Development of geotourism in Poland and examples of geosites from the *Catalogue of geotouristic objects in Poland*

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Geotourism is a branch of specialized tourism focused on objects of inanimate nature. Geotouristic object is a geological site, which, if properly developed and promoted, can become attractive for visitors and, thus, also for tourist industry as a base for preparation of a product available for customers of travel agencies. Geotouristic objects can be categorized using various criteria, e.g., geological and geomorphological features, scale, size, number and types of attractions, mode of development (Słomka & Kicińska-Świderska, 2004).

Geotourism aims to integrate Earth and environmental sciences with cultural and historical heritage. Such comprehensive knowledge is then offered to visitors in a variety of forms: from leaflets to extended guides and thematic books, commonly available also in electronic formats.

In Poland geotourism has been initiated by opening of "Geotourism" course at the Faculty of Geology, Geophysics and Environment Protection, AGH — University of Science and Technology in Cracow, in 1998 (Słomka, 2005). This initiative was a response to rapid expansion of tourist industry in Poland and in the world. In the next decade tourism may become one of the most important branch of world economy. Thus, there is a demand for specialists who gained an interdisciplinary education, which combines the relevant elements of natural sciences, human sciences and basic sciences together with perfect knowledge of two foreign languages (including English). Such education should facilitate the successful job-seeking efforts of graduates as they may well be employed in geology, environment protection or in tourist industry. Recently, education in geotourism and related specializations is run at several state and private universities in Poland.

According to the principles, geotourism must educate specialists capable to satisfy new expectations of modern tourists who not only want to see the abiotic nature objects but demand more detailed, professional explanations, e.g., how, when and why a particular object was formed or how the particular raw-material was extracted and processed.

In last years geotourism has been included into the statutory scientific activity of several universities and the Polish Geological Institute. Moreover, the Ministry of Environment has started to finance some geotouristic projects (catalogues, guides, maps, etc.).

Another important aim of geotourism is the promotion of geology and the whole Earth sciences. Geology plays a crucial role in the development of civilization by providing basic knowledge on the origin and history of the Earth. Moreover, as an applied science, geology supports the industrialization by prospecting for and exploring various mineral resources and by contributing to their beneficiation but also provides knowledge and data critical for various applications, as e.g. land development, resource management, environment protection. Unfortunately, the public opinion usually underestimates the importance of geology. Apart from its recreational aspects, geotourism provides new opportunities in promotion of geology by a variety of educational programs directed to various groups of tourists including young generation.

Promotion of geology requires the application of proper language and medial techniques, which will transform professional knowledge of specialists into information understandable to common tourists (non-professionals). Thus, the proper forms of transfer must be applied. "Classic" communication methods (papers, books, written guides, even CD and DVD data carriers) are recently replaced by electronic sources: on-line libraries, interactive datasets or guides, all accessible via the Internet. An example can be the web page www.geoturystyka.pl and its English version www.geotourismonline.com. However, mass appearance of electronic-based information brings serious risks, e.g., incidental or intentional spreading of false data. Therefore, there is a growing demand for trustful websites improving the education and promotion of Earth sciences.

The *Catalogue of geotouristic objects in Poland*

In recent tourist industry information is a crucial factor of exceptional value and importance. On the contrary to

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historical monuments and objects of cultural heritage, the geosites are much less known to the public. Thus, it is essential to provide basic information on such objects in the form acceptable by a common visitor who usually has rather limited knowledge and experience in the Earth and environmental sciences.

The first volume of the *Catalogue of geotouristic objects in Poland* was prepared by the working team from the Faculty of Geology, Geophysics and Environment Protection, AGH — University of Science and Technology in Cracow managed by Tadeusz Słomka (Słomka et al., 2006). The team invited to cooperation a number of leading experts in geology, geography and environmental sciences from various scientific institutions and administration units in Poland (Polish Geological Institute, Institute of Nature Conservation of the Polish Academy of Sciences, Wrocław University and others). The project was financed by the National Fund for Environment Protection and Water Management.

