THE AERIAL PHOTOS TO DETECT CHANGES IN THE LANDSCAPE AFFECTED BY BLACK COAL DEEP MINING

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ABSTRACT:

Aerial photos are the suitable data source for monitoring landscape changes. The black coal deep mining shows specific way in the landscape. During the coal extraction there is an anthropogenic transformation of surface. The anthropogenic forms of relief rise: waste banks, tailings ponds, handling areas, etc. A large influence on the relief changes has also undermining, which the images show in particular the emergence of the submerged ground subsidences and decrease buildings. As a result, there is a significant change in the land cover of the area.
The study deals with the symptoms of the black coal deep mining on the aerial photos. Changes in the landscape due to underground black coal mining are presented on the example of the central part of the Ostrava-Karviná Mining District (Czech Republic). As the data sources were used archival black and white aerial photos and contemporary color aerial photos from the period from the year 1947 to the year 2003.

1. INTRODUCTION

In the second half of the 19th century the Ostrava and Karviná regions became fast growing industrialized areas for beds of quality hard coal that had been discovered in the territory. One-time agricultural regions gradually change into industrial areas with dominant mining, metallurgic and chemical industries. All these activities, headed by hard coal mining, transform the landscape of the Ostrava and Karviná regions significantly.
The displays of hard coal deep mining in landscape involve the occurrence of anthropogenic landforms directly related to mining activities as well as land cover changes that are related to mining indirectly. A majority of these changes can be interpreted on the basis of aerial photos and their development analysed using multitemporal data.
Central parts of the Ostrava-Karviná Mining District (Karviná-Doly I, Karviná-Doly II and Darkov Allotments) have been chosen for aerial photo presentation of deep mining displays. The Ostrava-Karviná Mining District (OKMD) occupies approximately 50% of the Karviná region situated in the Moravskoslezský Region, in the north-east of the Czech Republic (Figure 1). Northern and eastern border of the Karviná region is the state border with Poland. The OKMD, where coal-bearing layers of the Carboniferous age are found (OKD, 2010), represents the southern part of the Upper Silesian Coal Basin whose major part lies in the territory of the neighbouring Poland (its area is 7000 km^2, 1500 km^2 of which in the territory of the Czech Republic). Hard coal deep mining has been taking place in the district since 1850s. The OKMD is divided into 3 parts: Ostrava, Karviná and Southern part. The Karviná District belongs to areas with ongoing hard coal deep mining.

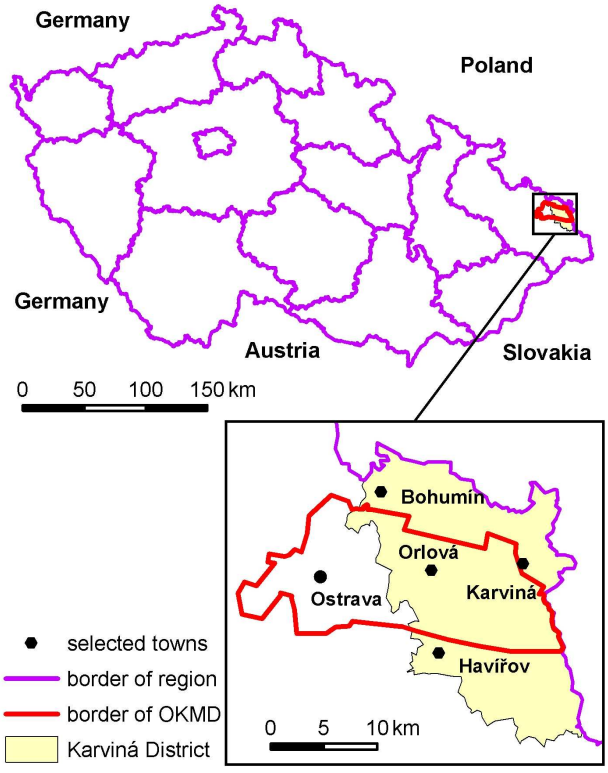


Figure 1. Localization of the Ostrava-Karviná Mining District (OKMD) and the Karviná region within the Czech Republic

Aerial photos represent a significant data source of ongoing landscape transformation with regard to relatively high dynamics of anthropogenically conditioned landscape changes in hard coal deep mining areas. The study of quality photos of mining displays in the landscape is based on the principles of

