditions. The origin of landforms that differ from the initial condition in terms of quality and quantity turns the state of the given geoecosystem into a new situation. It is evident that landform plays an important role as a differentiation element of geoecosystems (Minár et al., 2001; Minár, Evans, 2008).

Character of landforms affects the movement of water and substances while exposure and inclination influence the habitat microclimate. Thus, the georelief creates conditions for pedogenesis and affects vegetation particularly through hydrological, climatic and soil conditions of the habitat. According to Geertsema, Pojar (2007), biophysical diversity of terrestrial areas affected by slope failures is of a various scale. The authors discuss site diversity, soil diversity, and their derivative - habitat diversity. Our study concentrates on most of these.

In connection with the knowledge above, we will try to outline some of key landslide effects that are important for the occurrence and evolution of habitats in the territory of the Czech part of the Western Carpathians. As there are slope deformations of various types in the study area, the aim of this paper is to demonstrate specific reflections of their existence in the Carpathian landscape.

In a few case studies (hereinafter referred to as CS), we present the impact of slope deformations as a disturbance agent on landscape components and point out essential displays of geodiversity and biodiversity of selected localities. The choice of localities reflects not only various genetic types of slope deformations but also various displays of the consequent territorial diversity. The study does not deal with the predisposition factors and with the triggering mechanism of individual slope deformations in detail but rather aims at pointing out their geoecological context in the flysch landscape of the Czech part of the Carpathians.

2. Localization of the case studies

The areas of interest within the Outer Western Carpathians represent a typical, dynamically developing georelief. From the geological point of view, main features are nappe structure and flysch lithology of the Silesian Unit, which is a part of the external Silesian-Krosno principal unit of the Outer Western Carpathians (Menčík, 1983). It is the alternation of rock complexes with different physical parameters, tectonic structures and principally climatic triggers to the various types of landslides that rank the area under study with the areas of the highest concentration of landscape disturbances of this type in the Czech Republic (Fig. 1A).

The concerned localities include a territory with typical block slides of a deeper foundation in the eastern and central part of the Rožnovská hornatina Highland (CS

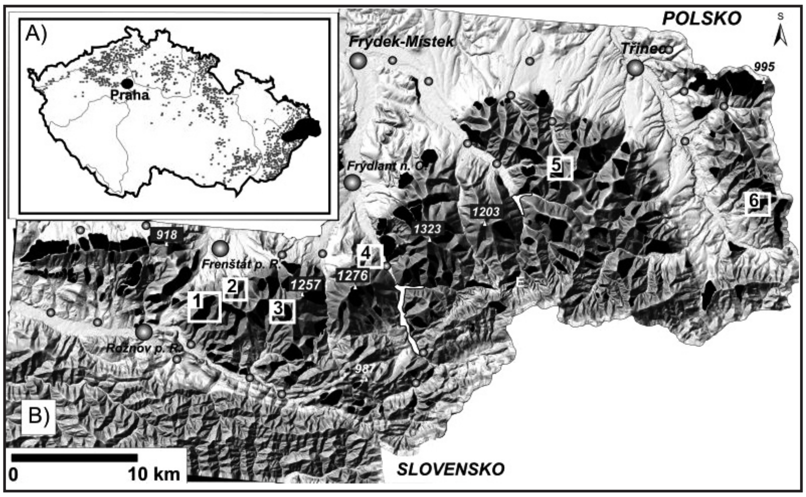

Fig. 1: Localization of the case studies within the Czech Republic (A) and the northern part of Czech part of the Western Carpathians (B): 1 – slope deformation of Černá hora Mt., 2 – slope deformation of Miaší Mt., 3 – slope deformation of Čertův Mlýn Mt., 4 – debris flows of the basin of the Bučací potok Brook, 5 – slope deformation of Ropice Mt., 6 – slope deformation of Groníček Mt.

1 – slope deformations of the Miaší Mt. and the Černá hora Mt., and CS 2 – deep-seated slope deformation of the Čertův Mlýn Mt.); translational landslide in the Silesian Beskids Mts. (CS 3 – slope deformation of the Groníček Mt.); debris flows in the central part of the Moravian-Silesian Beskids Mts. (CS 4 – the Bučací potok Brook) and a rock avalanche in the Ropická rozsocha Mts. (CS 5 – the Ropice Mt.). Location of the studied slope deformations is given in Fig. 1B.

3. Methods

The aim of this multidisciplinary research was to analyze and translate geomorphological displays of slope movements in relation to habitat conditions. Primary data collection was based on the geomorphological mapping. The results were translated and used to analyze other habitat characteristics. A few deformations were selected in order to record the spatial variability of soil patterns by using test pits, namely in relation to specific morphology. The analysis comprised the soil type (subtypes and varieties), character of humus-accumulated horizon, soil profile depth and a field analysis of particle size.

Time variability of habitats was analysed by radiocarbon dating (performed in the Radiocarbon Laboratory, Kiev) and by pollen analysis (provided by Dr. Zernitskaya from the Belorussian Academy of Sciences, Minsk). The samples were extracted from boreholes; as for the pollen analysis, they were extracted at intervals of 5 cm while in the case of radiocarbon dating, they originated from any layer of significant sedimentation change and from the base of the accumulation depression. Another method comprised geobiocoenological mapping of selected localities of slope deformations. The mapping took place both at the place of the specific landforms and on the nearest adjacent slope unaffected by landsliding but otherwise found in identical conditions (location, lithology, etc.). The geobiocoenological clasification was carried out in agreement with standard methods (Zlatník, 1976; Buček, Lacina, 1999; Kirchner, Lacina, 2004).

4. Results

Geoecological impact of various types of mass movements is documented by selected case studies. We present examples of soil, vegetation and palaeoenvironmental variability within the affected slopes in relation to mass movement disturbance.

4.1 Soil variability – case study of landslides at the Miaší Mt. and Černá hora Mt.

The Miaší Mt. slope deformation is situated on the eastern slope of the northern part of the Radhošťský hřbet Ridge. This rotational-planary block deformation is found at the contact of the Godula massif layers and manifold Godula and Lhota layers. The slope deformation was also predisposed by tectonic fractures of the NNW-SSE direction. The affected area is ca. 600 m long, 420 m wide and a total height difference is 250 m. Topography of the studied area is given by the typical block character of the deformation with a few partial headscarps and rotated blocks (Fig. 2 – see cover p. 2). The main headscarp, formed by conspicuous rock outcrops, is at an elevation of 880 m a. s. l. A major part of the headscarp is covered by debris detached from the rock outcrops. The headscarp verges on the horizontal surface of a rotated block void of debris. The horizontal surface is divided into two parts the elevations of which differ by 1.5 m. Within the deformation, there is a number of specific landforms connected with extension such as trenches of various depth or extended depressions. On the contrary, the compression zones contain convex forms.

Deformation of the southern slope of the Černá hora Mt. is characterised by more diversified morphology (Fig. 3). It is a more complex, presumably multigenerational slope deformation. Deep-seated deformations subsequently accelerated rather shallow slides and small debris flows. Specific features of the deformation include the absence of rock outcrops as well as thick debris layers in headscarps. Deep slope disintegration is indicated by the presence of pseudokarst landforms (e.g. Volařka Cave).

The above mentioned morphology of slope deformations played a significant role in the transformation of soil conditions. A thorough soil survey in relation to individual landforms showed that within the range of elevations and lithologies direct and undeformed slopes contain a dominant type of Cambisol, namely in two subtypes – Ranker Cambisol and Modal Cambisol. In the area of deformed slopes, it is Cryptopodzol that is dominant (Fig. 2 and 3). This trend is further modified in the area of specific landforms and shows itself by the presence of specific subtypes. Changes within the deformation are not striking only as to the soil type but also in terms of the thickness of subhorizons and total thickness of the soil profile.

4.2 Paleogeoecological history of a double-ridge trench - case study of Čertův Mlýn slope deformation

Slope failures have a significant palaeogeoecological potential given by the genesis of sedimentary infills of some depression forms (Fig. 4A). The varied morphology of slope deformations and the course of the landslide origin enable the preservation of sedimentary complexes that document the environment quality during the Holocene landscape development. However, there are not always optimal conditions for the genesis of the sediments. Basic condition is the presence of less permeable bedrock layers that cause surface water accumulation. The reason can be the existence of a rock layer with a higher content of clay particles or the development of a soil horizon enriched with clay particles. This phenomenon is sporadically observed in the case of deep-seated slope deformations in the area of Godula massif sandstones. More often impermeable depressions originate in thin-bedded flysch with a high incidence of less permeable rocks (see e.g. works by Margielewski, 2006 on the area of Polish Carpathians or by Baroň et al., 2004, dealing with the Vsetínské vrchy Hills).

The Čertův Mlýn area is affected by deep-seated gravitational disintegration of the whole range (Fig. 4B). Massive blocks of Godula sandstones progressively subside into plastic underlying formations of clayey flysch (Pánek et al., 2007). One of typical processes in progress in this type of deformations is lateral spreading accompanied by the development of double ridges that represent a potential space for sediment accumulation (Fig. 4A). Lateral disintegration of one of the ridges in the lower part of the affected area gave rise to approx. 50 m long and 10 to 20 m wide extended depression infilled with 3.6 m of sediments (Fig. 4A). Radiocarbon dating determined its minimum age to the Late Subboreal (3,410±120 14C BP) (more in Pánek et al., 2007).

Detailed information on the territory conditions was obtained by sediment sampling in the whole profile and by pollen diagram construction (Fig. 5). Any similar depression in temperate climate undergoes development that begins with its genesis as a consequence of

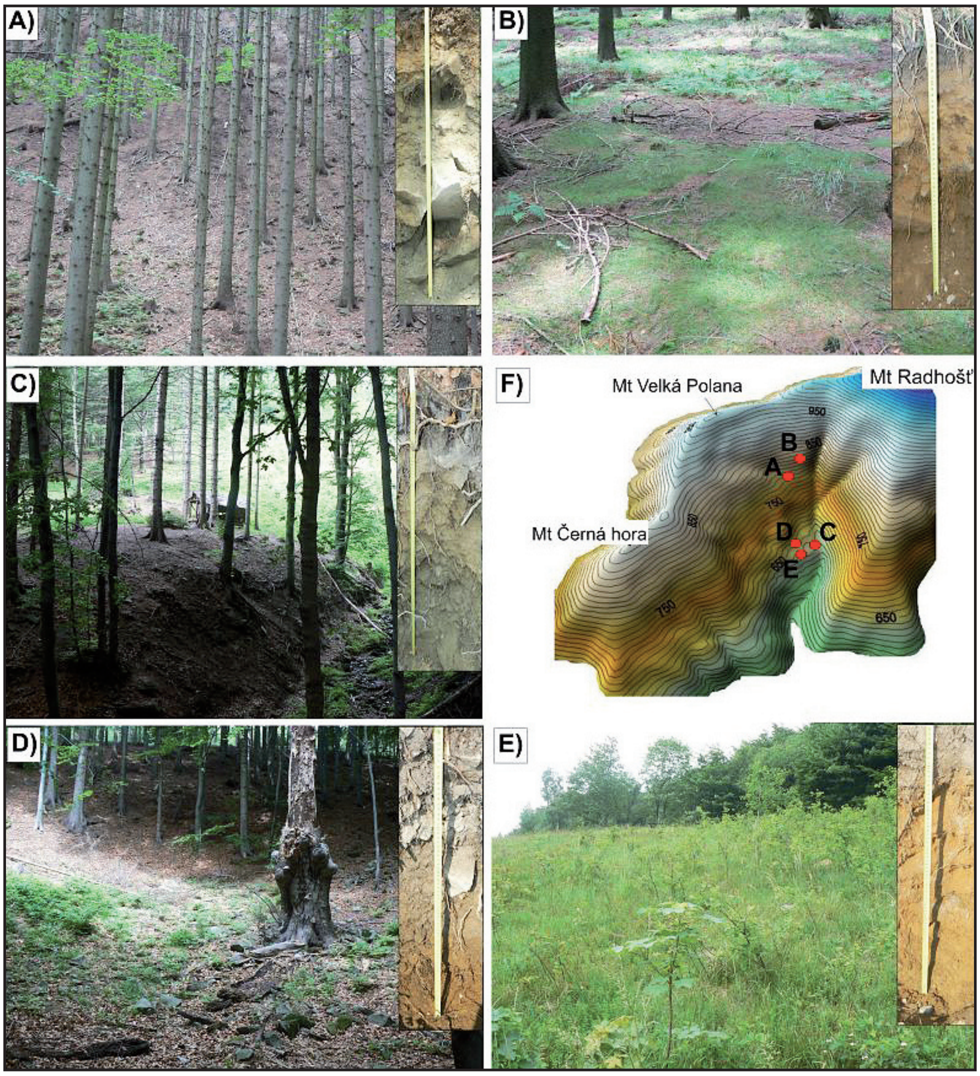

Fig. 3: Soil variability and vegetation of the Černá hora Mt slope deformation (used soil taxonomy after Němeček et al., 2001; taxonomy of potentional natural vegetation sensu Buček, Lacina, 1999): A) headscarp with Ranker with signs of podzolization, very high content of debris, vegetation of Abieti-fageta typica; B) rotated block Cryptopodzol, vegetation of Abieti-fageta C) terminal part of the accumulation zone with developed Cambisol and vegetation of Abieti-fageta typica; D) dell-like form in the hummocky relief in the accumulation zone with dominant Cryptopodzol and Ranker with rounded particles as a result of overflow, vegetation of Abieti-fageta aceris inferiora; E) compression zone in the accumulation part of landslide with developed Cryptopodzol, vegetation of Abieti-fageta aceris inferiora; F) localization of sampled areas

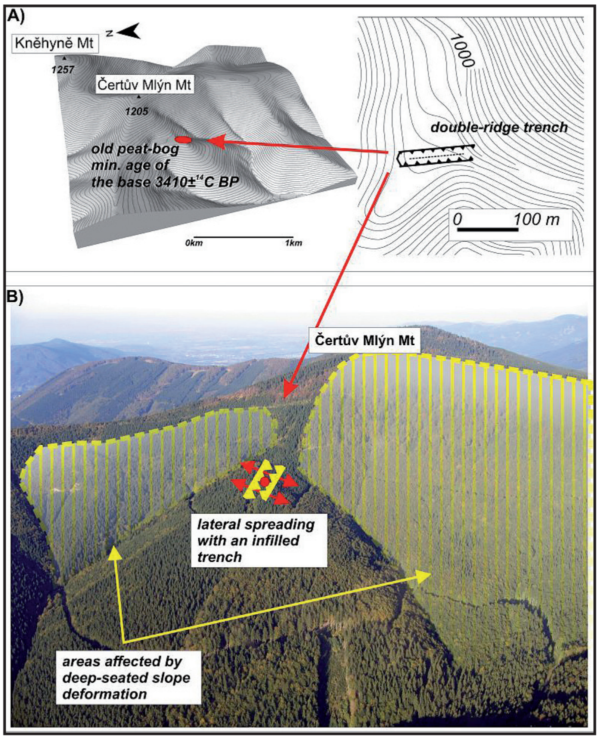

Fig. 4: Čertův Mlýn slope deformation: A) localization of a double-ridge trench and peat-bog; B) general view of deep-seated slope deformations and position of the studied trench landform

gravitational spreading of the massif and ends with complete or partial infill of the sediment of different character. The pollen diagram (Fig. 5) shows that the early depression phase involved space for a water body, which did not necessarily have to be permanent or too deep, however, it retained water. This is supported by the presence of algae members of Pediastrum sp. and also Diatom algae. According to Jankovská, Komárek (2000), these groups of organisms indicate the presence of oligodystrophic waters. The depression margins were probably occupied by the vegetation species of *Equisetum sp.*, grass species (*Poa sp.* and *Carex sp.*) and hydrophilic species of *Ranunculaceae* and *Galium sp.* Locations of an increased occurrence of debris and exposed areas were dominated by hygrophilic ferns (*Dryopteris filix-mas*). Sedimentologic analysis showed that further development led to gradual infilling of the whole depression mainly by organic material with a high concentration of fallen trunks.

