The transboundary Geopark Muskau Arch (Geopark Łuk Mużakowa, Geopark Muskauer Faltenbogen)

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In times of fast progress of globalization and unification, areas representing unique qualities like, for example an exceptional geological structure, deserve our special attention. The need to promote unique geological areas and objects was underlined in 1997 during the forum of UNESCO that actively supports the creation of a global network of geological sites by granting them status of geoparks (Eder & Patzeck, 2004). One area, for which efforts are made to bring it on the list of Europe's geoparks, is the Muskau Arch — characterized by a rare geological structure, unique natural environment and containing mining industry heritage. Another, very important feature of the area is its transboundary location.

Geopark
MUSKAUER FALTENBOGEN
ŁUK MUŻAKOWA

Fig. 1. Geographical location of the Muskau Arch push moraine and logo of the geopark, modified after promotional material issued by Association Geopark Muskau Arch

The Muskau Arch area is situated in the west of the Republic of Poland, south-west of Zielona Góra, and in the east of the Federal Republic of Germany, south-east of Cottbus and north-east of Dresden. The region lies in a triangle formed by the Federal State of Brandenburg, the Free State of Saxony (Germany) and the Lubusz Voivodeship (Poland) — Fig 1. The river Neisse cuts through the Arch and forms the border between Germany and Poland. The Muskau Arch extends on an area of 578.8 km^2 (in Germany: Brandenburg 166.4 km^2, Saxony 228.5 km^2, and in Poland — the Lubusz Voivodeship 183.9 km^2). The Polish part of the Muskau Arch has been identified in Poland since September 27, 2001, as a landscape park (Park Krajobrazowy) under the Polish nature conservation law. The German part of the area was recognized as the National Geopark of Germany on June 1, 2007 by the GeoUnion Alfred-Wegener-Stiftung. The idea of a transboundary park shall be manifested in all three parts of the geopark.

The outline of geology and typical landscape forms

The geological structure of the Muskau Arch and its immediate hinterland are covered by the geopark territory. It is a horseshoe-shaped lobe extending approximately 22 km from west to east and approximately 20 km from north to south. The Muskau Arch forms a reflection of a minor glacial lobe that is best visible within a whole range of hills created as a result of large-scale glaciotectonic disturbances and belonging to the Lusatia border wall and its easterly continuation, i.e. the Silesian Rampart.

The Muskau Arch represents an Elsterian push moraine cut by deep erosion. It is a particularly beautiful example of perfectly formed tongue-shaped ice thrust ridge with deep soft sediment deformations. This is why the best view of the Muskau Arch is obtained with help of satellite images or digital elevation models (Fig.2). The Arch, however, represents only the eroded remains of an originally much higher and more extensive push structure in Oligocene and Miocene sediments with brown coal layers. There is a nest of three or possibly even four part arches, with the two northerly arches eroded during the development of an Elsterian age basin (Fig. 3).

The geologists distinguish between ruptures (rotationary wedges) and three-dimensional deformations (diapirs and congruent folds). The three-dimensional deformations were caused by the ice load and the ruptures were formed around or in front of the ice rim. A special feature of the push moraines in the Arch is their enormous depth, ranging from 270 to 290 m below the glacier. The maximum geologically proven depth below currently deeply eroded surface is 236 m (Fig. 4).

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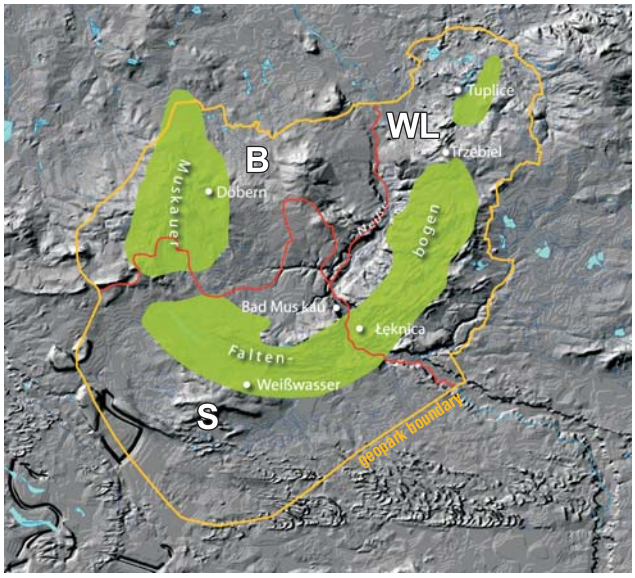


