Geodiversity of Poland

Tadeusz Słomka[1]

The area of Poland is a border zone between three principal structural units of Europe: the Precambrian East European Platform, the Paleozoic domain of Central and Western Europe and the Alpine orogenic belts of Southern Europe (Fig. 1A) (Znosko, 1986; Pożaryski, 1990; Dadlez, 1994; Guterch & Grad, 1996; Stupnicka, 2007).

The East European Platform occupies northeastern part of Poland. Here, Paleozoic and Mesozoic sedimentary cover rests upon Precambrian igneous and metamorphic basement. Its southwestern margin is a zone of deep fractures and faults known as the Trans European Suture Zone (TESZ).

The largest, south-western part of the territory of Poland belongs to the zone of Paleozoic fold belts formed during the Caledonian and the Variscan orogeneses. These are overlain by thick cover of Permian, Mesozoic and Cenozoic deposits. However, deep erosion has uncovered some Paleozoic massifs: the Sudety Mts., the Holy Cross Mts. (Świętokrzyskie Mts.), the Upper Silesian Coal Basin and the horsts of the Silesian-Cracow Upland. The Alpine structures are located in the southern Poland and include a fragment of the Carpathian Mts. fold belt and its vast Carpathian Foredeep. The Carpathians form a 1300-kilometer-long orogen of very diversified structure extended from the Alps in the west to the Balkan Mts. in the east and southeast. The Carpathians include two structural units: the Outer and the Central Carpathians. The Central Carpathians comprise Paleozoic crystalline basement and Mesozoic sedimentary cover. The Outer Carpathians embrace thick complex of flysch sediments deformed in several, huge nappes. The Outer and Central Carpathians are separated by the zone of transform faults which appear at the surface as the narrow Pieniny Klippen Belt of highly complicated tectonics built of Mesozoic and Cenozoic carbonates, clastics and siliceous rocks.

The recently observed relief of Poland has been shaped during the last several millions of years by endogenic and exogenic processes, the latter related mostly to abrupt climatic changes (Mojski, 2005). Particularly important for recent morphology of Poland was the Ice Age, which left behind a thick cover of glacial and post-glacial sediments as well as characteristic landforms (ridge crests, glacial rafts, proglacial valleys, various glacial lakes, etc.). Very significant was also the role of basement structures, particularly the fault tectonics. Moreover, the influence of vertical movements of the Earth crust is still insufficiently understood (Liszkowski, 1982). Undoubtedly, some old structures were uplifted and others were buried. The directions and the rates of these movements were changing and the amplitudes might have exceed even 100 m (Mojski, 2005).

The shallow geological structure and the relief of the territory of Poland are combined effects of various geological processes (Fig. 1B). Geological structure is also responsible for remarkable geodiversity of the country. Geo-