With regard to probably high forest coverage and location of the deposition area, we can expect that a range of indicated herb species grew in the immediate vicinity of the depression, i.e. in the location of the very slope deformation. A few tens of centimetres of the upper layer were typically occupied by the members of *Sphagnum sp.* At present, the peatbog is no longer active and its surface is dry; sporadically shallow depressions created by animal action can be found. The surrounding area is dominated by spruce monocultures with the rare occurrence of beech. The pollen record shows evident gradual development of phytocenoses. The progress of fir (*Abies alba*) was dated to the Subboreal followed by massive beech propagation (*Fagus sylvatica*), namely at the boundary of SA1 and SA2 chronozones (for details see Fig. 5). Within the slope deformation, the share of maple (esp. *Acer pseudoplatanus*) increased towards the end of the SA1 chronozone which is typically related to debris habitats that have been present in the given location along with the maple vegetation up to this day.

4.3 Peatbog habitat - case study of the Groníček Mt. slide

In the contemporary cultural landscape, spruce monocultures can largely be found on forest land. Similar situation can be observed also in the area of the flysch Carpathians where habitat conditions do not enable the cultivation of a cultural forest with dominant spruce.

In a number of cases, such habitats originate as a result of failure activity. A unique locality, from this point of view, is a slope deformation on the southern slope of Groníček Mt. (837 m a. s. l.) in the Silesian Beskids Mts. (Fig. 6A). It is a large landslide where conformably bedded layers of Istebna sandstones slid along the underlying clayey complexes of upper Godula layers. The deformation starts just under the Groníček Mt. at an elevation of about 830 m and ends above the valley floor of the Kotelnice Brook at an elevation of 575 m. Total length of the studied area is ca. 1,000 m and total height difference is 255 m; it reaches 600 m in its widest part. The landslide area is characterised by a relatively variegated morphology. The upper part of the area within the elevations of 830 and 700 m has character of a block field built by the group of moved and rotated blocks accompanied by internal drainage depressions and horizontal surfaces. Right below the upper headscarp there is a horizontal surface sized 150x100 m built by a sunken and moved block of Istebna sandstones. The lower part of the slide (roughly within 700 and 575 m) comprises an accumulation with the signs of lateral levees at the western and eastern limits of the landslide. The slid material is partially affected by minor failures as well. The accumulation area shows characteristic undulated topography with the presence of internal drainage depressions. A peatbog (Fig. 6B) sized 150x100 m formed in such an internal drainage depression at an elevation of 610 m a. s. l. (Hradecký et al., 2004). Central part of the peatbog revealed a peat thickness of min. 5 m. The radiocarbon dating of organic residues at the bottom of the depression determined a minimum age of the disturbance at 11,813±383 BP (Hradecký et al. 2004) indicating probably multiple phases of reactivation.

Geodiversity of this area is strictly conditioned by the diversity of landforms that predetermined formation of internal drainage depressions and concentrated the surface runoff of water and substance into their bodies.

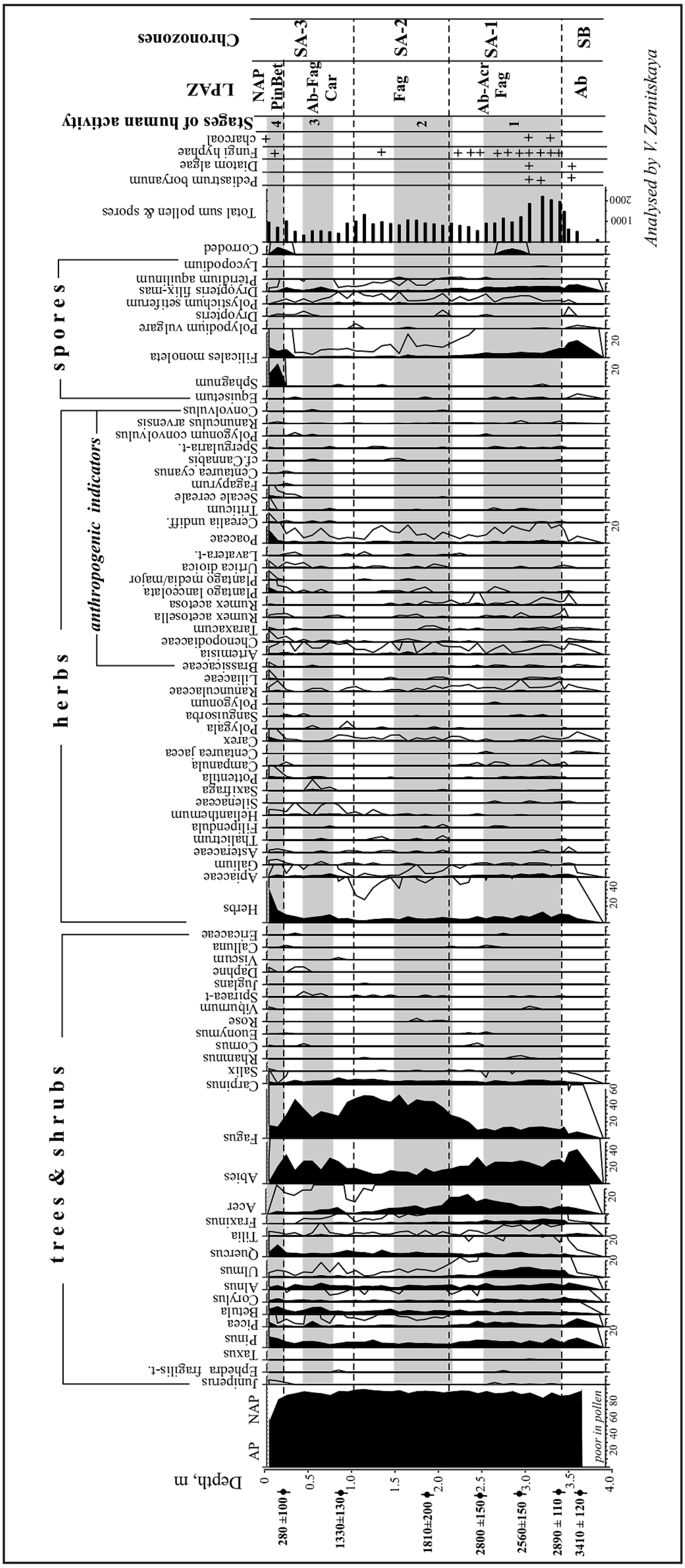

Fig. 5: Pollen diagram of the infilled trench of Čertův Mlýn Mt. slope deformation

Landsliding affected the transformation of hydrogeologic conditions whose result is a constantly high groundwater table. Long-term water stagnation in the trophically poor substratum led to the formation of peatbog dominated by *Sphagnum sp., Eriophorum sp., Carex sp.* and *Juncus sp.* (Fig. 6B, C and D). Tree vegetation is predominated by *Alnus glutinosa* and *Pinus syslvestris*. That is a typical example of an azonal biotope of transient peatbog in which the species composition reflects abiotic conditions controlled by the landforms. While *Abieti-Fageta* populations prevail on the surrounding non-deformed slopes, the location of the rotated block with the original intercolluvial depression is occupied by the *Piceeta sphagnosa* population (Fig. 7).

4.4 Ecotopes of high dynamics - case study of the Bučací potok Brook and Ropice Mt.

Flow type slope movements represent one of the most dynamic processes in the studied area. They particularly comprise displays of debris flows occurring at a high concentration in the massif of Smrk Mt. (more e.g. Hradecký, Pánek 2008; Šilhán, Pánek, 2007). Generations of debris flows fill the majority of valley forms in the Smrk Mt. area, which is built by massive layers of Godula sandstones. One of the most interesting localities from the geoecological point of view is the Bučací potok Brook basin on the northern slopes of Smrk Mt. (1,276 m a.

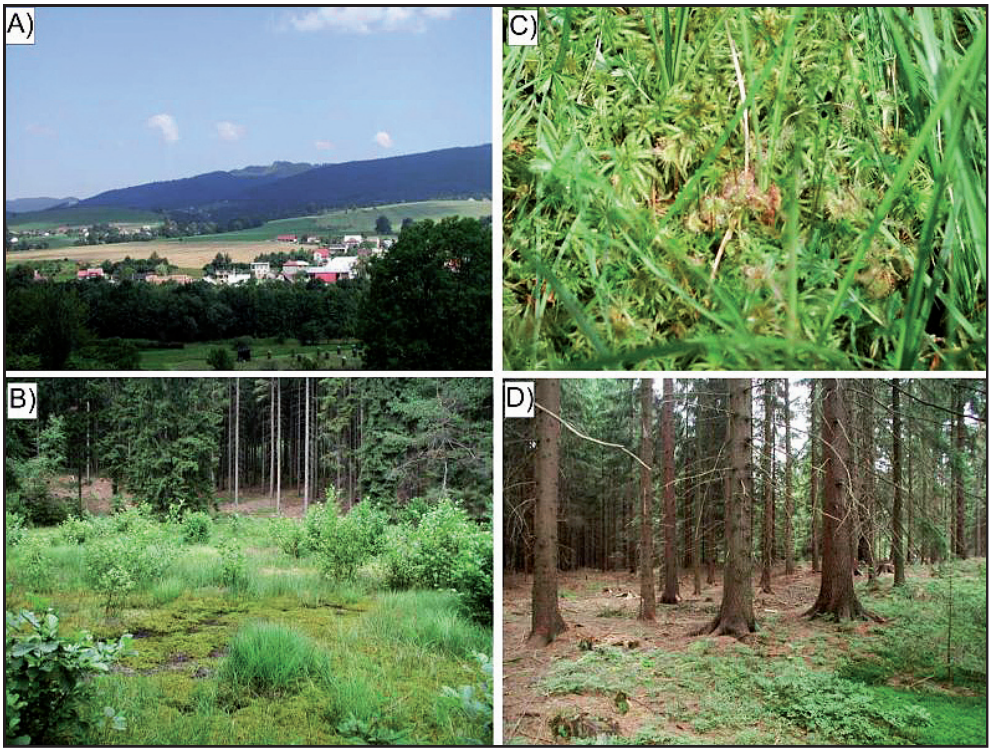

Fig. 6: Selected biotopes of the Groníček Mt. slope deformation: (A) - general view of southern slopes of Groníček Mt. affected by slope deformation, (B) – peat-bog with vegetation of Sphagnum sp., Carex sp., Juncus sp., Alnus glutinosa and Pinus sylvestris, (C) – protected plant Drosera rotundifolia growing in association with Sphagnum sp.; (D) – buffer zone between a peat-bog biotope and a cultural spruce forest

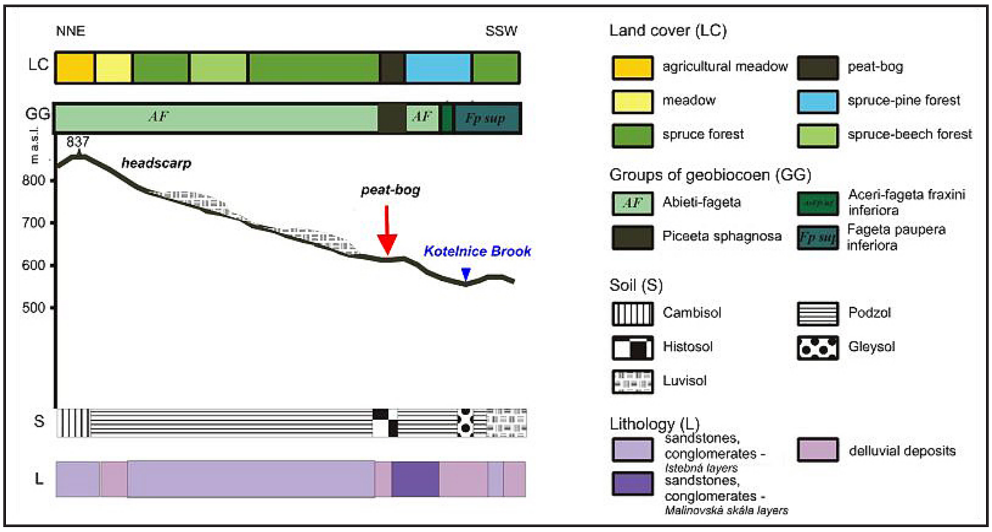

Fig. 7: Geoecological profile of the Groníček Mt. slope deformation

s. l.). Debris flows in the studied area show some basic features: evident debris flow recurrence and presence of multigenerational landforms related to the processes or typical presence of accumulation and erosion landforms upon which new habitats gradually form. This is a classic example of chronic geomorphologic disturbance that recurred several times under favourable climatic and morphogenetic conditions. Based on testing the weathering ratio of clastics by Schmidt Hammer method (Šilhán, Pánek, 2007), a few generations of disturbances were distinguished in the studied area. Habitats formed in conditions of a chronic disturbance show features of blocked succession with the presence of populations that can withstand the recurrent disturbance (Fig. 8A). Some disturbance zones can be identified according to relative age of the existing accumulation form (Fig. 9). We can suppose that the debris flow accumulations were reactivated several times and represented very variable habitats (Fig. 8B and C).

