Geotouristic bicycle path around Nowy Targ (Carpathians, Poland)

Geoturystyczna ścieżka rowerowa wokół Nowego Targu (Karpaty, Polska)

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Abstract: *The area in the vicinity of Nowy Targ is located within the northern part of the Orawa-Nowy Targ Basin and the southern slopes of the Gorce Mountains in the Polish sector of the Outer Carpathians. Geologically, the region is built of the Upper Cretaceous–Palaeogene turbiditic deposits representing sedimentary successions of the Krynica Subunit of the Magura Nappe and the Neogene–Quaternary fresh-water deposits filling the Orawa-Nowy Targ Basin. The Magura Nappe in the described area is represented by the thick-bedded sandstones of the Magura Formation and thin-and medium-bedded sandstone-shale deposits of the Malcov Formation, which are well-exposed in numerous outcrops, especially in the Łopuszna stream valley. The Magura Nappe deposits were folded and cut by a fault system in the Miocene. The presented area displays varied geomorphological relief and picturesque landscapes. Moreover, rare species of fauna and flora occurring here, as well as the still-alive culture of the Podhale Highlanders and continuously improving tourist infrastructure additionally contribute to the development of geotourism in this area. In addition, this area is an increasingly popular place among cyclists, thanks to the development of a network of bicycle paths, therefore the proposed geotourist bicycle path will extend the offer for this group of tourists.*

Keywords: *Gorce Mountains, Magura Nappe, Orawa-Nowy Targ Basin, geosites, Podhale highlanders' culture*

Treść: *Prezentowane okolice Nowego Targu zlokalizowane są w obrębie północnego obrzeżenia Kotliny Orawsko-Nowotarskiej oraz na południowych zboczach Gorców w polskim sektorze Karpat Zewnętrznych. Obszar ten zbudowany jest z późnokredowo-paleogeńskich utworów turbidytowych reprezentujących sukcesję osadową podjednostki krynickiej płaszczowiny magurskiej oraz lądowe osady neogeńsko-czwartorzędowe wypełniające Kotlinę Orawsko-Nowotarską. Formacja magurska w opisywanym terenie reprezentowana jest przez gruboławicowe piaskowce formacji magurskiej oraz cienko- i średnioławicowe utwory piaskowcowo-łupkowe formacji malcowskiej, które odsłaniają się w licznych odkrywkach, w szczególności w obrębie doliny potoku Łopuszna. W miocenie utwory płaszczowiny magurskiej zostały sfałdowane i pocięte systemem uskoków. Obszar ten ma urozmaiconą rzeźbę i malownicze krajobrazy. Jednocześnie występujące tu rzadkie gatunki fauny i flory, wciąż żywa kultura górali podhalańskich oraz coraz lepsza infrastruktura turystyczna sprzyjają rozwojowi geoturystyki w tym obszarze. Dodatkowo obszar ten jest coraz bardziej popularnym miejscem wśród rowerzystów, dzięki rozwojowi sieci ścieżek rowerowych, dlatego też proponowana geoturystyczna trasa rowerowa będzie poszerzeniem oferty dla tej grupy turystów.*

Słowa kluczowe: *Gorce, płaszczowina magurska, Kotlina Orawsko-Nowotarska, geostanowiska, kultura górali podhalańskich*

Introduction

Nowy Targ is the most important and the oldest town in the Podhale region considered as its 'capital'. Due to this rank, it is simply called "the town" by the local people. Nowy Targ is picturesquely situated in the eastern part of the Orawa-Nowy Targ Basin, at the south-western foothills of the Gorce Mountains, at the confluence of the Czarny and Biały Dunajec rivers. Its center is situated on a flat area of the Orawa-Nowy Targ Basin, while the northern part is located on the southern slopes of the Gorce Mountains. Towards the south, the town overlooks the Spisz-Gubałówka Foothills and the majestically elevated Tatra Mountains (Fig. 1). To the east, one can see the jagged hills of the Spisz Pieniny, and to the west, a flat plain of the Orawa-Nowy Targ Basin. Podhale is a region, where rich tradition and folk culture are still alive with extraordinary music, singing, clothes and architecture. Additionally, this area hosts habitats of unique species of plants and animals. Moreover, Nowy Targ is located where several major geological structures of the Western Carpathians occur. A few kilometres to the south from Nowy Targ, in Szaflary, a tectonic border runs between the two main geological structures of the Carpathians – the Inner Carpathians and Outer Carpathians (Watycha, 1975, 1976; Golonka *et al*., 2019a) (Fig. 2). These structures are separated by the Pieniny Klippen Belt. The Inner Carpathians include the Tatra Mountains, composed of crystalline rocks and their sedimentary cover units, which are covered by the Central Carpathian Palaeogene deposits represented mainly by the Podhale flysch. The Pieniny Klippen Belt is built of limestones, marls, cherts and flysch rocks (Birkenmajer, 1977; Golonka *et al*., 2019b).

Fig. 1. Panoramic view of the Tatra Mountains in the skyline and the Orawa-Nowy Targ Basin viewed from Turbacz Mount. Photos M. Szczęch unless otherwise noted