Fig. 2. Digital terrain model (shadow relief image) of the Muskau Arch showing geopark boundary (B — Brandenburg, S — Saxony, WL — Lubusz Voivodeship); from Application dossier to become a member of the European Network of Geoparks, 2007

The predominant geomorphological phenomena in the Muskau Arch are the so called *gieser* (both singular and plural: gieser). The name gieser or gjeser derives from a Slavic (Sorbian) term *jezero*: a swamp or a lake, that stemmed from a Slavic name of little lakes formed in these depressions. These are mostly straight, narrow valleys with no outlets. They occur where brown coal is cropped out whose seams were reduced in volume as a result of weathering under the influence of air and water (Fig. 5). Their average dimensions are as follows: depth 3–5 m, max. 20 m, width is 20–50 m, and length some 2–5 km. Most of them run parallel to each other with lateral distances between 50 m and 800 m, average 200–250 m.

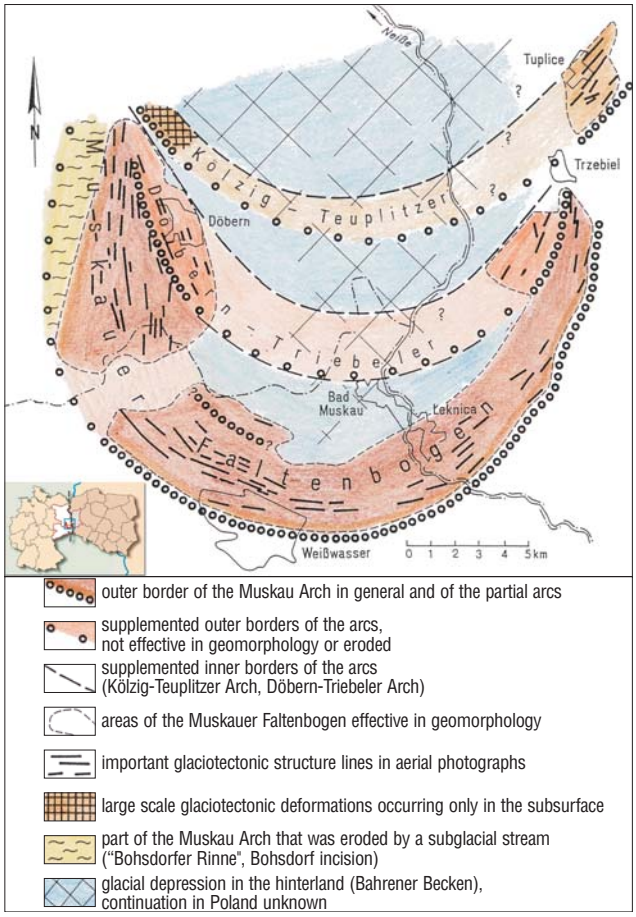


Fig. 3. Structural sketch map of the Muskau Arch (Łuk Mużakowa, Muskauer Faltenbogen); after Kupetz, 1997

Three general gieser types have been distinguished (see block diagrams in Fig. 4D):

1. thrust sheet type: at least 1–2 km long, extremely straight running gieser with a constant width;
2. diapir type: gieser with curved, sharp bended, interrupted, varying in width, and seldom ellipsoid run; its length is usually only some hundred of meters, normally fewer than 1 km;
3. seam fold type: areal, marshy depressions with the elongation parallel to the ice rim, the length 1–2 km, and the width of several hundred meters — the width is, however, always smaller than the length.

Glaciotectonic structural elements (thrust sheets, diapirs, several kinds of fold, rootless rafts) are not directly expressed in the terrain relief. Only the brown coal seams — as a part of such glaciotectonic unit — may be reflected in form of a gieser. In the research work the single, glaciotectonic structural element — the gieser — is used *as the first approximation*. One should, however, always remember that a gieser only approximately reflects a thrust sheet, a diapir, or other texture (Fig. 6).