A somewhat different type of slope disturbance we observed in the Ropice Mt. locality. The slope deformation has the character of a flow type landslide or, strictly speaking, of a rock avalanche (approx. 1 km long; 150 m wide; redislocated material volume estimated at 0.5-0.8 Mm^3) that evolved from a destabilized slope affected by a deep-seated rotational slump in the Godula sandstones (Pánek et al., in press). We assume that unlike debris flows in the Bučací potok Brook basin, only one major event took place in this case having a catastrophic effect on biotopes existing in the locality. Consequently, a wide range of new quality geotopes developed. The

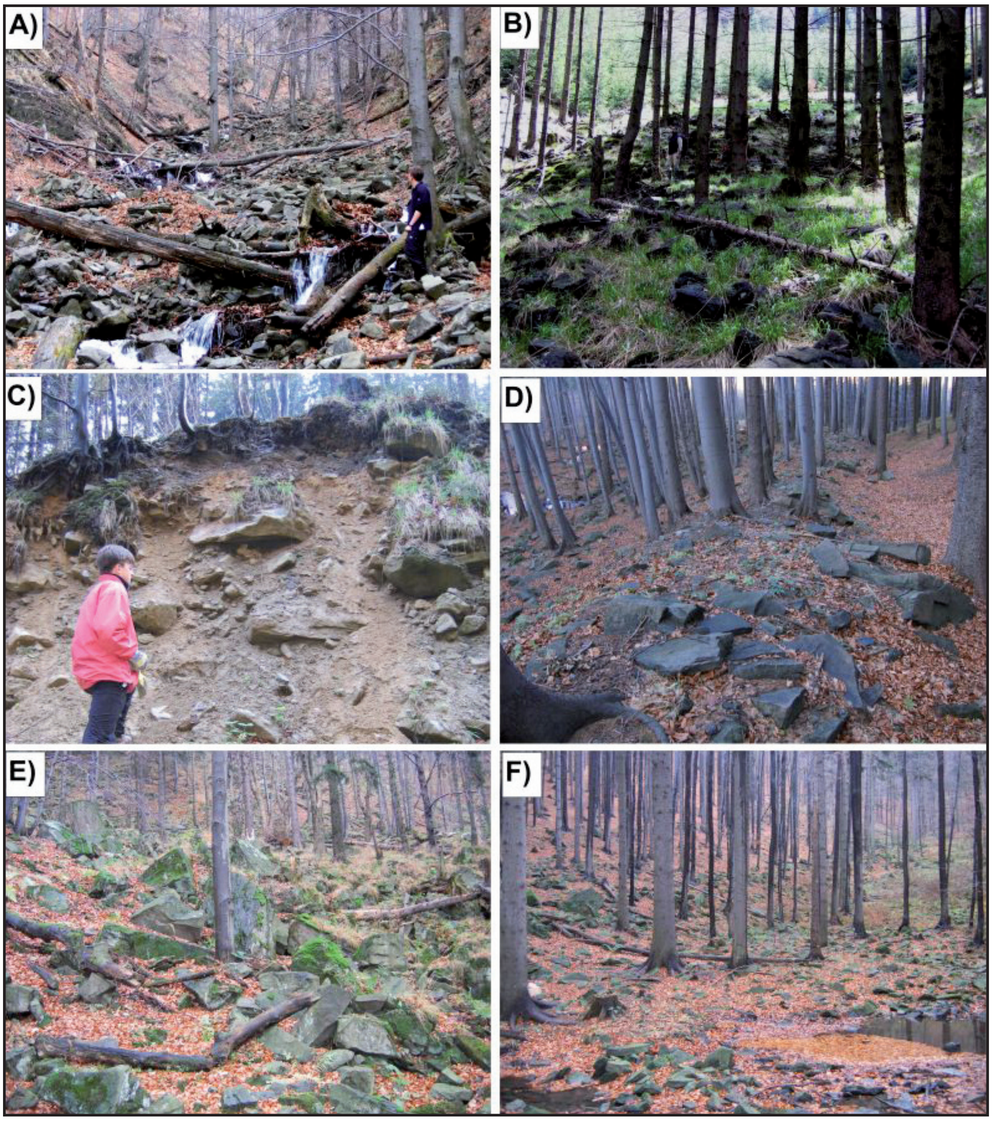

Fig. 8: Examples of disturbed and post-disturbed geotopes in areas affected by flow-like landslides – Bučací potok Brook (A-C) and rock avalanche of Ropice Mt. (D-F): A) the most active zone of debris flow is located in the stream channel of the Bučací potok Brook, deadwood artifacts of geomorphic disturbance; B) relatively young debris flow accumulation with vegetation of mosses and grass and poorly developed Ranker; C) composition of very old debris flow accumulation with evident humus horizon; D) geotope of lateral levee with a high content of debris and boulders; E) stony geotope under headscarp of rock avalanche with beeches and maples; F) aquatic geotope developed in the accumulation body of rock avalanche

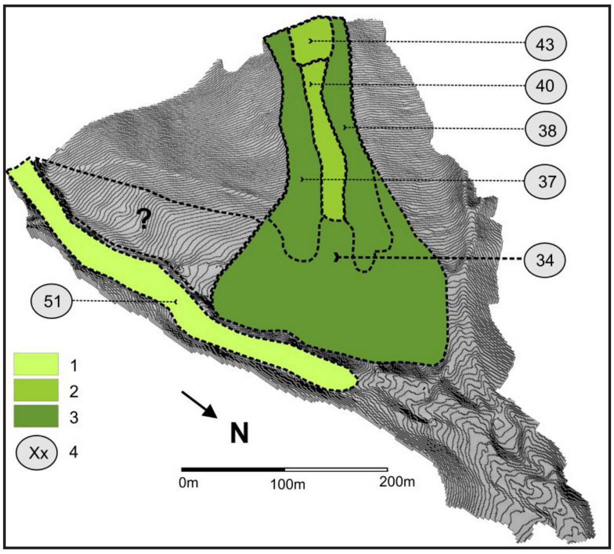

Fig. 9: Interpretation of a relative disturbance chronology in the debris flow area of the Bučací potok Brook basin – estimation of elapsed time from disturbance: 1 – short (≥50), 2 – long (40-49), 3 – very long (30-39), 4 – weathering ratio of the clasts in debris flow accumulation surface (Schmidt Hammer Method)

after-disturbance phase lasted for approximately 1,500 years and the landforms are still very fresh and untransformed. We can observe the presence of rock walls, transported rock blocks and block fields showing low abundance of vegetation types (Fig. 8D and E). These are locations with the suppressed pedogenesis and with the constant gradual rockfall and creep. Aquatic biotopes with both stagnating and running water emerged in the accumulation zone of the deformation (Fig. 8F). With respect to the presence of very permeable sediments in the accumulation part of the rockfall, the presence of water bodies constitutes an interesting phenomenon.

Discussion and conclusions

Landsliding of various genesis, intensity and spatial extent represents a natural morphogenetic process in the area of the Czech part of the Western Carpathians. At the same time, landsliding played a role in landscape evolution processes as a disturbance phenomenon (Fig. 10) affecting the conditions under which various types of azonal geotopes establish themselves in the landscape from the trophically poor and dry geotopes to the aquatic and trophically rich geotopes.

The mentioned types of slope deformations in the after-disturbance phase of the evolution of geotopes and landscape show themselves in different ways. Transformation of original slopes by block-type deformation is accompanied by the creation of distinctive discrete boundaries of new landforms concatenated into a system of headscarp – near-scarp depression – rotated block with intercolluvial depression – elevated part of rotated block. The compactness of forms and the contrast of boundaries lead to the development of specific ecotopes that differ distinctively in pedogenesis. Within the Miaší Mt. and Černá hora Mt. slope deformations, an increased presence of Cryptopodzols was identified in contrast to Cambisols that dominate undisturbed slopes at identical elevations, orientation and lithological conditions. At the same time, the slope deformation morphology limits the development of the zones of both humus-rich (concave landforms) and humus-poor soils (convex landforms). The evolution of peaty and gley soils (e.g. Mt. Groníček) is typical of intercolluvial depressions and near-scarp depressions. Identical situations described also Margielewski (2006) in the Polish Western Carpathians or Hradecký et al. (2007) in the Silesian Beskids Mts. Chronic disturbances of debris flow can limit pedogenesis (the presence of Rankers). This feature can be observed also in locations with exposed headscarps or in the colluvial zones of failures with increased occurrence of debris (e.g. the Ropice Mt.). These types of geotopes are occupied by specific vegetation populations that indicate different conditions of the habitat in disturbed and undisturbed parts of the slope (case study of the Groníček Mt.).

The presence of azonal geotopes of the type of trench in lateral spreading zones in areas affected by deep-seated slope deformations led to the evolution of a stagnotope, i.e. high bog (case study of the Čertův Mlýn Mt.). At the present, the biotope of peatbog has reached the regression stage (similar principles present Mather et al., 2003). Generally, these and other depression areas in slope deformations can be considered as suitable locations to study the palaeogeoecological evolution of the territory. Despite a relatively high age, some accumulation areas are still characterised by different

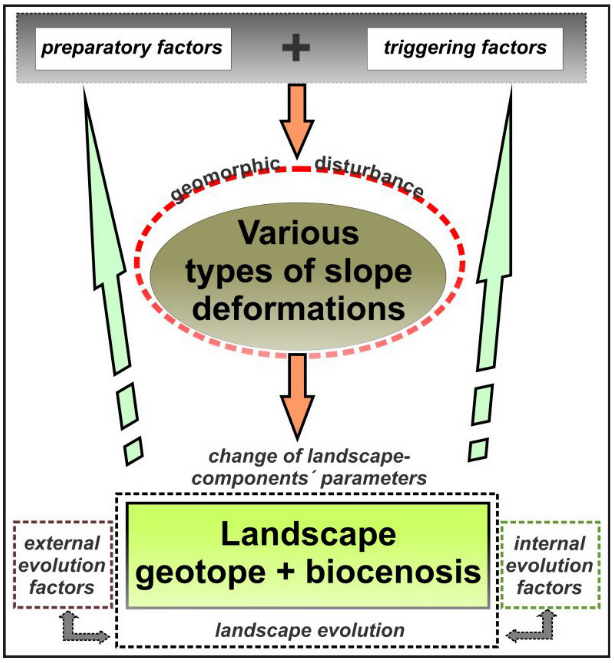

Fig. 10: Landsliding as an important landscape evolution factor in the area of flysch Carpathians

geotopes. This is given by the permanence of hydric conditions that preserve a high groundwater table within intercolluvial or near-scarp depressions. In the case of Groníček Mt. slope deformation, the slide disturbance has already existed in the landscape more than 11 ha (Hradecký et al., 2004).

At present, active displays of debris flows and rock avalanches in the studied area are minimal. In spite of this fact, the geoecological effect of their disturbance activity in mountainous geotopes is still evident. The extremity of geotopes formed in this way can be observed in the presence of mainly coarse-grained substratum upon which pedogenesis occurs only very sporadically. Presently, the highest activity of debris flows is connected with high-gradient streambeds. These line geotopes are episodically exposed to high disturbance energy.

Disturbance effect of landslide activity in the flysch landscape deserves attention in the future, namely in connection with the anticipated climate change which can bring both climate-conditioned changes in the character of habitats and changes caused by the increased dynamics of geomorphologic processes (see e.g. Renschler et al., 2007). A highly interesting, but so far little investigated phenomenon is geoecology of the Carpathian pseudokarst that emerged due slope instabilities and now creates rare habitat conditions.

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IDENTIFICATION OF FLOODPLAIN ELEMENTS SUITABLE FOR USE IN INTEGRATED FLOOD PROTECTION USING HYDROMORPHOLOGICAL MAPPING. CASE STUDY: UPPER OPAVA RIVER BASIN (CZECH REPUBLIC)

Jakub LANGHAMMER

Abstract

A new mapping methodology for stream network and floodplain modification rates for the purposes of flood risk analysis is presented in this article: as a case study, it is applied to the upper Opava River basin, Czech Republic. The methodology, HEM-F, represents a tool to identify anthropogenic modifications of watercourses and floodplains, which have a negative impact on the course and consequences of floods, and on the retention and transformation potential of the river basin. The results show that geomorphological conditions, as well as anthropogenic pressures on landscape utilization, leave only limited space for using the natural potential of the landscape and floodplain in the Opava River basin to transform the runoff in floods and to increase the retention rate in the landscape.

Shrnutí

Identifikace kritických prvků říční sítě z pohledu potřeb integrované protipovodňové ochrany na příkladu povodí horní Opavy, Česká republika

Příspěvek představuje novou metodiku mapování upravenosti říční sítě a údolní nivy pro účely analýzy povodňového rizika a její aplikaci na povodí horní Opavy. Metodika mapování antropogenní upravenosti toků, údolní- nivy a následků povodní HEM-F představuje nástroj pro identifikaci antropogenních úprav toků a údolní nivy, které negativně ovlivňují průběh a následky povodní a retenční a transformační potenciál povodí. Metodika je definovaná s ohledem na možnosti využití dat standardního hydromorfologického monitoringu a kompatibilitu s požadavky Rámcové směrnice o vodní politice ES. Výsledky ukazují, že geomorfologické poměry i antropogenní tlaky na využití krajiny poskytují v povodí Opavy relativně omezené možnosti pro využití přírodního potenciálu krajiny a údolní nivy k transformaci odtoku při povodni a zvýšení retence v krajině.

Key words: *floods, risk, hydro-morphology, floodplain, flood protection, mapping, Upper Opava River Basin, Czech Republic*

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1. Introduction

One of the factors mentioned frequently in connection with devastating floods in developed as well as developing countries is the presence of extensive changes in the landscape, especially by anthropogenic interventions in river basins and in stream networks, which affect runoff processes and often cause worsened consequences of floods on local and regional levels.

The relationship between anthropogenic modifications of watercourses and floodplains and the course of floods has been the subject of the research of many authors (e.g. Kundzewicz, 2002; Maidment, 1993; Nienhuis and Leuven, 2001; Sparks et al., 1998). Although direct statistical linkage between watercourse modifications and flood magnitude is difficult to prove in most cases, it is apparent that certain modification types cause changes to river flow and lead to the occurrence of serious flood damages. Such modification types include flow obstructions in the riverbed or in the floodplain, stream straightening, modifications of the longitudinal profile, or changes in floodplain land use.

This principle is reflected by a shift in the general flood protection paradigm that has resulted in the widely accepted concept of integrated flood protection (Hladný, 2003; Yin and Li, 2001). This principle combines maximum utilization of the retention and transformation potential of the landscape in places where safe spillovers are possible, and structural measures in areas where the protection of human lives, property, and cultural resources is required.

In order to apply an integrated approach to flood protection, such elements in the landscape need to be localized and identified so they can be incorporated into this system. Elements forming obstructions to the full utilization of the landscape potential for retention and watercourse transformation must be identified as well. For this purpose, the need for relevant and consistent information and tools for acquiring and analyzing these data arises.

A significant source of information on watercourse and floodplain state and modifications is represented by data from monitoring the hydromorphological quality of streams, which has been introduced gradually in practice in EU countries in connection with the implementation of WFD (EC, 2000). This directive represents an essential milestone in the field of hydromorphological monitoring, for it leads to a unification of approaches to evaluate this water quality component. For the purpose of unifying the large number of methodologies, the European standard EN 14614 – Water Quality – Guidance Standard for Assessing the Hydromorphological Features of Rivers (CEN 2005) was adopted, which represents a framework to define methodological approaches applied in individual membership countries. It defines a uniform hierarchical approach, monitoring methodology, and structure of the indicators assessed, and is also the basis for the Czech national methodology HEM (Hydro Ecological Monitoring, Langhammer, 2007).

In the framework of hydromorphological monitoring, there are indicators which can be used to identify potentially critical elements of stream networks and elements usable for efficient utilization of the retention potential of a given territory.