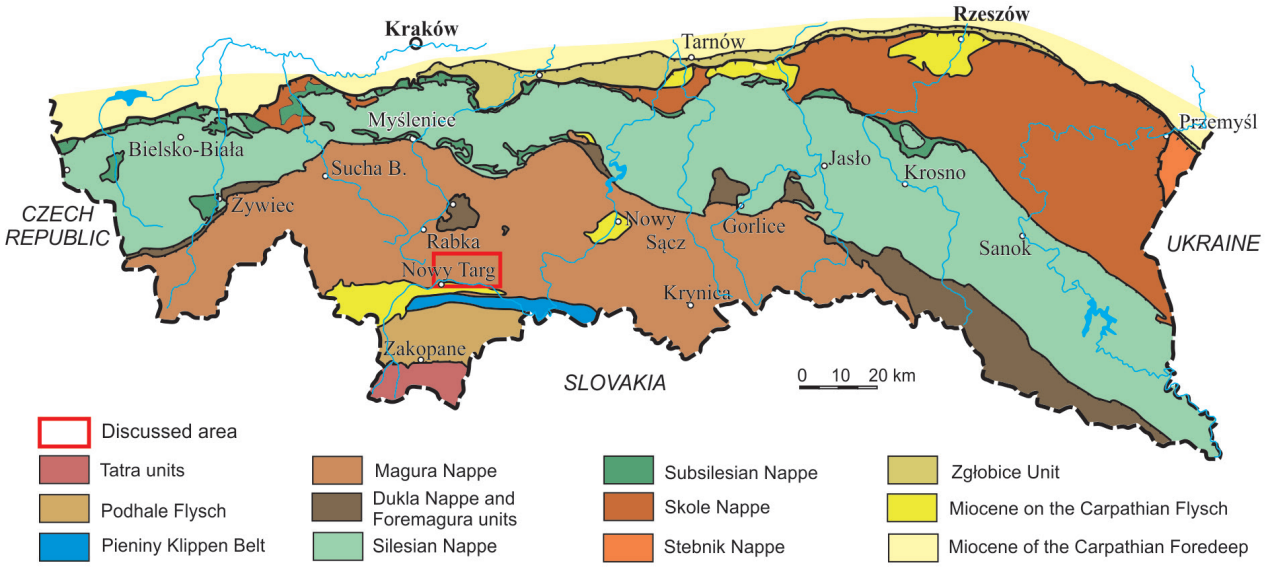

Fig. 2. Location of the discussed area on the geological sketch map of the Polish sector of the Carpathians (Cieszkowski *et al*., 2017)

The Outer Carpathians are represented by a group of nappes composed mainly of flysch deposits (Golonka *et al*., 2005, 2021; Ślączka *et al*., 2006). The Magura Nappe is thrust over the deposits of the Foremagura Nappes, which were confirmed by deep boreholes: Chabówka 1 (Cieszkowski, 1979b, 2006b) and Obidowa IG-1 (Cieszkowski *et al*., 1974; Cieszkowski & Sikora, 1975; Cieszkowski, 1985a). In the southern part of the Gorce Mountains, the Cretaceous–Palaeogene deposits of the Krynica Subunit of the Magura Nappe occur (Cieszkowski *et al*., 1998; Szczęch *et al*., 2016, Szczęch & Cieszkowski, 2021). The Orawa-Nowy Targ Basin is filled by Neogene terrestrial and freshwater deposits, with lignite layers, as well as Quaternary deposits (Watycha, 1977a, 1977b; Chowaniec & Cieszkowski, 2009). In the Orawa-Nowy Targ Basin, unique Holocene raised peat bogs also occur (Łajczak, 2006, 2009).

Such a geological and geographical location makes Nowy Targ and its surroundings a unique and valuable geotouristic location containing a significant number of geosites. Moreover, this area has become a well-known destination for bicycle tourism in the last few years through the development of a network of bicycle paths. Hence, the authors propose in this paper an undemanding bike route with a length of about 35 km, presenting the geological values of the southern slopes of the Gorce Mountains and the Orawa-Nowy Targ Basin near Nowy Targ.

Geological settings

The presented area is located in the Western Outer Carpathians composed mainly of flysch deposits, Cretaceous to Palaeogene in age (Książkiewicz, 1977; Cieszkowski *et al*., 1985; Cieszkowski, 2003; Golonka *et al*., 2005, 2021; Oszczypko, 2006; Ślączka *et al*., 2006). These sediments were deposited in basins separated by ridges in the Northern Tethys. In the Miocene, these deposits were detached from their basement, folded, and formed a sequence of nappes, thrust one upon another and cut by faults (Ślączka *et al*., 2006; Golonka *et al*., 2019b). The Magura Nappe, which occurs in the discussed area, remains in tectonic contact with the Pieniny Klippen Belt in the south, while towards the north it is a thrust over the Dukla and Foremagura tectonic units (Fig. 2).

Stratigraphy of the Magura Nappe succession

The Magura Nappe is spatially differentiated in terms of lithostratigraphy, facies and tectonic features. As a result, it was divided into several tectonic-facies subunits (Koszarski *et al*., 1974). The Nowy Targ area and the southern part of the Gorce Mountains, with the highest peak, Turbacz Mount (1310 m a.s.l.), are composed of the deposits of the Krynica Subunit, the innermost subdivision of the Magura Nappe. In the southern part of the studied area, the Magura Nappe deposits are covered by freshwater deposits filling the Orawa-Nowy Targ Basin (Cieszkowski, 1992; Chowaniec & Cieszkowski, 2009) (Fig. 3).

Krynica Subunit

The succession of Krynica Subunit in the study area is represented by the Upper Cretaceous (Campanian–Maastrichtian)–Miocene flysch deposits (Fig. 3A, B). The oldest sedimentary rocks outcropping in the vicinity of the study comprise the **Ropianka Formation** (Campanian–Palaeocene) previously called Szczawnica Formation, which is composed of thin- and medium-bedded sandstone-shale turbidites intercalated by thick-bedded sandstones (Burtan *et al*., 1978; Birkenmajer & Oszczypko, 1989; Cieszkowski *et al.*, 1998; Szczęch *et al*., 2016; Szczęch & Cieszkowski, 2021) (Fig. 4A, B). The sandstones in thin- and medium-bedded facies are usually fine and medium-grained, well-sorted, normally graded, hard, steel grey when fresh, lighter grey or grey-brownish when weathered, with characteristic rusty coating associated with the presence of iron compounds. Convolute lamination is a characteristic feature of the sandstone beds in this formation. Concentrations of muscovite, with admixtures of plants detritus are often observed on the lamination surfaces. Lower surfaces of sandstone layers commonly are covered with sole marks. The shales are grey, dark grey, greenish grey, usually weakly calcareous. The thick-bedded sandstones form single layers or complexes with a thickness ranging from several to dozen meters. These sandstones are grey or greenish-grey, coarse-grained or conglomeratic. Among these layers of conglomerates also occur.