The present, unique landscape of the geopark has been influenced not only by the natural glaciotectonic structures that occur in its basement, but also by mining activities. Shallow occurrence of Miocene brown coal seams brought about the development of mining which, in turn, became a driving force for the local ceramics, glass, saw-mill and farm and food industry. Other mineral resources that were mined included ceramic clays, alum clays, glass sands and natural aggregates. The greatest development of the mining industry that had an over 130 year history took place in the mid-19th century, during the so called economic revolution. The last mine, *Babina*, located in the Polish part of the areas was closed down in 1973. Coal was initially mined by the underground method, and later in open-pit mines. Seams were reached by shafts or slants, and the workings were liquidated by means of collapse. Elongated, narrow depressions formed as a result of subsidence of the surface above the exploited underground workings. Nowadays they are dry or — most often — filled with water like the old open-pits and some of the Giesers.

This unique relationship between geology and objects formed as a result of old mining activities was the reason for commencing work in order to create a geopark in the Muskau Arch area.

Unique features (the main theme or motto of the Muskau Arch Geopark)

The expert report on geotope protection (Hübner, Meier & Rascher, 1999; Koźma et al., 2001) explored and assessed the potential of the specific geographic feature of the Muskau Arch for the development of a geopark. The geotopes occurring in the Muskau Arch were surveyed, analyzed and mapped in the expert report on geotope conservation and in the feasibility study. The same methodology was applied in the parts situated in Brandenburg,

Saxony and Poland (mainly as presented in the *Arbeitsanleitung Geotop-schutz in Deutschland, Leitfaden der Geologischen Dienste*... 1996). Ten types of geotopes (groups) and 31 geotopes (single geotopes) have been identified in the Muskau Arch (tab. 1).

This cluster of geotopes is a key aspect in the presentation of geomorphological phenomena and outcrops, in that it permits a concentrated study in one small area of a multitude of geotopes which would typically be spread over a wide area in a „normal glacial landscape".

