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GEOMORPHOLOGICAL TASKS IN PLANNING THE REHABILITATION OF COAL MINING AREAS AT PÉCS, HUNGARY

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Large areas of Pécs are affected by the remains of mine excavations and spoil tips from former hard coal and uranium mining and also deposits of fly-ash and slurry from Pécs power plant, which was coal-fuelled but is now converted to biomass technology. In 210 Pécs, with Essen, becomes Cultural Capital of Europe, and this has given impetus to clean up its industrial legacy of derelict land. This paper reports on the activities of the academic part of a research consortium that has been established to promote land reclamation. It aims to support urban development planning by reconstructing the history of landscape transformation and by comparing current conditions and pre-mining using Geographical Information Systems; by geomorphological evaluation of the new artificial landscapes created by reclamation; by the identification of pollution hazards and by converting wastelands near built-up areas into green space available for new uses.

KEY WORDS: Anthropogeomorphology, Land reclamation, Coal mining, DEM, Mecsek Mountains (Hungary).

INTRODUCTION

The Mecsek Mountains contain Hungary's only source of hard coal, deposits of Lower Jurassic (Lias) age. Their greatest development is near Pécs, where the coal-bearing sequence has a total thickness of 1200 m, divided into hundreds of coal seams by marly interbeddings (Némedi Varga, 1998). Despite many problems in mining, due to largescale tectonic displacement of coal seams, and in utilisation, due to high sulphur content, coal extraction in the Mecsek Mountains has been important in supplying fuel for coking, heating and electricity generation. Coal mining has a long history, commencing with the manual working of surface outcrops in the 1790s but quickly expanding into large-scale extraction (Szirtes, 1994). In the 19th century, it fuelled the First Danube Shipping Company (DDSG) and then the Hungarian State Railways (MÁV). In the 20th century, it was also used in gas manufacturing for street lighting and electricity generation and, after 1950, the iron and steel industry of Dunaújváros on the Danube.

Both coal and uranium mining exerted a decisive influence on the economy, social life and urban fabric of Pécs city. Its environmental impacts are detailed by Lóczy & *alii* (2006) and its impacts on urban development by Lovász & Nagyváradi (2000). However, after 1989, economic and political transition ushered in new concerns. Environmental considerations (air pollution, release of greenhouse gases contributing to climate change) came to the fore while the reshaping of Hungarian energy policy led to mine closures. In 2004, the conversion of Pécs power plant to biomass fuelling led to the cessation of hard coal mining and the last two open-cast mining sites closed.

Today, a major task in regional planning is to survey the legacy of mining activities in the environs of Pécs (fig. 1), to turn the damage into advantage through carefully designed land reclamation measures and to rehabilitate the land to socially productive use (Hannan, 1995).

PREVIOUS STUDIES OF ENVIRONMENTAL IMPACTS OF MINING

The coal basin included 100 million tonnes of workable reserves. Mining began at the surface but, as the dimensions the reserves became known, deep mining commenced. The first shaft was sunk by German entrepreneurs in 1846. Between the World Wars, the number of

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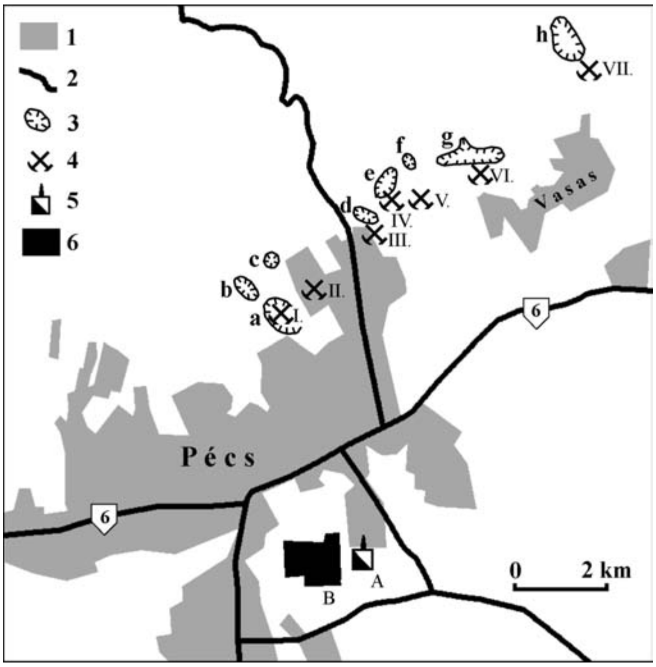

FIG. 1 - Location of areas affected by mining and waste disposal related to electricity generation around Pécs, with a need for land reclamation (drawn by P. Gyenizse). 1 = built-up area; 2 = main roads; 3 = open-cast mines; 4 = major spoil tips; 5 = power plant; 6 = slurry pools.