The catalogue is the first attempt to present to the public some selected, highly interesting and valuable geosites. In the near future next volumes will be completed showing other, similarly interesting objects.

The *Catalogue…* is a proposal for those who are interested in visiting the geosites and in improving their knowledge of Earth history, geological and geomorphological processes, environmental problems and mining heritage.

The catalogue is a sample of 100 thematically diversified geotouristic sites located in all districts. Thus, it presents to the reader the geodiversity of the country as this selection is representative for complex geological history of Poland and includes a variety of lithostratigraphic units, structures, fossil accumulations, mineral occurrences and deposits, geomorphological forms, etc. These sites not only illustrate geological processes active over millions of years of geological history but also promote the beauty of abiotic nature.

The sites presented in the *Catalogue…* were selected from over 600 initial proposals and described in a standard form of the *Record Sheet of Documentation Site*. Such record includes localization (state administration units, geographical regions, geological units), geological description (i.e., structural unit, stratigraphic column, geological history and origin), geological and tourist assessment, history and cultural heritage, and other touristic attractions in the vicinity (e.g., trails, protected areas of biotic nature). Each site is localized on 1 : 25 000 scale topographic map and supplied with representative photographs.

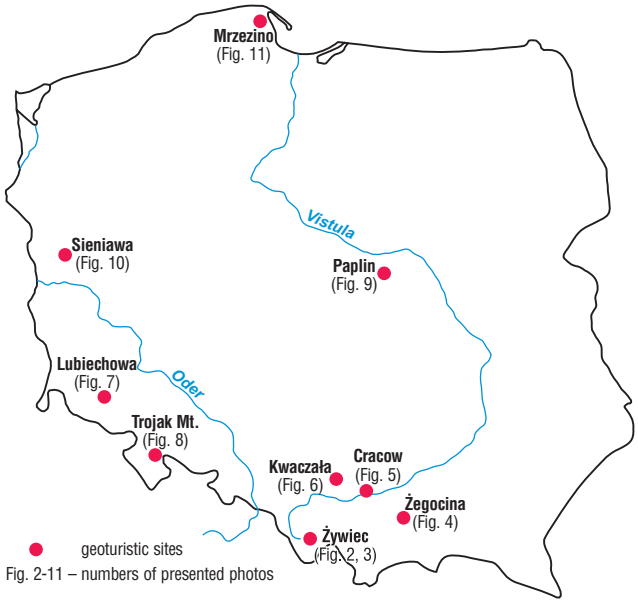

Fig. 1. Localization of described geotouristic sites

In this article, the samples of geotouristic sites described in the *Catalogue…* are presented together with sample photographs (for site localization see Fig. 1). The first example: the Grojec Mt. in Żywiec presents the full record of data on a geosite. The remaining sites are only briefly described.

The Grojec Mt. in Żywiec

The Grojec Mt. is located in the confluence of the Soła and the Koszarawa Rivers. The area is covered by flysch deposits representing the three Outer Carpathian units: Silesian, Sub-Silesian and Magura. In several abandoned quarries and in numerous natural outcrops along the banks of the Soła River valley and its tributaries the Cieszyn Beds are perfectly exposed (Słomka, 2001).

The flysch succession of the Grojec Mt. includes the Lower and the Upper Cieszyn Limestones, and the Upper Cieszyn Shales. The Lower Cieszyn Limestones are thin- to medium-bedded, detrital and pelitic limestones, marls and marly shales (Fig. 2). In detrital limestones graded bedding, cross-bedding and parallel lamination can be observed. Massive, pelitic limestones either form individual beds or alternate with the detrital limestones. The Upper Cieszyn Beds include the increasing proportion of pelitic limestone beds of thicknesses exceeding

