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GEOTOPES OF THE PROPOSED MUSKAU ARCH GEOPARK — INVENTORY, CLASSIFICATION AND EVALUATION

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Abstract. Criteria of estimation of geotope (geosite) value from the viewpoint of different social requirements (museum value, scientific research, nature-knowledge, youth education, countryside science) are not clear nor easy to define. The system of valorisation criteria of geotopes applied by the German Geological Survey looks like a good proposal for answering this question.
The system mentioned above has been used for assessment of the geotopes value for the planned "Muskau Arch Geopark" area, located at the crossborder area of Poland, Brandenburg and Saxony. 95 geotopes have been registered and evaluated with the uniform criteria within the whole Geopark area, on both Polish and German sides; 34 of them are located in the Polish part. From the viewpoint of scientific research, 32 geotopes (of these 12 on the Polish side) have been assessed as valuable and of special value. As far as teaching and tourism values were concerned, 32 geotopes (of these 14 on the Polish side) have been evaluated there. In the light of that, the Polish part seems to become a substantial part of the planned Geopark.

Key words: geotope, geopark, valorisation criteria, Muskau Arch.

Abstrakt. Ustalenie kryteriów umożliwiających klasyfikację geotopów (geostanowisk) z punktu widzenia rozmaitego rodzaju zapotrzebowania społecznego (wartość muzealna, badania naukowe, edukacja przyrodnicza młodzieży, krajoznawstwo) budzi wiele wątpliwości. System waloryzacji geotopów stosowany przez Niemiecką Służbę Geologiczną wydaje się być dobrą propozycją wprowadzenia takich kryteriów.
Wspomniany wyżej system został zastosowany przy ocenie wartości geotopów na terenie planowanego transgranicznego Geoparku Łuk Mużakowa, leżącego u zbiegu granic Polski, Brandenburgii i Saksonii. Na całym obszarze geoparku, po stronie polskiej i niemieckiej, zinwentaryzowano i poddano ocenie na podstawie jednolitych kryteriów 95 różnych geotopów, z których 34 znajduje się w polskiej części obszaru. Za wartościowe i szczególnie wartościowe z punktu widzenia badań naukowych należy uznać 32 geotopy (w tym 12 w części polskiej), a z punktu widzenia wartości dla edukacji i turystyki – także 32 geotopy (w tym 14 w części polskiej). W świetle tych wyników polska część projektowanego geoparku „Łuk Mużakowa" stanowi jego istotny element.

Słowa kluczowe: geotop, geopark, kryteria waloryzacji, Łuk Mużakowa.

INTRODUCTION

The Muskau Arch is an area of well-preserved glaciotectonical structures, formed during the Mid-Polish Glaciation at a foreland of an isolated ice-shield lobe. A belt of frontal moraines and hills of uplifted pre-Cenozoic deposits (push moraine) created the scenic landscape with objects of inanimate nature, important for both the scientific research and general education. Numerous abandoned open pits of Tertiary lignite and clay, recently filled with water, contribute to the unique character of this area closely fulfilling the criteria of the UNESCO International Geopark Programme.

In 1997, the Geological Survey of Brandenburg in co-operation with some other organisations and institutions

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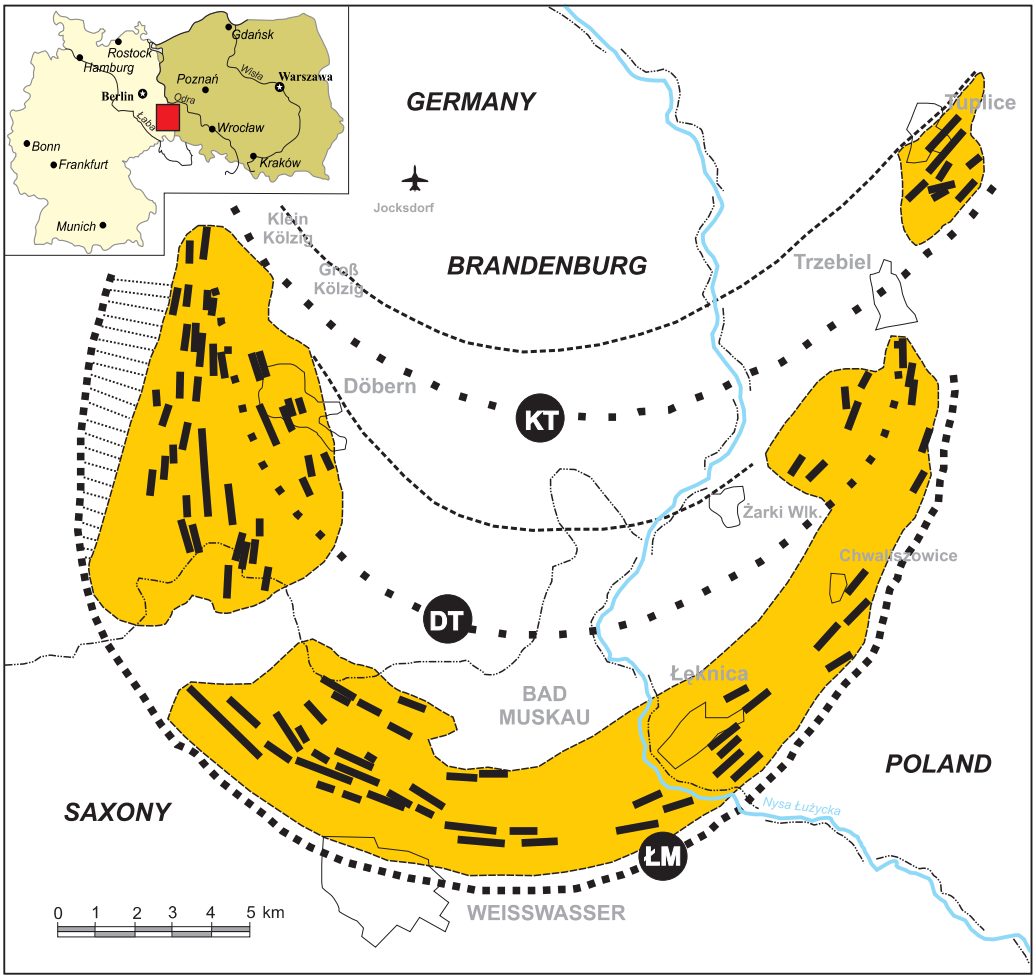
of Brandenburg and Saxony initiated efforts for establishing the "Three-State Geopark" in the Muskau Arch region, at the crossborder area of Brandenburg, Poland and Saxony. The Polish Geological Institute, invited by the German side, since 2000 takes part in the first-stage preparations on the Polish part of the Muskau Arch. The first inventory activity (Koźma *et al.*, 2001) included classification and scientific/educational evaluation of the inanimate nature phenomena (so-called "geotopes") in this area and were a base to analyse this area from the viewpoint of the possibility to establish a "Three-State Geopark" (Kasiński *et al.*, 2000; Badura *et al.*, 2002; Rein *et al.*, 2002).