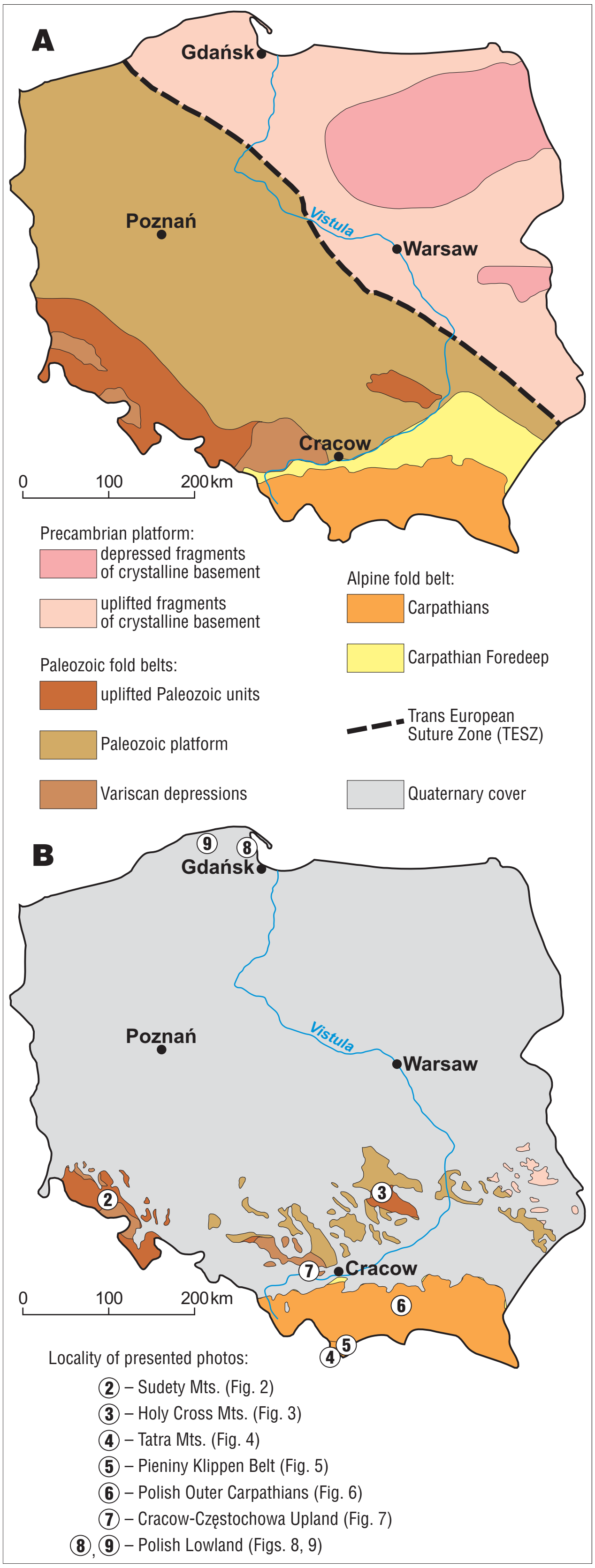

Fig. 1. A — structural map of Poland (after Znosko, 1998, simplified); **B** — superficial geological map of Poland

[1]Faculty of Geology, Geophysics and Environment Protection, AGH University of Science and Technology, ul. Mickiewicza 30, 30-059 Kraków, Poland; slomka@geol.agh.edu.pl

Fig. 2. The Karkonosze Mts. granitoid intrusion in the Sudety Mts. Photo by A. Walanus

logical sites which can be presented as touristic products (Słomka & Kicińska-Świderska, 2004) have originated from the past and the recent geological processes: weathering, erosion and mass movements as well as by human activity, e.g., exploitation of mineral raw materials. Below, the brief characterization is presented of principal geological units which are exposed at the surface and which give rise to tremendous geodiversity of Poland.

The **Sudety Mts.** comprise a mosaic of igneous, metamorphic and sedimentary rocks ranging in age from the Proterozoic to the Cenozoic. This area is a typical example of block tectonics. The horst of the Sudety Mts. was formed in the Neogene by rejuvenation of old tectonic lines. The recent relief is a combined effect of weathering, erosion and mass movements. Complicated structure of the Sudety Mts. together with diversity of lithology, led to the formation of a number of excellent geotouristic objects, e.g., monadnocks, ravines, waterfalls, caves (Fig. 2). Of special interest are the occurrences of minerals and rocks, which fascinate the collectioners. Exploitation of various mineral raw materials exposed fragments of intrusions, volcanic cones and sedimentary successions. In the Sudety Mts. the excellent underground touristic trails were organized in the old, inactive ore mines, as well as in the underground factories and warehouses built by Nazi Germans during the World War II. Very popular among tourists are also numerous health resorts, famous of their mineral and therapeutic waters. Finally, the Sudety Mts. are full of historical monuments, e.g., old castles built onto the tops of mountains and hills.

The **Holy Cross Mts.** (see p. 618) also represent a tectonic horst uplifted during the Alpine orogeny along deep faults. The horst comprises a variety of Paleozoic rocks folded during the Variscan orogeny and enveloped by Permian-Mesozoic successions. Lithology includes various sedimentary rocks: clastics, carbonates, siliceous and ferruginous deposits. Long-lasting geological history left behind countless interesting objects, e.g., screes, folds, faults, caves, fossiliferous strata full of trilobites, graptolites, brachiopods, corals, crinoids, gastropods and ammonites. Other interesting sites are numerous historical mining camps where metal ores were mined as well as related smelting sites with the relics of primitive furnaces (Fig. 3). The Holy Cross Mts. are an interesting area which deserved public attention as an excellent target for motorized tourism and for hiking due to its natural beauty and historical monuments.

Internal structure of the **Carpathians** is a very complicated. Mesozoic and Cenozoic rocks are deformed and thrusted northward as several nappes. The basement of the nappes comprises Paleozoic igneous and metamorphic rocks, and Mesozoic deposits. In the territory of Poland the Carpathians include three megastructures: the Tatra Mts., the Pieniny Klippen Belt (see p. 670) and the flysch belt of the Outer Carpathians (see p. 688).