Fig. 2. Limestones in flysch from the Grojec area. Photo by T. Słomka

Fig. 3. Debris-flow deposits exposed in the Soła River bank. Photo by T. Słomka

1 m. Coarse-grained limestones are rich in bivalves, aptychi and echinoderms. The Upper Cieszyn Shales are dark grey and black, marly shales interbedded with dark grey, fine-grained, calcareous sandstones and frequent layers of clayey siderites up to tens of centimeters thick. Siderites were mined here in the 19th century as an iron ore. The shales contain fauna of ammonites and belemnites. The Cieszyn Beds were deposited between 140 and 120 Ma ago, in a basin bordered from the north and the south by cordilleras. Initially, pelagic environment prevailed with rare episodes of deposition from currents. Then, submarine fan sediments were laid down by density currents, which transported clastic material from the littoral zone to the base of active cordilleras.

In the Cieszyn Beds sills of Lower Cretaceous teschenites can be found. The teschenites are olive-green igneous rocks composed of pyroxenes, amphiboles and variable amounts of feldspars. The teschenites magma originated from deep-seated sources.

In the exposures along the Soła River valley the debris flows were recognized. Such structures document the uplift, which transformed the submarine Silesian Ridge into the active cordillera (Fig. 3).

The Grojec Mt. is an interesting site, as it presents complicated geological structure and fascinating history. Archaeological studies revealed the relics of Lusatian and Celtic cultures. The settlements dated back to the 9th and 10th centuries AD presumably belonged to the Great Moravian Empire. In the 14th and 15th centuries a wooden castle had existed atop the mountain. In the center of Żywiec town there is a palace built in the 19th century by the member of Habsburg royal family and surrounded by the park covering 25 ha.

The Grojec Mt. is a perfect example of geosite located in the flysch mountains, which illustrates various aspects of this specific depositional environment (the *Record Sheet of Documentation Site* was prepared by T. Słomka and E. Słomka).

The Grodziszcze Beds quarry in Żegocina

One of the most interesting geosites in the Outer Flysch Carpathians is the quarry in Żegocina village. The village is located at the border of the Beskid Wyspowy ("Island Beskid") mountain group and the Wiśnicz Foothills. Flysch sediments are exposed in an abandoned quarry, some 500 m south from the village. This is a 45-meter-thick fragment of the Grodziszcze Beds succession accepted as a stratotype for this member (Fig. 4).

Exposed layers are marine strata deposited in a deep-water (up to 3.5 km), elongated basin from gravity flows (mostly density currents) in an environment of submarine fans located at the base of continental slope. Geological data indicate the frequency of such gravity currents as one event per 20 000 years. Deposition rate was 2–3 m/1000 yr, hence, the whole succession has been accumulating for 0.5–1.0 Ma (Malik & Olszewska, 1984). The exposed beds host all sedimentary structures typical of flysch strata: gradational bedding, horizontal and ripplemark lamination, hieroglyphs, casts of current and organic structures. Fossil assemblages include ammonites, belemnites and aptychi.

In the lower part of the quarry sediments of submarine slides can be observed. These are products of dense currents transporting large amounts of various clastic fractions and disturbing the surrounding sediments.

The coarse-grained fractions of sandstones and conglomerates comprise gneiss, limestone, lydite and quartz grains. Interesting clastic components are pebbles of Carboniferous coals, up to several centimeters long. These coals are similar to those known from the Upper Silesian Coal Basin as the Carboniferous formations occur in the basement of thrusted flysch nappes.

The quarry in Żegocina is an interesting geosite of high cognitive and educational value. The site is well-developed and easily accessible from the local road Bochnia–Żegocina–Limanowa (the *Record Sheet of Documentation Site* was prepared by T. Leśniak).

Fig. 4. Flysch deposits in Żegocina. Photo by A. Joniec

The Dragon's Cave (Smocza Jama) in the Wawel Hill (Cracow)

The Dragon's Cave is located in the Wawel Hill, under the Royal Castle, in the town center. The Wawel Hill is a tectonic horst surrounded by grabens. Its framing faults show throws from 20 to 70 m. The hill is built mostly of massive, locally of thick-bedded Upper Jurassic limestones. At the top surface of the hill lenses of Cretaceous marls, Miocene ostrean limestones and Quaternary sands and clays were encountered.