GEOLOGICAL SETTING AND CULTURAL HERITAGE

The Muskau Arch is an area of horseshoe-shaped belt of front moraines and glaciotectonical structures — push moraines (Figs. 1, 2). This structure is about 40 km long and 3–6 km wide. Both arms terminals of this structure, one near Mattendorf (Brandenburg) and second in Tuplice (Poland), are about 20 km away from one another. Neogene deposits as well



extend of glacitectonic deformation of the Muskau Arc

external edges of the glaciotectonically disturbed zones

suspected location of the other arcs, both the recorded in morphology and eroded ones

area of glaciotectonic deformations recorded in morphology

characteristic glaciotectonic structures evidenced on the air photographs

boundaries of states and lands

fragment of the Muskau Arc eroded by a subglacial channel

DT — Döbern–Trzebiel Arc

ŁM — Muskau Arc

KT — Kölzig–Tuplice Arc

as Pleistocene sediments occur in the push moraines. The Neogene deposits consist mostly of clays and lignites of Middle Miocene age, representing the Ścinawa/Lower Brieske, Pawłowice/Upper Brieske and Poznań/Rauno formations. Quaternary sediments (mostly tills, sands and gravels) are related to the Mid-Polish/Elstere Glaciation, when the whole structure was originated through separated ice-lobe activities (Dyjor, Chlebowski, 1973). Glaciotectonical deformations reached down to 270 m, and the belt of glaciotectonical deformations in front of the ice lobe was 490–720 m wide (Kupetz, 1997). Thickness of the lobe has been estimated at 430–530 m (Kupetz, Keßler, 1997).

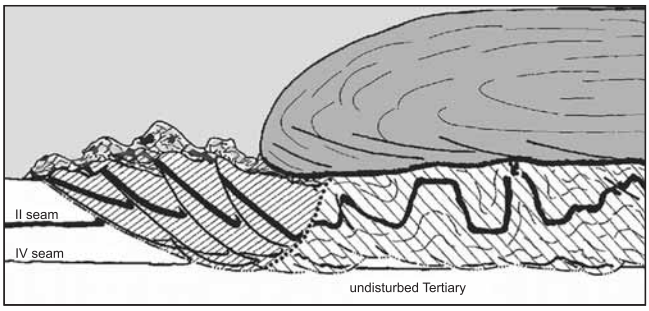


Fig. 2. Origin of glaciotectonical structures (push moraines) in front of glacier (after Kupetz, 1997)