The **Tatra Mts.**, shared by Poland and Slovakia, represent an alpine range (elevations of tallest peaks exceed 2500 m a.s.l). This area shows high-mountain relief controlled by geological structure, i.e., the presence of Paleozoic crystalline core composed of eroded Carboniferous granitoids and their metamorphic envelope, and Mesozoic sedimentary cover. Recent relief of the Tatra Mts. is a result of glacial processes active during the last million years. Geotouristic attractions are, e.g., steep cliffs, deep glacial troughs, cirques occupied by lakes filled with pure water, waterfalls, caves and breathtaking, scenic views (Fig. 4).

Fig. 3. The Krzemionki Opatowskie archaeological and nature reserve — an example of ancient flint mining district. Photo by T. Ostrowski

Fig. 4. Dolina Pięciu Stawów (Five Ponds Valley) in the Polish part of the Tatra Mts. Photo by G. Madeja

For many visitors interesting objects can also be the relics of old mining camps. For experienced hikers and backpackers the top attractions are extremely difficult high-mountain trails (e.g., the so-called "Eagle's Trail" which connects several tallest peaks in the High Tatras). Additionally, there are several ski centers and quite well-developed infrastructure. All these features make the Tatra Mts. one of the most popular touristic regions in Poland.

Fig. 5. The Białka River gorge in the Pieniny Klippen Belt. Photo by T. Słomka

The **Pieniny Klippen Belt** is a low mountain range built almost exclusively of sedimentary rocks: carbonates, clas tics and siliceous deposits. They were laid down in a vast marine basin, then they were subjected to multistage deformations and finally uplifted as a horst of complicated internal structure, framed from the north and the south by deep fractures. Despite low elevations (about 1000 m a.s.l.), the Pieniny Mts. attract thousands of tourists with their towering peaks, cliffs and rock pinnacles built of white limestones, deep gorges and exposed fossiliferous rocks full of excellent specimens of ammonites, bivalves, brachiopods and crinoids (Fig. 5). Supplementary attractions are Medieval castles, towns and villages of preserved historical architecture as well as the top-class touristic object — the picturesque, antecedent Dunajec River gorge, which cuts through limestone formations. Rafting down the river which meanders between almost vertical, high limestone walls is an unforgettable experience.

Fig. 6. Folded flysch strata of the Carpathian Mts. Photo by L. Jankowski

The **Beskidy Mts.** constitute the most part of the Polish Outer Carpathians. These are moderately high mountains built of flysch — the specific successions of alternating conglomerates, sandstones and shales with minor limestones and siliceous rocks. This suite was deposited in a deep-water basins located along the northern extension of the Tethys Ocean. During the Alpine orogeny the flysch strata were separated from the basement and folded into huge nappes, then faulted and uplifted. Combined effect of weathering, erosion and mass movements produced deep, V-shaped river and stream valleys, waterfalls and boulder fields (Fig. 6). In the mountain slopes there are numerous spring holes, ravines, clefts, tectonic caves and landslides. There are many erosional features, e.g., monadnocks built of thick-bedded sandstones and conglomerates. Finally, there are scenic views of the gently rounded, forested mountains and broad, deep valleys.

The **Carpathian Foredeep** is a broad zone formed as foreland depression during the folding of the Carpathian flysch nappes. In the Miocene, marine transgression invaded the depression and deposited thick succession of clays. In the Middle Miocene the shallowing of the basin resulted in the precipitation of evaporite formation. The Miocene salt beds have been mined since the Medieval ages at the two famous mines: Wieliczka and Bochnia (see p. 663). Recently, both mines are top-class touristic and geotouristic attractions. The Wieliczka Underground Museum has been appointed the leading touristic object in Poland in 2007.

