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Klimkówka Lake in Beskid Niski – geotouristic aspects

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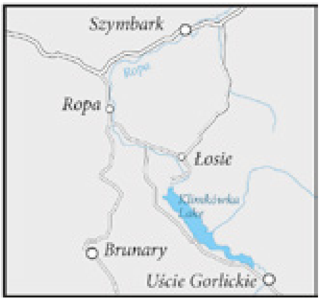

Abstract: *The Klimkówka Lake geotouristic site is one of the greatest attractions of the Beskid Niski Mountains of the Polish Carpathians Mts. Nearly 20 years of existence of the artificial dam lake generated the development of tourism in the area. The great advantage of Klimkówka Lake region is the presence of a number of spectacular surface rock outcrops situated in convenient locations for visitors, in which crop out the youngest rocks of the Rača Zone of the Magura Nappe. The area around the Klimkówka Lake is a great training ground to acquire knowledge of the geology of the Outer Carpathians, as well as different varieties of sedimentary rocks, and sedimentary and tectonic structures.*

Key words: *dam lake, Klimkówka, Outer Carpathians, geotourism*

Introduction

There are over 100 artificial reservoirs in Poland with a total capacity of more than 1 million cubic metres of water. Their main purpose is to regulate the flow of the rivers. The latest such reservoir is located at Świnna Poręba village close to Sucha Beskidzka town in the Carpathians. Despite the fact that these lakes are of anthropogenic origin, they are well etched into the Beskid landscape becoming an integral part of it. The creation of reservoirs is important for the environment.

New artificial lakes, in a short time of existence, generate new geological processes in their vicinity. One such process is the activity of destructive waves, which is a major factor creating and modelling the coastal zone.

In the first period of the dam functioning, the edges of the lakes are under intense destructive processes, which favour the formation of new exposures. Dam reservoirs should be considered as good geotouristic areas, where these processes could be observed. The numerous exposures provide insight into the geological structure of the substrate.

One of the earliest of such lakes is the Klimkówka Lake (also known in the nomenclature as Klimkowskie Lake, Klimkowieckie Lake) which for nearly 20 years enhances landscape features of the Beskid Niski Mountains (Fig. 1).