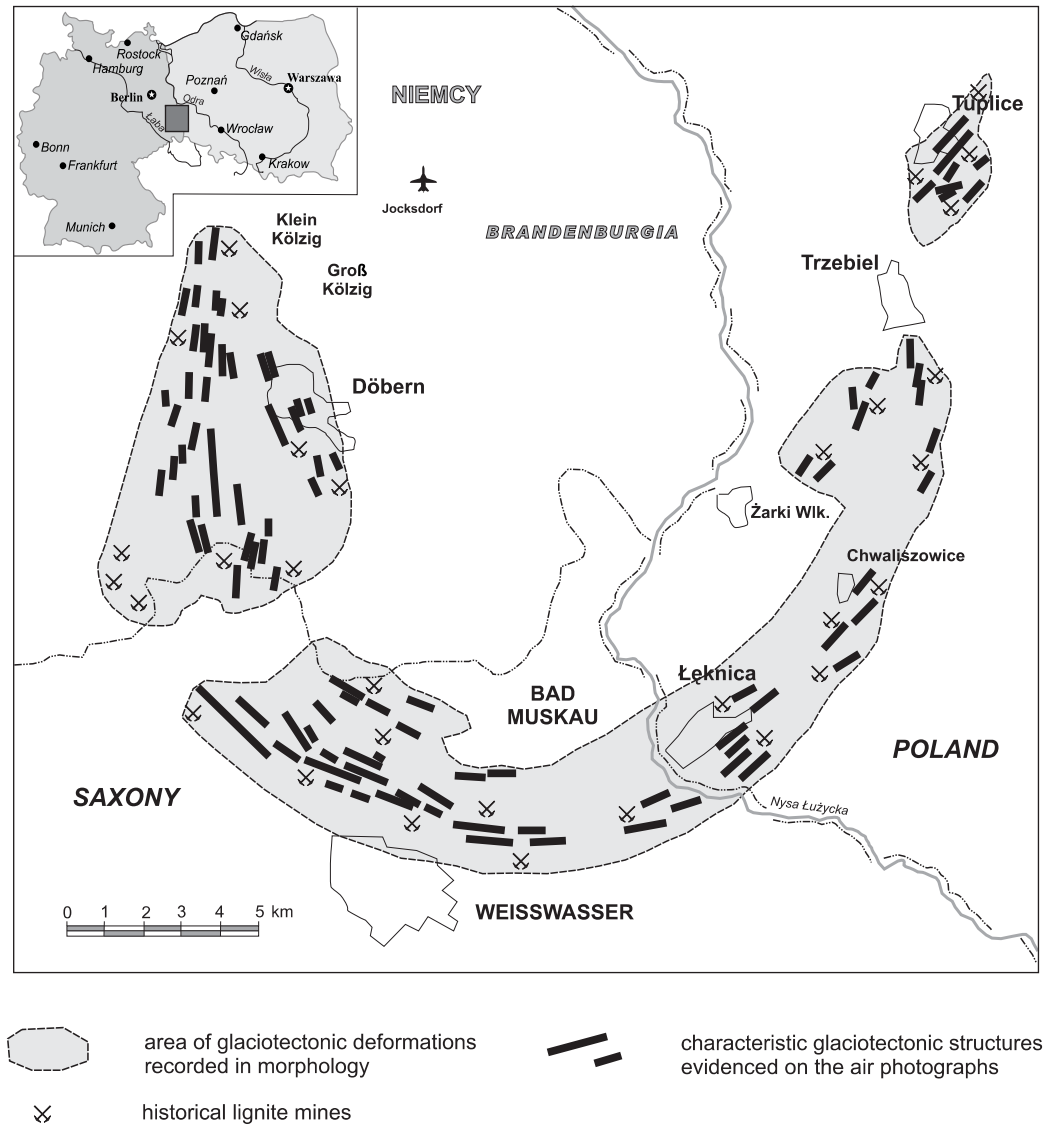


Fig. 3. Abandoned lignite mines within the Muskau Arch glaciotectonical structures (after Kasiński, Piwocki, 2003)

Fig. 1. Schematic geomorphological map of the Muskau Arch (after Kupetz, 1997)

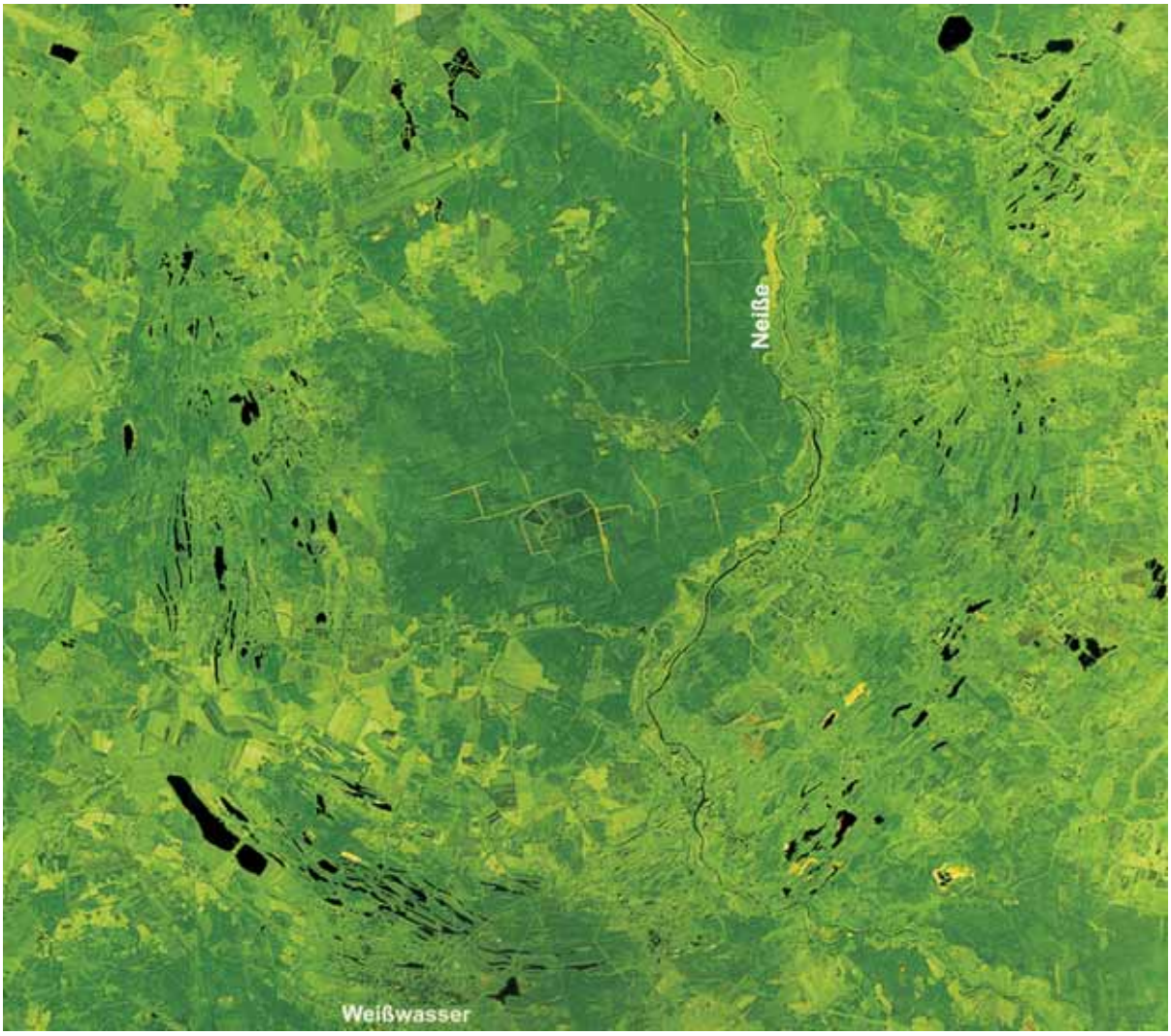


Fig. 4. Artificial lakes (water filled abandoned open cast mines), located along the lignite and clay exposures within the glaciotectonical slices

Traditions related to mining industry were the most important culture-creating elements in this area, caused by occurrence of several raw materials (lignite, ceramic clay, natural aggregate). The oldest lignite mines started already in 1840. There were small underground mines, excavating lignite mostly with dip galleries, later also with shafts and open-pits (Fig. 3). During the time of the maximal activity, more than 60 underground and surface mines operated there (Kasiński, Piwocki, 2003). Since the end of the 19th century, also pottery clays, alum clays (for alum production) and natural aggregates were exploited in numerous open pits. Recently, lignite and clay mines are abandoned, but their traces are distinctly visible in form of narrow belts of elongated artificial lakes, located along the lignite and clay exposures, within the glaciotectonical slices (Fig. 4). These belts, as well as moraine hills, create really scenic landscape.