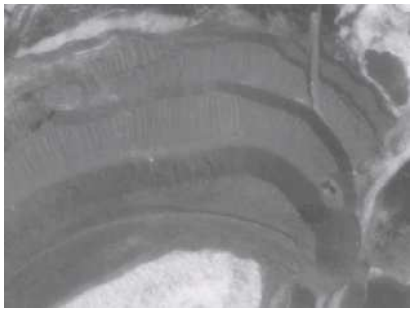
visual photointerpretation whose aim is to identify individual objects and assess their importance (Philipson, 1997, McGlone, 2004 in Jensen, 2006). Aerial photo interpretation starts from visual perception related to objects of the outer world Ciolkosz, Miszalski, Oledzki, 1999).
The displays of deep coal mining in the landscape were detected using contact copies of archive black-and-white aerial photos from the period of 1947 to 1995 (provided by the Military Geography and Hydrometeorology Office in Dobruška) and a coloured orthophoto from 2003 (map service of the Portal of the Public Administration of the Czech Republic).
The surface consequences of hard coal deep mining are characterized by the occurrence of anthropogenic landforms directly related to mining (waste banks, submerged ground subsidences, tailings ponds, manipulation areas etc.). Secondary subsurface coal mining leads to the process of abandonment (e.g. the transformation of continuous urban fabric into green urban areas), the occurrence of reclamation areas aimed to deal with the consequences of mining activity, or the construction of communications.

2. DISPLAYS OF HARD COAL DEEP MINING

2.1 Primary displays

Hard coal deep mining is primarily manifested by anthropogenic landforms directly related to mining activity. These include post-mining landforms (waste banks, ground subsidences) and industrial landforms (tailings ponds, manipulation areas).

2.1.1 Waste banks: Waste banks represent convex landforms whose area can reach from a few areas to tens of hectares (Havrlant 1980). They originate as a result of the deposition of extracted coal waste. The OKMD area includes the following types of waste banks (Havrlant 1980): cone-shaped waste banks, waste piles, plate-shaped waste banks, terrace-like waste banks, flat waste piles or their combinations. Active waste banks in the photos represent vegetation-free surfaces with clearly visible contours (Figure 2). They are generally found in the proximity of mine buildings.


a

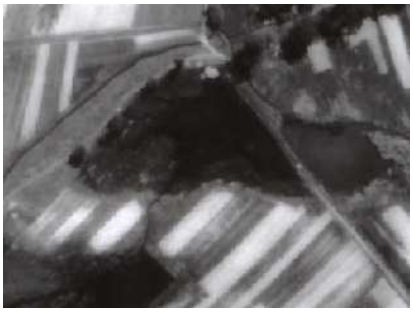

b

Figure 2. Waste banks in (a) an aerial photo from 1947 (© MO ČR/GeoSI AČR) and (b) an aerial photo from 2003

Waste banks are reclaimed after waste piling is terminated (Figure 3).

Figure 3. The part of reclaimed waste bank in 2003

2.1.2 Ground subsidences: Ground subsidences originate as a result of the surface subsidence above the mined-out space (Demek, 1988). It concerns flat subsidences whose size depends on geological conditions, tectonics and the area and thickness of coal-seams (Havrlant, 1980). The subsidences can be filled with water. Submerged ground subsidences are displays of unfavourable disturbance of the regime of surface and subsurface waters the level of which has infiltrated above the bottom of subsided terrain (Zapletal, 1969).
The occurrence of ground subsidences is therefore a primary display of mining activity. Aerial photos help to interpret particularly submerged ground subsidences that represent a secondary display of undermining and that, to a large extent, take part in the process of submerging. Unlike other water surfaces they usually have an irregular broken shape (Figure 4). Submerged ground subsidences positively affect ecological value of landscape as they increase species diversity of the territory. Their banks are occupied by wetland plant species, rare invertebrates (e.g. specially protected dragonflies, crayfishes, shells) and other important animal species.


a

b

Figure 4. Submerged ground subsidences (a) in an aerial photo from 1947 (© MO ČR/GeoSI AČR) and (b) in an aerial photo from 2003

2.1.3 Tailings ponds: Hard coal deep mining area involves also a few types of ponds: flotation tailing ponds, coal ash ponds, coal sludge ponds and final sedimentation ponds. It particularly concerns water surfaces of a regular, often geometric, shape in the proximity of mine buildings (Figure 5).