This paper introduces a methodology for hydromorphological monitoring data usage to evaluate watercourse and floodplain modification rates in relation to flood risk and to identify watercourse modifications that may have a negative impact on the course and consequences of floods. At the same time, it allows the identification of elements of the stream network that are usable in the system of integrated flood protection, for efficient usage of the natural transformation and retention potential of the landscape.

2. Materials and methods

2.1 Methodological background

The methodology, which allows for direct usage of hydromorphological monitoring data of watercourses, was designed to identify those types of watercourse and floodplain modifications that have impact on runoff in floods. The methodology stems from knowledge gained in analyses of the courses and consequences of extreme floods in 1997, 2002 and 2006 (Křížek, Engel, 2003; Langhammer, 2006). Evaluation of these events, as well as work performed in different geographic conditions, confirm that certain types of watercourse and floodplain modifications are usually accompanied by increased and more intense erosion, as well as by destructive manifestations of the flood at high water-levels. These modifications can thus be assessed as potentially critical in terms of flood risk (Vilímek, Langhammer, 2003).

Research and testing of methodological approaches for mapping watercourse modification rates in relation to flood risk (Langhammer, 2006) showed that indicators significant for the identification of segments that, due to the anthropogenic modifications, may have a negative impact on the course and consequences of floods, are analogous to indicators used in hydromorphological monitoring which conform to the EN 14614 standard. Although the mapping of hydromorphological elements of watercourse quality has a different aim and applies a different assessment system, the source data can be used successfully to identify critical segments of watercourses in relation to the flood risk and the needs of an integrated flood protection system.

In practice, however, various problems are encountered that result from the lack of uniformity of methodological approaches applied in various countries (e.g. Davy-Bowker and Furse, 2006; Janauer, 2000; Kamp et al., 2007; Rosgen, 1996; Szoszkiewicz et al., 2006; Victoria, 2003) and from insufficient territorial data coverage. This problem is significant in the Czech Republic, where the hydromorphological monitoring methodology was not adopted until 2007. Because routine mapping is at its very beginning and full coverage of the backbone network of watercourses has been planned for 6 years, such data are not available for the current evaluation of particular territories, and these data need to be obtained by means of purpose-oriented terrain mapping.

2.2 Mapping methodology

To identify the potentially critical segments, a new methodology was developed as a tool for the acquisition of data required to perform the assessment. The methodology designated as HEM-F (Hydro Ecological Monitoring – application for assessment of Flood risk) stems from the framework defined by the EN 14614 standard and the HEM hydromorphological monitoring methodology defined in the Czech Republic (Langahmmer, 2007), while using a subset of indicators assessed within the HEM methodology (Fig. 1).

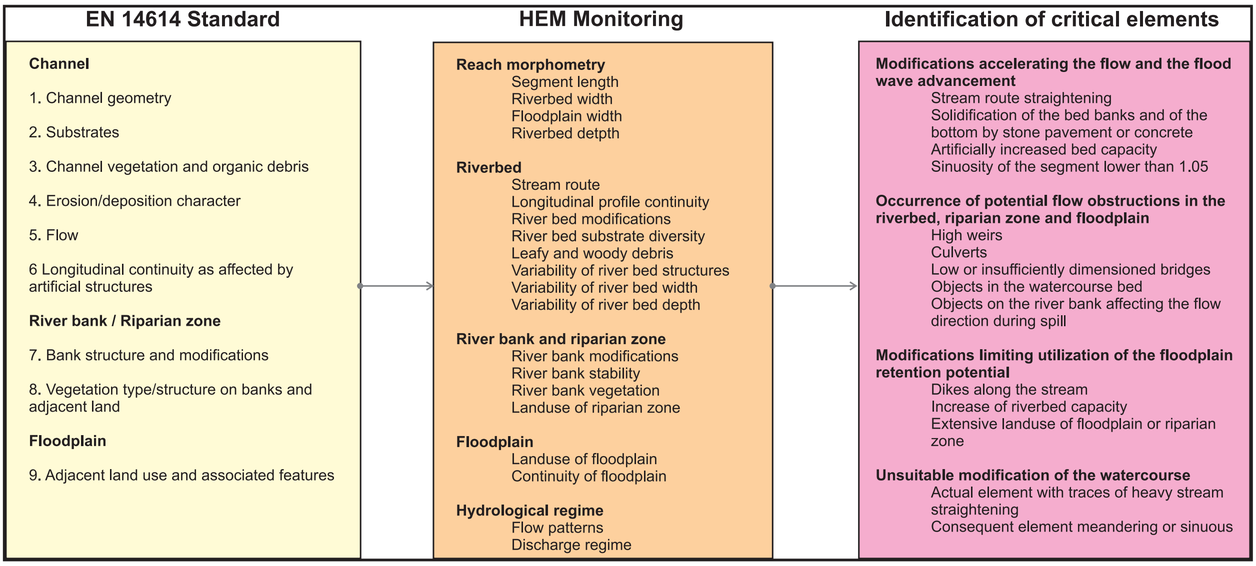

Fig. 1: Relationship between the structure of indicators used for the mapping and evaluation of watercourse modification rate and flood consequences, the HEM hydromorphological monitoring methodology, and the standard EN 14614

The range of indicators selected for mapping and assessment is limited to parameters that affect the flow during a flood (Tab.1). The methodology monitors concurrently the watercourse modification and the flood consequences, thus allowing the assessment of the flood course character and consequences as well as relationships between anthropogenic stream modifications and flood consequences. Detailed descriptions of the mapping methodology, including the mapping instructions and forms are available at http://floodserv.natur.cuni.cz.

The primary spatial unit for mapping is represented by watercourse segments delimited according to homogeneity of key parameters of watercourse and floodplain modification rate – modification rate of the watercourse route, modification rate of the riverbed, and modification rate of the circumlittoral zone and floodplain. Values determined for the terrain are recorded in a form, and subsequently transferred into a database integrated in GIS environment, which serves as platform for the spatial and statistical analysis as well as for the visualization of results.

2.3 Typology and identification of critical stream modifications

Indicators that assess the riverbed and floodplain modifications which, under high water-level stages, may affect the flow and flood spill were used as inputs for the identification and localization of critical forms of watercourse modification which affect the course and consequences of floods. The typology of critical segments stems from gradual development and testing of various mapping methodologies and assessment of watercourse modifications in relation to flood risk (Langhammer, 2006).

The following aspects of stream modifications are considered as critical in respect of the flood risk:

- Modifications accelerating the flow and the flood wave advancement
- Occurrence of potential flow obstructions in the riverbed, riparian zone and floodplain
- Modifications limiting utilization of the floodplain retention potential
- Unsuitable modification of the watercourse

Individual critical modification types are identified based on the combination of data from the mapping of hydromorphological watercourse features. The identification and typology are performed using database analysis in the GIS environment.

2.3.1 Modifications accelerating the flow and flood wave advancement

Intensive modifications of watercourses, such as straightening the watercourse route, and/or modifications of the watercourse bed in the stream profile, may accelerate flood wave advancement in some cases.

Straightening of watercourse routes is a phenomenon seen in Europe in the last 200 years, and intensively used throughout the 20th century (Tockner, Standford, 2002). In that period, numerous streams were straightened for the purposes of transportation, stabilization of agricultural lands, and especially to provide flood protection (Langhammer, Vajskebr, 2003). The straightening of streams leads to the flow acceleration and to the shortening of the time of flood wave advancement through the river basin.

Moreover, stream straightening is usually accompanied by the increase of riverbed capacity and by the solidification of banks and bottom so that they can better resist faster flows and more intensive manifestations of fluvial processes (Fig. 2). The solidification of banks and bottom, using stones or concrete, or an overall

Indicator group	Indicator	Parameters	Data type
Segment identification	Segment code Length Watercourse name Mapper Date		Value
Morphometry of the watercourse and floodplain	Bed width		Value
	Floodplain width		Value
	Bed deepening		Value
	Valley shape	Canyon-type, U valley shape, V valley shape, trough-type, asymmetric, flat valley	Category
Watercourse and floodplain modification rate	Modification rate of the longitudinal profile	Low degree, slip, weir above 1 m, culvert, dam	Number of occurrences
	Modification rate of the watercourse route	Running wild, branched, meandering, winding, straight, artificially straightened	Category
	Bottom modification rate	Natural, poking, addition of load sediments, solidified by stone pavement, solidified by concrete, enclosed in pipes	Category
	Bank modification rate	Vegetation solidification, gabions, semivegetation shaped bricks, stone casting, stone pavement, concrete	Category
	Bank vegetation	Wood, gallery vegetation, individual trees, tall herbs, without vegetation	Category
	Circumlittoral zone utilization	Wood, meadow, agriculture, scattered built-up area, urban area, expanses of water	Category
	Floodplain utilization	Wood, meadow, agriculture, scattered built-up area, urban area, expanses of water	Category
	Passability of the floodland	Flood dikes, line buildings parallel to the riverbed, line buildings across the plain	Category
Flood course and consequences	Spill nature	Water did not leave the bed; remained within the dikes; spill in the circumlittoral zone or floodplain shallow/deep	Category
	Geomorphological manifestations and flood consequences	Bed overlaying; bridge/weir destruction; small/extensive partial cracks; small/extensive accumulations in the bed; small/extensive accumulations in the plain; removal of boulders; destruction/damage of buildings; rupture of the dam	Number of occurrences
	Potential flow obstructions	Bridge, culvert, obstruction in the bed, reduced bed capacity, narrowed inundation, unsuitably located buildings	Category
Flood protection	Flood protection	Strong flood dike, mobile dike, increased capacity of the bed, polder, left meander, flood-plain forest, peatbog, wetland	Category

Tab. 1: Parameters used within the HEM-F methodology in mapping the watercourse modification rate and consequences of floods

geometric modification of the profile, causes a decline in bed roughness, which translates to flow acceleration in the stream.

Hydromorphological mapping data are used to identify the segments where the character of modifications may contribute to accelerated runoff and accelerated flood wave advancement, while the following selection criteria are applied to the data:

- Occurrence of artificial straightening of the stream route in the given segment
- Artificial solidification of riverbed banks and bottom by stone pavement or concrete
- Artificially increased bed capacity by its deepening
- Sinuosity of the segment lower than 1.05

Identification of segments that suit the criteria above is performed in the GIS environment, and the selection is conditioned by simultaneous incidence of the criteria mentioned.

2.3.2 Occurrence of potential flow obstructions in the riverbed, riparian zone and floodplain

Objects capable of changing the flow nature, of deflecting the flow direction, or acting as temporary flow obstructions in high water-level stages are identified as potential flow obstructions.

The assessment of flood consequences in 1997, 2002 and 2006 in the Czech Republic showed that in the floods of high magnitude, flow obstructions changing the floodwave progress, accelerating the fluvial processes or deflecting the flow direction, are a frequent cause of extraordinarily intensive destructive erosion or accumulation manifestations of the flood (Kalvoda, Vilímek, 1998; Křížek, Engel, 2003).

These are objects that – under normal water-level conditions and/or in floods of low intensity – are usually not in contact with the flow or have only a marginal influence on the flow. However, in extreme situations, they become engaged in the runoff process and may have a considerable impact on it by deflecting the flow direction or by forming temporary obstructions (Langhammer, 2007). Examples are insufficiently sized structures of bridges or culverts, which are easily blocked with wood and other materials carried by the flood, leading to creation of a barrier that retains the flow and to destruction of the original object upon its subsequent rupture (Fig. 3).

The following object types were sought as potentially critical to identify critical segments:

- High weirs
- Culverts
- Low or insufficiently sized bridges
- Objects representing a flow obstruction in the inundation area
- Objects in the watercourse bed
- Buildings on the river bank affecting the flow direction during spill

Objects representing potential flow obstructions are usually captured by various indicators of hydromorphological monitoring. To be specific, these are selected parameters of continuity of the longitudinal profile and floodplain, which record steps in the riverbed, weirs or culverts, as well as dikes and embankments crossing the inundation area. Identification of other objects, especially insufficiently sized bridges and other objects in the watercourse bed or inappropriately situated buildings on the bank, is usually possible only within the scope of specialized mapping; however, such objects can be identified partially based on mapping data or from orthophotographs.

2.3.3 Modifications limiting the use of the floodplain retention potential

Numerous segments of the floodplains have only limited usability of their natural retention and transformation potential due to anthropogenic interventions. Most common type of restrictive modification is represented by dikes, protecting against water spill in areas with low levels of flood protection priority.

Flood control dikes are irreplaceable in areas where they protect residential areas, industrial objects or important buildings. However, in the past, dikes were often built to protect agricultural land – fields, orchards, as well as pastures. Although they have positive effect at a local level by protecting agricultural crops, their effect on a scale of the whole river basin is highly negative. Lack of usage of the natural potential of floodplains to transform and reduce flood culmination reflects in the need for more costly protective measures in urban areas and in the occurrence of greater flood damages in a comparable event (Vilímek, Langhammer, 2003).

Those watercourse segments where protective dikes are present without the occurrence of objects with priority protection level, e.g., residential areas or industry in the inundation zone, are considered in the identification of potentially critical segments in this category.

2.3.4 Inappropriate modification of the watercourse

Inappropriate modification of the watercourse route represents the occurrence of significantly straightened watercourse segments leading to meandering or sinuous segments. In such places, extraordinarily intensive manifestations of erosion or accumulation occur, possibly connected with the destruction of objects on the watercourse and in the riparian zone (Křížek, Engel, 2003).

The spatial linkage of segments with inappropriate modification of the stream route is assessed by means of spatial analysis in the GIS environment. The localities where a sinuous or meandering segment is preceded by a segment with sinuosity lower than 1.05 and with the concurrent traces of significant artificial modification are selected as potentially critical stream segments.

2.4 Application of the methodology in the Opava River basin

According to the above described methodology, field mapping using the HEM-F methodology was performed in the Opava River basin during the summer and fall 2007. The mapping was focused on capturing the current conditions of modification rate of the watercourses and floodplain as factors affecting the runoff process and retention potential of the area. The mapping, performed immediately after the flood in September 2007, allowed the accurate characterization of the course, manifestations and consequences of the flood in individual parts of the river basin.

A total of 85 watercourses in the Czech part of the river basin were mapped, having a total length of 548 km (Fig. 4). The watercourses mapped and the corresponding parts of the floodplain were divided into 1,189 segments, forming basic spatial units for the assessment.