The **Magura Formation** deposits (Eocene) in the stratigraphic section of Krynica Subunit are dominated by thick-bedded sandstones (Birkenmajer & Oszczypko, 1989; Cieszkowski *et al*., 1998; Szczęch *et al*., 2016; Szczęch & Cieszkowski, 2021). The sandstones are medium- and coarse-grained, sometimes conglomeratic, grey or blue-grey when fresh, yellow-grey when weathered. A characteristic feature of these sandstones in Krynica Subunit is the occurrence of red grains of volcanic rocks and sandstones, as well as pink grains of feldspar and quartz (Cieszkowski *et al*., 1998). In this formation, three members were distinguished: the Piwniczna Sandstone Member, the Kowaniec Member and the Poprad Sandstone Member (Birkenmajer & Oszczypko, 1989; Cieszkowski *et al*., 1998; Szczęch & Cieszkowski, 2021). The sandstones of this formation form the highest peaks of the Gorce Mountains culminating with Turbacz Mount (1310 m a.s.l.). Slabs of the sandstones can be found as elements of the local urban and rural architecture. In the past, they were most often used as building stone for foundations of highlanders' houses and farm buildings.

The **Piwniczna Sandstone Member** (Lower–Middle Eocene) is represented by frequently amalgamated layers of thick-bedded sandstones (Fig. 4C). The sandstones are medium- and coarse-grained, in some parts conglomeratic and can be accompanied by fine conglomerates. The thick-bedded sandstones are intercalated by packages of thin- and

medium-bedded sandstone-shale turbidites of the Beloveža Formation-type (Cieszkowski *et al*., 1998), usually several centimetres or several dozen centimetres thick, but occasionally reaching several meters (Fig. 4D). The sandstones in the Beloveža Formation type are calcareous, grey or blue-grey, fine-grained. There are numerous trace-fossils and sole marks on the lower surfaces of the layers. The shales are calcareous, bluish-grey, yellowish-grey and olive-green. The **Kowaniec Member** (Middle Eocene) is distinguished from other members in the Magura Formation by the occurrence of other rock types (Fig. 4E) besides thick-bedded sandstones (Fig. 4E).

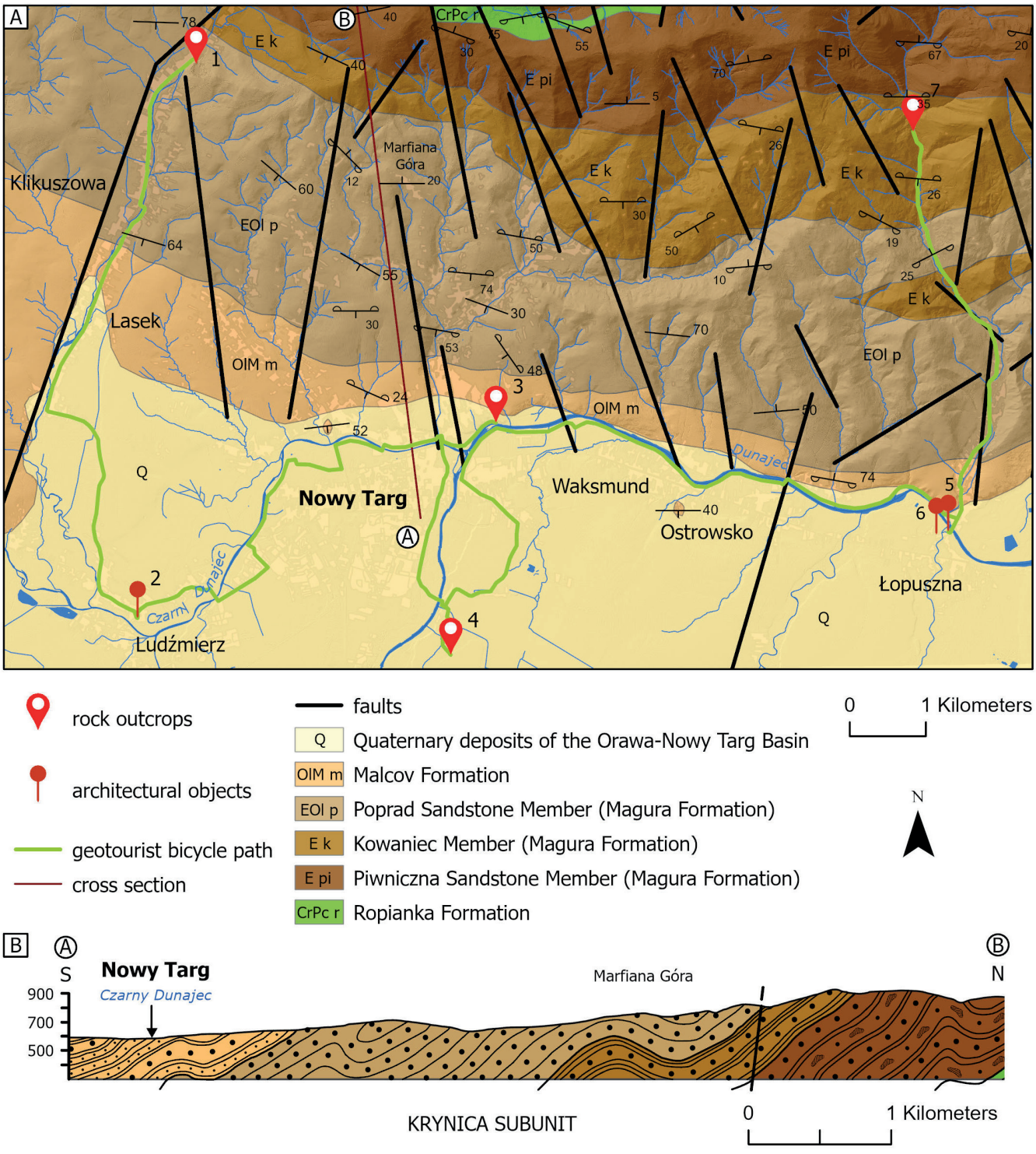

Fig. 3. Geological sketch of the described area (after Szczęch & Cieszkowski, 2021): A – geological map of the discussed area with the bicycle path shown in green and numbered observation points; B – geological cross-section of the Magura Nappe in the described area