Fig. 1. Panorama of Klimkówka Lake a view from the dam, photo A. Waśkowska

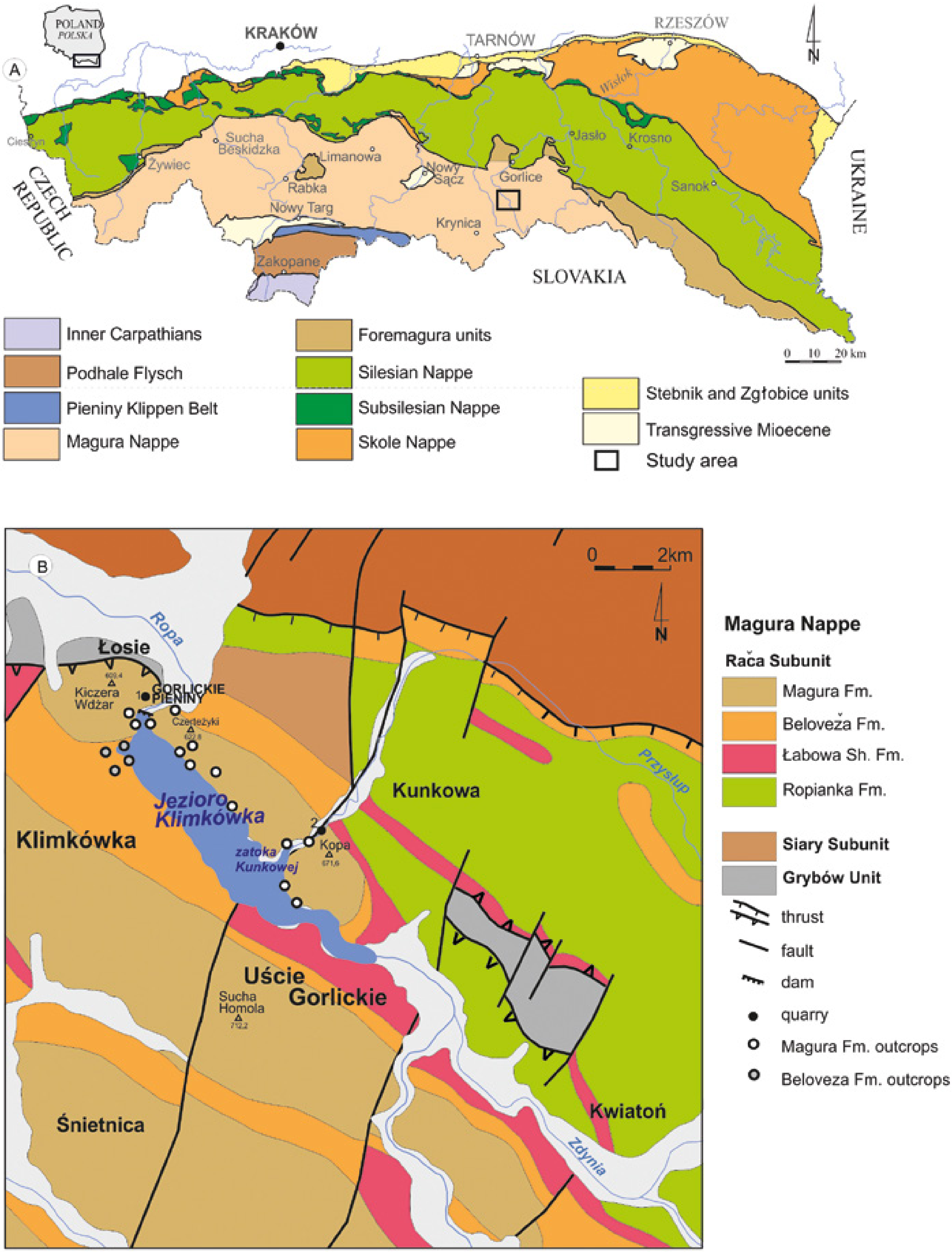

Fig. 2. Location of the studied area on the background of geological structures. A – area of the Łosie-Uście Gorlickie against structural--tectonic units of the Polish Carpathians, B – Geology of the Klimkówka Lake region (based on Rączkowski *et al.*, 1992 – modified and supplemented)

The main goal of this paper is a brief geological outline of the lake area and an indication of the geotouristic objects in its immediate vicinity.

Study area

Klimkówka Lake is located in the Beskid Niski Mts. of the Polish part of the Northern Carpathians, in Hańczowskie Rusztowe Mts., about 20 km south of Gorlice town. This lake was created by damming the Ropa mountain river by a semi-concrete dam, situated in the village Klimkówka (Fig. 2A, B). This relatively narrow (800–200 m) reservoir, of length approximately 6 km (Fig. 2B, Fig. 3) spreads from Klimkówka to Uście Gorlickie villages. It is surrounded by forested mountains (altitudes of about 600–700 meters above sea level), from which numerous mountain streams flow down, now having an outlet into the lake. The system of the surrounding hills is characteristic of the Rusztowe Mts. that create long, heaped and relatively steep hills with small amplitudes within the top parts of the mountain ranges stretching SE- NW. From the SW the reservoir is surrounded by Sucha Homola Mt. range (the culmination of 712 m a.s.l.) from NE by Czerteżyki Mt. (622 m asl) and Kopa Mt. (671 m asl) mountain ranges separated by the Przysłupianka valley. Klimkówka Lake is a typical mountain reservoir. Its coastline is diversified by numerous bays associated with zones of the estuaries (Fig. 4); the largest of them Kunkowa Bay, located in the NE part of the lake is created by Przysłopianka creek estuary, the largest and most important tributary of Klimkówka Lake (Fig. 2B).

Origin of the lake, parameters and functions

In historical times, the variable water flow regime of the Ropa river and the corresponding water overflowing periods caused flooding of urban areas along the valley, as well as water deficiency during periods of drought. In the 70's the Polish authorities took the decision to construct the reservoir, which will regulate the flow of the river.