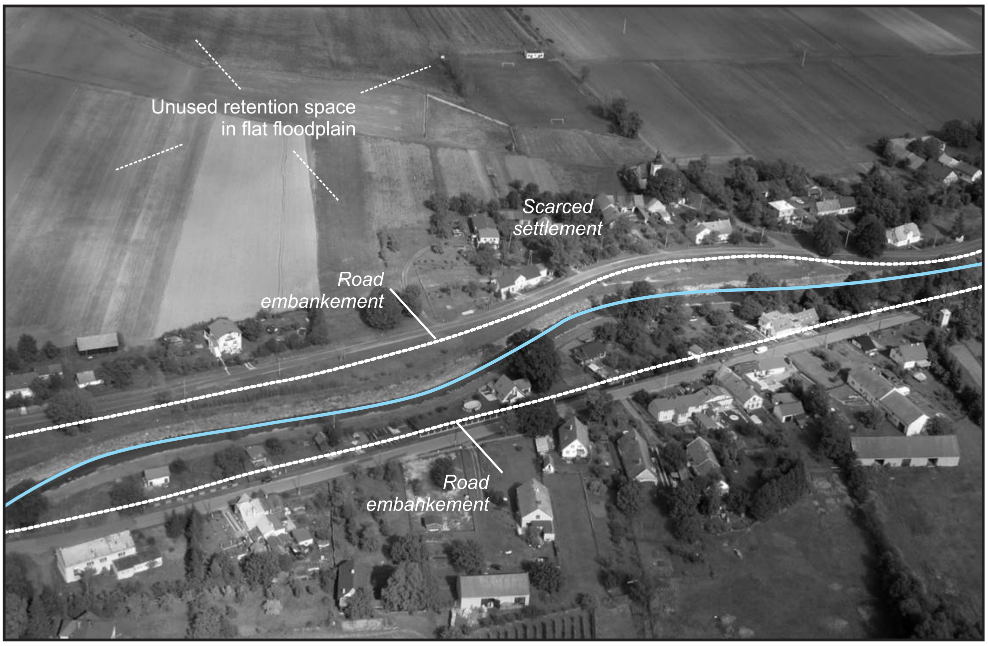

Fig. 2: Straightening and capacity increase of the Opava River in Zátor. Complex watercourse modification contributes considerably to accelerated flow; at the same time, the higher protection level thanks to scattered built-up areas and the road sidewall limits the floodplain area usage for the transformation spill. (Photo J. Langhammer, 2007)

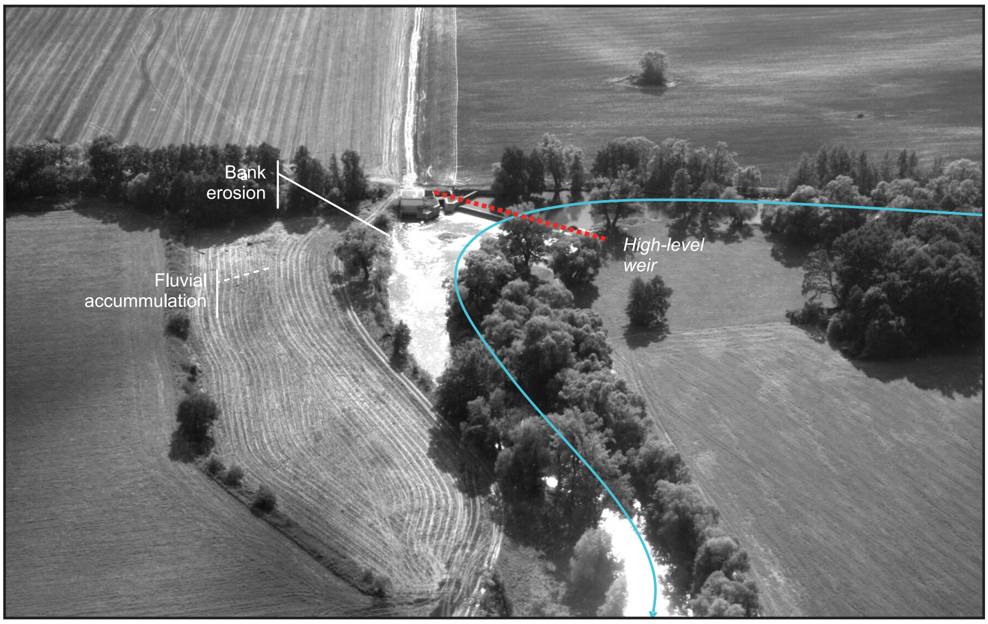

Fig. 3: Example of inappropriately situated weir as a potential flow obstruction. Location of the high weir in the watercourse meander causes acceleration of erosion and accumulation processes during the flood. Lower reach of the Opava River at Kravaře. (Photo J. Langhammer, 2007)

3. Results

The results indicate a highly variable spatial concentration and frequency of the occurrence of critical elements in the river pattern of the upper Opava River basin. The greatest share of potentially critical segments was found in the central Opava watercourse and in the area between Vrbno pod Pradědem and Krnov. The least intensively transformed regions were the spring area of the river basin, namely the White, Middle and Black Opava subcatchments (Fig. 5).

The inner structure of critical elements of the stream network within the river basin is highly variable as well. Modifications accelerating runoff from the river basin in the upper reaches – on the Opavice River and on the upper and middle reaches of Opava River – represent nearly 50% of all critical segments. In contrast, modifications limiting the retention potential are found most frequently in the middle and lower part of the river basin. The representation of potential obstructions to the flow is relatively uniform in all partial river basins (Fig. 5).

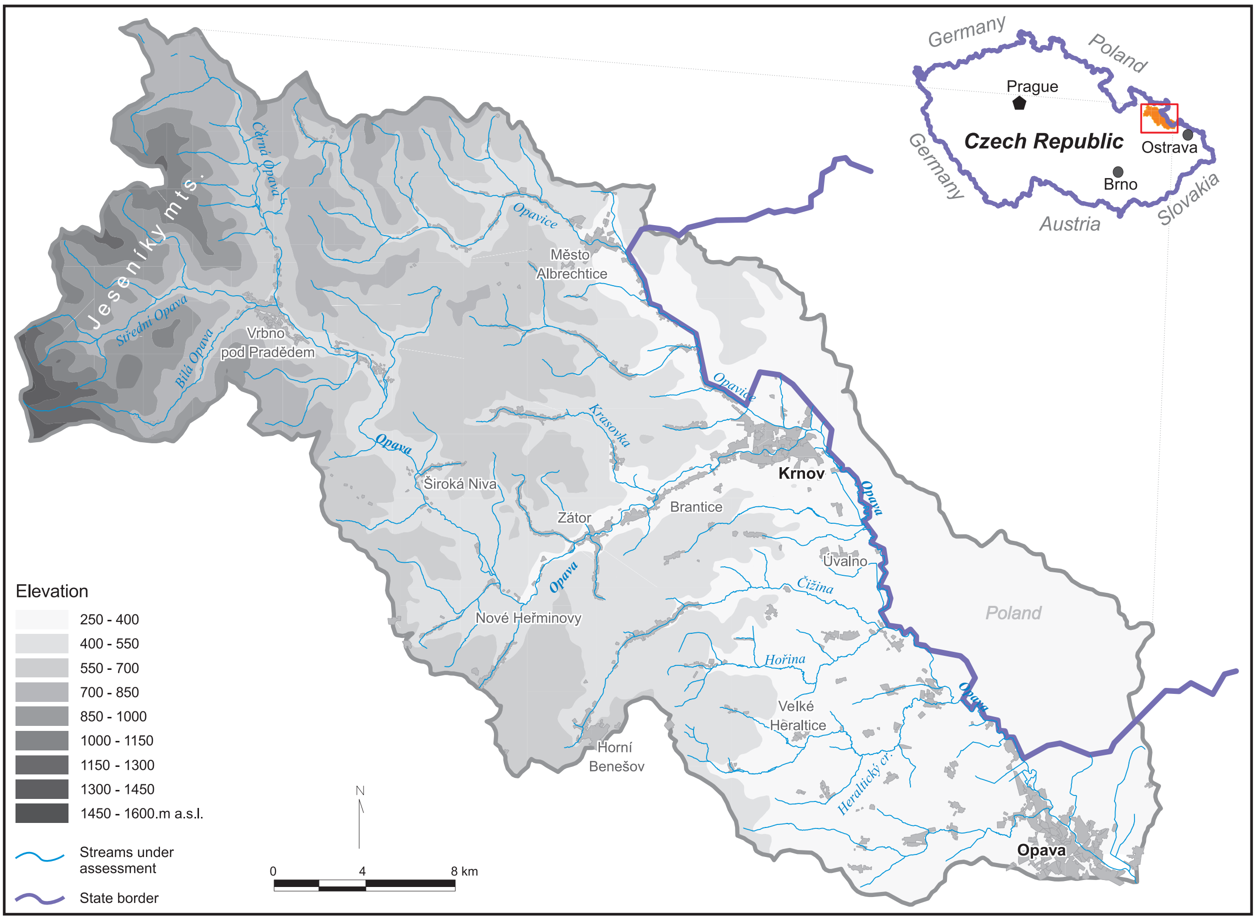

Fig. 4: Study area – The Opava River Basin

Runoff accelerating modifications represent the most frequent type of critical watercourse modifications in the Opava River basin. Potentially critical segments in this aspect are concentrated especially on main watercourses in urban areas and zones of scattered settlement, representing more than 20 percent of the total length of watercourses evaluated.

The high occurrence of such modification types results mainly from the relief character and from the spatial

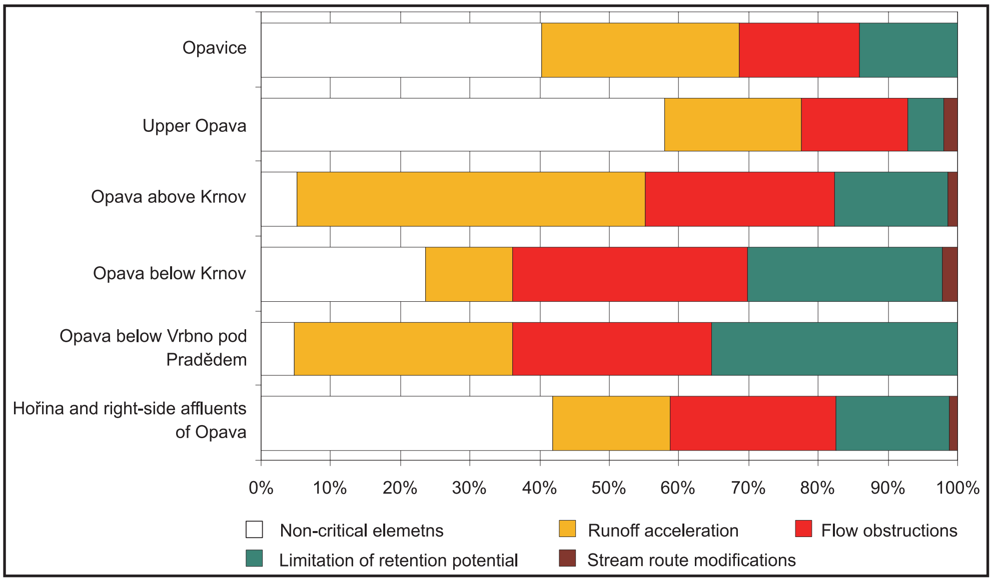

Fig. 5: Structure and distribution of critical stream segments in the Opava River basin. The graph shows relative shares of numerous stream elements classified according to the form of potentially critical modifications in key Opava River subbasins. Data: Mapping 2007

of built-up areas. Watercourses with relatively high gradients flow through the narrow valleys with built-up areas covering long and compact segments of the floodplain, mainly in the upper and central parts of the basin. Thanks to the protection of such residential areas by increased riverbed capacity, solidification of embankments or flood dikes, an overall acceleration of runoff occurs. This results in more intense geomorphological consequences of the flood below such modified segments.

Modifications of watercourses and objects, which act as flow obstructions during floods were identified along virtually the entire area of the river basin with the exception of spring areas of the Opava R. Only the objects having a significant impact on the course and consequences of floods types were chosen to identify critical segments: culverts, high weirs, objects in the watercourse bed and modifications reducing the bed capacity.

The high number of culverts is especially alarming, as these tend to be frequent points of extreme erosion and destruction. The high spatial concentration of obstructions in the upper river basin is critical as well. Although the flow obstructions act selectively during floods according to the course of the particular event and depending on its magnitude, the high occurrence of obstructions, especially in zones with high watercourse energy, represents a potential risk especially with respect to a possible occurrence of flood damage to property and infrastructure.

Modifications leading to limitation of the retention and transformation potential of the floodplain are located mainly in the middle and lower part of the river basin. These are represented typically by the restriction of the space for flood spill due to road embankments, protection of scattered housing areas, or excessive capacity increase of the riverbeds.

The space to increase the floodplain retention potential in the Opava River basin is limited, especially in the lower part of river basin below Krnov. However, partial space for retention, which is not fully used at present, offers itself also in the natural segment of the Opava River floodplain between Vrbno and Nové Heřminovy (Fig. 5).

Segments where *unsuitable altering of the watercourse route modifications* is observed, i.e., leading of direct segments into meandering segments, are not common in the Opava River basin. However, analyses of flood consequences in other areas confirm that such watercourse route modifications have a large impact on the extent of flood damage. Extensive fluvial accumulations occur regularly in segments with such a type of route modification, as well as significant bank erosion and damage to buildings and regulating objects. In the Opava River basin, fifteen elements with such an inappropriate alteration of the watercourse route were found in the Opava River basin, concentrated especially in the middle and lower reaches of the river (Fig. 6).

4. Discussion and Conclusion

The presented research aimed at finding appropriate methods of utilization of the floodplains may help to harmonize the needs for effective flood control with requirements of nature conservation and sustainable socioeconomic development. The issue is presently subject of research activities as well as of legislative and administrative measures adopted in most European countries. The authors concerned with the subject in different geographical regions mostly conclude that the use of natural retention and transformation potential of streams and floodplains should be considered as keystone for efficient flood protection in the future and that flood protection measures based on these principles are not restricting the socioeconomical development of affected floodplains (Birkland et al, 2003; Blackwell, Maltby, 2006; De Roo et al., 2001; Stacey, Withersby, 2005).

The paper introduces a new methodological tool for the identification of stream elements suitable for reinforcement of the natural retention and transformation potential of floodplain via hydromorphological mapping. A new HEM-F methodology is proposed and tested that was defined on the basis of experience from mapping in previous years, which takes into account also the compatibility with the newly adopted methodology of HEM hydromorphological mapping. The analysis was performed within a research project framed by the Ministry of the Environment of the Czech Republic, aimed at defining new strategies for sustainable management of floodplains.

Application of the methodology in the Opava River basin revealed good opportunities for using the hydromorphological monitoring data for the location of potentially critical watercourse segments as stream elements in which current modifications potentially worsen the course and consequences of floods or do not fully use the area potential for the enhancement of retention and transformation effect of the floodplain.

A particular benefit of the presented approach is uniform methodology of the hydromorphological data collection that complies to requirements of the EC Framework Directive and to EN 14614 Standard.