Unique geological setting, scenic landscape and rich geological heritage allowed to include the Muskau Arch area into a small group of the most valuable geodiversity protection areas also in Poland (Alexandrowicz, Alexandrowicz, 2003).

INVENTORY OF GEOTOPES

For the practical reasons, the authors have applied a definition of a geotope after German Federal Authority of Nature Protection (Look, 1996): "geotope is a geological feature of the inanimate nature which provides information on the development of the Earth or of life". This definition includes rock exposures, particularly those showing fossil soils, minerals of special interest, and fossil plants and animals, as well as individual natural phenomena and outstanding natural features of

landscape. Geological significance of those geotopes, rarity, uniqueness and beauty as well as substantial value for science, research, and teaching were a base for their classification and evaluation. The results of interactive influence of natural environment and human activity (e.g. the anthropogenic lakes) have also been considered. During the first stage of the work, 95 geotopes have been defined, inventoried and evaluated in the Muskau Arch region (34 in the Brandenburgian part, 34 in the Polish, and 27 in the Saxonian one).

CLASSIFICATION OF GEOTOPES

Several different elements and forms, included into the main thematic groups of the natural and anthropogenic geotopes (see Rascher *et al.*, 2001) are presented in Table 1.

Table 1

Geotope types of the Muskau Arch
(partly after: Look, 1996 and Hübner *et al.*, 1999)

No.	Geotope type	Description
1	**Stratigraphy and tectonics**	
1.1	glaciotectonical structures	steep tectonical folds and slices caused by ground squeezing at the front of overthrusting ice lobe
1.2	lithological borders visible in geomorphology	geological borders cropped out in the result of quick weathering of less-resistant geological units
2	**Elements of glacial and periglacial morphology**	
2.1	front moraines	moraine hills consisting of material deposited in front of ice lobe: till with significant addition of boulders and debris
2.2	till	clastic, low-sorted material of bottom moraine
2.3	kettle hole	outletless depression at bottom moraine surface caused by melting of the death-ice block; often filled with water
2.4	glacial boulder	allochtonic boulder (mostly from Scandinavia) transported by ice lobe
2.5	boulder field	glacial boulder fields formed due to washing of front moraine sediments
2.6	weathering ditch (*Gieser*)	elongated depression on an exposure of steep-standing lignite seam, which part located above groundwater level (in aeration zone) has been weathered
3	**Eolian structures**	
3.1	sand dune	positive morphological form (hill) of eolian origin with characteristic shape, consisting of fine- and medium grained sand
3.2	faceted boulder	boulder with few surfaces plained with wind activity limited with some sharp edges
4	**Fluviatile structures**	
4.1	oxbow	closed fragment of meandering river channel
4.2	river terrace	flat surface at the river-valley bottom, formed as the result of flowing water erosion (erosional terrace) or accumulation of clastic material (accumulation terrace)
4.3	river valley	valley with characteristic V-shape formed by erosional activity of flowing water

No.	Geotope type	Description
4.4	river valley gap	river valley cutting mountain range or other positive morphological form (e.g. front moraine) perpendicularly to its elongation
5	**Swamps and mires**	
5.1	mire (fen) in weathering ditch (*Gieser*)	peat-fen supplied with flowing water on wet bottom of weathering ditch
5.2	raised bog	raised bog supplied with precipitation water, hanged on valley slope without any contact to drainage network
5.3	peat-fen	peat-fen supplied with flowing water within large depression, e.g. on alluvial plain
6	**Springs**	
6.1	spring	natural or artificial water outflow on soil surface
6.2	watersheed between flooded mining excavations	separation line of groundwater outflowing into neighbouring areas, located within abandoned mining excavations
7	**Mineral raw materials**	
7.1	meadow ore	chemogenous iron sedimentary rock, originated at soil surface
7.2	natural aggregate	loose clastic rocks (mostly quartz ones) with grain size of 0.063–2 mm (sand) and 2–63 mm (gravel)
7.3	peat	phytogenic rock (kaustobiolite) originated through accumulation and shallow diagenesis of phytogenic matter (plant remains) under anoxic conditions
7.4	lignite	phytogenic rock (kaustobiolite) originated through accumulation and medium diagenesis of phytogenic matter (plant remains) in the result of peat transformation
7.5	alum clay	dark-grey clay consisting mostly of aluminium-potassium sulphate (alum), rich in organic matter
7.6	clay	fine-grained loose clastic/chemogenous rock with grain size below 0.002 mm, consisting of quartz and clay minerals
8.	**Lakes in mining excavations**	
8.1	acidified lakes in abandoned excavations of lignite mining	abandoned excavations of lignite mines, filled with water acidified in the result of pH-decreasing by sulphides from lignite and barren rocks
8.2	oligotrophic lakes in abandoned excavations of lignite and gravel mining	abandoned excavations of lignite mining, filled with water, non-acidified with regard to chemism of excavated matter
8.3	lakes in abandoned excavations of clay mining	abandoned excavations of ceramic clay mining, filled with water
9.	**Buildings of glacial boulders**	
9.1	buildings of field-stone	living-houses (or their fragments) and farm buildings constructed of field-stone; also field-stone pavements
10.	**Geological landscape objects**	
10.1	basalt columnar structure	exposures of basalt with visible columnar joint forming columns
10.2	glacial boulders in garden-architecture	elements made with glacial boulders in park and garden construction

VALORISATION OF GEOTOPES

When more or less numerous collection of geotopes is already inventoried and classified, the most substantial is the question, which ones should be particularly protected. An answer for this question is not easy because the criteria (what to protect: typical or ?unique scientific valuable or ?scenic etc.) are not clear and sharp (Wimbledon, 1999; Alexandrowicz, 2003). A system applied by the German Geological Survey (Look, 1996), considering significance of the geotopes from some different viewpoints, looks like the one which may partly answer to this. Using it all, the geotopes have been valorised from the viewpoint of their significance for scientific research, education and tourism (Table 2) into four classes: (1) of minor value, (2) significant, (3) valuable, and (4) of special value.