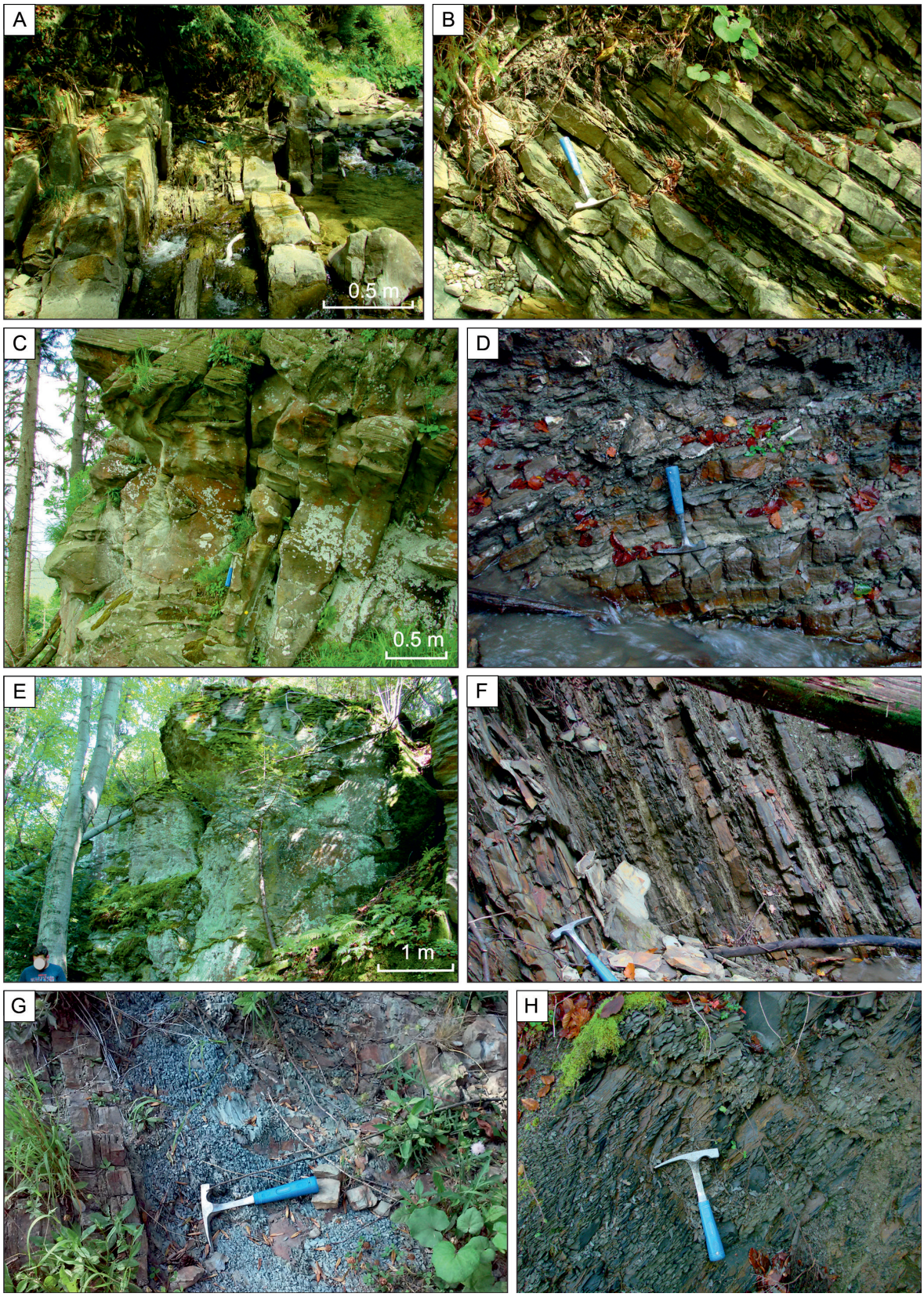

Fig. 4. Rocks of Krynica Subunit of the Magura Nappe: A – thick-bedded sandstone with an intercalation of thin- and medium-bedded sandstone-shale turbidites (Ropianka Formation; Lepietnica valley, Obidowa); B – thin- and medium-bedded sandstone-shale turbidites of the Ropianka Formation (Obidowa); C – thick-bedded sandstones of the Piwniczna Sandstone Member (Białe Skały); D – thin- and medium-bedded sandstone-shale of the Beloveža lithotypes in the Piwniczna Sandstone Member (Łopuszna); E – thick-bedded sandstones of the Kowaniec Member (Wysznia Mount, Łopuszna); F – thin-and medium-bedded sandstone-shale turbidites of the Hieroglyphic beds lithotypes in Kowaniec Member (Łopuszna valley); G – thick-bedded marls of the Łącko Marl lithotypes in the Kowaniec Member (Łopuszna valley); H – thick-bedded green shales in Kowaniec Member (Łopuszna valley)

These rocks are thin- and medium-bedded Hieroglyphic beds-type (Fig. 4F), thick-bedded, non-calcareous, grey-greenish shales (Fig. 4G) and thick-bedded marls of the Łącko Marl-type (Watycha, 1976; Cieszkowski, 1979a; Cieszkowski *et al*., 1998; Szczęch *et al*., 2016) (Fig. 4H). However, their total share constitutes no more than 20–30% of this formation. Thick-bedded sandstones are weakly calcareous. The Kowaniec Member is practically lacking conglomeratic-sandstones and conglomerates. In the Hieroglyphic beds-type strata, the sandstones are grey, grey-greenish, fine- and medium-grained. The shales are weakly calcareous or non-calcareous, greenish, grey-greenish.

