MINING SUBSIDENCE IN OŚWIĘCIM BASIN (CARPATHIAN FOREDEEP)

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The aim of research presented in the paper was to establish whether it would be possible to conclude from an analysis of topographic maps at a large scale about relief changes occuring during a short time period between ten or several dozen years. Contemporary, large relief changes during such a short period occur among other things in areas of underground mining in Oświęcim Basin, where intensive extraction of hard coal is carried out by method of roof falling. During several dozen years, mining subsidence caused such significant changes in the relief, that they have been visible in the counter drawing of topographic maps dating from different periods. The research carried out proves that making of hypsographic curves and morphological profiles for areas of mining subsidence has its own grounds because they, in a measurable way, allow us to prove the human impact on the relief.

Key words: mining subsidence, morphometric analyses, Oświęcim Basin

INTRODUCTION

In the Carpathian Foredeep, there occurs a considerable amount of natural resources which were formed in the Miocene, including salt, gypsum, sulphur, oil and gas. In the substratum of the western part of the foredeep, i. e. within Oświęcim Basin, there appear also very large resources of the Carboniferous hard coal. These have been extracted since the 19th century, usually from considerable depth, from under the Miocene and Quaternary overburden. Intensive mining, especially in the late 20th century resulted in anthropogenic transformation of the relief into the form of waste rock heaps and continuous and non-continuous deformations of the surface.

In the following article, the possibilities of research into geomorphological effects of mining subsidence in Oświęcim Basin with the use of cartographic materials dating from different periods have been presented. A topographic map is an important tool in geomorphological research because it enables an objective analysis of different morphometric features of the relief (RICHLING 1973, BARTKOWSKI 1974, ŻYNDA 1976). Within the last few years, growing interest in cartographic research methods can be observed, which is connected, among other things, with the possibilities created by systems of geographical information (GIS). It is so because results of morphometric analyses can well supplement traditional field methods and in many cases they clearly orient them. The aim of research presented in the following paper was to establish whether it would be possible to conclude from an analysis of accurate topographic maps at a large scale about relief changes occuring during a short time period between ten or several dozen years. In our times, large relief changes during such a short period occur among other things in areas of underground mining in Oświęcim Basin, where intensive extraction of hard coal is carried out by method of roof falling.

THE STUDY AREA

Oświęcim Basin is located entirely within the Carpathian Foredeep. To the north it is bordered by the tectonic edge of the Silesian Upland, and to the south by escarpment of the Carpathian Foothills, being in line with the flysch overthrust (**Fig. 1**). In Carpathian Foredeep lie Miocene clays of up to several hundred metres in thickness and Quaternary deposits of thickness from several to tens of metres (clays, sands, gravels, loess) (KAZIUK and LEWANDOWSKI 1980). Deeper substratum is built of carboniferous rock. Locally, horst hummocks elevate over the surface of the Quaternary covering. They are built of Carboniferous sandstones, shales and coal with „caprock" of the Triassic limestones, dolomites and marls.

The relief of Oświęcim Basin is diversified, and hence, several distinctive geomorphologi-