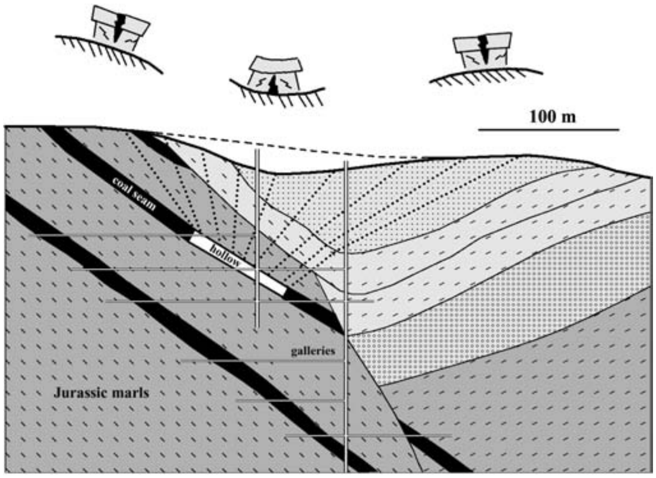

FIG. 2 - Land subsidence and deformation in surface structures as a consequence of deep mining in the area of Pécs (after Erdősi, 1987).

new shafts grew rapidly - mostly in immediate vicinity to built-up areas. Spontaneous combustion was not uncommon for the spoil heaps of shafts and air quality deteriorated in the miners' settlements close to the shafts. In the late 1950's and early 1960's, the time of peak coal production, a huge plume of air contaminated with sulphur-dioxide could be detected extending several kilometres along the northern margin of the residential areas of Pécs city. Simultaneously, these deep excavations caused surface subsidence and, the deeper the shafts, the larger the radius of ground surface subsidence. Scientific studies of this process resulted in the first comprehensive Hungarian work on «anthropogenic geomorphology» (Erdősi, 1987). These investigations revealed the mechanisms of compaction and their surface expression as mining hollows (fig. 2). The revegetation and surface stabilization of spoil tips was also examined (e.g. Lehmann, 1980).

However, damage from land subsidence was so serious and demanded such high compensatory payment, that the state-owned Mecsek Coal-Mining Company launched a survey to establish the true rates of movements (Fleck, 1968). This found that the city area is crossed by a major lineament, the Mecsekalja tectonic zone, which, although mostly inactive, helps transmit changes underground to the surface. The extent to which these changes find surface expression depends on local geological conditions. However, especially large-scale vertical movements can occur along those fault-lines that reach the surface at very steep (50-70°) angles (Erdősi 1987). A later engineering geological study examined zones of land subsidence in the northern parts of the city (Balázs & Kraft, 1998). The largest subsidence trough extended over an area of 13.5 km^2 and had a maximum surface-level drop of 27 m (fig. 3). Fortunately, no residential area was directly affected. Locally, step-like vertical displacements of maximum 7 m drop accompanied by horizontal shifts are observed. Survey data suggested horizontal displacements up to 1m in 130 years, which proved particularly damaging for transmission pylons but thousands of dwellings were also affected although relatively few (ca 300), those built upon fault-lines, were rendered uninhabitable (Balázs & Kraft, 1998). However, all the buildings that had been constructed with due regard to building regulations survived without major damage apart from some tilting.

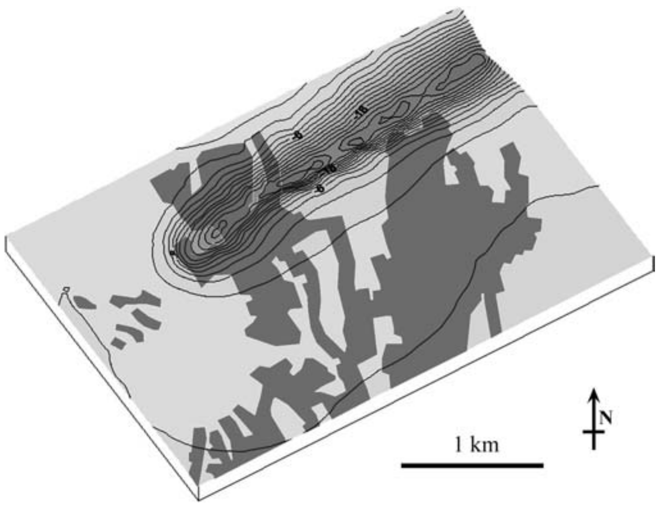

FIG. 3 - Subsidence zone northeast of the city centre of Pécs (by P. Gyenizse from the surveying data of Mecsek Mine Properties Utilization Ltd 2005).