Table 2

Criteria of a geotope geoscientific assessment (partly after: Look, 1996)

No.	Branch of valorisation	Value (points)
1	**General geoscientific significance**	
	Branches: soil science (pedology), glacial geology, hydrogeology, engineering geology, mineralogy, petrography, geomorphology/palaeogeography, palaeontology, economical geology, sedimentology, stratigraphy, structural geology/tectonics, volcanology	
	one of the above positions	1
	2–4 of the above positions	2
	more than 4 of the above positions	3
2	**Significance for the regional geology**	
	none	0
	local significance	1
	significant for a geological area	2
	significant for a geological region	3
3	**Significance for education, research and teaching**	
	none	0
	significant for local nature, local history and geography, tourism	1
	significance for scientific excursions, teaching and research	2
	special scientific reference locality or type locality	3
4	**Preservation status**	
	very poorly preserved (damaged, recultivated, filled in)	1
	poorly preserved (weathered, debris covered, dirty, overgrown)	2
	well preserved	3
5	**Frequency of similar geotopes in a geological region**	
	common (> 7 similar geotopes)	1
	several (2–7 similar geotopes)	2
	rare (1 similar geotope)	3
6	**Number of geological regions with similar geotopes**	
	common (> 4 geological regions)	1
	several (2–4 geological regions)	2
	rare (1 geological region)	3
Total geoscientific value of the geotope		
	of minor value	**1**
	significant	**2**
	valuable	**3**
	of special value	**4**

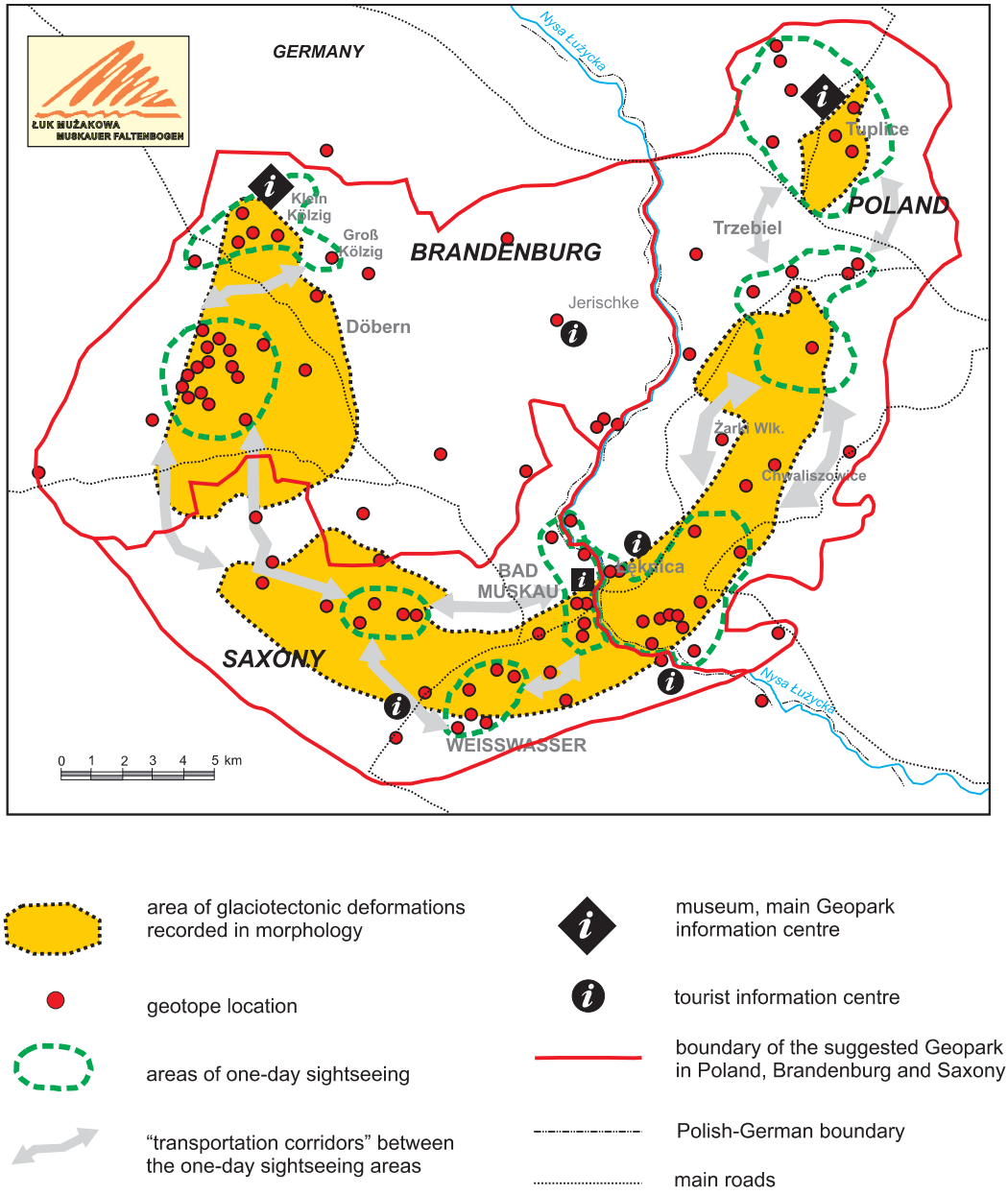


Fig. 5. Geotopes of the Muskau Arch (after: Hübner *et al.*, 1999; Koźma *et al.*, 2001)

Evaluation of the need for protection should also be determined. In this, some important levels of threat have to be considered:

— general relation to mining of raw materials (no resources, no active mining, current mining, current mining destroying the geotope);
— stage of mining (recovery completed, quarry to be reclaimed, planned to fill, being filled);
— relation to nature protection (location in high-protect area, location in semi-protected area, planned for exploitation).

Geoscientific value of all the geotopes defined within the Muskau Arch Geopark area (Fig. 5) has been presented in the Table 3.

95 geotopes have been registered and evaluated in accordance with the uniform criteria in the whole Geopark area, at both Polish and German sides; 34 of them are located in the Polish part. Two geotopes of special value: (1) post-mining excavation filled with acidic iron-rich water (Fig. 6), and (2) iron-rich spring water, both in surroundings of Łęknica (Fig. 7), have been recognised in the Polish part of the Muskau Arch. From the viewpoint of scientific research, 32 geotopes (including 12 in the Polish part) have been estimated as valuable and of special value. From the viewpoint of teaching and tourism value, also 32 geotopes (in this 14 in the Polish part) have been evaluated there.