The Dragon's Cave comprises two parts: older (with the Altha, Grabowski and Szyszko-Bohusz Chambers) and new (with recently discovered, several small rooms) (Fig. 5). Total length of corridors reaches 276 m. The lower entrance opens at the boulevard of the Vistula River and the upper one is located in a small tower in the castle walls. The bottom of the cave is covered with about 2-meter-thick clastic residuum. Small ponds at the cave floor are settled by rare crustacean *Niphargus tatrensis*, typical resident of such environment. The genesis of the Dragon's Cave is related to the artesian circulation of waters of increased temperature. Under phreatic conditions potholes were formed in the roof and in the walls of the cave. Diameters of these forms vary from 30 to 200 cm.

Fig. 5. Accessible part of the Dragon's Cave under the Wawel Hill. Photo by M. Szelerewicz

The Dragon's Cave belongs to the oldest known caves in Poland. Traces of human activity were dated back to the end of the 16th century. In the 17th and 18th centuries the cave was occupied by a tavern. Due to its location and well-known legend on the dragon who once lived under the Wawel Hill, it is one of the top-class tourist attractions in Cracow, first open to the visitors in 1843. The dragon's sculpture standing at the lower entrance and temporarily jetting gas flames is particularly respected by youngest tourists. This is a perfect site to recognize development of karst processes in a limestone formation (the *Record Sheet of Documentation Site* was prepared by R. Gradziński).

Fig. 6. Fragment of petrified tree trunk from the Kwaczała Arcose. Photo by R. Molenda

The Kwaczała Arcose in Gródek Gorge in Kwaczała

In Małopolska region, in the Kwaczała village located at the Cracow-Częstochowa Upland the visitor can examine a unique rock — the so-called Kwaczała Arcose. Outcrops are located in several gorges which dissect a steep, southern slope of the Paleozoic Tenczyn Bulge.

The very thick-bedded rocks contains sand and conglomerate fractions composed of quartz and large amount of red feldspar grains, which is responsible for characteristic, reddish color of this rock.

Petrographic variability of clastic components is best-visible in conglomeratic variety of the arcose. Clastic grains are igneous, sedimentary and metamorphic rocks cemented with clay matter or clay-iron oxide mixture, which makes the rock rather soft although relics of hard, weathering-resistant, calcite-cemented arcose can be found in the gorge walls and bottom. The layers host examples of various sedimentary structures, particularly large-scale trough beddings with the bottoms of erosional troughs paved with pebbles. The Kwaczała Arcose records paleogeographic features and geological processes active in the Upper Carboniferous (Stephanian). Sediment was laid down onto the northern foreland of a mountain range built of a crystalline core and sedimentary cover. Intensive weathering and erosion under dry climate conditions combined with occasional heavy rains causing torrent flows resulted in abrupt removal of weathering crusts and fluvial deposition.

The exceptional feature of the Kwaczała Arcose is the presence of petrified coniferous trees of the genus *Dadoxylon*, colloquially called "araucarias". Commonly, the wood structure is well-preserved in the fossil trunks and colored with iron oxides, which makes "araucarias" a valuable ornamental stone, still appreciated and sought by collectioners (Fig. 6).

Fig. 7. Pillow lavas from Lubiechowa. Photo by R. Kryza

This geosite of high scientific and educational value is easily accessible (the *Record Sheet of Documentation Site* was prepared by A. Joniec).

Pillow lavas from Lubiechowa

In the Kaczawa Mountain Range (the Western Sudetes), three interesting cliffs rise some 800 m east from the summit of the Okół Mt. and about 700 m northwest from the pass cut by the Lubiechowa–Kapela road. The cliffs are built of greenschists, which protolites were Cambrian-Ordovician pillow lavas. The lavas belong to the lower part of the Kaczawa Succession formed 542–443 Ma in an initial rift and then subjected to metamorphism under consecutive, blueschist and greenschist facies conditions. The pillow lavas show perfectly visible, primary volcanic structures which enabled the author to determine the primary paleohorizon and the succession of rocks in this part of the Kaczawa Mts. (Fig. 7).