Underground pumping associated with deep coal mining and uranium ore extraction have altered the hydrology of Pécs' environs. This artificial lowering of the groundwater table has caused many springs to run dry. Dragon Spring, originally a major source of water, with a 1.8 m^3min^{-1} discharge, was among the first to run dry in 1873. However, by the end of the 20th century, 420 wells and 25 natural springs had dried completely and 38 others registered major declines in discharge. In 1992, when the last deep shaft was closed and the galleries backfilled with mainly impervious debris, a network of observation wells was established and by 1996, these showed a significant recovery in the groundwater. However, Somosvári (1998) suggests that this may not be entirely the direct result of mine closure and the cessation of pumping, since the expansion of water piping without canalization, which affected these areas in the 1990's, usually involves higher water consumption and infiltration. In addition, there was relatively high precipitation in the 1990's, which has been followed by dry years in the early 21st century.

Open-cast coal extraction began in the 1950's and by the 1970's its production exceeded that from deep mining. Existing problems related to the accumulation of waste-tips and land subsidence was supplemented by new kinds of impact. Open-cast mining affects smaller areas but its topographic and ecological transformation of the areas affected is far greater. This study examines two areas of land degraded land by the environmental problems of open-cast mining. Both are located within 2 km of Pécs city centre. They are: the recently closed Karolina pit, the largest landscape scar in Pécs, and an extensive slurry pool area associated with the power plant located in the foothills to Pécs' south, (fig. 1).

BASELINE SURVEY OF ENVIRONMENTAL CONDITIONS

In these early years of the 21st century, the elimination and rehabilitation of lands damaged by mining ranks among the highest priorities of Pécs' local government environmental policy. A multidisciplinary team from the University of Pécs has been commissioned to provide some scientific foundations for land rehabilitation and to work in cooperation with the companies taking responsibility for, or affected by, the environmental damage due to coal or uranium extraction. In 2001, the team filed a research grant application with the newly launched governmental National Research and Development Programme (abbreviated NKFP). The project's title was «Development and application of a complex waste treatment and land reclamation technology and monitoring system for the reduction of environmental pressure in Southern Transdanubia», registered as NKFP-3/050/2001, and to run from 2001 to 2003. Its other project participants included several major companies interested in environmental protection, joint-stock ventures like the BIOKOM (waste management) Ltd, the Pécs Leather Works Ltd, the Pannon-Power Holding (coal mining and electricity generation) and the MECSEK-ÖKO (uranium mine reclamation) Ltd. The project was financed in a public-private partnership (PPP) scheme; its costs were shared approximately equally between the participating companies and the government.

The project's primary objectives were as follows:

1. to find safe disposal sites for the large amounts of waste produced by the technological processes of the participating firms;
2. to reclaim the derelict land resulting from mining and related activities for new land uses beneficial to the urban population;
3. to combine the above goals for the restoration of semi-natural conditions on degraded lands using industrial organic wastes to help enhance soil formation and revegetation.

The enterprise, a novelty in this region, called for close cooperation between participants from the university specialized in research and enterprises active in production.

Several departments of the Institute of Geography became involved in the scientific research. The geomorphologists' contributions included:

1. a baseline survey of physical conditions, including drainage and man-made topographic features;
2. expansion of the existing environmental monitoring network for the better prediction of environmental change;
3. modelling and prediction of landscape evolution with special regard to erosion hazard.

Gullying around mine excavations and on spoil tip surfaces is already widespread while the large areas of derelict land also represent a landscape ecological hazard. Biologists worry about the opportunities they offer for the spread of invasive weeds like ragweed *(Ambrosia elatior)*, giant goldenrod *(Solidago gigantea)* and wild cucumber *(Echinocystis lobata)*.

1. *The Karolina Pit*

Open-cast mining operations began here in 1968 (Szirtes, 1994). The pit gradually expanded to a length of: 1200 m, width of 600 m and depth ca 115 m (fig. 4). By the time the pit closed in 2004, around 15 million m^3 of hard coal had been extracted from its 70 ha area. An almost equal volume of spoil (ca 13 million m^3) was produced and tipped next to the pit. A maximum local relief of more than 250 m was created between the floor of the pit and the summit of the spoil tips. In addition to this artificial relief, the man-made topography has other properties which are also alien landscape elements:

– slopes steeper than usual for this footslope zone of the mountains;
– unnatural slope profiles: typically, the spoil tips have linear slopes, while the excavation is a series itself has a terraced cross-section with 12 steps of flats and risers;
– the excavation collects surface and underground waters from a catchment area of >12.5 km^2, so changing the natural pattern of waterheds and drainage.