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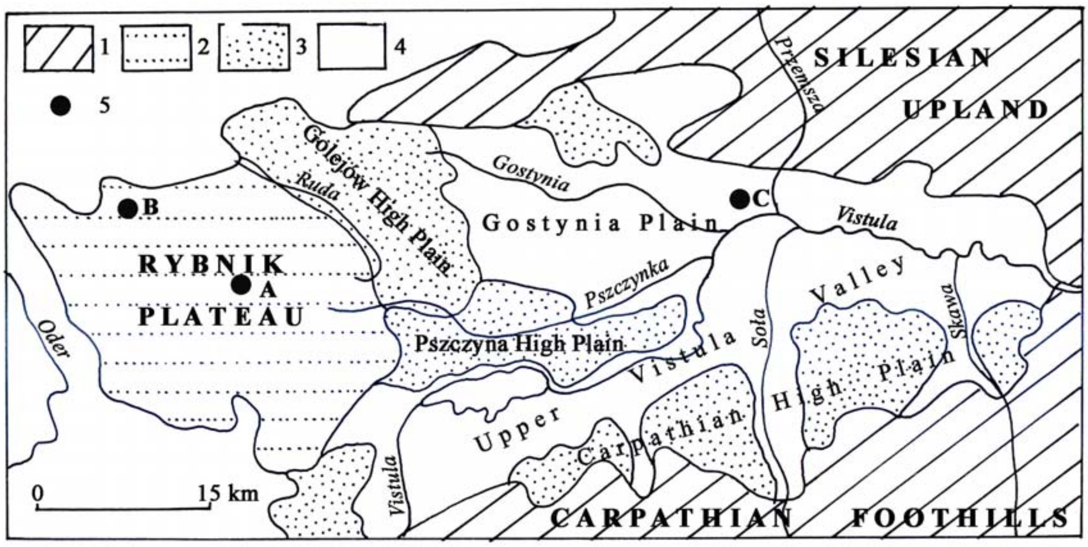

Fig. 1 Location of the investigation sites in Oświęcim Basin
1 – uplands and foothills, 2 – plateaus, 3 - high plains, 4 – sandy plains, 5 – investigated sites

cal units can be observed in this area. The highest part of it, elevated up to 310 m a.s.l. and strongly divided by valleys, is Rybnik Plateau (**Fig. 1**) which closes the basin to the west. Towards the north-east, hilly Golejów High Plain is located, and towards the east – wavy Pszczyna High Plain of hilltop situated at the height of 260-275 m a.s.l. Relief of similar character is typical of the Carpathian High Plains (280-300 m a.s.l.) located to the south. They are covered with a relatively thick loess cover. Northern and eastern parts of the basin are occupied by the Upper Vistula Valley with Gostynia Plain. Within it, two sandy levels can be distinguished (260-270 and 240-245 m a. s. l.) connected with sand fans accumulated during the Oder glaciation. Towards the east, they turn into the Vistula terraces (KLIMEK and STARKEL 1972).

RESULTS

The beginnings of hard coal mining in Oświęcim Basin date back to 1792. In the 19th century, extraction was carried out on a relatively small scale in places of the least thickness of carbon oberburden and therefore, it did not cause any relevant changes in the relief. Essential development of mining took place in the 20th century, and foremost in its latter half, when more than half of the mines in Oświęcim Basin were opened (11 out of 20, **Fig. 2**). Although it is the youngest mining area in the Upper Silesian Coal Basin (USCB), it is characterized by a large coal extraction; annual extraction in „Ziemowit" and „Piast" coal mines currently exceeds 4 mill. tons, which gives them the top position in the entire USCB. During the past 215 years, 2.3 billion tons of coal (LUK-SA 1959, STATYSTYKA PRZEMYSŁU WĘGLOWEGO 1945-2006) were extracted in Oświęcim Basin, 63 % of which on Rybnik Plateau, approximately 30 % in the Upper Vistula Valley, and 7 % on Golejów, Pszczyna, and Carpathian High Plains. The largest amount was extracted in „Ziemowit" coal mine (**Fig. 2**), i. e. 278 mill. tons during the 60 years of its activity, which comprises 12 % of the entire amount extracted in Oświęcim Basin.

Extraction was mainly carried out by method of roof falling, which led to intensive subsidence, and thus, in places, the surface was lowered by even more than 25 m. The range of subsidence is diversified—the largest subsidence appears in the eastern part of Rybnik Plateau (**Fig. 3**) and in the northern and middle part of the Upper Vistula Valley. Morphological effects of the subsidence are changes in relative heights, length, gradient, and shape of slopes, and longitudinal profiles of valleys. Moreover, non-drainage subsidence basins were formed in many locations. These tranformations appear in a short period of time (several to several dozen years) and so they influence the course of geomorphological processes.