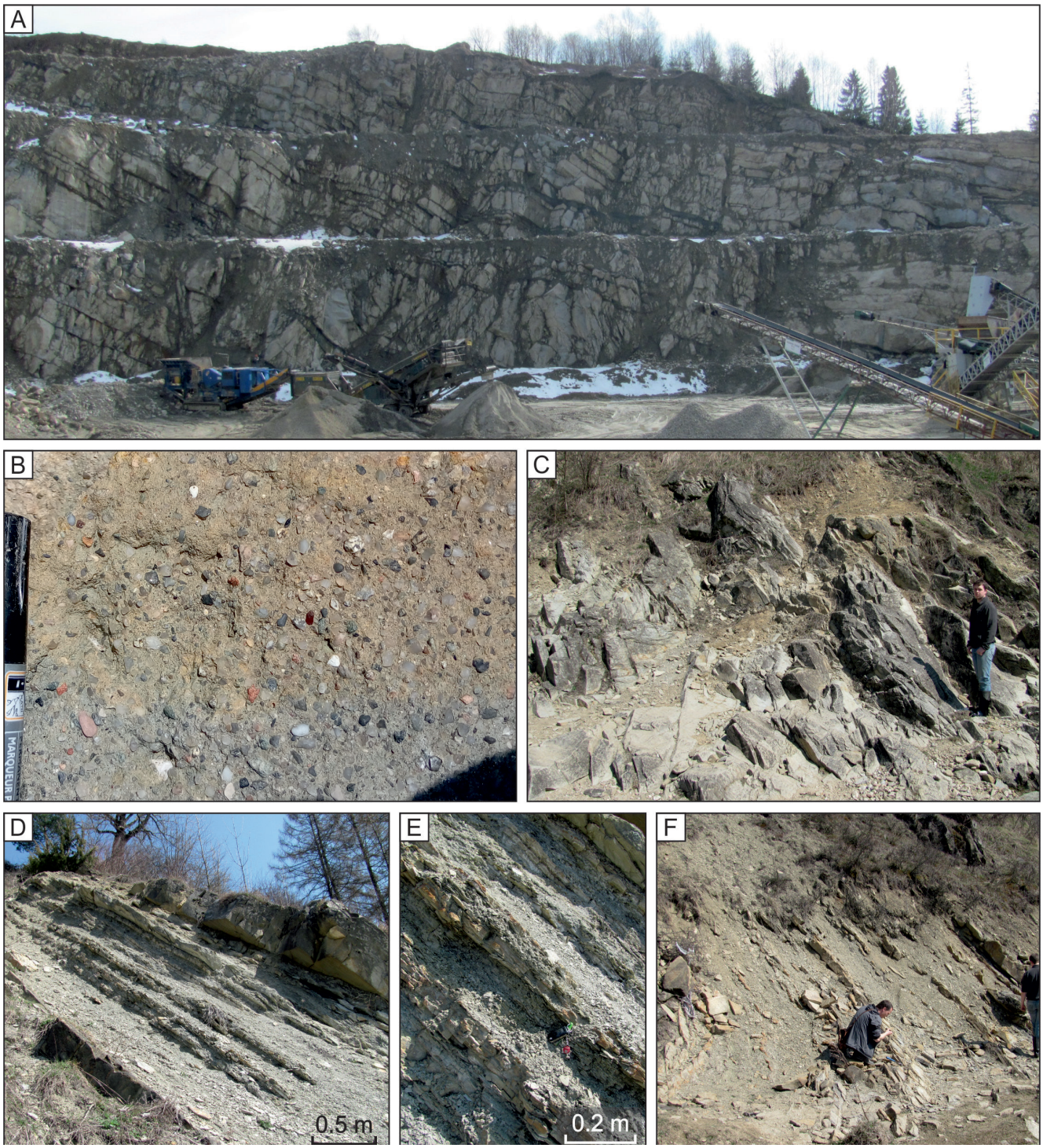

Fig. 5. Deposits of Krynica Subunit of the Magura Nappe: A – thick-bedded sandstones of the Poprad Sandstone Member in Klikuszowa quarry; B – coarse-grained conglomeratic sandstones of the Magura Formation with the characteristic red and pink grains (Kowaniec, Nowy Targ); C – thick-bedded sandstones of the Magura Formation-type in the Malcov Formation (Samorody, Nowy Targ); D, E – thin- and medium-bedded sandstone-shale turbidites of the Malcov Formation (Samorody, Nowy Targ); F – thin- and medium-bedded sandstone-shale turbidites with intercalations of thick-bedded sandstones – the Malcov Formation (Samorody, Nowy Targ)

The Łącko Marl-type strata are turbidites, composed of bi-partite beds consisting of sandstone in the lower part that evolves upwards into grey, grey-bluish marl. The **Poprad Sandstone Member** (Upper Eocene–Oligocene) is the youngest member of the Magura Formation. It is dominated by thick-bedded sandstones (Fig. 5A, B). Shale beds reach several cm in thickness, are rare and practically absent in the central part. Participation of the shales and thin and medium-bedded sandstone-shale turbidite intercalations between the thick-bedded sandstones is rising rapidly in the uppermost part of the section. The shales are olive-green, often gritty and non-calcareous.

The youngest deposits of the Magura Nappe in the area are represented by the **Malcov Formation** the Oligocene–Early Miocene in age (Cieszkowski & Olszewska, 1986; Cieszkowski, 1992, 1995; Oszczypko-Clowes *et al*., 2018) (Fig. 5C–F). The main facies of this formation consists of thin- and medium-bedded sandstone-shale turbidites (Fig. 5D–F). Apart from them, packages of thick-bedded sandstones of the Magura Formation-type also occur there (Fig. 5C) in that thick-bedded shales, soft marls and hard marls of the Łącko Marl-type. The thin- and medium-bedded sandstones are grey-blue, light grey when fresh, yellow-grey when weathered, strongly calcareous, fine- and medium-grained. Black manganese coatings often occur on sandstone surfaces. The shales are marly, grey, grey-blue, bluish, yellowish. Traces of gold were found in the deposits of the Malcov Formation in the Grel area in Nowy Targ (Cieszkowski *et al*., 1999).