Fig. 3. Winter view on Klimkówka Lake, photo A. Waśkowska

Fig. 4. Bay estuary zone of a lake in the creek at low lake water level, photo A. Waśkowska

Fig. 5. The dam and the hills Kiczera-Zdżar towering around, photo A. Waśkowska

The narrowest part of the Ropa valley forming part of the so-called Gorlickie Pieniny (Fig. 5) was chosen for the dam placement. In this area the Ropa River, over a distance of less than 1 km, forms a picturesque gorge and flows in a narrow trough between steep Kiczera Żdżar (610 m a.s.l.) and Ubocz (617 m asl) hills. A soil dam with the crown length of 210 m and a height of 33 m was constructed at the 54.4 km of the Ropa river (Henning, Martyniak, 1992). The project was completed in 1994, after 19 years of construction, and the process of stacking water and functioning of the Lake Klimkówka started. The maximum surface of the lake reservoir is 266 ha, its average depth is 13m and a maximum depth reaches to 30 m (Łagosz, 2000). The bowl of the lake can hold 43.5 million m^3 of water: capacity – 2.5 million m^3, capacity of 33 million m^3 of compensatory and flood capacity – 8 million m^3 (Gawlik). Since its inception the reservoir water level in the lake reached the expected maximum state in the year 2010 (Wojciech Waśkowski, oral communication). The level of water raised by the dam is normally located at an altitude of 395.8 m asl; the depth of the reservoir close to the dam is 31.80 m (Łagosz, 2000). The dam is closed to tourists.

Fig. 6. Hydroelectric power station and the Ropa river valley (Gorlice Pieniny) – view from the dam crest, photo A. Waśkowska

Fig. 7. The wide terraced coastal zone of the lake at low water level, during the rainfall deficit – February 2011, photo A. Waśkowska

The dam construction and creation of the lake permanently changed the natural environment of the Beskid Niski Mts., by transforming many of its components. Changes affected morphology of landforms, local climate, geological processes, vegetation and fauna as well as influencing on the cultural landscape and the related economic development. Previously, the urbanized area in Klimkówka village and part of Ujście Gorlickie had flooded. The creation of the lake was connected with carrying out expropriations and evictions, construction of new road infrastructure, implementing technology and so on. Klimkówka Lake is a typical mountain reservoir that affects greatly the hydrological system of the area. Ropa River is a typical mountain river, which is characterized by the flow variables associated with weather seasonal changes. The presence of an artificial reservoir regulates the supply of water through its controlled outflow. In times of drought the reservoir secures continuous supply, in times of surplus it stores water, reducing its flow and floods, which consequences are often catastrophic. The construction of Klimkówka Lake is of great importance for Jasło and Gorlice urban areas located in the lower part of the Ropa valley. Since the existence of the artificial lake the flow of the river has improved significantly, especially during dry periods, reducing deficit in water supply for agglomerations. Both agglomerations supply water to inhabitants and industrial plants, where the demand is high. The average 2 m^3/s flow is maintained. This value is about 20-times higher than the minimum flow reaches 0.08 m^3/s (Henning, Martyniak, 1992). Maximum flood flows may be reduced by one third, from 420 m^3/s to 140 m^3/s (Łagosz, 2000).

The Klimkówka Lake adjusts the flows in periods of drought and improving water quality by diluting pollutants. Increase of tourism activity in this region is one of the important functions of the Klimkówka Lake, which is used as a facility for recreation. The functioning of Lake Klimkówka is also associated with acquisition of green electricity. The energy derives from the flow of water and a small hydroelectric power plant in Łosie (Fig. 6). It is located at the foot of the dam on its north side, connected by the 110 m steel pipe with the dam bottom output, which is transmitting a stream of water directly to the turbine. The hydroelectric power plant has 1.1 MW capacities; the average annual production is estimated at 5.4 GWh. In the memorable year 2010, when intense and prolonged precipitation caused flooding and flood conditions, the reservoir on the Ropa River did its job well and protect the region. However, during the exceptionally dry season of the 2011 and 2012 years, the Beskid Niski Mts region suffered from severe water shortages. Controlled flow, securing water supply for the valley of Ropa River region, extensively used water inventory of the lake. Therefore, the area of the lake significantly decreased (Fig. 7) and the bottom was exposed in its distal part (Uście Gorlickie).

Geological background

The Klimkówka Lake is located in the Outer Carpathians, which are built of Mesozoic and Cenozoic rocks. These rocks were deposited between 200 and 15 million years ago during Jurassic-Miocene times, within the Carpathian deep sea, which constituted part of ancient ocean called Tethys.