Table 3

Geoscientific evaluation of the Muskau Arch geotopes
(after: Hübner *et al.*, 1999; Koźma *et al*., 2001)

Geotope characteristics			Scientific value			
No.	**Geotope type**	**Science branches**	**Regional geological significance**	**Significance for science, research and teaching**	**Summarised value**	
Brandenburg						
B 1	peat-fen		local form at the Muskau Arch	regional nature monument, object of didactic presentation	significant	2
B 2	glacial boulder, glaciotectonical slices	glacial geology, stratigraphy, tectonics	trans-boundary significance	object of countryside presentation, target of scientific excursions	valuable	3
B 3	boulder field with Tertiary erratics	stratigraphy, palaeo-geography, tectonics	local form at the Muskau Arch	object of countryside and didactic presentation	significant	2
B 4	glacial boulder	glacial geology, stratigraphy	trans-boundary significance	object of countryside and didactic presentation, target of scientific excursions	valuable	3
B 5	gravel, glaciotectonical slice, glacial boulder	raw-material geology, pedology, stratigraphy, tectonics	trans-boundary significance	reference significance for the Earth sciences	of special value	4
B 6	glacial boulder	petrology	small	small	of minor value	1
B 7	acidified lake within lignite final excavation	raw-material geology	small	regional object of didactic presentation	significant	2
B 8	weathering ditch (*Gieser*)	glacial geology, tectonics, hydrogeology	global significance	fundamental reference significance for the Earth sciences	of special value	4
B 9	boulder field with Tertiary erratics	stratigraphy, petrology	local form at the Muskau Arch	object of countryside and didactic presentation	significant	2
B 10	front moraine	glacial geology, tectonics	trans-boundary significance	*locus typicus*	valuable	3
B 11	oligotrophic lake (almost natural) within lignite final excavation	hydrogeology	small	regional object of didactic presentation	of minor value	1
B 12	kettle hole	glacial geology, sedimentology	small	object of countryside and didactic presentation	significant	2
B 13	sand	raw-material geology	local form at the Muskau Arch	object of countryside and didactic presentation	significant	2
B 14	watershed between excavations	hydrogeology	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
B 15	lake within flooded lignite final excavation	stratigraphy, hydrogeology, raw-material geology	local form at the Muskau Arch	regional object of didactic presentation	significant	2
B 16	weathering ditch (*Gieser*)	glacial geology, tectonics, hydrogeology	trans-boundary significance	object of countryside and didactic presentation, object of scientific excursions, *locus typicus*	valuable	3
B 17	lignite; acidified lake within lignite final excavation	raw-material geology, hydrogeology	trans-boundary significance	regional object of countryside and didactic presentation, subject of scientific research	significant	2

Geotope characteristics			Scientific value			
No.	**Geotope type**	**Science branches**	**Regional geological significance**	**Significance for science, research and teaching**	**Summarised value**	
B 18	Sand (glass sand)	sedimentology, stratigraphy, raw-material geology	local form at the Muskau Arch	regional object of didactic and countryside presentation	significant	2
B 19	river terrace	geomorphology, palaeogeography	local form at the Muskau Arch	regional object of countryside and didactic presentation, subject of scientific excursions	valuable	3
B 20	raised bog	pedology, hydrogeology	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
B 21	oxbow	countryside science	small	small	of minor value	1
B 22	end moraine	glacial geology	local form at the Muskau Arch	regional object of countryside and didactic presentation, subject of scientific excursions	valuable	3
B 23	kettle hole	glacial geology	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
B 24	spring	hydrogeology, tectonics	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
B 25	kettle hole (overgrown)	tectonics, stratigraphy, glacial geology, countryside science	global significance	object particularly interesting with fundamental reference significance for the Earth Sciences	of special value	4
B 26	river valley (overgrown); till	glacial geology, stratigraphy, hydrogeology, palaeogeography	global significance	object particularly interesting with fundamental reference significance for the Earth Sciences	of special value	4
B 27	mire within a weathering ditch (*Gieser*)	pedology, countryside science	over-regional significance in the European scale	*locus typicus*	valuable	3
B 28	garden architecture with using of glacial boulders	countryside science	small	small	of minor value	1
B 29	building of field-stone	countryside science	small	small	of minor value	1
B 30	river valley	hydrogeology, countryside science	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
B 31	gravel	raw-material geology, stratigraphy	trans-boundary significance	object of countryside and didactic presentation, object of scientific research and scientific excursions	valuable	3
B 32	weathering ditch (*Gieser*)	tectonics	trans-boundary significance	regional object of countryside and didactic presentation, *locus typicus*	valuable	3
B 33	oligotrophic lake (almost natural) within lignite final excavation	tectonics, engineering geology	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
B 34	front moraine	glacial geology, tectonics, stratigraphy	trans-boundary significance	object of countryside and didactic presentation, object of scientific excursions	valuable	3
Poland						
P 1	glacial boulder	glacial geology	local form at the Muskau Arch	regional object of countryside and didactic presentation	valuable	3