FIG. 4 - The Karolina Pit just after the end of mining activities (photo by D. Lóczy).

Although models predict that the auto-compaction of the spoil heaps should cease within 5-6 years, this time frame permits the possibility that rising groundwater levels may lead to new slope instability and slumping.

This all suggests that the hydrological impacts of opencast mining may be greater than those of deep mining. Even within the pit, problems develop. In the case of the Karolina pit, a ponding occurred following the exceptional rains of 2005. In 2005, annual precipitation approached 900 mm (annual average 750 mm) and the water table rose to ca 145 m altitude. Threatened with widespread pit slope failure, the mining authority ordered its successor company, the Mecsek Coal Mines Enterprise, to reduce the water accumulation by pumping the mine water directly into the nearest water-course. Pollution problems were the result, since the dissolved salt content of the mine water was higher than permitted maxima.

2. *The slurry pools of the power plant*

The most extensive waste disposal sites of Pécs are found, the south of the centre, next to the power plant; the Tüskésrét area has a total area of 230 ha (of a total urban area of 16,261 ha). Since 1950's, large amounts of slurry, coarse-grained solid residues (partly marketed and partly used for landfill) and fly-ash, by-products of hard coal combustion from the Pécs power plant, were deposited here in slurry pools at the lowermost point of the Pécs Basin in the Pécs region. The level a waterlogged depression of 120-125 m altitude was raised by 15-20 m; in fact to the level of the power plant, which is sited on interfluvial ridge of Upper Miocene sediments. From the landfill surface, a terraced slope leads to the bottom of the basin, where a nature reserve has been established. Again, the topography is alien to the natural landscape: too steep ramps separate too flat plateaus.

Slurry disposal took place in two forms:

- diluted slurry technology, where the slurry was transported in pipelines, but the slurry ponds undergo very slow rates of drainage and compaction processes and are difficult to reclaim;
- dense slurry technology involves minimum water demand and creates surfaces that are relatively easy to reclaim.

Slurry pools represent and environmental hazard for the city and reclamation is essential. However, the almost flat surfaces of drained slurry deposits are fine-grained and extremely vulnerable to both wind and water erosion. Where new slurries were added to existing, easily eroded surfaces, miniature fluvial landscapes were created (fig. 5). One positive aspect of this was that, briefly before reclamation, the landscape could be used as valuable teaching laboratory for the study of geomorphological processes such as: gullying, channel trenching, drainage network evolution, meandering, and the formation of alluvial fans.

During reclamation, the slurry was mantled covered with local Upper Miocene sands and silts and clays. In most cases, a 5-10 cm clay layer of low (10^{-5} to 10^{-7} cm s^{-1}) hydraulic conductivity has been used to cap the slurry. However, official regulations require that the the final cover should have a minimum thickness of 30 cm.

GEOMORPHOLOGICAL INVESTIGATIONS SERVING LAND RECLAMATION

Toy & Hadley (1987), suggest that the following knowledge is an essential prerequisite for effective land reclamation:

1, surface and deep geology of the environs of mines;
2, surface and near-surface hydrological conditions;
3, land use, property and built-up conditions;
4, possible landslide and collapse hazard;
5, sediment transport to neighbouring areas;
6, proper conditions for obtaining filling material;
7, visual value of the landscape;
8, location and quality of wetland habitats in the environs;
9, water quality in water-courses;
10, opportunities for water storage on the surface;
11, planned utilisation and after use.

Geomorphological research can provide information to Points 2, 4, 5, 7, 10 and 11.

FIG. 5 - Miniature gorge formed in the slurry of the disposal pools at Tüskésrét before land reclamation (photo by J. Kovács).

In the case of the degraded land around Pécs, the minimum targets of reclamation were:

1. to create surfaces which could not be considered environmentally hazardous and which sourced no chemical, physical or visual pollution;
2. to create or maintain seminatural, self-regenerating, green areas beneficial to the urban environment;
3. to provide town-dwellers with opportunities for recreation, education and
4. to provide nature conservation areas.