a

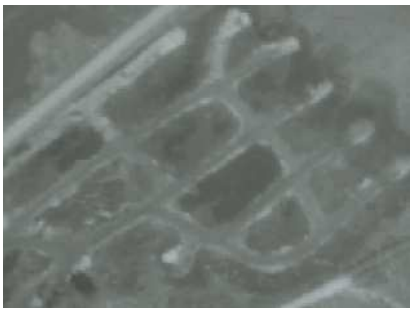
b

Figure 5. Tailings ponds in (a) an aerial photo from 1947 (© MO ČR/GeoSI AČR) and (b) an aerial photo from 2003

Final sedimentation ponds can have a character of natural water surfaces, which makes their interpretation in aerial photos difficult (Figure 6).

Figure 6. Final sedimentation pond in an aerial photo from 2003

2.1.4 Manipulation areas: Manipulation areas are generally found in the proximity of mine buildings, tailings ponds, or waste banks. It concerns bare surfaces, either convex or concave, serving as manipulation areas for e.g. transport (Figure 7).



a

b

Figure 7. Manipulation areas (a) in an aerial photo from 1947 (© MO ČR/GeoSI AČR) and (b) in an aerial photo from 2003

2.1.5 Mine buildings: Individual mine buildings including a winding tower and other mining-related buildings can be identified in aerial photographs (Figure 8).

a

b

Figure 8. Mine buildings (a) in an aerial photo from 1947 (© MO ČR/GeoSI AČR) and (b) in an aerial photo from 2003

It can include temporary buildings that are renovated after the mining activity termination. For example, the area of the ČSA 3 Mine (Jindřich Pit), which is visible in aerial photos from 1971 in the western part of the Karviná-Doly I Allotment, was

covered with soil and grassed after the demolition of buildings. A contemporary orthophoto shows trees, scrub and herbaceous vegetation associations in this area. What points to one-time mining activities in this area are the foundations of old mining buildings that are visible in the orthophoto from 2003 (Figure 9).

Figure 9. Area of the ČSA (a) in an aerial photo from 1971 (© MO ČR/GeoSI AČR) and (b) in an aerial photo from 2003

2.2 Secondary displays

Hard coal deep mining has also secondary displays in the landscape which are characterized by the occurrence of anthropogenic landforms indirectly related to mining (reclamation areas, dry tailings ponds, communications) or land cover change (vegetation-free surfaces).

2.2.1 Reclamation areas: It concerns temporary convex landforms in a shape of low flat waste banks. These should be aligned with the surrounding landscape after the termination of reclamation works. Reclamation areas are created in order to deal with negative effects of hard coal deep mining. The photos facilitate easy interpretation of new reclamation areas in the form of bare surfaces (Figure 10).

Figure 10. Reclamation areas in an aerial photo from 2003

2.2.2 Dry tailings ponds: These are shallow concave vegetation-free landforms that appear in the landscape after the termination of sludge management activities (Figure 11). Filled tailings ponds dry out and if no reclamation is carried out, they gradually overgrow with self-seeded vegetation.

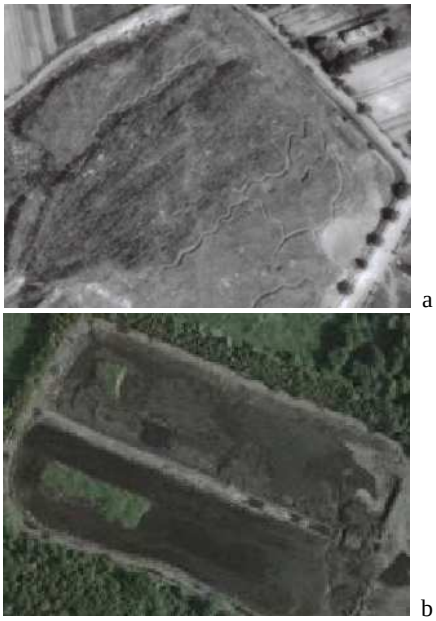


Figure 11. Dry tailings ponds (a) in an aerial photo from 1947 (© MO ČR/GeoSI AČR) and (b) in an aerial photo from 2003

2.2.3 Communication landforms: In the case of undermined area embankments are created to level surface deformations damaging communications. As a result of the modification of communication height embankments reaching up to a few meters are built. The types of embankments, which are characterized by line shapes and therefore easily identifiable in aerial photos, involve railway and road embankments as well as embankments of engineering networks (Figure 12).