The possibility of research into relief transformation in area of mining subsidence carried

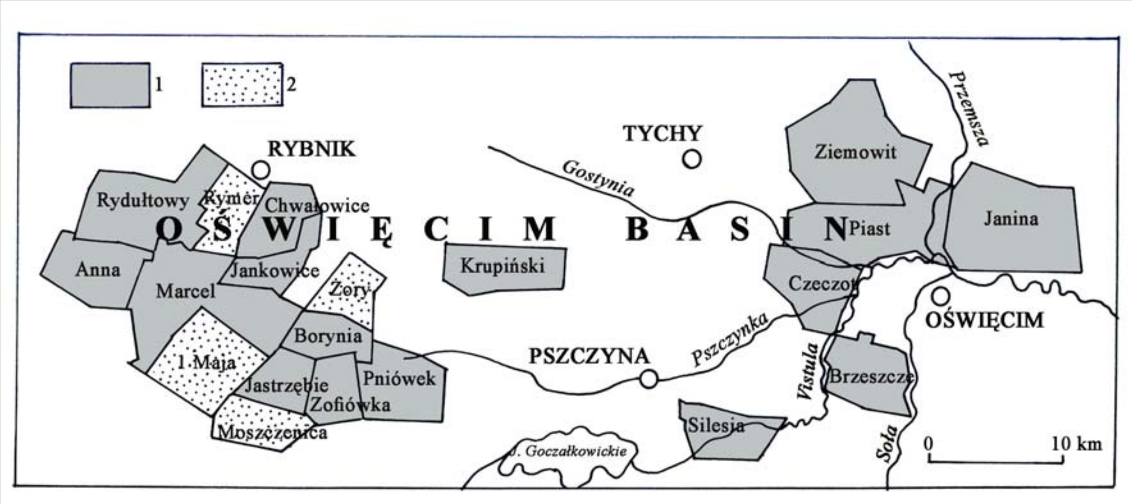

Fig. 2 Location of the hard coal mines in Oświęcim Basin
1 – active mines, 2 – closed mines

out on the basis of hypsographic curves has been shown on the example of the tributary of the Radziejowski Stream catchment on Rybnik Plateau (**Fig. 1, A**). The cartometric analysis was carried out on the basis of a topographic maps at a the scale of 1:10 000 for two time cuts – 1974 and 1993 (MAPA TOPOGRAFICZNA 1974, 1993). After determining the catchment border, the measuring of areas within particular hypsometric zones in height intervals per 5 m was made. Then hypsographic curves for both years were drawn, and mean terrain height as well as the coefficient of rocky mass volume were calculated (STRAHLER 1952).

The area of the catchment in the study comprises nearly 0,9 km^2. It is located in south-western part of the mine field of „Chwałowice" mine (**Fig. 2**), where hard coal has been extracted since 1907. At the beginning of the 1980s, the subsidence of the catchment ex-