Geotope characteristics			Scientific value			
No.	**Geotope type**	**Science branches**	**Regional geological significance**	**Significance for science, research and teaching**	**Summarised value**	
P 2	river terrace gravel	sedimentology, stratigraphy, raw-material geology	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
P 3	lignite	raw-material geology	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
P 4	building of field-stone	countryside science	small	small	of minor value	1
P 5	gap river valley, river terrace	palaeogeography	trans-boundary significance	object of countryside and didactic presentation, object of scientific research and scientific excursions	valuable	3
P 6	garden architecture with using of glacial boulders	countryside science	small	small	of minor value	1
P 7	spring	hydrogeology	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
P 8	kettle hole	glacial geology, geomorphology, countryside science, stratigraphy	trans-boundary significance	object particularly interesting with fundamental reference significance for the Earth Sciences	valuable	3
P 9	river valley	geomorphology, stratigraphy	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
P 10	river terrace	geomorphology, stratigraphy	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
P 11	oxbow	countryside science	local form at the Muskau Arch	regional object of countryside and didactic presentation	of minor value	1
P 12	river valley	river valley glacial geology	trans-boundary significance	object of didactic presentation and scientific excursions	valuable	3
P 13	till	glacial geology, stratigraphy	local form at the Muskau Arch	object of didactic presentation	significant	2
P 14	watershed between excavations	hydrogeology, tectonics	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
P 15	springs	hydrogeology, tectonics	trans-boundary significance	regional object of countryside and didactic presentation, object of scientific excursions	valuable	3
P 16	front moraine	tectonics, glacial geology	trans-boundary significance	regional object of countryside and didactic presentation, object of scientific excursions	valuable	3
P 17	river valley, spring	hydrogeology, geomorphology, countryside science	local form at the Muskau Arch	object of countryside and didactic presentation, object of scientific excursions	valuable	3
P 18	dune	geomorphology, countryside science	local form at the Muskau Arch	object of countryside and didactic presentation	significant	2
P 19	building of field--stone	countryside science, petrology	small	object of countryside and didactic presentation	of minor value	1
P 20	clay	raw-material geology, hydrogeology	local form at the Muskau Arch	object of countryside and didactic presentation, object of scientific excursions	significant	2
P 21	building of field-stone	countryside science, petrology	small	object of countryside and didactic presentation, object of scientific excursions	significant	2

Geotope characteristics			Scientific value			
No.	**Geotope type**	**Science branches**	**Regional geological significance**	**Significance for science, research and teaching**	**Summarised value**	
P 22	gravel and sand	raw-material geology	small	small	of minor value	1
P 23	glacial boulder	glacial geology	local form at the Muskau Arch	object of countryside and didactic presentation	significant	2
P 24	lignite	raw-material geology, countryside science	trans-boundary significance	object of countryside and didactic presentation, object of scientific excursions	valuable	3
P 25	building of field-stone	countryside science	small	object of countryside and didactic presentation, object of scientific excursions	valuable	3
P 26	building of field-stone	glacial geology, countryside science	local form at the Muskau Arch	object of countryside and didactic presentation	of minor value	1
P 27	push moraine	glacial geology, tectonics, palaeogeography	local form at the Muskau Arch	object of countryside and didactic presentation, object of scientific excursions	valuable	3
P 28	acidified lake within lignite final excavation	geomorphology, raw-material geology, countryside science	local form at the Muskau Arch	object of countryside and didactic presentation	valuable	3
P 29	lignite	raw-material geology, countryside science	trans-boundary significance	object of countryside and didactic presentation, object of scientific excursions	valuable	3
P 30	push moraine	glacial geology, palaeogeography	local form at the Muskau Arch	object of countryside and didactic presentation, object of scientific excursions	valuable	3
P 31	clay	raw-material geology, geomorphology, stratigraphy	local form at the Muskau Arch	object of countryside and didactic presentation, object of scientific excursions	significant	2
P 32	acidified lake within lignite final excavation	raw-material geology, countryside science	trans-boundary significance	object of countryside and didactic presentation, object of scientific excursions	of special value	4
P 33	spring	hydrogeology, mineralogy, tectonics	trans-boundary significance	object of countryside and didactic presentation, object of scientific excursions	of special value	4
P 34	gravel and sand	raw-material geology, sedimentology	small	object of countryside and didactic presentation, object of scientific excursions	significant	2
Saxony						
S 1	spring	hydrogeology	small	regional object of countryside and didactic presentation	of minor value	1
S 2	alum clay	raw-material geology, countryside science	small	regional object of countryside and didactic presentation	significant	2
S 3	glaciotectonical slice	sedimentology, palaeogeography	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
S 4	peat	countryside science	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
S 5	garden architecture with using of glacial boulders	countryside science	small	small	of minor value	1

Geotope characteristics			Scientific value			
No.	**Geotope type**	**Science branches**	**Regional geological significance**	**Significance for science, research and teaching**	**Summarised value**	
S 6	river valley, river terrace, raised bog	geomorphology, countryside science stratigraphy	trans-boundary significance	object of scientific research and scientific excursions	valuable	3
S 7	clay	raw-material geology	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
S 8	gap river valley, river terrace	palaeogeography	trans-boundary significance	regional object of countryside and didactic presentation, object of scientific research and scientific excursions	valuable	3
S 9	weathering ditch (*Gieser*)	glacial geology, geomorphology	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
S 10	dunes	countryside science	trans-boundary significance	regional object of countryside and didactic presentation	valuable	3
S 11	lake within clay final excavation	raw-material geology	small	small	of minor value	1
S 12	peat-fen	geomorphology, hydrogeology, palaeogeography	local form at the Muskau Arch	regional object of countryside and didactic presentation, object of scientific research	valuable	3
S 13	weathering ditch (*Gieser*)	glacial geology, geomorphology	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
S 14	clay	raw-material geology, stratigraphy, sedimentology	trans-boundary significance	regional object of didactic presentation, *locus typicus*	valuable	3
S 15	meadow ore	raw-material geology, countryside science	trans-boundary significance	object particularly interesting with fundamental significance for the Earth Sciences, *locus typicus*	valuable	3
S 16	sand (glass sand)	raw-material geology	small	regional object of countryside and didactic presentation	of minor value	1
S 17	geological border visible in geomorphology	sedimentology, stratigraphy, geomorphology, palaeogeography	local form at the Muskau Arch	regional object of didactic presentation, object of scientific excursions	significant	2
S 18	geological border visible in geomorphology	pedology, sedimentology, stratigraphy, glacial geology	local form at the Muskau Arch	regional object of countryside and didactic presentation	of minor value	1
S 19	weathering dith (*Gieser*)	tectonics	local form at the Muskau Arch	regional object of didactic presentation	valuable	3
S 20	glaciotectonical slice, lignite	tectonics, raw-material geology	local form at the Muskau Arch	regional object of didactic presentation, object of scientific excursions	valuable	3
S 21	basalt pillars	volcanology, palaeogeography	small	object of countryside and didactic presentation	of minor value	1
S 22	gravel	tectonics, glacial geology	trans-boundary significance	object of scientific research and scientific excursions	valuable	3
S 23	lignite, acidified lake within lignite final excavation	tectonics, raw-material geology	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
S 24	gap river valley	pedology, geomorphology, hydrogeology	trans-boundary significance	regional object of didactic presentation, object of scientific research	valuable	3