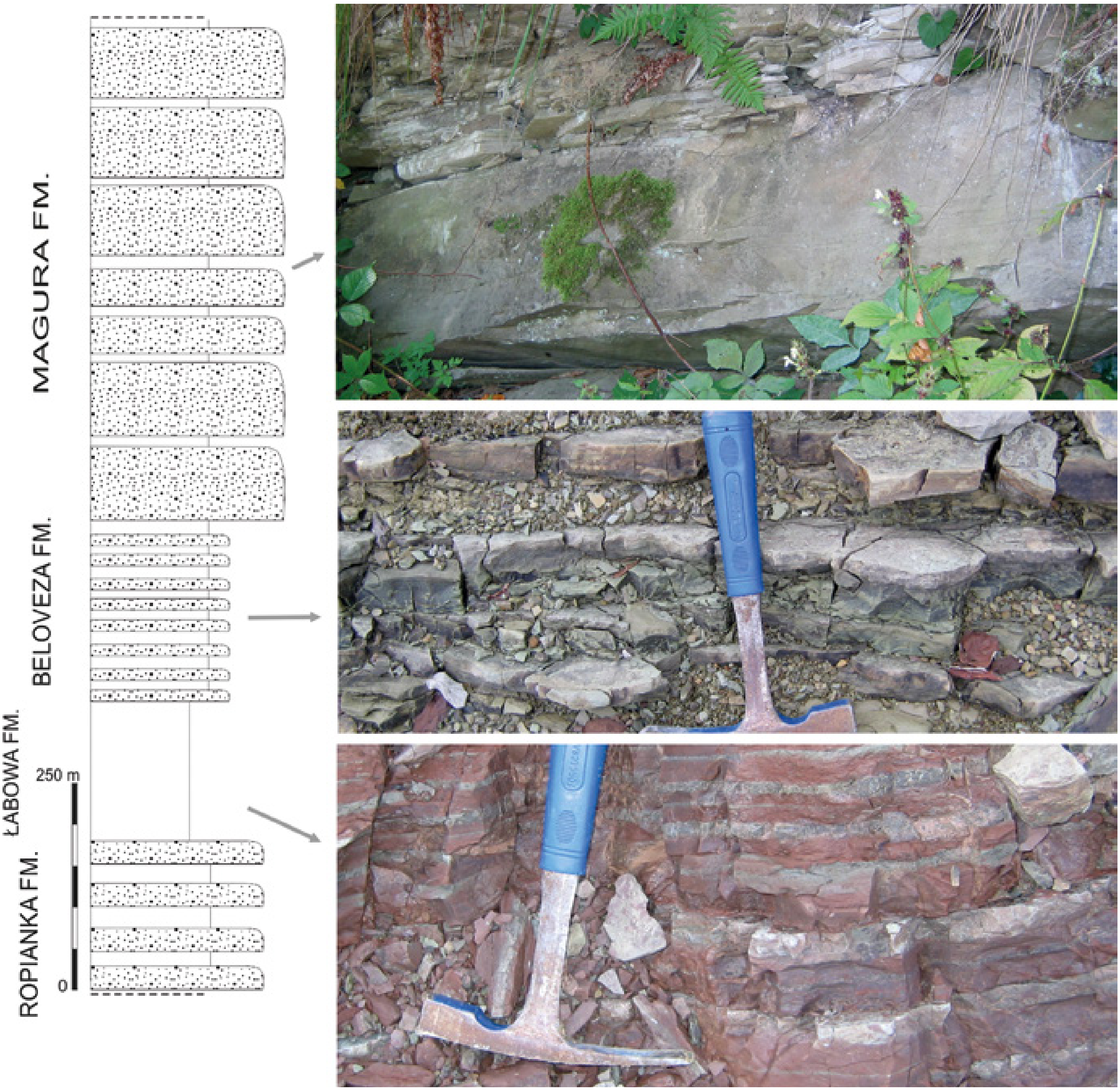

Fig. 8. Lithology of the Magura Nappe, Racza Unit, in the region of Hańczowskie Rusztowe Mountains (Beskid Niski, Outer Carpathians), photo A. Waśkowska

This sea consisted of smaller basins, which were separated from each other by underwater ridges called cordilleras. The Magura Basin was the largest one. Carpathian deep seas were filled with sediments called a flysch, which today form the thick series of rocks in the Beskid Niski Mts. Flysch is composed of sandstone layers and/or sandstones and conglomerates intercalated with shales, siltstones and claystones. These deposits are the result of sedimentation of material supplied to the basin and transported by gravity on its slopes into deep areas.