Figure 12. Railway embankment in an aerial photo from 2003

2.2.4 Vegetation-free surfaces: Vegetation-free surfaces that represent secondary displays of deep mining are most often related to bare surfaces appearing particularly after building demolition (Figure 13). Their duration is relatively short as they gradually overgrow with self-seeded vegetation.

a b

Figure 13. Vegetation-free surfaces (a) in an aerial photo from 1947 (© MO ČR/GeoSI AČR) and (b) in an aerial photo from 2003

3. PROCESSES RELATED TO DEEP MINING

Time series of aerial photos enable to observe landscape changes on the basis of ongoing processes that can be visually interpreted indirectly from land cover changes. The most frequent mining-related processes involve submergence and abandonment that can consequently lead to the process of forestation.

3.1 Abandonment

As based on multitemporal aerial photos, the process of abandonment can be identified at places where artificial surfaces, agricultural areas, forests or water bodies transform into semi-natural areas of trees, scrub and/or herbaceous vegetation associations (Figure 14).

a

b

Figure 14. The process of abandonment in the artificial surfaces (a) an aerial photo from 1947 (© MO ČR/GeoSI AČR) and (b) an aerial photo from 2003

Undermining that causes land surface deformations generally leads to the disturbance of the structural mechanics of buildings and consequently to their demolition. The photos clearly show a visible decrease in the build-up area and its gradual overgrowth by self-seeded vegetation. A typical example is the Church of St. Peter of Alcantara in the northern part of the Karviná-Doly II Allotment (Figure 15). As a result of mining activity the church subsided by 36 m.

Figure 15. Contemporary view of the Church of St. Peter of Alcantara

All buildings in the proximity of the church have been demolished. A submerged ground subsidence is located to the east of the church (Figure 16).

Figure 16. Church of St. Peter of Alcantara and its vicinity in an orthophoto from 2003

Aerial photos also help to identify the process of abandonment in originally agricultural areas which being disused gradually turn into semi-natural areas.

3.2 Forestation

In most cases, the process of abandonment is succeeded by the process of forestation in which abandoned areas overgrow with self-seeded vegetation in the first phase followed by a subsequent gradual transition to forest stands.

3.3 Submersion

Submersion represents a process of the change of artificial surfaces, agricultural areas, forests and semi-natural areas into water bodies. New water surfaces originate primarily as related very closely to mining (tailings ponds) or secondarily as a consequence of undermining (submerged ground subsidences). Aerial photo time series facilitate the identification of the process from both spatial and temporal points of view (Figure 17).

Figure 17. The area before (year 1947, © MO ČR/GeoSI AČR) and after (year 2003) the occurrence of a submerged ground subsidence

4. CONCLUSION

The aerial photo analysis of the effects of mining on landscape showed that both direct and indirect signs must be taken into consideration in visual photointerpretation. In order to identify the primary and secondary displays of mining activities stress is put on direct signs contained in a respective photo: shape, size, tone, colour, texture and structure of an object. However, these signs must be complemented with the interpretation of indirect signs, i.e. logical signs that require deep knowledge on the research phenomena (Ciolkosz, Miszalski, Oledzki, 1999). Indirect signs used in the interpretation of anthropogenic landforms include particularly the location of an object and its relations to other objects in a photo.

Unlike the primary and secondary mining displays, the processes are absent in the photos, however, they can be derived from multitemporal analysis of aerial photos. Such processes are presumed on the basis of indirect signs in combination with supporting information used in order to differentiate between mining-related processes and other processes that take place in the landscape.

Correct interpretation of the displays of deep mining depends on interpreter's direct experience with events taking place in the mining landscape. Subsequently, accurate visual interpretation of the displays of deep mining enables us to quantify the extent of changes, determine their direction and analyse processes in heavily anthropogenically-affected landscape. Aerial photos represent an important source of information in the study of territorial differentiation of changes, their intensity, character and causes. Complex understanding of these processes makes it possible to predict the landscape development and ecological and social consequences in the landscape affected by hard coal deep mining.

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