The main obstruction to using such data in practice is the fact that hydromorphological monitoring programs are at a very beginning of their development, and thus no comprehensive database is available. This obstruction

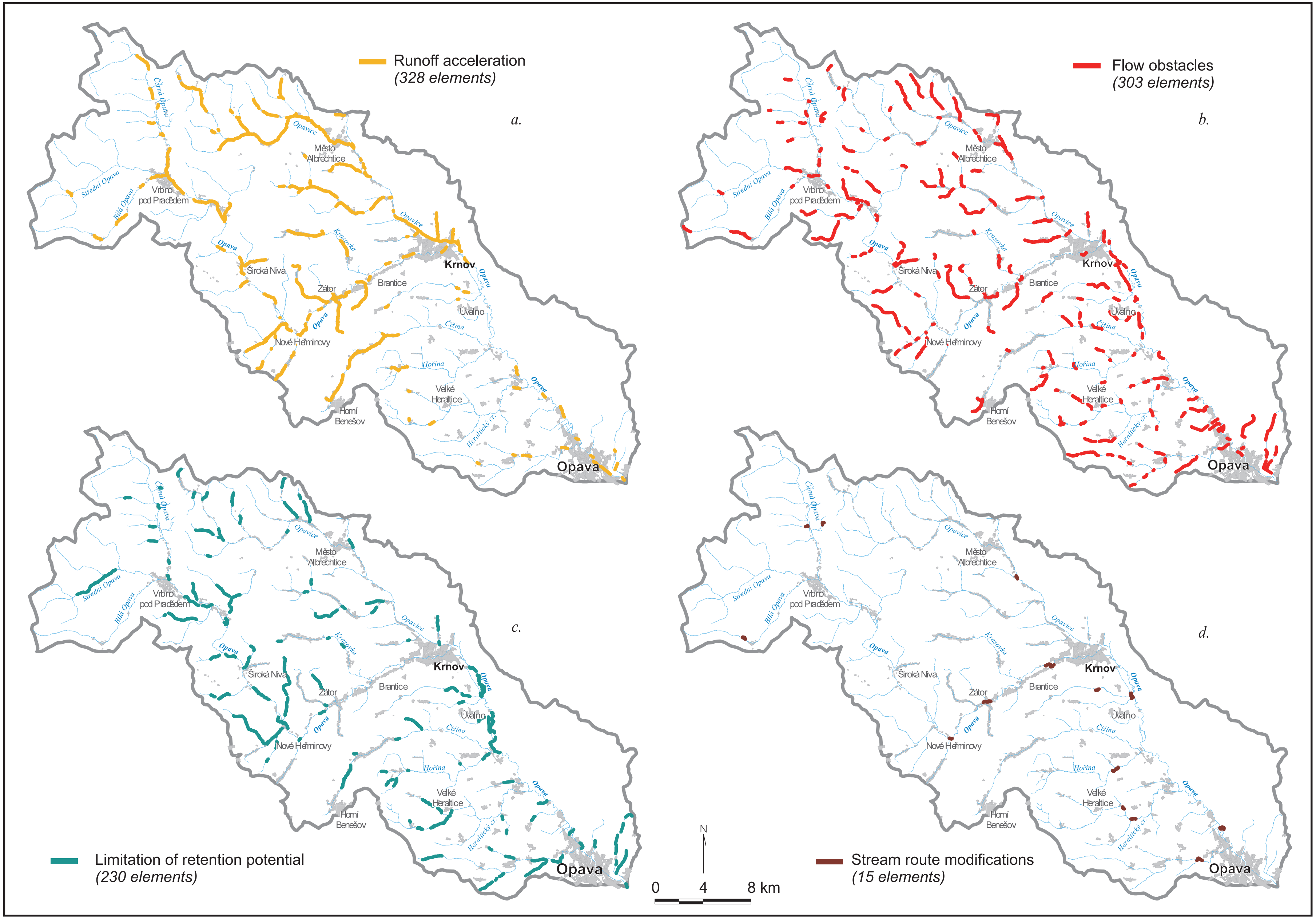

Fig. 6: *Critical segments – distribution of the main types of critical segments in the Opava River basin: a – Runoff accelerating modifications; b – Flow obstructions; c – Modifications limiting the floodplain retention potential; d –Inappropriate watercourse route structure. Data: Mapping 2007*

is reported in most countries where the regular hydromorphologial monitoring has been recently adopted (Furse et al., 2006; Davy-Bowker, Furse, 2006; Zalevski et al., 1997). However, the significance of this problem will decline gradually with the advancement of stream network coverage by the regular hydromorphological monitoring.

The second problem is the specific structure of hydromorphological monitoring data, which does not include some specific types of modifications and objects that may have an impact on the flood course and do not evaluate flood manifestations and flood damages. This deficit may be overcome by the application of supplementary data sources like the orthophoto images, detailed maps, or field surveys (Legleiter et al., 2004; Gilvear et al., 2004).

The analysis performed in the Opava River basin pointed to sensitive aspects of river network modifications with regard to their potential for flood mitigation. The results proved that the overall intensity of the watercourse and floodplain modification rate is high in this basin, even in the spring area. The overall intensity of modifications has the highest values in the Opavice River basin, in the spring area of the basin.

Factors limiting utilization of the landscape's natural retention potential result from two different aspects. The first limiting factor is represented by geomorphological features of the basin, where watercourses in the upper river basin area show a high gradient and flow through narrow valleys. The floodplain is developed only in a limited extent here, and thus provides a limited space for retention and transformation of the floodwave. The second limiting factor consists of intensively built-up areas of the valleys, covering long and compact segments especially in the mountain part of the basin. Due to the need for protection of such residential areas against floods, the capacity of most watercourse beds had been increased and the streams were modified so that they let the water flow quickly through the given territory, and cannot utilize the natural potential of the floodplains to mitigate the flood waves.

The floodplain areas potentially suitable for safe spills and runoff transformation are concentrated especially in the lower reach of the Opava River, between the towns of Krnov and Opava. Utilization of the Opava R. floodplain area in the region between Vrbno pod Pradědem and Krnov is partially limited by insufficient width of the plain in the upper segment part and by intensive linear built-up areas in its lower reach. Moreover, this part of the watercourse is extraordinarily important from the viewpoint of flood protection of the river basin as a whole, and the transformation potential of the floodplain, especially in localities with natural and undisturbed character.

Acknowledgment

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CONTRIBUTION TO THE METHODOLOGY OF CLIMATIC REGIONALIZATION OF THE CZECH REPUBLIC

Evžen QUITT

Abstract

When the new Climate Atlas of the Czech Republic based on the climatic characteristics of the 1961–2000 monitoring period was published in 2007, it provided an opportunity of utilizing its final maps to define climate regions in a similar fashion to the first Climate Atlas of Czechoslovakia published in 1958 summarizing the results of monitoring between 1901 and 1950. This enabled at least a partial comparison of the results of earlier climatic regionalizations with newly demarcated climate regions.

Shrnutí

Příspěvek k metodologii klimatické regionalizace České republiky

Vydáním nového Atlasu podnebí Česka v roce 2007 vycházejícího z klimatických charakteristik pozorovacího období 1961 - 2000 se naskytla možnost využít těchto finálních map k vymezení klimatických regionů podobně jak tomu bylo u prvého atlasu podnebí Československa vydaného v roce 1958 a shrnujícího výsledky pozorování za léta 1901 až 1950. Umožnilo to alespoň částečné srovnání výsledků dřívějších klimatických regionalizací s nově vymezenými klimatickými oblastmi.

Keywords: *climate, climatic regions, Czech Republic*

1. Introduction

When the new Climate Atlas of the Czech Republic based on the climatic characteristics of the 1961–2000 monitoring period was published in 2007, it provided an opportunity of utilizing its final maps to define climate regions in a similar fashion to the first Climate Atlas of Czechoslovakia published in 1958 summarizing the results of monitoring between 1901 and 1950. This enabled at least a partial comparison of the results of earlier climatic regionalizations with newly demarcated climate regions.

2. Climatic regionalization of F. Rein and M. Konček from 1958

The authors defined three principal climate regions – warm, mildly warm and cold (Fig. 1). At doing so, they had based them on data acquired between the years 1901 and 1950 or possibly between 1926 and 1950. Boundary to divide the warm and mildly warm regions was a limit of 50 average summer days or July 15 as a date of the beginning of winter rye harvest time. The mildly warm region used to be distinguished from the cold region by average July temperature of 150C. Further classification was elaborated with the use of Konček‘s moisture index or other criteria (for further details refer to the explanatory text of Tab. 1).

3. Climatic regionalization by E. Quitt from 1971

The delimitation of climate regions was conducted according to the data from the 1901–1950, or potentially 1926–1950 monitoring period, collected in the Climatic Atlas of Czechoslovakia.

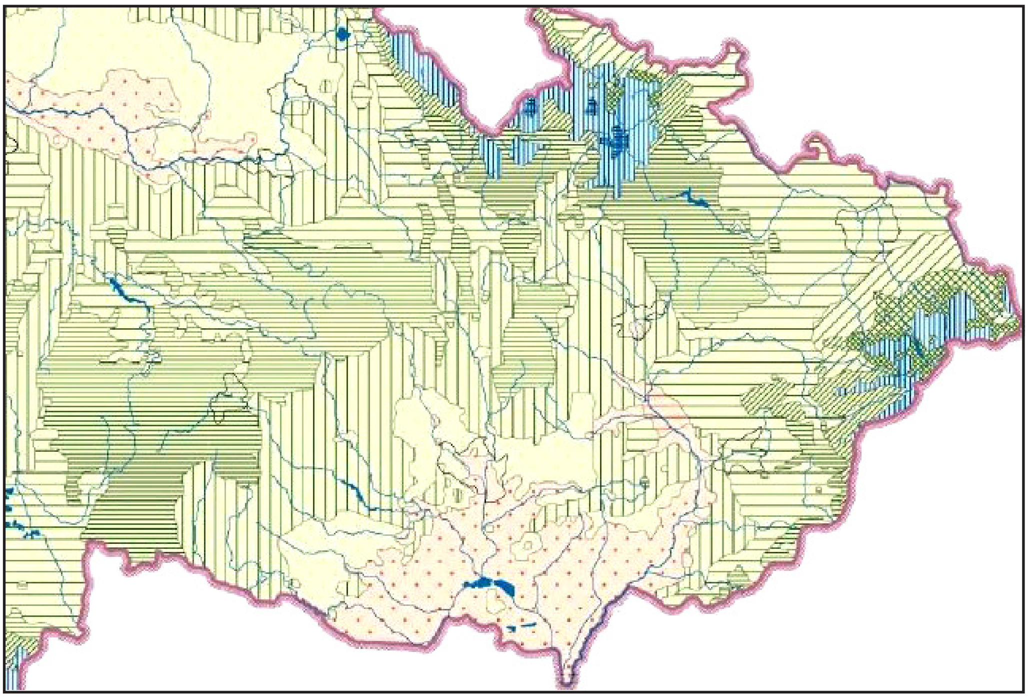

Fig. 1: Example of the delimitation of climate regions in the eastern part of the Czech Republic by F. Rein and M. Konček from 1958.

Region	Subregion characteristics	I_z	District		
			Designation	District characteristics	Climatic or terrain attributes
Warm region	dry	< -20	A1	warm, dry, with mild winter and longer sunlight	temperature in January above -3°C, sunlight in the growing period over 1,500 hours
			A2	warm, dry, with mild winter and shorter sunlight	temperature in January above -3°C, sunlight in the growing period less than 1,500 hours
	mildly dry	-20–0	A3	warm, mildly dry, with mild winter	temperature in January above -3°C
			A4	warm, mildly dry, with cold winter	temperature in January between -3°C and -5°C
	mildly humid	0–60	A5	warm, mildly humid, with mild winter	temperature in January above -3°C
			A6	warm, mildly humid, with cold winter	temperature in January between -3°C and -5°C
Mildly warm region	dry	< -20	B1	mildly warm, dry with mild winter	temperature in January above -3°C
	mildly dry	-20–0	B2	mildly warm, mildly dry, predominantly with mild winter	temperature in January above -3°C
	mildly humid	0–60	B3	mildly warm, mildly humid, with mild winter, highland	temperature in January above -3°C, maximum altitude 500 m a.s.l.
			B4	mildly warm, mildly humid, with frigid winter, valley	temperature in January below -5°C
			B5	mildly warm, mildly humid, upland	maximum altitude 1,000 m a.s.l.
	humid	60–120	B6	mildly warm, humid with mild winter, highland and flatland	temperature in January above -3°C, maximum altitude 500 m a.s.l.
			B7	mildly warm, humid with cold or frigid winter, valley	temperature in January below -3°C
			B8	mildly warm, humid, upland	maximum altitude 1,000 m a.s.l.
	very humid	> 120	B9	mildly warm, very humid, highland	maximum altitude 500 m a.s.l.
			B10	mildly warm, very humid, upland	maximum altitude 1,000 m a.s.l
Cold region	identical with the region	not decisive	C1	mildly cold	temperature in July between 12°C and 15°C
			C2	cold, montane	temperature in July between 10°C and 12°C
			C3	frigid, montane	temperature in July below 10°C

Tab. 1: Excerpt from the legend to the climate regions map by F. Rein and M. Konček from 1958.

This compact data set provided an overview of the thermal (31 maps), precipitation (24 maps) and other climate characteristics (15 maps). Fourteen most significant maps selected from this set furnished a relatively detailed picture of the climatic conditions. These were maps of the mean temperatures of January, April, July and October characterizing the annual course of temperature and maps providing an overview of the number of summer, frost and ice days and days with the minimum temperature of 10°C. The precipitation was characterized by its total amount in the growing and winter seasons and the number of days with precipitation of at least 1 mm and days with snow cover. Among other characteristics is the number of clear and cloudy days. For the purposes of zoning, we divided the territory of the republic into squares with each side 3 km long. Every square was represented by a punch card with all of the 14 climate characteristics. First cards to be sorted out were the ones with similar or equivalent values of the fourteen key climate characteristics. These were then further grouped into larger units until finally three climate regions became defined – warm, mildly warm and cold (Fig. 2). Boundaries between the regions were running at places with the highest number of changes between the individual squares. A similar procedure was used to define subregions (Tab. 2). In Czechoslovakia, the warm region included 5 of these subregions (T1 through to T5), with Subregion T5 being the warmest and the driest, and Subregion T1 being the coldest and most humid. The mildly warm region comprised 11 subregions (MT1 through to MT11) with Subregion MT11 being again the warmest and driest and Subregion MT1 being the coldest and most humid. The cold region was divided into 7 subregions (CH1–CH7).

4. Climatic regionalization by D. Moravec and J. Votýpka from 1998

This regionalization follows out from the digital model of climate data from 85 observation stations in the CR for the period between 1961 and 1990. In the course of its preparation, diversely modified cumulative series in the S-42 coordinate system with a small spatial unit for elaboration of 100x100 m converted into the S-JTSK coordinate system were used. The impact of morphometric characteristics, gradient, aspect, insolation, convexity and concavity of the spatial unit (Fig. 3) was also included. In the final stage of processing the database information from the climatic stations of the Czech Hydrometeorological Institute (CHI), the authors divided the territory of the CR into ten classes on the basis of the following characteristics (Tab. 3): Average number of days with air temperature of 10°C and higher, annual precipitation amount of over 580 mm and annual precipitation amount of maximum 580 mm with the precipitation-free period shorter than 22 days or longer than 22 days.