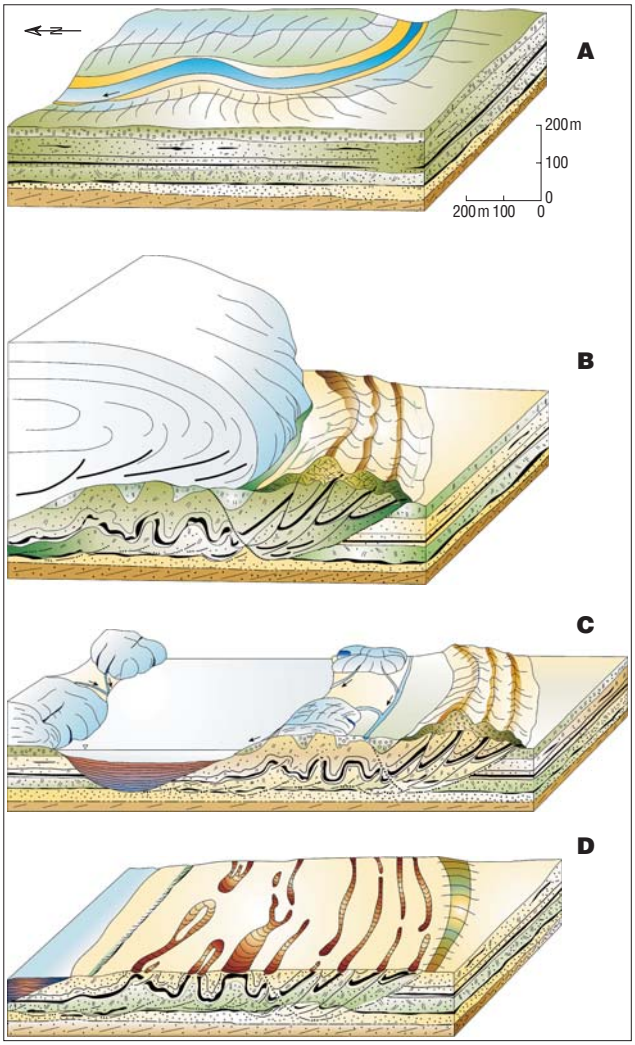


Fig. 4. General deformation process of the Muskau Arch in block diagrams (from Rascher et al., 2000). The ruptural deformation (thrust sheets) represents a real existing situation in a cross section.
A — Landscape before glaciation: in a comparatively flat area perhaps a river runs form south to north and marks the later position of the Muskau glacier. This river is not the former river Neiße! The landscape level was about 170–190 m above see level i.e., about 40–100 m above recent level.
B — The approximately 430–510 m thick Muskau glacier dislocates the horizontal layered bed of the Tertiary and the minor Quaternary essentially by loading and only subordinated by horizontal push. The glacier deforms down to a depth of about 270–290 m beneath the ice base. Under the glacier the soft sediment predominantly became folded in ductile style and under the ice rim and in the foreland the deformation process is predominantly a ruptural one.
C — After melting the water collects in the newly built glaciotectonic depression (Bahrener Becken) and the basin is filling up with slaty varved rocks.
D — A later glacier advances (Elsterian, South Polish and Saaleian, Middle Polish glaciation, respectively) on the peneplaine and onto the ice thrust ridge. Gieser begin to depress, this process continues recently.

The Muskau Arch was compared to 25 push moraines in western, central and eastern parts of Europe and in North America. The study showed that the best preserved end moraines are the ice thrust ridges in the Dirt Hills and Cactus Hills in Saskatchewan in West Canada. The most beautiful examples of push moraine outcrops are the chalk cliffs on Rügen Island in Mecklenburg-Vorpommern. Nevertheless, the Muskau Arch emerges from this comparison as the most explored, researched and documented push moraine.

The unique feature can be defined as follows:

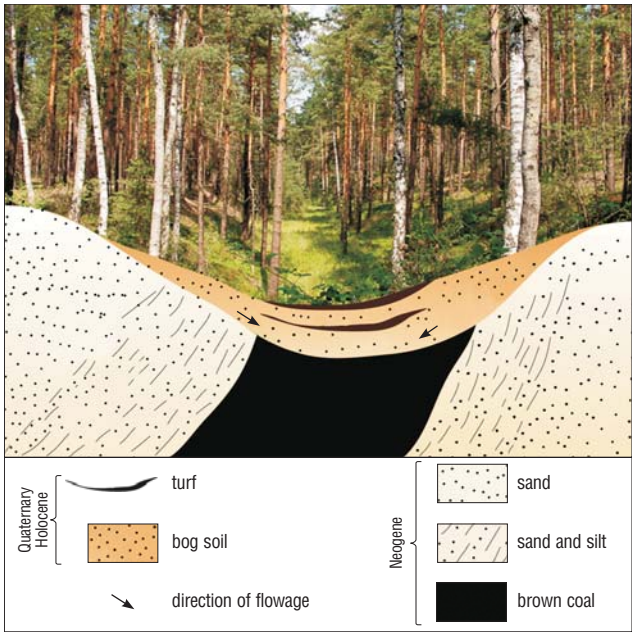
- ❏ the Muskau Arch is a particularly well-formed push moraine with a naturally-defined boundary, its structure representing a good geological and geomorphological example of a Nordic glacial landscape;
- ❏ the arch is a representative post-mining and cultural landscape characterized by its special geogenic features and stemming from 130 years of localized and resource-based industrial development between 1840 and 1973;
- ❏ the geopark offers a cluster of different types of geotopes in a concentrated area.

The geopark takes on different emphasis in the three countries in keeping with the respective brief. Therefore the overall concept of a transnational, three-state geopark was developed: Brandenburg — Quaternary geology, glacial geology, glacial morphology, glacial tectonic; Saxony — Quaternary geology, post-mining landscapes and use of Quaternary geomorphology to create the historic *Fürst-Pückler-Park* in Bad Muskau (UNESCO world heritage) and *Kromlau Park*, Active surface mining at Nochten by Vattenfall Europe Mining AG; Poland — interdependency between geotopes and biotopes (geogenic relativity of biotope formation and network), man-made landscape of post-mining lakes, classic nature conservation (Fig. 7).

Creating access to geotopes in the geopark — selected examples

The cluster of geotopes, shown in tab. 1, and on a map in Fig. 8, is a key aspect in the presentation of geomorphological phenomena and outcrops, in that it permits a concentrated study in one small area. The aim is to present as many as possible different kinds of attractive geological outcrops and geomorphological features in the field. The Muskau Arch Geopark already has a well-developed network of cycle paths and hiking trails. There are three general cycle routes in the Polish part (Trzebiel–Jasien, Łęknica–Żary and one unnamed cycle path). A network of specialized geo-tours was planned in the policy guidelines for the landscape park. Another example is a geological hiking path through the former brown coal mine *Babina* near Łęknica. It belongs to the above-named *Babina pit landscape conservation area and geological reserve*.