Strong tectonic movements of the Alpine Orogeny resulted in tectonic deformations, caused the origin of the Carpathian orogen, which include Beskid Niski Mts. These movements took place during the Miocene stages – about 14 million years ago. The Outer Carpathian rock complexes consist of sediments deposited within the Carpathian basins, were thrust over each other and arranged into the characteristic imbricated structure. These complexes are known as nappes (Fig. 2A).

Klimkówka Lake is geologicaly located in the Magura Nappe (Fig. 2A, B), which is divided into several tectonic-facies zones as Krynica, Bystrica, Rača and the outermost Siary zones. Hańczowskie Rusztowe Mts. are located in the Rača Zone, and are built of Senonian-Paleogene deposits including several rock-formations such as Ropianka, Łabowa, Beloveža and Magura formations (Golonka & Waśkowska, 2012; Rączkowski et al., 1992; Węcławik, 1969a, b, and literature therein) (Fig. 8). The last three stratigraphic formations form the bedrock of the Klimkówka Lake.

Fig. 9. The diversified fraction and the degree of roundness of the stones of the sand beaches at the lake – gravels of varying morphology, photo A. Waśkowska

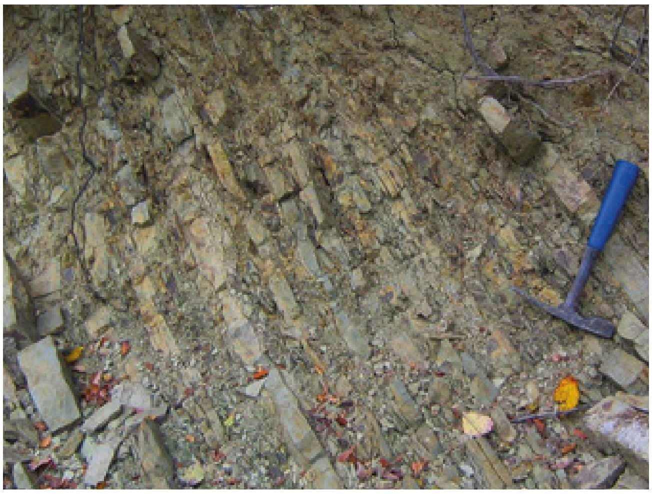

Fig. 10. Deposits of the Beloveža Formation exposing at the cliffs of Klimkówka Lake, photo A. Waśkowska

The southernmost part of the Klimkówka Lake and areas that are directly adjacent to the south consist of Łabowa Shale Formation, which is characterized by the occurrence of relatively soft red shales and claystones, intercalated with green, grey and bluish shales (so-called – variegated shales) (Fig. 3B, Fig. 8). These deposits are intercalated with very fine-grained and thin-bedded Lower Eocene quartzitic sandstones.

Change of the sedimentation' nature and the increase of the supply of coarser clastic material occurred during middle Eocene times. Sandstones become more common within flysch sediments. Variegated shales deposits were replaced by gray and green mudstones, partly calcareous, commonly intercalated by fine-grained thin- and mediumbedded of grey quartzitic sandstones. These thin-bedded flysch deposits belong to the Beloveža Formation (Fig. 8), which occurs in the western part of the Lake Klimkówka basement (Fig. 2B). Sandstones are characterized by a large concentration of hieroglyphs both mechanical and organic in origin, located on bottom surfaces of the bed. Variegated shales represent the dominant lithotype, which is present in the complexes up to several meters thick, with co-occurrence of bentonitic layers. Towards the top the number and thickness of sandstone intercalations increases. This type of sedimentation continued upward, in which the rocks of Magura Formation were deposited (flysch sandstones mostly). These are complexes dominated by thick and very thick-bedded grey sandstones (Fig. 8) separated by thick and medium-bedded sandstones with very thin intercalations of gray mudstone. Magura Formation build the eastern part of the lake, and being erosion-resistant it also builds the surrounding hills (Fig. 3B). The geological structure determines the asymmetry of the Ropa valley in the vicinity of the lake. At the west side, where there are a lot of soft mudstones in the ground, not resistant to erosion, the banks of the valley are gently sloping (Fig. 3).