Geotope characteristics			Scientific value			
No.	**Geotope type**	**Science branches**	**Regional geological significance**	**Significance for science, research and teaching**	**Summarised value**	
S 25	peat-fen, peat	stratigraphy, geomorphology	trans-boundary significance	object of scientific research	valuable	3
S 26	raised bog	pedology, hydrogeology	local form at the Muskau Arch	regional object of countryside and didactic presentation	significant	2
S 27	garden architecture with using of glacial boulders	countryside science	small	small	of minor value	1

Fig. 6. Special-value geotope P 32 — post-mining excavation filled with acidic iron-rich water near Łęknica (after: Koźma et al. 2001)

Fig. 7. Special-value geotope P 32 — iron-rich water spring near Łęknica (after Koźma *et al*., 2001)

CONCLUSIONS

System of geotope classification, adopted by the German Geological Survey, includes fairly objective classification criteria, allowing to assess geotopes value from several different viewpoints: museal value, scientific research, education and tourism. Evaluation of the geotopes of the Muskau Arch may be a good example of the application of this system.

Muskau Arch is an unique area in Europe and its geotopes represent high value in all assessed fields. From the viewpoint of geotope value, the Polish part of the structure is the most important in the whole Three State Geopark.

The first-stage study of geotope inventory and evaluation, made in the Polish part of the Muskau Arch, certainly did not include all the interesting geotopes in the studied area and this work should be completed in the future.

REFERENCES

ALEXANDROWICZ Z., 2003 — Ochrona dziedzictwa geologicznego Polski w koncepcji europejskiej sieci geostanowisk. *Prz. Geol*., **51**, 3; 224–230.

ALEXANDROWICZ Z., ALEXANDROWICZ S.W., 2003 — Geoparks – most valuable landscape parks in Southern Poland. *In*: Geological heritage concept, conservation and protection policy in Central Europe. Abstracts and field trip guide-book (eds. A. Ber, Z. Alexandrowicz): 11–12. Polish Geol. Inst., Warsaw.

BADURA J., GAWLIKOWSKA M., KASIŃSKI J.R., KOŹMA J., KUPETZ M., PIWOCKI M., RASCHER J., 2002 — Geopark „Łuk Mużakowa" – proponowany transgraniczny obszar ochrony georóżnorodności. *Prz. Geol.*, **51**, 1; 54–58.

DYJOR S., CHLEBOWSKI W., 1973 — Budowa geologiczna polskiej części łuku Mużakowa. *Acta. Univ. Wratisl.*, *Pr. Geol. Miner*., **192**, 3; 3–41.

HÜBNER F., MEIER J., RASCHER J., 1999 — Geotopschutzgutachen für den Muskauer Faltenbogen im Rahmen des gleichnamigen IBA-Projektes zur Entwicklung eines länder- und staatsübergreifenden Geoparkes – Abschlußbericht. "GeoMontan" Ges. angew. Geol. mbH, 95 p., Arch. Gemeinsame Landesplanungabteilung Länder Berlin u. Brandenburg, Cottbus.

KASIŃSKI J.R., BADURA J., GAWLIKOWSKA M., KOŹMA J., PIWOCKI M., 2000 — Program realizacji międzynarodowego obszaru ochrony i konserwacji („Geopark") na terenie Polskiej części Łuku Mużakowa. Centr. Arch. Geol. Państw. Inst. Geol., Warszawa.

KASIŃSKI J.R., PIWOCKI M., 2003a — Dawne górnictwo węgla brunatnego na obszarze polskiej części łuku Mużakowa. *In*: Konf. Polsko-Niemiecka „Geopark Łuk Mużakowa – transgraniczny obszar ochrony georóżnorodności" (eds. J. Koźma, M. Gawlikowska): 13–18. Państw. Inst. Geol., Warszawa.

KOŹMA J., BADURA J., GAWLIKOWSKA E., KASIŃSKI J.R., 2001 — Geotopschutzgutachen für den Muskauer Faltenbogen. Polnische Teil. Centr. Arch. Geol. Państw. Inst. Geol, Warszawa.

KUPETZ, M., 1997 — Geologischer Bau und Genese der Stauchendermoräne Muskauer Faltenbogen. *Brandenburgische Geowiss. Beitr.*, **4**:2; 1–19, Kleinmachnow.

KUPETZ M., KEßLER J., 1997 — Eismächtigkeitsabschätzung für den „Muskauer Gletscher". *Freib. Forschungshf.*, **C-470**: 53–64.

LOOK E.-R., 1996 — Geotope conservation in Germany. Guidelines of the Geological Surveys of the German Federal States. *Angew. Landschaftsökologie*, **9**: 1–105.

RASCHER J., MEIER J., KUPETZ M., 2001 — Der Geopark Muskauer Faltenbogen – Grundlagen, Stand Perspektiven. *In*: Der Geopark Muskauer Faltenbogen (eds. M. Kupetz, J. Rascher). *Exkurs. f. u. Veröfftl*., **215**; 14–23.

REIN H., BRUST M.K., KASIŃSKI J.R., KASTNER H., KOŹMA J., KRUKENBERG E., KUPETZ M., RASCHER J., SCHWIERZY A., 2002 — Der "Geopark Muskauer Faltenbogen" – Machbarkeitsstudie als Meilenstein zur Entwicklung eines UNESCO – Geoparks. *Brandenburgische Geowiss. Beitr.*, **9**, 1/2; 139–152, Kleinmachnow.

WIMBLEDON W.A.P., 1999 — Geosites – an International Union of Geological Sciences initiative to conserve our geological heritage. *In*: Representative geosites of Central Europe (ed. Z. Alexandrowicz). *Polish Geol. Inst. Sp. Papers*, **2**: 5–8.