The brown-coal mine *Babina* was created in 1921 as one of larger mines within the Muskau Arch area. In 1937 the coal production reached 225.5 thousand tones. After the WW2 both the underground and open-pit workings were developed. In 1973, following the deteriorating mining conditions and the related increase in costs, the mine was closed down. Workings, that became flooded with water in a natural process, were only partly rehabilitated by means of levelling of the slopes. After the coal



Ryc. 5. Cross section through a soil profile and vegetation preserved Gieser; modified after promotional material issued by Association Geopark Muskau Arch

mining was stopped, fire clays were extracted in small pits until the late 1990s. The total area of post-mining land of the *Babina* mine is estimated at around 430 ha.

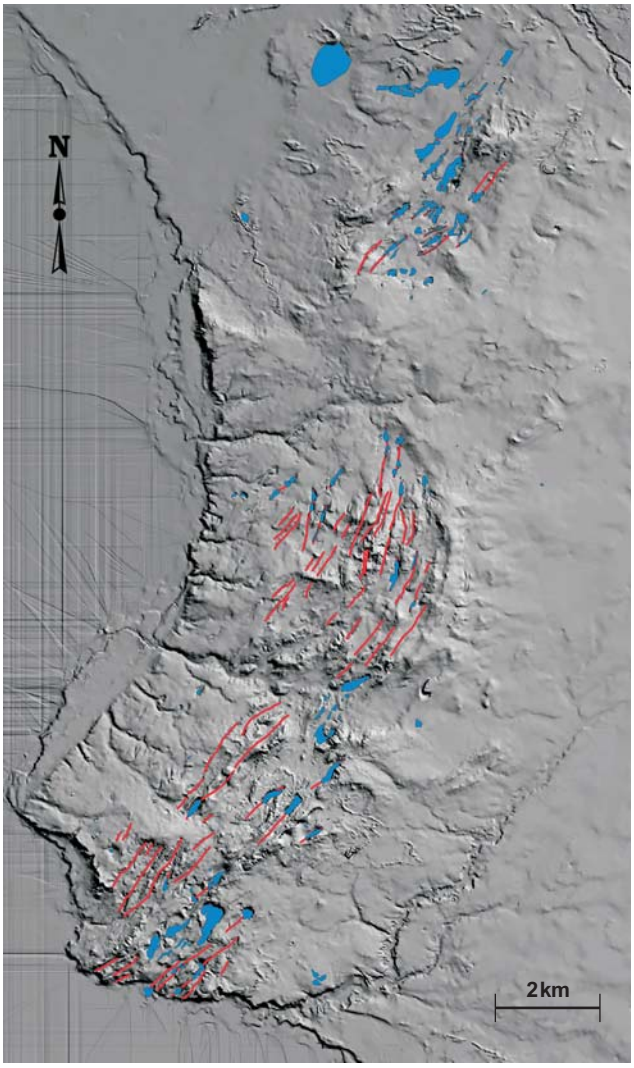
In order to present natural, environmental processes taking place on areas that were strongly altered by mining activities, a decision was taken to open a geological-tourist trail near one of the largest pits of the *Babina* mine that is marked on mining maps as a *saddle* (German — *Mulde*). Along a 4-kilometer-long path there are several geological sites located around 600 m from one another (Figs. 9, 10) which include:

- ❏ a vertical profile of a coal seam that will be artificially exposed in the pit slope;
- ❏ an outcrop of brown coal (1 m thick) with a well-marked transverse fault;
- ❏ a land depression in the area of an old underground mine, flooded with acid water characterized by changing colors;
- ❏ a spring of acid water surrounded with crusts of chemical compounds, chiefly with high amounts of iron;
- ❏ an outcrop of fine-grained sands and silts with fragments of coals strongly deformed by the glacial tectonic phenomena;
- ❏ numerous forms of deep erosion by rain water developed on the sediments of mine heaps (edges of workings, overburden heaps).

A convenient location of geological sites near the headquarters of the Landscape Part authorities in Łęknica creates a chance to plan several variants of visiting routes.