This side is also covered by the tourism infrastructure, which includes swimming areas and areas covered by summer resort, as well as main roads running along the lake towards Wysowa and energy networks. The opposite eastern shore of Klimkówka Lake is undeveloped because of its morphology, steeply descending to the lake, consisting of resistant sandstone of Magura Formation.

The main tectonic dislocation in this area – Kunkowa fault, cuts across the geological structures from SW to NE, constitutes an important element of the lake's bottom surface. The footwall is located on the lakes' south side in the region of Uście Gorlickie. The Kunkowa Bay is located directly on the fault line (Fig. 2B).

The geological objects

On first sight monotonous flysch deposits are increasingly valued and promoted as interesting objects for geotouristic (e.g. Słomka *et al.*, 2006; Miśkiewicz *et al.*, 2011; Bartuś *et al.*, 2012 and literature therein). There is quite a lot of flysch outcrops in the Polish Carpathians, but their accessibility is limited. Usually the outcrops are located in valleys of streams and rivers, with no suitable routes nearby.

Klimkówka Lake has existed for already several years. During this time, its coastal zone has been changed under the influence of abrasion processes. These processes involved coastal erosion and landslides, that led to the exposure of the bedrock in many places, and created numerous outcrops. Around 5 m^3 of the material eroded from each linear meter of the lake shore during 13 years of the lake's existence (Wiejaczka, 2009). Analysis of the shores of the lake indicates that the active processes are dominating by erosion, because 53% of the coastline displays abrasive edge, and 43% represents the abrasive-accumulation type. Up to 2m high cliffs constitute a common structure of the coastline (Fig. 9), while the wide pebble beaches are rare (Wiejaczka, 2008). Numerous landslides developed on the lake's slopes causing problems for roads and buildings construction and maintenance.

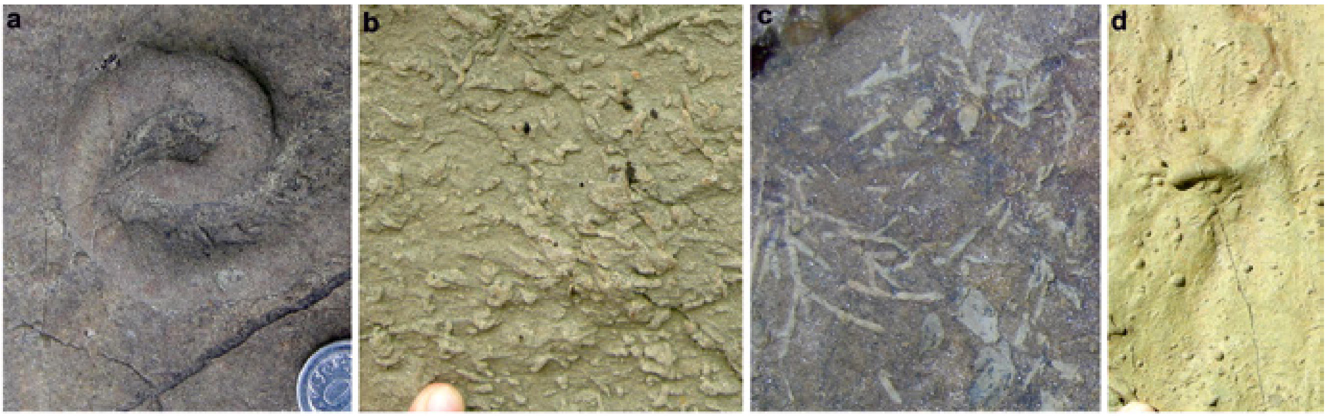

Fig. 11. Examples of biogenic structures preserved in sandstone of Beloveža Formations, photo A. Waśkowska

The rocks of Łabowa Shale Formation (Fig. 10) are poorly exposed here. They form a substrate in the distal part of the lake and its backwaters. This formation is often covered directly by thick Quaternary sediments. Small outcrops at the banks that existed in the first phase of the lake functioning are now covered by reddish mud. The outcrops of Łabowa Formation deposits can be seen in the close vicinity of the reservoir, in the Ropa River, in Uście Gorlickie village.