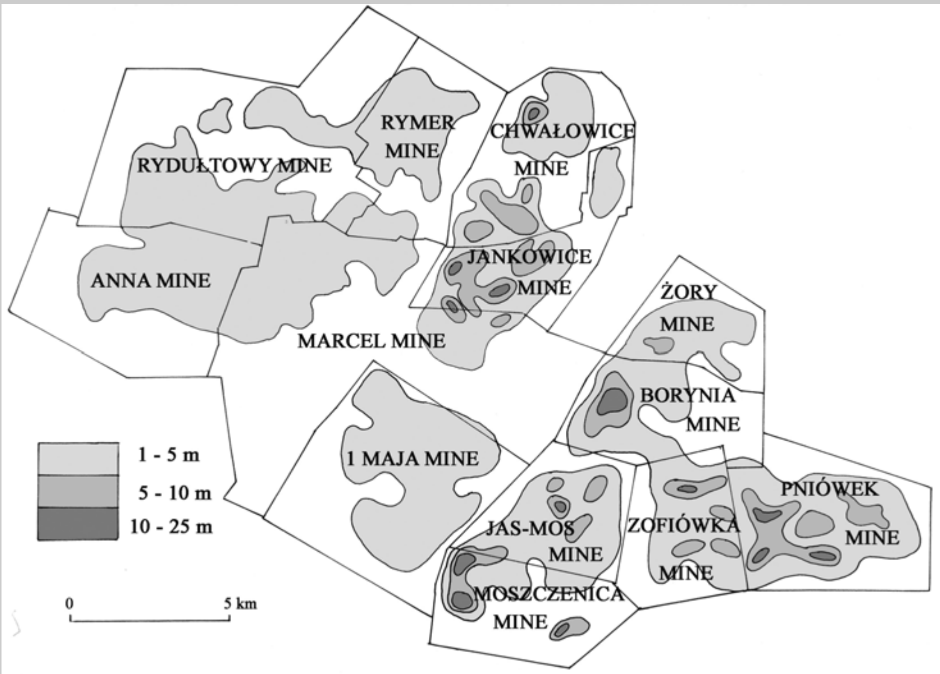

Fig. 3 Isolines of mining subsidences in Rybnik Plateau (after JANKOWSKI 1986, supplemented)

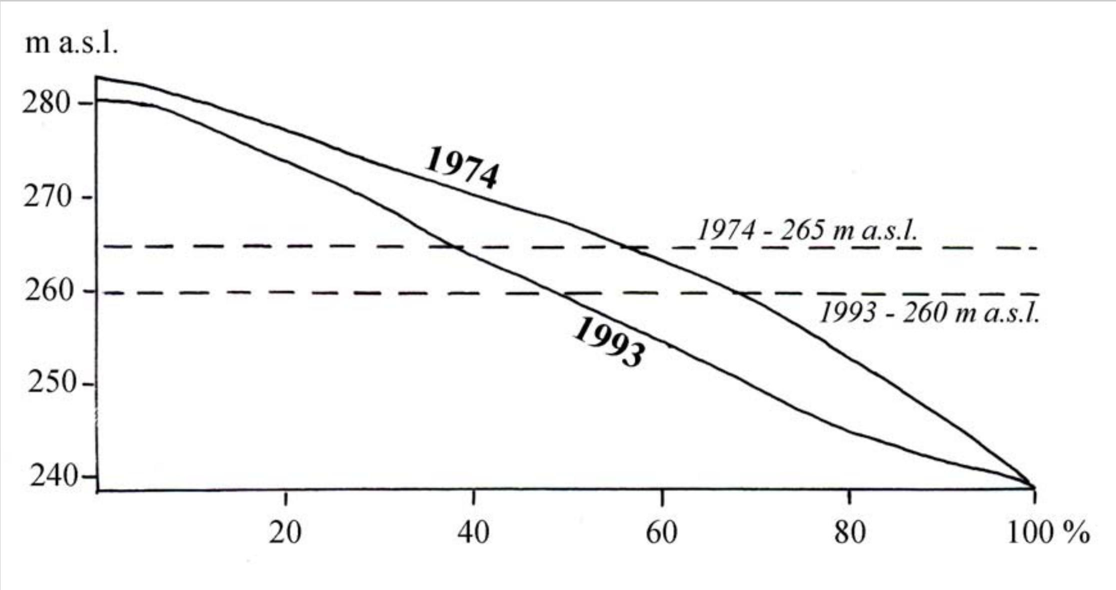

Fig. 4 Hypsographic curves for catchment of tributary of the Radziejowski Stream for 1974 and 1993