Tab. 1. Types of geotopes found in the Muskau Arch (after Rascher, Meier & Kupetz, 2000)

Types of geotopes (group) regarding to colours in Fig. 8	Geotopes (single geotopes)	Map symbol (Fig. 8)
Stratification conditions/tectonics	Glaciotectonic dislocations	glLst
	Geomorphologically visible lithological boundary	geoG
Glacial and periglacial erosion and deposition forms	End moraine	Em
	Till	Gm
	Kettle hole/ morainic lake	So
	Erratic boulder	Fi
	Gravel and boulders	Bl
	gieser valley (local name for small valleys in the top of coal seams lying near ground surface)	Gie
Aeolian erosion and deposition forms	Dune	Dü
	Widespread occurrence of wind-blown pebbles	Stso
Fluviatile erosion and deposition forms	Abandoned river course	Aa
	Fluvial terrace	Ft
	Valley, ravine	T, S
	Transverse valley	Dt
Fens	Fen in gieser valleys	MoG
	Hanging bog	GMo
	Flat bog	FMo
Springs	Spring	Qu
	Overflow between post-mining lakes	Wü
Raw materials	Meadow ore	Ra
	Gravel and sand	K, S
	Peat	To
	Brown coal	Brk
	Alum clay	At
	Clay	T
Post-mining lakes	Acidic lakes left by brown coal mining	sRG
	Oligotrophic semi-natural lakes left by brown coal mining and gravel extraction	oRG
	Lakes left by clay extraction	TRG
Cobblestone buildings	Cobblestone buildings (German: Feldsteinhäuser; historical buildings consisting of erratic boulder rock)	Fh
Geological objects used for landscape gardening	Basalt columns for park creation	B
	Erratic boulder used for landscape gardening	gaF



Ryc. 6. Location of Gieser and artificial depression of the land (red line), water-filled mining pits in the Polish part of the Muskau Arch — based on a digital model of the area; after Koźma, 2007

The variety represented by the sites offers a chance of seeing numerous phenomena that concern for example the rehabilitation of acid soils, chemical transformations in waters that fill pits after brown coal extraction, contemporary processes of terrain relief changes, plant successions changes in relation to the rocks in the basement etc.

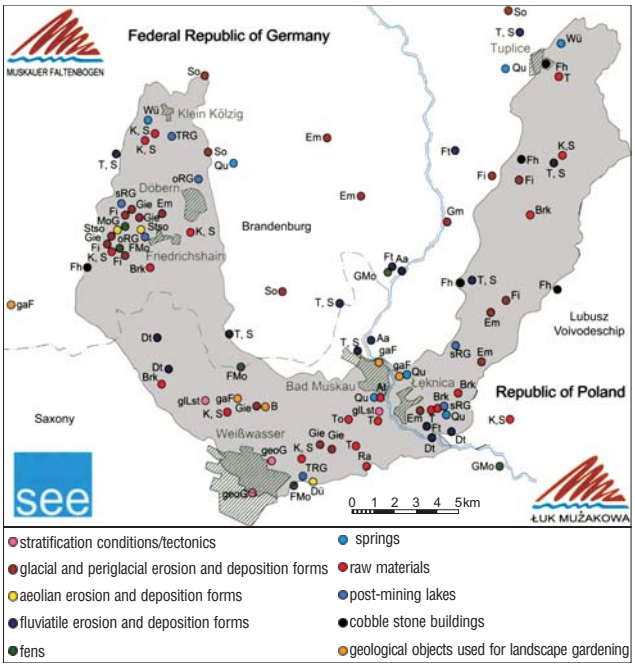
It would not be possible to present all the existing and planned geological-tourist tours and objects in the required size of the paper, therefore the authors would like to mention some of the thematic tours available in the German part: the Historical Mining Tour, the Glass Tour, Jerischke End Moraine/Neisse Valley Tour and the Hermannsdorf Cycle Path (Figs. 11,12). More information may be found in publications some of which have been listed at the end of this paper.

It should be stressed that the aim of the geopark development is also to improve the structural quality of this network in Poland and to enhance its appeal by adding further information boards in Saxony and Poland. Therefore, it is planned to open a new tourist bridge on September 5, 2008, across the river Neisse and connect the geopark parts of Poland and Brandenburg near the villages Sielec and Zelz.