Outcrops of the Beloveža Formation are located along the beaches and in the streams flowing into the lake (Fig. 2B). High cliffs, up to 1.5 m, have been formed within the deposits of Beloveža Formation. They reveal the variety of thin-bedded flysch, typical for this formation (Fig. 10). Sandstones are especially interesting for tourists displaying educational sedimentological features like parallel straight, wavy, and less often diagonal bedding and lamination, with muscovite and bioglyphs, which reflect traces of deep-sea fauna living on the seabed during the Middle Eocene times (Fig. 11). Bioglyphs of fossil organisms are very diversified. It is also one of the characteristic feature of this formation. Younger visitors are particularly fond of outcrops of Beloveža formation. They used to have fun using mudstones, like plasticine, for construction of various decorative elements (Fig. 12). Beloveža Formation mudstones contain a significant amount of clay minerals, which are plastic and swell when exposed to water. Usually within the outcrops minor tectonic structures can be observed, such as faults with small amplitudes and folds of different geometry, as well as joint systems manifested mainly by regular cracks intersecting each other at a similar angle, well visible in sandstones (Fig. 13). The cracks are often filled with crystal calcite.

An interesting rock sequence crops out at one of the beaches in the NW part of the shores of Klimkówka Lake. This sequence encompasses the boundary between Magura and Beloveža formations displaying dynamic sedimentary transition. Magura Formation begins with a thick sandstone bed (Golonka, Waśkowska, 2012) overlying thin- and medium-bedded flysch of the Beloveža Formation. This bed begins with a sequence of medium- to thick- bedded shale-sandstone flysch, in a short distance passing into the -sandstone dominated flysch. The deposits of the Magura Formation are resistant to erosion, forming the best outcrops in the Klimkówka Lake region.

Fig. 12. Work of art made of Beloveža mudstone, photo A. Waśkowska

Fig. 13. Tectionic structures in Beloveža sandstones, photo A. Waśkowska

Fig. 14. Magura Formation outcropping at the dam, photo A. Waśkowska

Fig. 15. Łosie Quarry, photo A. Waśkowska

Fig. 16. "Devil's egg" of Phallus impudicus – fungus protected, photo A. Waśkowska

Fig. 17. Bearing fruit Daphne mezereum – protected plant species, photo A. Waśkowska

Fig. 18. Panorama of the dam and Gorlickie Pieniny from the vantage point along the path of education, photo A. Waśkowska

Gorlickie Pieniny Gorge, which landscape resembles the world-wide known Dunajec Gorge in the Pieniny Mts. (Golonka, Krobicki, 2012) provide a perfect example of the rock outcrops serving as geotouristic objects. The gorge, in which the dam is situated, constitutes a v-shaped valley cut into the Magura Formation rocks (Fig. 5). The Ropa River deeply cuts into the Beskid Niski Mountains using tectonic faults. The narrow Ropa River valley was formed at the site of thick and compact complex of thick- and very thick-bedded sandstones. Many outcrops of the formation are located along the road leading to the dam (Fig. 14) in an abandoned quarry in the Łosie village, along the shores of the lake and in the tributary streams valleys. While natural outcrops are characterized by poor accessibility, this collection of artificial outcrops is located very conveniently. The very large area of observation, with a wide range of educational features constitutes a very important asset. These objects belong to the best geotouristic places for studies of the lithology of the Carpathian rocks.

Therefore Łosie quarry was for many years used as a teaching facility for students, recommended as a prime geotouristic object (Doktor *et al.*, 2005) and entered into the Central Registry of Geosites of Poland (Fig. 15). The quarry is located on the left bank of Ropa river, below the dam, close to the hydroelectric power plant (Fig. 2B). Asphalt road leads to the quarry. It is a fairly extensive exposure 300m long, being a continuation of the outcrop in the escarpment road to the dam. For several years, these outcrops have been combined with the educational path – Gorlickie Pieniny, which runs over the dam, through NE slope of Zdżar Mt. The route is short and neat; the leading issues are botanical subjects, like Beskid Niski Mts.' beech and other dendroflora of the forest. On the slopes of Kiczera-Wdżar, many rare species appear along the route, there are several positions of plant and fungi species protected in Poland (Fig. 16, Fig. 17). In addition to small outcrops of the Magura Formation, this is the route with several panoramic viewpoints to Gorlickie Pieniny and Klimkówka Lake (Fig. 18).