Deposits filling of the Orawa-Nowy Targ Basin

The southern part of the discussed area is located on the northern edge of the Orawa-Nowy Targ Basin, in its eastern part – the Nowy Targ Basin. The latter is filled with the Neogene and Quaternary fresh-water deposits, which overlay the Magura Nappe deposits. The Neogene formations are covered by the Pleistocene and Holocene sediments and are outcropping in a few places (i.e. Domański Wierch, Chochołów, Mizerna and Kluszkowce). Their recognition was possible thanks to deep drillings in the Orawa-Nowy Targ Basin, i.e. Czarny Dunajec IG 1 (Watycha, 1977b), Nowy Targ IG 1 borehole (Paul & Poprawa, 1992). The sedimentation of these deposits is related to the subsidence of the basin, which in the Nowy Targ Basin was less intense (amounts to approx. 100 m), than in the western part of the Orawa-Nowy Targ Basin (more than 1000 m). The Neogene deposits are mainly represented by sand and gravel, but silts and silt-clays and layers of lignite also occur there (Watycha, 1977b; Chowaniec & Cieszkowski, 2009; Wysocka *et al.*, 2018; Ludwiniak *et al.*, 2019). The detrital material filling the Orawa-Nowy Targ Basin was delivered from the south from the Pieniny Klippen Belt, the Gubałówka Ridges and the Oravska Magura Mountains, and from the north from the Babia Góra Ridge and the Gorce Mountains (Chowaniec & Cieszkowski, 2009).

The Quaternary deposits of the Orawa-Nowy Targ Basin are represented by fluvial sediments in the upper part of the section, and in the lower part by fluvial-glacial deposits (Watycha, 1977b; Chowaniec & Cieszkowski, 2009). These sediments are represented by sands and gravels. Clays reaching up to 5 m in thickness also occur there. The gravels are mainly dominated by pebbles of the Tatra-derived crystalline rocks. The sediments record marked climatic fluctuations during the Pleistocene, and even the Holocene, through variable dynamics of erosion and accumulation processes and changes in the composition of the deposited material (Chowaniec & Cieszkowski, 2009).

Tectonics

The described area is located in southernmost part of the Magura Nappe, which is represented here by Krynica Subunit deposits (Koszarski *et al*., 1974). The Magura Nappe deposits were folded into a sequence of synclines and anticlines in the Miocene (Golonka *et al*., 2005, 2019a). The approximate west-east direction of their axial planes strike is related to the main fold structures in this part of the Carpathians (Książkiewicz, 1977). However, the folds are usually small and occur locally in the discussed area (Fig. 6). Only some of the folds in the southern part of the Gorce Mountains continue beyond the boundaries of this range. Such structures include the Sieniawa Syncline and the Pyzówka Anticline located in the northern part of the Lepietnica stream valley, which continues to the west beyond the study area (Cieszkowski *et al*., 1998) (Fig. 6). Fold structures are cut transversely or diagonally by strike-slip or oblique-slip faults. The length of faults varies significantly. Some complex fault zones play an important role in the tectonics of the Gorce Mountains and its surroundings (Fig. 6). The Waksmund-Ponice fault extends beyond the studied area towards the north and joins with the Skawa fault (Książkiewicz, 1977). This fault extends also southwards, reaching Trybsz in the Orawa-Nowy Targ Basin (Watycha, 1975, 1976). The fault's axis shifts. The Lepietnica fault, which runs along the Lepietnica stream valley in the villages of Klikuszowa and Obidowa constitutes an important structure. This fault continues further to the south in the Orawa-Nowy Targ Basin (Baumgart-Kotarba *et al*., 2004; Struska, 2008). The Lepietnica fault is one of the several faults causing a clear down-throw of the geological structure of the Orawa-Jordanów Foothills (Książkiewicz, 1970; Szczęch, 2013). In the southern part of the area, there is a tectonic Orawa-Nowy Targ Basin (Figs. 2 and 3). It originated under transtension conditions associated with the system of oblique strike-slip faults (Ludwiniak *et al*., 2019). This basin is filled with Neogene and Quaternary deposits (Watycha, 1977b; Struska, 2008; Chowaniec & Cieszkowski, 2009).