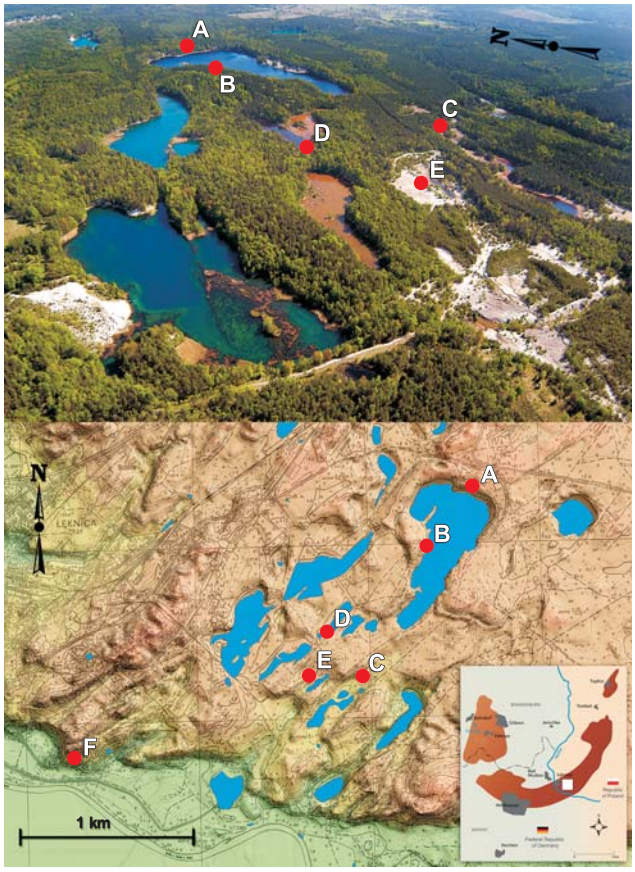
Implementation of sustainable development for the Muskau Arch Geopark

The entire area of the transboundary Muskau Arch Geopark is geared to the future with regard to the principles of ecology, economy and social interests. The conservation of the biosphere, cultural areas and the post-mining landscape, and the development of tourism not only help locals to identify with their region but also contribute to the projected economic trend. The key approach to regional development is the one which is reliant on the sources of endogenous potential. Long-term plans and concepts drawn up by the individual geopark partners as well as their mutual consultation and cooperation constitute the basis

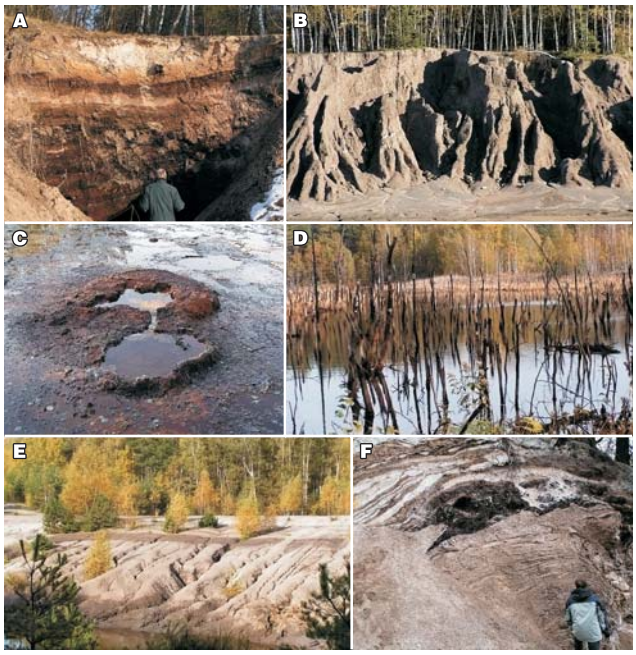
Ryc. 7. The main themes of the geopark various parts, modified after unpublished material of Association Geopark Muskau Arch



Ryc. 8. Location of geotopes within the Muskau Arch Geopark; explanations as in tab. 1 (after Rascher, Meier & Kupetz, 2000)



Ryc. 9. Aerial view and map of geotouristic route planned in the area of the dormant, brown-coal mine *Babina*; points explanations as in Fig 10; aerial photo by Peter Radke with cooperation Manfred Kupetz and Almut Kupetz, by permission of Association Geopark Muskau Arch



Ryc. 10. A — coal seam profile, B — rainwater erosion forms in man-made sediments developing on edges of workings, C — spring of iron-rich waters with crusts, D — flooded area of an underground mine, E — coal outcrop, F — outcrop of glaciotectonic deformed sediments. Photo by J. Koźma

Ryc. 11. The four geotouristic paths in the Brandenburgian part of the Geopark Muskau Arch, after promotional material issued by Association Geopark Muskau Arch

for the sustainable establishment and composition of the geopark.