Fig. 19. Flutes on the Magura sandstone bottom surface, photo A. Waśkowska

Fig. 20. Layers of the Magura sandstone formations in Łosie, photo A. Waśkowska

Deposits of the Magura Formation are characterized by diversity in lithology. They contain widespread massive thick-bedded sandstones often amalgamated with submarine slumps and structures with numerous petals sludge, a variety of parallel, cross and convolute laminations, clastic dykes, structures from escape of water, cup-shaped structures, and a variety of hieroglyphs, mainly flutcasts, indicating sea-bottom currents (Fig. 19) and other traces. The rock layers are deflected by tectonics at an angle 50^0 in the dam area (Fig. 20, 21). Small scale tectonic structures are represented mainly by joints and by the fault-type discontinuous deformations. A large fault is exposed in the south-western part of the quarry. Blocks of sandstones moved by gravity to the bottom of the quarry excavation provide a kind of sedimentological field museum (lapidary). The walls of the quarry are not protected, so the approach is associated with the risk of falling loose rock blocks. The quarry has retained a residual infrastructure related to the extraction of stone represented, among the others by a bunker located at the northern side of the quarry a few feet above the highway. A forestry Bulletin Board is present, in the quarry informing of bats, which are quite common in the area of Gorlickie Pieniny. They favour rock shelters and caves, which are typical for Magura sandstone outcrops and known also from the area of the excavation in Łosie. Sandstones of the Magura Formation called "Magura Sandstone" are known as the best building materials originating from Outer Carpathians. Stone used in the local constructions was collected by local people from natural exposures, that were extended and converted into quarries. Several pits exist in the close vicinity of Klimkówka Lake. One of the biggest is in the valley of the Przysłopianka stream. Magura Formation is developed there in the form of a thick and medium- bedded flysch, in which the layers of sandstone are rich in a variety of sedimentary structures and intercalated with mudstone shale packages.

On steep slopes made of Magura Formation series of small waterfalls and cascades were formed on thick and very thick sandstone beds. One of these waterfalls is present at the periodic stream flowing through educational path Gorlice Pieniny, close to the hydroelectric power and Łosie village. Easily accessible numerous outcrops, can be seen in the valley of the Przysłup stream. This lazy streams transforms into a rushing river of high erosive power in periods of increased atmospheric water supply. The Magura Formation deposits crop out also in several locations along the escarpment of road linking Klimkówka and Uście Gorlickie villages, as well as at the banks of the lake cliffs. Occurrence of deposits with a predominance of siltstone and/or mudstone (Łabowa and Beloveža formations) on the slopes of valleys is associated with the generation of the landslide slopes. Landslide morphology is visible in the eastern coastal zone of the reservoir (Fig. 22). Its forms displaying various stages of development, different slope dynamics are visible in this area, although the creation of the reservoir in Klimkówka greatly reduced the development of landslides, which previously existed in the Ropa valley (Rączkowski, 2007).

It should also be noted that this is the area of special historical and cultural significance, associated with the presence of the Łemko ethnic group. Many architectural objects like valuable churches, shrines, cemeteries, and historic residential buildings exist in the vicinity of Klimkówka Lake.

Fig. 21. Panorama of the Łosie Quary, photo A. Waśkowska

Fig. 22. Colluvium landslide at NW shore of Klimkówka Lake, photo A. Waśkowska

This is the area of the occurrence of mineral waters, which are used in balneological medicine (Miśkiewicz *et al*., 2011). Hańczowskie Rusztowe Mts. have their own unique atmosphere, being far from the cities and in the natural environment, with large areas of woodland.

Discussion and summary

Klimkówka Lake belongs to the greatest attractions of Beskid Niski Mts. It is an object that attracts tourism, mainly due to the high aesthetic and a wide range of recreational values associated with relatively large water reservoir. Nearly 20 years of existence of the lake generated the development of tourism infrastructure securing both the accommodation and the realm of sports and recreation.

Another advantage of Klimkówka Lake is the presence of a number of spectacular surface rock outcrops located in convenient locations. Special educational value posses the quarries, which in the Beskid Niski Mts. are objects that are rarely encountered and providing a large range of observations.

The area around the lake is a great training ground to get acquainted with the geological structure of the area, the geological history of the Carpathians, as well as with different varieties of sedimentary rocks, and sedimentary and tectonic structures.

Rocks on the rocky beaches and quarries are of tourist interest. The message they bring is highly diversified, and therefore providing an important element is to raise awareness of geology, especially geologic history and origin of deep water geological formations that built Beskid Niski Mts.

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