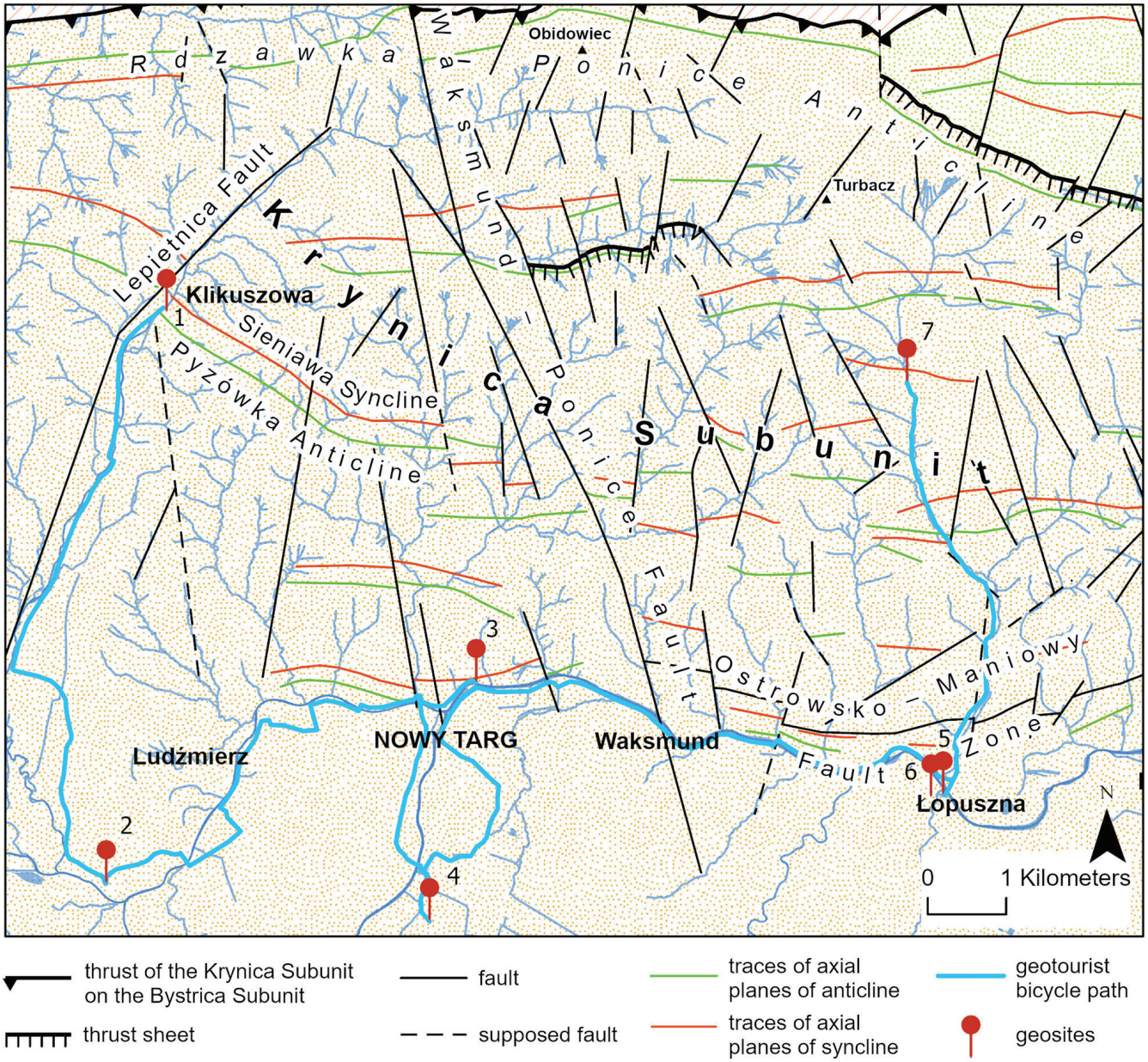

Fig. 6. Tectonic sketch of the described area (after Szczęch & Cieszkowski, 2021)

Geotouristic bicycle path

The proposed bicycle path is about 35 km long (Fig. 3). It begins in Klikuszowa and leads to Ludźmierz, and then to Nowy Targ and further along to the northern border of Orawa-Nowy Targ Basin to Łopuszna. It is an easy route with slight gradients (Fig. 7). This path presents well geological features and geotouristic values in the vicinity of Nowy Targ.

Location 1: Klikuszowa Quarry

The route starts in Klikuszowa village in the quarry of the sandstones located near the boundary between Obidowa and Klikuszowa villages on the northern slopes of the Skałka Mount (49°31′48.9″N, 19°59′42.7″E). It is a classic outcrop of the Poprad Sandstone Member deposits of the Magura Formation. In this locality, several hundred meters thick complex of the sandstones can be observed. This complex is almost completely devoid of shale intercalations (Fig. 5A). The walls of the quarry expose joint and fault systems of low amplitude. These sandstones were used in Ludźmierz to make decorative elements, for example the rosary garden at the local sanctuary of Our Lady of Ludźmierz, Queen of Podhale.

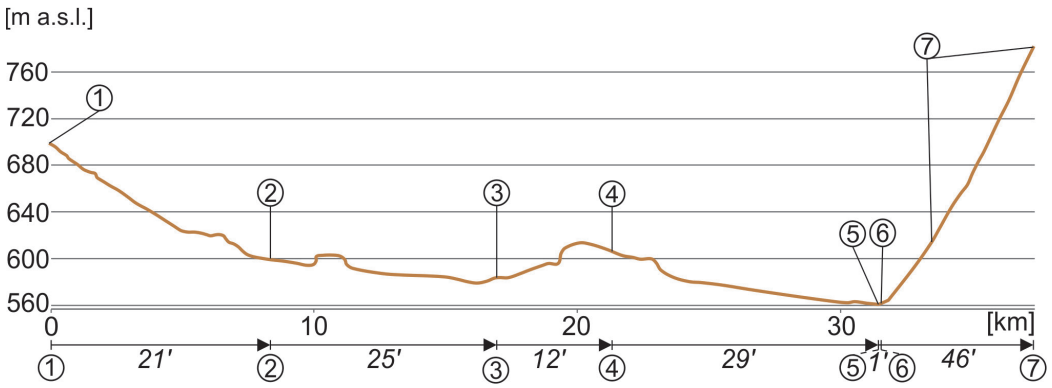

Fig. 7. Klikuszowa–Łopuszna bicycle road elevation profile, with the travel time between geosites

Location 2: Sanctuary of Our Lady of Ludźmierz

Ludźmierz is the oldest parish in Podhale, founded in 1234 (49°27′54.9″N 19°59′00.5″E). It is an important place of the Marian cult in Podhale. In the church, in the main altar is the St. Mary statue sculptured approximately at the beginning of the 15th century (Fig. 8A).

The foundation of the statue is related to the legend of a Hungarian merchant, who during his journey, got stuck with his entire load in the nearby swamps. However, he was miraculously saved and in return he founded the Holy Mother statue in a nearby church (Bukowski, 1991). The present, neo-Gothic church is entirely built of sandstone. Its furnishings also include a baptismal font carved in the sandstones of the Magura Formation (Fig. 8B). The poet Kazimierz Przerwa-Tetmajer was baptized in this font. The floor of the church is carved in white marble and red nodular limestone (the *Ammonitico Rosso* type). The limestone contains fossils, i.e. ammonites, belemnites and stems of crinoids. In a rosary garden, which is located behind the church and to the east, many elements of decoration and architecture are carved in sandstones from the quarry at Klikuszowa. The sandstones are medium- and coarse-grained as well as conglomeratic, usually massive or graded, but also showing parallel and convolute lamination. Some slabs display sole marks (Fig. 8C), e.g. flute casts (Fig. 8D) and also trace fossils, i.e. *Scolicia* (Fig. 8E).