ceeded 12 m (MAPA PRZEOBRAŻEŃ 1982). Thus, a topographic map dating from 1974 presents the already changed relief owing to almost 70-years lasting extraction of hard coal. The analysis of height relations revealed that in 1974, 56,2 % of the area rose up to the height above 265 m a.s.l., whereas 20 years later, only 37,6 % belonged to this hypsometric range. On the other hand, areas located below 255 m a.s.l. occupied respectively 32,9 and 52,1 %. Changes in height relations are well reflected by hypsographic curves (**Fig. 4**). The curve for 1974 can be divided into two sections, namely the upper section - almost straight and moderately inclined, and the lower one - similarly inclined but gently convex. In the course of the curve for 1993, three sections are outlined: the upper - balanced, the middle almost straight and the lower one - slightly concave the last two moderately inclined. Average area height in 1974 reached 265 m a.s.l., and in 1993 - 260 m a.s.l., i.e. during 20 years it lowered by 5 m. This means that the rate of subsiding amounted on average to 290 mm/year. The coefficient of rocky mass volume also changed in time - from 58,9 % in 1974 to 50,6 % in 1993. Curve shapes as well as the coefficient of rocky mass volume calculated seem to point to the transition of the catchment area from the stage of youth into the stage of maturity.

The above-presented results can be compared with data gathered for the neighbourhood of Szeroka ("Borynia" mine, **Fig. 2**) in Rybnik Plateau obtained from Flak (oral information). On the basis of hypsographic curves, this author calculated that during the years 1984-1997 mean height of this area decreased by 1 m, i.e. the subsiding rate amounted to about 77 mm/year. The coefficient of rocky mass volume was high, but during 13 years it decreased from 77 (1984) to 74 % (1997). Similar results were obtained by DULIAS (2006a) for a small catchment in the area of nearby "Zofiówka" coal mine (**Fig. 2**). During the years 1974-1993, this terrain lowered by 84 mm/year on average. Mean terrain height decreased by 1.6 m, but the coefficient of rocky mass volume changed to a relatively small extent - from 69,1 % to 68 %.

The use of topographic maps dating from different periods for making the longitudinal pofiles of valleys in areas of mining subsidence has been shown on the example of the Rydułtowski Stream (**Fig. 1, B**). The valley is situated in the area of „Rydułtowy" coal mine – the oldest coal mine in Oświęcim Basin (**Fig. 2**). In the 19th and the first half of the 20th century, the valley was dry, which is confirmed by archival topographic maps (TOPOGRAPHISCHE KARTE 1881, MAPA TOPOGRAFICZNA 1933, 1960). In the 1960s, as a result of mining subsidence the valley lowered by about 5-6 m, whereas in the upper part of the watershed, arose a sinkhole over an old, shallow underground working. The sinkhole filled in with water, which, flowing out of the pond, gave rise to the contemporary Rydułtowski Stream – 1.42 km long. During

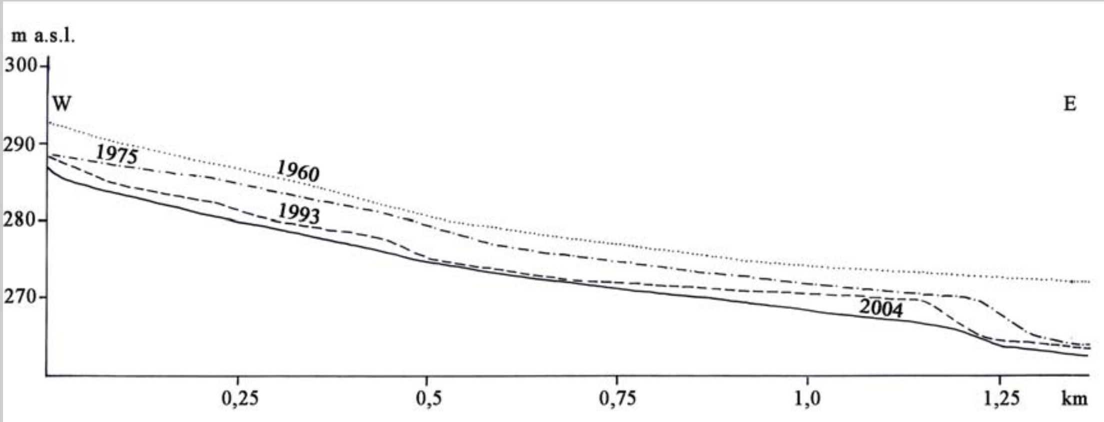

Fig. 5 Impact of mining subsidence on the change of longitudinal profile of the Rydułtowski Stream valley in 1960-2004 years