	T2	T4	MT2	MT3	MT4	MT5	MT7	MT9	MT10	MT11	CH4	CH6	CH7
1	50-60	60-70	20-30			30-40		40-50			0-20	10-30	
2	160-170	170-180	140-160	120-140	140-160						80-120	120-140	
3	100-110		110-130	130-160	110-130	130-140	110-130				160-180	140-160	
4	30-40		40-50					30-40			60-70		50-60
5	-2 - -3		-3 - -4		-2 - -3	-4 - -5	-2 - -3	-3 - -4	-2 - -3		-6 - -7	-4 - -5	-3 - -4
6	8-9	9-10	6-7				7-8				2-4		4-6
7	18-19	19-20	16-17					17-18			12-14	14-15	15-16
8	7-9	9-10	6-7				7-8				4-5	5-6	6-7
9	90-100	80-90	120-130	110-120		100-120				90-100	120-140	140-160	120-130
10	350-400	300-350	450-500	350-450			400-450			350-400	600-700		500-600
11	350-400	300-350	450-500	350-450			400-450			350-400	600-700		500-600
12	40-50		80-100	60-100	60-80	60-100	60-80		50-60		140-160	120-140	100-120
13	120-140	110-120	150-160	120-150	150-160	120-150					160-150	150-160	
14	40-50	50-60	40-50			50-60	120-150				30-40	40-50	

Tab. 2: Example of the delimitation of climate regions in the eastern part of the Czech Republic by E. Quitt from 1971

1 - summer days; 2 - temperature 10°C and more; 3 - frost days; 4 - ice days; 5 - average temperature in January; 6 - average temperature in July; 7 - average temperature in April; 8 - average temperature in October; 9 - days with the precipitation of 1 mm; 10 - precipitation in the growing period; 11 - precipitation in the winter period; 12 - days with snow cover; 13 - cloudy days; 14 - clear days

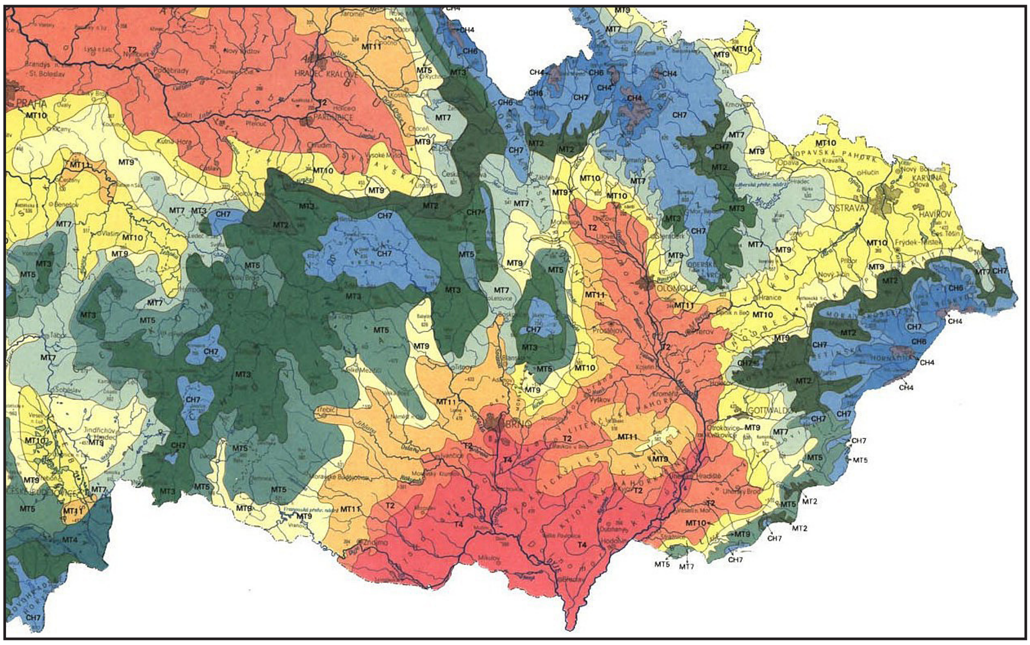

Fig. 2: Example of the delimitation of climate regions in the eastern part of the Czech Republic by E. Quitt from 1971.

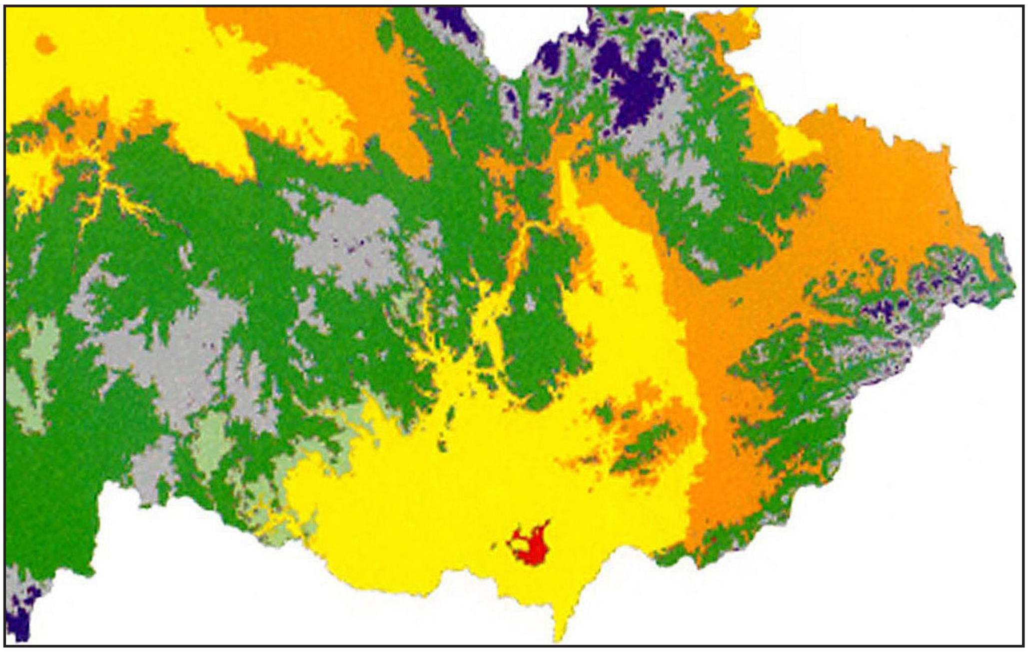

Fig. 3: Example of the delimitation of climate regions in the eastern part of the Czech Republic by D. Moravec and J. Votýpka from 1998

5. Climatic regionalization by E. Quitt from 2007

The publishing of the Climatic Atlas of the Czech Republic in 2007 opened up a possibility of utilizing this source of data for an attempt at delimiting the climate regions, which would be based on the monitoring between the years 1960 and 2000. Thus, a possible comparison suggested itself for the distribution of the principal types of climate regions based on the monitoring between 1900 and 1950 with the most recent data acquired in the period between 1960 and 2000. The division of the new atlas and the content of the individual maps however did not make possible a full use of completely identical method for the delimitation of climate regions as that employed during the regionalization in 1971. Some characteristics were therefore replaced by ones that were more suitable; mean January temperature was for example replaced by average temperature of winter months and mean April temperature was substituted by average temperature of spring months that were not available in the old atlas. Most importantly however, the technical preparation of the new atlas, in which individual intervals of climate

class	Average number of days with air temperature ≥10	Mean total annual precipitation >580 mm	Mean annual total precipitation <580 mm		Example of locality	colour
			Period without precipitation > 22 days	Period without precipitation < 22 days		
I	178 and more		10,282 ha		S. Moravia, Prague	red
II	160-177	1,141,895 ha			E. Bohemia, NE Moravia	orange
III			1,800,032		Elbe R. Basin, S. Moravia	yelow
IV				7,785 ha	E. Bohemia	blue
V	142-159	2,932,874 ha			S. Bohemia, NE Bohemia, Bohemian-Moravian Upland	dark green
VI			574,898 ha		W. Bohemia, S. Bohemia	light green
VII				41,356 ha	W. Bohemia,	dark grey
VIII	124-141	997,687			W. Bohemia, Bohemian-Moravian Upland	light grey
IX			3,433 ha		W. Bohemia	dark pink
X	Up to 123	387,621			mountanian locations	violet

Tab. 3: Excerpt from the legend to the map of climate regions by D. Moravec and J. Votýpka from 1998

characteristics are not demarcated by actual isolines, practically did not allow us to read the required values directly. The individual source maps were therefore transformed by means of a psychedelic filter conversion into utilizable form. Suitable choice of the psychedelic filter grade made it possible for us to choose applicable intervals of characteristics for regionalization from the atlas source maps.

Similarly to the previous regionalization and with some degree of simplification in mind, the length of the season according to the number of days with characteristic temperatures was selected as a crucial criterion for the definition of principal climate regions. This was the number of summer days for the summer period and conversely the number of ice days for the length of the winter period. This subsequently led to the definition of **5 principal climate regions**: very cold, cold, mildly warm, warm and very warm:

- **Very warm climate region** has a very long summer with over 50 summer days and a very short winter period of less than 40 ice days (Fig. 4).
- **Warm climate region** is characterized by a long summer with 40 to 50 summer days and a shorter winter with 40 to 50 ice days (Fig. 4).
- **Mildly warm climate region** has a long summer with 20 to 40 summer days on average and a mean length of winter of 50 to 60 ice days.
- **Cold climate region** is characterized by a short summer with the number of summer days lying between 10 and 20 and a long winter with 60 to 70 ice days (Fig. 5)
- **Very cold climate region** is characterized by a very short summer period with less than 10 summer days and a very long winter with more than 70 ice days (Fig. 5)

Another complementary data used to specify the individual regions was the mean temperature of the seasons. These data were however not decisive for the classification into a specific climate region. So for example, one such a complementary piece of information was the number of frost days characterizing the length of the transition period, which is accordingly:

- very long with over 180 frost days
- long with 160 to 180 frost days
- moderate (of medium length) with 140 to 160 frost days
- short with 100 to 140 frost days and
- very short with less than 100 frost days.

The principal climate regions were further classified according to summer/winter precipitation amounts. In this way subregions with low precipitation (below 200 mm in the summer) or with abundant precipitation (totalling over 600 mm in the summer half-year) were defined. By a synthesis of the data of thermal and precipitation characteristics, we obtained a rough demarcation of boundaries between the individual climate regions and subregions which was then further revised according to the hypsometry of the terrain (Figs. 7, 8).

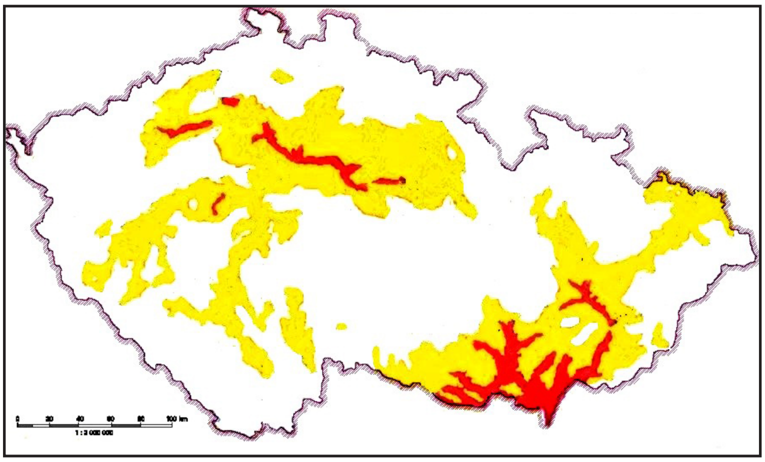

Fig. 4: Warm and very warm regions extracted by means of the psychedelic filter method from the map of "Average number of summer days" of the Climate Atlas of the Czech Republic

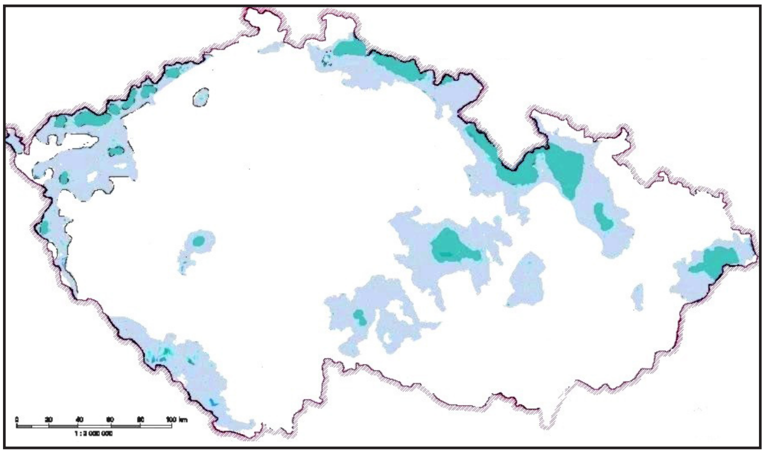

Fig. 5: Cold and very cold regions extracted by means of the psychedelic filter method from the map of "Average number of ice days" of the Climate Atlas of the Czech Republic

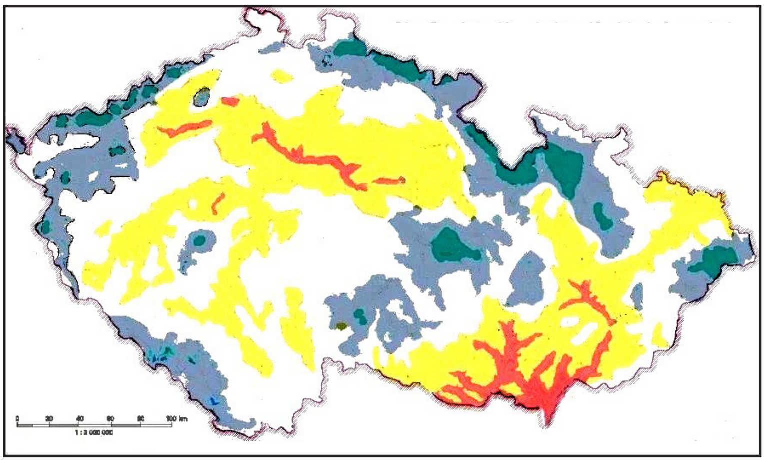

Fig. 6: Merging of the two preceding maps

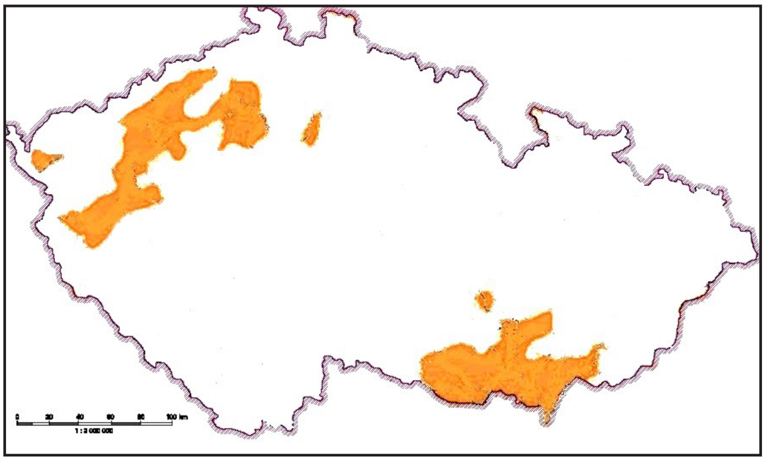

Fig. 8: Region with abundant precipitation extracted by means of the psychedelic filter method from the map of "Precipitation amounts" of the Climate Atlas of the Czech Republic