The primary volcanic features: cooled margins, radial joints and randomly distributed amygdaloids filled with secondary calcite stand for the unique character of this site. The shape of pillows and their arrangement allow the visitor to identify approximate geometry of layering whereas the relation to cleavage permits to reconstruct tectonic position of lavas in the limb of an anticline, which dips to the south at high angle. The tops of highest cliffs are composed of massive lavas produced during intensive submarine eruptions. The area shows high scientific, natural and touristic values. It is planned to be included into the future Kaczawa Mts. Landscape Park. In the vicinity there are three other landscape parks: the Bóbr River Valley, the Chełmy and the Rudawy Janowickie parks.

This site brings to the visitor the details of ancient, submarine volcanic eruptions active since the beginning of Earth's history (the *Record Sheet of Documentation Site* was prepared by R. Kryza).

The Rock Gate in the Trojak Mt.

The Lower Silesia hosts numerous, diversified and amazing geosites. One of many examples is the Rock Gate in the Trojak Mt. at Lądek Zdrój village.

The Trojak Mt. (766 m a.s.l.) is one of peaks in the southern part of the Golden Mountains near Lądek Zdrój. The mountains are built of Precambrian–Lower Paleozoic Gierałtów-Śnieżnik formation. The Rock Gate consists of two projecting cliffs, up to 15 m high. The eastern cliff called "Stone Eagle" is larger (60 × 20 m), the western cliff is smaller (about 35 × 20 m). Cliffs are separated by a 30-meter-long, steep rock corridor of overhanged (up to 30°) eastern wall (Fig. 8). The regular cliff walls result from three systems of joints perfectly visible in all cliffs, which controlled the denudation processes and shapes of the cliffs. At the base of the cliffs characteristic rockfall taluses were produced by intensive physical weathering and mass movements.

The Rock Gate is built of the Gierałtów Gneiss — a fine-blastic, banded metamorphic rock with well-visible

Fig. 8. The Rock Gate in the Trojak Mt. Photo by T. Bartuś

foliation, composed of plagioclases, microcline, quartz, biotite and muscovite in variable proportions, accompanied by accessory garnets, zircon, apatite and titanite. In the cliff walls migmatitic gneisses are also present with characteristic folded structure and well-visible ptygmatic folds. The rocks were subjected to ultrametamorphic processes with partial melting. Age and origin of the Gierałtów Gneiss is still a matter of discussion, which raises the valor of the site. Hence, legal protection of the Rock Gate was proposed as documentation site of abiotic nature.

The Rock Gate and other cliffs projecting from the slopes and the top of the Trojak Mt. are located in the vicinity of Lądek Zdrój health resort. The area is touristically very well-developed and play the role of a natural park. The mountain is crossed by a blue tourist trail leading from Lądek Zdrój to Old Gierałtów village and by a thematic, nature trail (the *Record Sheet of Documentation Site* was prepared by W. Mastej and T. Bartuś).

Fig. 9. Glacitectonically folded till in the Paplin gravel pit. Photo by S. Bębenek

The gravel pit in Paplin

The gravel pit in Paplin is localized in the western slope of the Chojnatka valley, west of Kowies village and belongs to the Mid-Poland Anticlinorium. In a 10-meter-high pit wall the visitor can examine the succession of Pleistocene deposits of the Rawa Plain: boulder clays, fluvioglacial sands and gravels as well as muds deposited in stagnant lakes, all related genetically to the Warta River glacial period.

The boulder clays are melt-out sediments composed of coarse-clastic material (with boulders up to 1.8 m across) mixed with medium and fine fractions. Sand-gravel fluvioglacial sediments reveal all typical features: variety of grain size, variable sorting, diversified lithology and interesting sedimentary structures (e.g., large-scale trough bedding). In the silt sediments forming the uppermost part of the exposure horizontal and wavy laminations can be observed, typical of sediments laid down in stagnant lakes (Fig. 9). Pro-glacial folds produced by pressure from the glacier terminus and base can also be observed.