the following 50 years, the valley was lowering quite evenly on its entire length, except for its lower part (MATUSZEK 2002, **Fig. 5**). In the 1970s, a distinctive treshold appeared, which persisted until 1990s, simultaneously going back by about 50 m at the same time. During several ensuing years, the breaks in longitudinal profile were levelled, and at present, the longitudinal profile is evened out and similar in shape to the one from the 1960s. (MAPA TOPOGRAFICZNA 1974, 1993, MAPA SYTUACYJNO-WYSOKOŚCIOWA 2004).

Similar changes in longitudinal profiles were also revealed in other valleys of Oświęcim Basin, for instance Szotkówka, Marklówka, Mszanka, Potok od Brychawca, Kolejówka, Nacyna, Dębinka or Potok od Gogołowej (JANKOWSKI 1986, MADOWICZ 2001, MATUSZEK 2002, DULIAS 2006b, 2008). In different places, deformations brought about by extraction may affect either the whole valley or just its different sections. When a significant subsidence takes place in the upper section of the valley, it may occasionally turn into a non-

Fig. 6 Anthropogenic embankments along the Goławiecki Stream (Upper Vistula Valley). Photo: R. Dulias

drainage basin, and then, the valley gets shortened and its area diminishes. If the middle or lower section subsides, the river overflows its banks. Due to mining subsidence, some dry valleys gain permanent watercourses as a consequence of the subsiding ground cutting through the first water-table.

Nevertheless, not all areas affected by mining subsidence may be studied with the use of morphometric analysis on the basis of topographical maps dating from different periods. It has been shown on the example of the Goławiecki Stream valley situated within the mining area of „Ziemowit" and „Piast" mines (**Fig. 1, C, Fig. 2**) in the Upper Vistula Valley. During the pre-mining period, the stream had cut the almost flat valley to a depth of only several dozen centimetres. Due to mining, the valley was undergoing continuous deformations of surface, which caused the floodings along its course. Hence, the need arose to build embankments which required regular banking up along with continual subsidence. At present, on both sides of the water channel lie several dozen metre wide „anthropogenic terraces" built of mining waste (**Fig. 6**); their thickness reaches 5-8 m. At 2 to 5 metres below these artificial flattenings occurs a narrow bed, which, on its entire length, has lost its natural character. Anthropogenic embankments levelled the morphological effects of subsidence, and therefore, longitudinal profiles of the valley prepared with the use of maps dating from the pre-mining and mining periods have only depicted the lowering of the water bed, while the longitudinal profile was subject to a large error. Similar results were obtained for several other valleys, where subsiding bottoms were being raised with anthropogenic embankments. This has been a common practice on plain areas of the eastern part of Oświęcim Basin.

CONCLUSION

About 1/5 of the area of Oświęcim Basin lies within the range of mining industry. The biggest subsidence is observed on the relief of Rybnik Plateau and the middle and northern parts of the plain Upper Vistula River Valley. During several dozen years, mining subsidence caused such significant changes in the relief, that they have been visible in the counter drawing of topographic maps prepared at a large scale in the 20th century. The research carried out proves that making of hypsographic curves and morphological profiles for areas of mining subsidence has its own grounds because they, in a measurable way, allow us to prove the human impact on the relief. In areas, where terrain subsiding proceeds in a very intensive way, the hypsographic curve changes its shape even in a short time period of a dozen years. From the methodological point of view, the most reliable will be the curves drawn on the basis of topographic maps at a scale of 1:10 000 for the counter interval not larger than 5 m. The use of cartographic materials for the purpose of morphometric analyses is restricted only in case of the areas, where subsidence basins are filled up with mining waste.

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