The research was primarily based on the integration of topographic, soils, drainage pattern and microclimate data in an ArcView Digital Elevation Model constructed from the digitization of input maps at 1:10,000 and 1:25,000 scale using Surfer, Idrisi and Carta Linx programs. Interpretations reveal the expected slope conditions and pattern of drainage after reclamation, the focal sites of erosion hazard, water and heat availability for plant growth. The DEM was also a useful tool in the selection of monitoring sites.

PERSPECTIVES

International experience suggests that, in favourable circumstances, the final land use can be established in reclaimed coal spoil areas within 5 to 7 years of reclamation treatment, although most recognise that the land will continue to require special treatment for many years thereafter (Hannan, 1995). Similar time frames seem to apply to power plant slurry pools; at least those dumped using dense slurry technology. In Pécs, various uses for reclaimed land are envisaged, which include green areas, city parks, sports and cultural facilities. These urban development plans target the year 2010, when Pécs and Essen, acting as «Cultural Capitals of Europe» will be subject to unusual outside scrutiny. Further geomorphological research could serve the implementation of these plans with reliable prognoses of future environmental conditions.

REFERENCES

BALÁZS F. & KRAFT J. (1998) - *Pécs város településfejlődésének mérnökgeológiai vonatkozásai (Engineering geology of the urban development of the city of Pécs).* JPTE Egyetemi Kiadó, Pécs. 183 p.

ERDŐSI F. (1987) - *A társadalom hatása a felszínre, a vizekre és az éghajlatra a Mecsekben és tágabb térségében (Human impact on the surface, waters and climate in Mecsek Mountains and environs).* Akadémiai Kiadó, Budapest.

HANNAN J.C. (1995) - *Mine Rehabilitation. A Handbook for the Coal Mining Industry.* 2nd Edition. New South Wales Minerals Council, Sidney.

LEHMANN A. (1980) - *A bányászat hatása a növény- és talajtakaróra Pécs területén Impact of mining on vegetation and soils in the area of Pécs).* Földrajzi Közlemények, 104 (28), 1-2, 228-256.

LÓCZY D., NAGYVÁRADI L., GYENIZSE P., PIRKHOFFER E. & DEZSŐ J. (2006) - *Umweltfolgen und Rekultivierung in Steinkohlenbergbaugebieten bei Pécs.* In: AUBERT A. & TÓTH J. (eds.), «Stadt und Region Pécs. Beiträge zur angewandten Stadt- und Wirtschaftsgeographie». Universität Bayreuth, Bayreuth. 65-78. (Arbeitsmaterialien zur Raumordnung und Raumplanung Heft 243).

LOVÁSZ GY. & NAGYVÁRADI L. (2000) - *A természeti erőforrások változó szerepe Pécs és Komló fejlődésében (The changing significance of natural resources in the urban development of Pécs and Komló).* University of Pécs, Pécs. (Papers of the Department of Physical Geography, 13)

NÉMEDI VARGA Z. (1998) - *A Mecsek és a Villányi-hegység jura képződményeinek rétegtana (Jurassic stratigraphy of Mecsek and Villány Mountains).* In: BÉRCZI I. & JÁMBOR Á. (ed.), «Magyarország geológiai képződményeinek rétegtana (Stratigraphy of geological formations in Hungary)». MOL Rt. - MÁFI, Budapest. 319-336.

NKFP (2003) - *A dél-dunántúli régió könyezetterhelésének csökkentésére irányuló komplex hulladékkezelési és rekultivációs technológia, valamint monitoring rendszer kifejlesztése és alkalmazása (Development and application of a complex waste treatment and land reclamation technology and monitoring system for the reduction of environmental pressure in Southern Transdanubia).* Final research report. Manuscript, Pécs. 202 pp.

SOMOSVÁRI ZS. (1998) - *"Pécs-Mecsekszabolcs" bányatelken észlelhető felszínemelkedések és vizesedései jelenségek értékelése és prognozisa (Evaluation and prediction of vertical movements and wetting damage on the mine plot "Pécs-Mecsekszabolcs".* Manuscript Expert's Report. Geoconsult, Miskolc.

SZIRTES B. (ed.) (1994) - *A mecseki kőszénbányászat (Hard coal mining in Mecsek Mountains) Vols I-II.* Kútforrás Kft, Pécs. 690 pp.

TOTAL KFT. (1997) - *A pécsbányai külfejtéses területek tájrendezése (Landscape restoration at the Pécsbánya open-cast pit).* Manuscript Expert's Report. Pécs. 29 pp.

TOY T.J. & HADLEY R.F. (1987) - *Geomorphology and Reclamation of Disturbed Lands*. Academic Press, New York.

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