The idea of developing a Muskau Arch Geopark was first conceived back in 1994. Building on a 1999 report on geotope conservation, concepts were hammered out in 2001 for the transnational three-state geopark in the *Feasibility Study on the Muskau Arch Geopark* issued by the Berlin-Brandenburg Joint Regional Planning Department. Despite its title, it goes beyond a „feasibility study" in the conventional sense and is more of an integrated overall model conceived with the involvement of the three states and with the participation of both governmental and non-governmental agencies. The document includes far-reaching statements for Brandenburg while outlining the main features of the future geopark for Saxony and Poland. This concept has undergone a gradual process of rollout since 2001 in Brandenburg. An additional in-depth analysis of the potential for Saxony was conducted in 2005. A report entitled *Initiation of cross-border cooperation for the Muskau Arch territory* was drafted in March 2006 as a strategic basis for planning with a project schedule spanning 2006–2013. Similarly, policy guidelines were drafted for the Park Krajobrazowy national landscape park in the autumn of 2007. This is the central concept of the geopark development constantly reiterated by the Internationale Bauausstellung Fürst-Pückler-Land GmbH.

The geopark adopts an integrative approach. In terms of its ecological dimension it links Quaternary geology and geomorphology with the use of the abundant local resources, the resulting post-mining landscapes and the interaction between the geotopes in the natural and man-made landscape. This strategic approach forms the basis for the content and structure of the geopark.

In terms of its economic dimension the formation of networks through the forming of nine networks and the running of the Brandenburg-Saxony-Poland cooperation project from 2006 onwards will secure the extensive involvement of the funding agencies in the geopark and their reciprocal presentation of the geopark.

In terms of the social dimension the geopark project has very deep roots at local level because most of the work has been done on a voluntary basis. It is a paradigm of democracy carved out with a European dimension. Originating with the local and district authorities, the geopark has evolved into a German-Polish project through its acceptance as a project of the Internationale Bauausstellung *Fürst-Pückler-Land* and through the

Ryc. 12. Example of geotourist objects and their location in the German part of the Muskau Arch area. A — Look-out tower by the lake Felixsee, B — geopark info-centre in Jerischke, C — Lusatian boulder park in Nochten, D — information board by a tourist path near Felixsee. Photo by J. Koźma

development of the support associations in Germany and Poland.

Further information

Two websites have been created in order to provide information and help to pan a visit in the Muskau Arch Geopark — www.oksir.pl and www.muskauer-faltenbogen.de. Several publications listed below could also be helpful:

- ❏ Koźma et al. (2005): 1) Park Mużakowski i atrakcje geotourystyczne okolic Łęknicy (Muskauer Park und die geotouristischen Sehenswürdigkeiten in der Umgebung von Łęknica). 2) A description of geology as well as economic development (e.g. brown coal mining) and culture (UNESCO World Heritage Fürst-Pückler-Park) of the Polish part of the Muskau Arch.
- ❏ Janowscy et al (2005): Park Krajobrazowy *Łuk Mużakowa* — hard cover book, photographic impressions of the Park Krajobrazowy Łuk Mużakowa.
- ❏ Kupetz M. (2003): The Muskauer Faltenbogen — a large-scale glaciotectonic feature and its geomorphological texture on the earth's surface, geological excursion guide in the German part of geopark.
- ❏ Kupetz M. et al. (2004): Der Muskauer Faltenbogen — ein geologisches Phänomen, Grundlage einer 130jährigen standortgebundenen Wirtschaftsentwicklung und Geopark in Brandenburg, Sachsen und der Wojewodschaft Lebuser Land, an overview about Muskau Arch geological structure and region, 2. Edition is planned for 2008.

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