In common opinion (popular even among some geologists) the youngest (Quaternary) sediments do not show features attractive for professionals and, ever more, for tourists. The gravel quarry in Paplin is a positive example, as it can tell the story on processes active during glacial epochs, i.e., the youngest episodes of geological history of Poland (the *Record Sheet of Documentation Site* was prepared by A. Galińska, A. Kicińska-Świderska, S. Pytliński, P. Strzeboński and S. Bębenek).

Fig. 10. Brown-coal formation from the Sieniawa lignite deposit. Photo by R. Dobracki

The lignite mine in Sieniawa

The mine is localized in Sieniawa village (Lubusz District), in the marginal zone of the Łagów Landscape Park. Initially, in the 1960s lignite was worked with underground methods then replaced by open-pit operations. In the walls of the pit an interesting succession of Miocene brown-coal formation is exposed. Its lower part of comprises sand-mud beds and lignite seams with xylites deposited between 16 and 11 Ma ago. The lignite seam is overlain by fine sands and sandy muds with micas as well as by brownish, coaly clays and greenish-grey clays.

The Miocene brown-coal formation was strongly glacitectonically folded during the Pleistocene ice epochs which left thick cover of glacial sediments (Fig. 10).

The central part of the pit is occupied by a nice pond. The pit is well-preserved and tectonic structures are well-visible in steep walls.

Fig. 11. Fluvioglacial sediments capped by till bed in the Mrzezino gravel pit. Photo by A. Joniec

The geosite is accessible from state road No. 137 from Sulęcin through Templewo to Sieniawa, then turning right to country road (near the housing estate) and driving some 2 km to the mine (the *Record Sheet of Documentation Site* was prepared by M. Schiewe and R. Dobracki).

Post-glacial sediments from the gravel pit in Mrzezino

The gravel pit is located in Mrzezino village, a dozen kilometers from Puck town, about 1.5 km from the coast of the Puck Bay. The pit is several meters long and its walls are up to 20 m high. In its eastern, inactive part an interesting succession of post-glacial sediments can be examined (Fig. 11).

The oldest rock is glacitectonically disturbed, a 10-meter-thick till. It is followed by fluvioglacial sediments of eroded upper surface onto which the younger till was laid down.

Such succession documents geological history of the region: sediments deposited by an older, Mid-Poland glacial epoch were invaded by ice sheet of the younger, Northern-Poland epoch, which disturbed initial structure of the older till. During interglacial period the ice sheet retreated to the north and its proglacial rivers deposited a pile of fluvioglacial strata which was partly removed by advancing ice of the younger glacial epoch and covered with its own, younger till sequence during recession (the *Record Sheet of Documentation Site* was prepared by T. Leśniak).

Conclusions

The *Catalogue of geotouristic sites in Poland* plays an important role in presenting to the public the striking geodiversity of Poland. By spreading the knowledge on geosites and geodiversity, it helps to build the awareness of protection of inanimate nature among the society and contributes to common understanding of the importance of Earth heritage.

The *Catalogue*… is directed to both the professionals and the amateurs, to all who are interested in the improvement of their knowledge of geological and geomorphological processes by visiting the sites where these processes can be observed and interpreted.

The standardized format of the *Catalogue*… makes it a valuable database suitable not only for tourists planning their holiday trips but also for decision-makers at various levels of state and local administrations responsible for land development and management, and for tourism development/promotion at various levels, for travel agencies (particularly those offering the specialized products, e.g., educational trips) and for full range of educational institutions, from primary schools to universities.

The formula of the *Catalogue*… is open and forthcoming volumes are in progress, which will contain descriptions of new geosites. Moreover, the electronic version will be available.

Sincere thanks are due to the Ministry of Environment and to the National Fund for Environment Protection and Water Management for supporting the initiative and financing the project.

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