The **Cracow-Częstochowa Upland** (see p. 647) belongs to the large structural unit — the Silesian-Cracow Monocline. The basement includes Paleozoic and Mesozoic rocks arranged in a huge rock slab which dips gently to the northeast. The southern part of the upland is dissected by faults into several blocks forming a system of horsts and grabens. Erosion exposed Paleozoic sedimentary rocks and

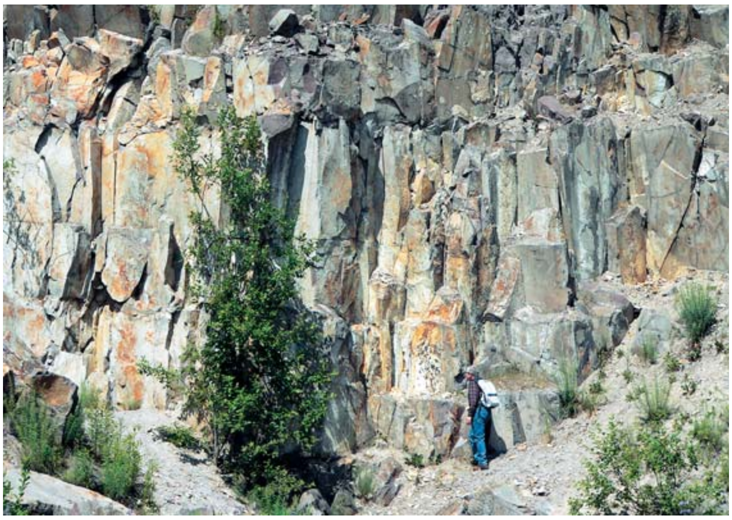

Fig. 7. Volcanic rocks from the vicinity of Cracow. Photo by R. Gradziński

Touristic attractions are also coast cliffs where post-glacial sediments are exposed along with glacial rafts transported by advancing ice sheet. Among the rocks affected by glacitectonic movements are Paleogene lignite seams and Cretaceous carbonates.

The territory of Poland is geologically diversified and interesting from geotouristic point of view. Rocks exposed represent all geochronological units. Most part of the country is covered by thick successions deposited during the consecutive glacial epochs. In the northern and central Poland the ice sheet decisively shaped the recent relief and the structure of near-surface zone. Such high geodiversity makes the area of Poland very attractive for geotourism and, as we all hope, it may inspire the tourists to visit our country and to recognize not only our history and culture but also our geotouristic sites.

volcanics (Fig. 7) in the southwestern part. The whole upland is covered by Jurassic and Cretaceous carbonates. Typical landforms are limestone monadnocks of unusual shapes, deep valleys, numerous caves and quarries where the visitor can examine sedimentary successions and volcanic suites. There are also Medieval castles and relics of old ore mine workings for silver, zinc, lead and iron.

The most part of the northern and central Poland is covered by glacial sediments (Fig. 8). Geotouristic attractions are common but less diversified. These are mostly the landforms of glacial origin: eskers, drumlins, kames, terminal moraines, glacial lakes, proglacial valleys, planation surfaces. Common are erratics used by local communities as excellent construction or even decorative stones. Interesting details of glacial deposition can be studied in numerous gravel and sand pits where sedimentary structures and stratigraphic successions reflect the history of the last 1 Ma (Fig. 9).

Fig. 8. Fluvioglacial sediments from the northern Poland. Photo by A. Joniec

Fig. 9. Moving dunes at the Baltic Sea coast. Photo by A. Joniec

References

DADLEZ R. 1994 — Polska — Tektonika. [In:] Dadlez R. & Jaroszewski W. Tektonika. Wyd. Nauk. PWN, Warszawa.

GUTERCH A. & GRAD M. 1996 — Seismic structure of the Earth's crust between Precambrian and Variscan Europe in Poland. Publications of the Institute of Geophysics Polish Academy of Sciences, vol. M-18, iss. 273: 67–73.

LISZKOWSKI J. 1982 — Geneza pola współczesnych pionowych ruchów skorupy ziemskiej na obszarze Polski. Rozprawy UW, 174: 7–179.

MOJSKI J.E. 2005 — Ziemie polskie w czwartorzędzie. Państwowy Instytut Geologiczny, Warszawa.

POŻARYSKI W. 1990 — The Middle Europe Caledonides — wrenching orogen composed of terranes [in Polish, English summary]. Przegląd Geologiczny, 1: 1–9.

SŁOMKA T. & KICIŃSKA-ŚWIDERSKA A. 2004 — Geoturism — the basic concepts [in Polish, English summary]. Geoturystyka (Geotourism), 1: 2–5.

STUPNICKA E. 2007 — Geologia regionalna Polski. Wyd. UW, Warszawa.

ZNOSKO J. 1986 — Polish Caledonides and their relation to other European Caledonides. An. Soc. Geol. Pol., 56: 1-2: 33–52.

ZNOSKO J. (ed.) 1998 — Tectonic atlas of Poland (in Polish). Państwowy Instytut Geologiczny, Warszawa.