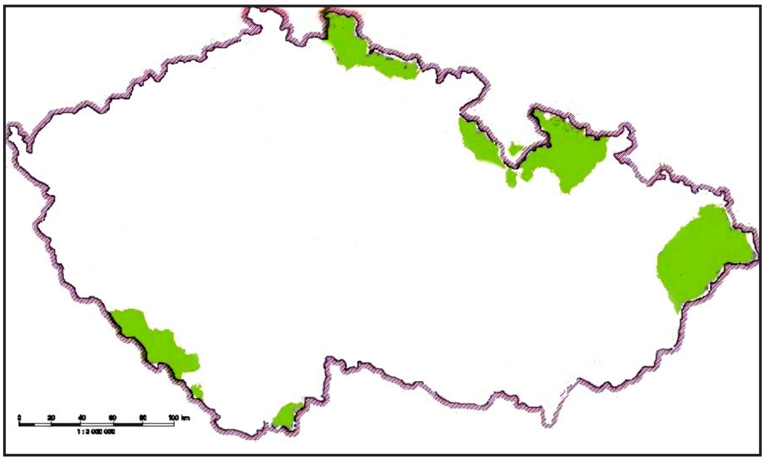

Fig. 8: Region with abundant precipitation extracted by means of the psychedelic filter method from the map of "Precipitation amounts" of the Climate Atlas of the Czech Republic

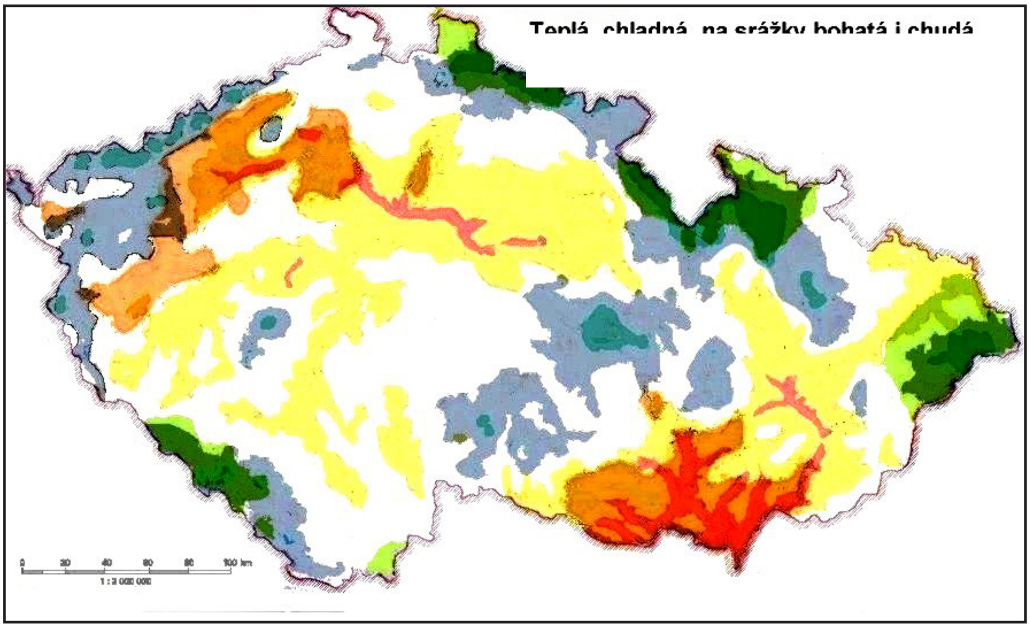

Fig. 9: Merging of all preceding maps (legend see Fig. 10)

Designation on the map	Climate region	Characterization
VCH	**Very cold**	Very short **summer** with less than 10 summer days, very cold with a mean temperature below 12°C, very moist with precipitation within the range of 300-400 mm and more than 140 days with precipitation over 1 mm. Very long **transition period** with more than 180 frost days, very cold spring with a mean temperature below 3°C and cold autumn with a mean temperature of less than 4°C. Very long **winter** with over 70 ice days, very cold with an average temperature of less than -4°C, abundant precipitation from 300 to 400 mm and a long duration of the snow cover of over 120 days.
VCHD	**Very cold with abundant precipitation**	Very short **summer** with less than 10 summer days, very cold with an average temperature below 12°C, very moist with precipitation of over 400 mm and more than 140 days with precipitation over 1 mm. Very long **transition period** with more than 180 frost days, very cold spring characterized by a mean temperature of below 3°C and a cold autumn with a mean temperature below 4°C. Very long **winter** with more than 70 ice days, very cold with an average temperature below -4°C, abundant precipitation of over 400 mm and a long duration of the snow cover of over 120 days
CH	**Cold**	Short **summer** with 10-20 summer days, cold characterized by an average temperature of 12-13°C, moist with precipitation within the range of 200-400 mm and more than 140 days with precipitation of more than 1 mm. Very long **transition period** with more than 180 frost days, very cold spring and an average temperature below 3°C and cold autumn with a mean temperature of less than 4°C. Very long **winter** with more than 70 ice days, very cold characterized by an average temperature below -4°C, precipitation within the range of 200-400 mm and a long duration of the snow cover from 80 to 120 days
CHS	**Cold with low precipitation**	Short **summer** with 10-20summer days, cold characterized by an average temperature of 12-13°C, drier with precipitation below 200 mm and less than 140 days with precipitation over 1 mm. Very long **transition period** with more than 180 frost days, very cold spring characterized by a mean temperature of less than 3°C and cold autumn with an average temperature below 4°C. Very long **winter** with more than 70 ice days, very cold with a mean temperature below -4°C, precipitation of less than 200 mm and a long duration of the snow cover of 80-120 days
CHD	**Cold with abundant precipitation**	Short **summer** with 10-20 summer days, cold with an average temperature of 12-13°C, very humid with precipitation over 400 mm and more than 140 days with precipitation above 1 mm. Long **transition period** with 160-180 frost days, cold spring characterized by a mean temperature of 3-5°C and cold autumn with an average temperature of 4-6°C. Long **winter** with 60-70 ice days, cold with an average temperature of -3 to -4°C, abundant precipitation of over 400 mm and a long duration of the snow cover between 80-120 days,
MT	**Mildly warm**	Moderate **summer** with 20-40 summer days, mildly warm with a mean temperature of 13-15°C, moderately humid with precipitation within the range of 200-400 mm and 100-140 days with precipitation over 1 mm. Moderately long **transition period** with 140-160 frost days, cold spring with an average temperature of 5-7°C and a mildly warm autumn characterized by s mean temperature of 6-8°C. **Winter** of ordinary duration with 50-60 ice days, mildly cold with an average temperature between -2 and -3°C, moderate precipitation of 200-400 mm and a moderate duration of the snow cover of 50-80 days,
MTS	**Mildly warm with low precipitation**	**Summer** of ordinary duration with 20-40 summer days, mildly warm with an average temperature between 13-15°C, dry with precipitation below 200 mm and less than 100 days with precipitation of over 1 mm. Moderately long **transition period** with 140-160 frost days, cold spring characterized by a mean temperature between 5-7°C and a mildly warm autumn with an average temperature between 6-8°C. **Winter** of normal duration with 50-60 ice days, mildly cold with a mean temperature falling within the interval of -2 and -3°C, precipitation below 200 mm and a rather shorter duration of the snow cover of 50-60 days,

MTD	**Mildly warm with abundant precipitation**	**Summer** of ordinary duration with 20-40 summer days, mildly warm with an average temperature between 13-15^{o}C, humid with precipitation above 400 mm and frequently with over 140 days with precipitation higher than 1 mm. Moderately long **transition period** with 140-160 frost days, cold spring and a mean temperature between 5-7^{0}C and a mildly warm autumn with an average temperature of 6-8^{0}C. **Winter** of normal duration with 50-60 ice days, mildly cold with an average temperature between -2 to -3^{0}C, higher precipitation of over 400 mm and a rather shorter duration of the snow cover between 50-60 days,
T	**Warm**	Long **summer** with 40-50 summer days, warm with a mean temperature within the range of 15-16^{o}C, moderately humid with precipitation between 200-400 mm and 100-140 days with precipitation of more than 1 mm. Short **transition period** with 100-140 frost days, mildly warm spring characterized by an average temperature of 7-8^{0}C and warm autumn with an average temperature between 8-9^{0}C. **Winter** of normal duration with 50-60 ice days, mildly cold with mean temperature between -2 and -3^{0}C, more abundant precipitation of over 400 mm and a rather shorter duration of the snow cover of between 50-60 days,
TS	**Warm with low precipitation**	Long **summer** with 40-50 summer days, warm with a mean temperature between 15-16^{o}C, dry with the precipitation amount below 200 mm and less than 100 days with precipitation of more than 1 mm. Short **transition period** with 100-140 frost days, mildly warm spring with average temperature of 7-8^{0}C and warm autumn with a mean temperature between 8-9^{0}C. **Winter** is shorter with 40-50 ice days, mildly warm with a mean temperature from 0 to -2^{0}C, dry with low precipitation and precipitation amount between 200-400 mm and a rather shorter duration of the snow cover of between 50-60 days,
TD	**Warm with abundant precipitation**	Long **summer** with 40-50 summer days, warm with a mean temperature between 15-16^{o}C, more humid with a precipitation amount around 400 mm and more than 140 days with precipitation of over 1 mm. Short **transition period** with 100-140 frost days, mildly warm spring with a mean temperature between 7-8^{0}C and warm autumn with an average temperature of 8-9^{0}C. **Winter** is shorter with 40-50 ice days, mildly warm with average temperature between 0 and -2^{0}C, higher precipitation amount of more than 400 mm and a shorter duration of the snow cover of roughly 80 days,
VT	**Very warm**	Very long **summer** with more than 50 summer days, very warm with an average temperature of over 16^{o}C, moderately humid with a precipitation amount around 400 mm and less than 100 days with precipitation above 1 mm. Very short **transition period** with less than 100 frost days, warm spring with an average temperature of above 8^{0}C and warm autumn with an average temperature higher than 9^{0}C. **Winter** is very short with fewer than 40 ice days, warm with mean temperature higher than 0^{0}C, average precipitation amounts within the range of 200-400 mm and a short duration of the snow cover of less than 50 days,
VTS	**Very warm with low precipitation**	Very long **summer** with over 50 summer days, very warm with an average temperature of over 16^{o}C, very dry with precipitation amount lower than 200 mm and less than 100 days with precipitation of more than 1 mm. Very short **transition period** with less than 100 frost days, warm spring with an average temperature of over 8^{0}C and warm autumn with a mean temperature higher than 9^{0}C. **Winter** is very short with less than 40 ice days, warm with an average temperature higher than 0^{0}C, dry with an average precipitation amount below 200 mm and a short duration of the snow cover of less than 50 days.

Fig. 10: Legend to the map of Climate Regions of the Czech Republic (2007).

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HISTORICAL PATHWAYS IN GEOGRAPHIC AND ARCHAEOLOGICAL STUDIES

Radan KVĚT

Workshops of this name have been held in Brno since 2006. The group of devoted stibologists (stibology is a discipline studying historical pathways) met in the afternoon of 14 March already for the fourth time. The Workshop was held under the auspices of the South-Moravian Branch of Czech Geographic Society.

The Workshop agenda included issues of the historical routes of individual pathways, evidence of their existence, geographic, archaeological and local conditions for their development, use of aerial photographs for the backtracking of their routes in rural landscape and some linguistic problems. Friendly discussion following each presentation provided a possibility for the participants to be active and to gain relevant information. The gradually developing discipline of stibology offers completely novel views in the field of prehistorical research, which covers themes such as a pattern of pathways, their documentation and links of stibology to other scientific disciplines – namely archaeology, but also to religionistics, residential or transport geography as well as to ecology and biogeography. Close links exist also to the views of landscape ecology, architecture or linguistics. Key role is played by the interpretation of geomorphological and hydrological networks. All this has to be taken into account in the chronological framework reaching from the Neolithic to the Middle Ages.

The methodological base may vary; nevertheless, most important for the delineation of historical pathways are natural conditions and documentation by archaeological tools. Thus, with its knowledge of communication links, stibology covers a period that stands in general outside the interest, a period with transport on foot, on horseback or – later – on carriages. Not only in our country but also in abroad, ancient communication links are investigated namely from the Roman times. In central Europe, this particularly concerns Austria and Germany where abundant findings documenting the Roman settlement still occur.

At the time of globalization and development of information society, transport acquires a new significance, being among other things understood as a fast, immediate connection by means of electromagnetic waves. In spite of this, it should be borne in mind that the old pathways played a role of information network at a certain stage of humankind development. Their primary function, i.e. a reliable transport connection over hundred or thousand kilometres has remained the same for centuries, though. The only difference consists in the length of transport, which corresponds to technical possibilities of the era.

Regarding the presently increasing interest in the history of socio-cultural relations, we can expect an increasing interest in studying the first communication grid (i.e. patterns of historical pathways) in the landscape. To learn this communication pattern, it is necessary to develop further the knowledge of landscape and people living in it.

The next workshop will be held in March 2009 and detailed information is available on the e-mail address: kallabova@geonika.cz.

INSTRUCTIONS FOR AUTHORS

Moravian Geographical Reports publishes the following types of papers:

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All scientific papers are subject to a peer review process, with two anonymous independent reviewers (one of whom preferably would be from outside the Czech Republic) appointed by the Editorial Board. The criteria for the review process include the following: an evaluation of the topicality and originality of the research problem; level of theoretical and methodological understanding of the problem; the methods used; the relevance of sources and references to the literature; and contribution to the development of the scientific area under study.

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Scientific announcements present information about scientific conferences, events and international cooperation, about journals with geographical and related issues, and about the activities of geographical and related scientific workplaces. The scientific announcements preferably will be published with colour photographs. Contributions to jubilees or obituaries of prominent scientific personalities are supplied exclusively by request from the Editorial Board. The maximum text length of a scientific announcement is 5 thousand characters.

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Figs. 10a, b: Botanical Garden and Arboretum in Štramberk (Photo: I. Smolová, 2007)

Illustrations related to the paper by Irena Smolová

Fig. 9a: Extraction of gravel sands and sands (Vernéřovice) in the Broumovsko PLA

Fig. 9b: Extraction of building stone (Rožmitál, Javoří hory Mts.) in the Broumovsko PLA (Photo: I. Smolová, 2007)

Illustrations related to the paper by Irena Smolová