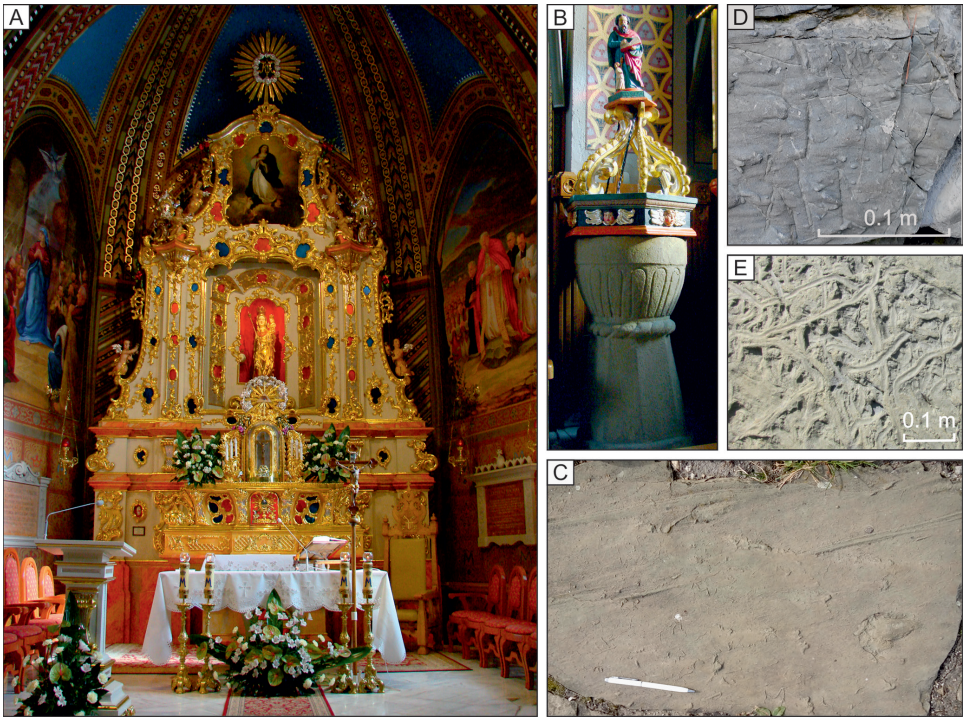

Fig. 8. Sanctuary of Our Lady of Ludźmierz: A – main altar with the statue of Our Lady of Ludźmierz; B – baptismal font carved in the sandstones of the Magura Formation; C – trace fossils and sole marks on the base of sandstone bed; D – flute casts on the base of sandstone; E – *Scolicia* trace fossil

Location 3: Samorody nad Dunajcem

Samorody nad Dunajcem (49°29′15.9″N, 20°02′54.1″E) is a well-exposed outcrop of the Malcov Formation (Halicki, 1959, 1961; Watycha, 1963, 1976; Cieszkowski, 1985b, 1992, 1995), one of the youngest lithostratigraphic divisions of the Magura Nappe (Fig. 9A–E). The name of this outcrop was introduced into the literature by Watycha (1963). The advantages of this locality are emphasized by numerous publications (Halicki, 1959, 1961; Watycha, 1963, 1976; Cieszkowski, 1985b, 1992). Moreover, the Samorody nad Dunajcem was described as a parastratotype of the Malcov Formation by Birkenmajer and Oszczypko (1989). It is located on 15 m high left bank of the Dunajec River near Kokoszków district of Nowy Targ, slightly below the confluence of the Biały Dunajec and Czarny Dunajec rivers. The outcrops show steeply dipping layers of thin- and medium-bedded sandstone-shale turbidites (Fig. 5D–F) with intercalations of thick-bedded sandstones and fine conglomerates of the Magura Formation-type with characteristic red grains (Fig. 5C). Sole marks (Fig. 9D), as well as trace-fossils (i.e. *Scolicia* and *Zoophycos*; Fig. 9E), can be observed on the lower bedding surfaces. Deformational structures include a submarine landslide with disrupted layers of thick-bedded sandstone (Fig. 9B) and faults (Fig. 9C) with accompanying tectonic structures such as tectonic striations and slickensides. The tectonic step-like features are visible on the slickenside surfaces (Fig. 9C).

Location 4: Bór na Czerwonem Nature Reserve

Bór na Czerwonem Nature Reserve is a peat bog reserve, which is located near the Nowy Targ airport on the Vistulian terrace of the Biały Dunajec River (49°27′52.1″N, 20°02′21.3″E). It is a classical highland bog, one of a dozen similar bogs that occur in the Orawa-Nowy Targ Basin, with a characteristic dome and the surrounding peat forest. Its formation was possible thanks to favourable hydrological conditions, the occurrence of many springs, which were important at the initial stage of the development of the peat, and an approximately 2 m thick layer of poorly permeable clay underlying it (Łajczak & Obidowicz, 2009). Important factors favourable for the formation of the peat bogs in the Orawa-Nowy Targ Basin are also the gentle slopes in the area, as well as a cool and humid climate. The beginning of the formation of the peat bog is dated at 6,930 ±240 years (Wójcikiewicz, 1979). The bog stands out as a different landscape feature resulting from the characteristic vegetation inhabiting this acidic and mineral-poor environment, e.g. *Sphagnum* moss, bog cranberry, tussock cottongrass, round-leaved sundew, marsh Labrador tea, bog blueberry, *Pinus rhaetica* (Fig. 9F). The peat layer average growth in the Carpathians is about 0.5 mm per year (Łajczak, 2009). Peat bogs are also a valuable source of information on the climatic and environmental conditions in the basin recorded in peat layers. The Bór na Czerwonem peat bog has been significantly degraded and decreased in size due to the exploitation of peat since the 19th century. It is under protection since the 60's of the 20th century, to preserve the existing habitats. The implemented measures of active protection are to restore the natural conditions, habitats and values of this peat bog. The State Forests also created an educational path here presenting the natural values of the raised bog and bog forest (Fig. 9G).

Locations 5 and 6: Church of Holy Trinity and manor house in Łopuszna

Łopuszna is a village situated on the Dunajec River at the tributary of the Łopuszna stream, sources of which are located in the Turbacz ridge. In the village, there is a church erected at the turn of the 15th and 16th centuries (Fig. 10A; 49°28′26.4″N, 20°07′48.7″E). It is one of the most valuable monuments of Podhale. In the main altar is a triptych, which is a work of medieval painting from the 15th century. The triptych is painted on a wooden board, and the main painting presents the coronation of the Mother of God (Fig. 10B). Due to its location, the church was flooded many times by the Dunajec River. Some of the flood waves height are marked on the flood plaques placed on the northern wall of the church (Fig. 10C). One of the most geologically interesting objects in the church is a stone holy water font located outside at the side entrance (Fig. 10D). It is made of stones that came from the Pieniny Klippen Belt and Outer Carpathians. The base of the font is made of the Czorsztyn Limestone Formation from the Pieniny Klippen Belt with a characteristic nodular structure and pinkish-red colour, and the bowl is of coarse-grained sandstones of the Magura Formation. The wall surrounding the church (flood barrier) and its foundations are constructed of sandstones of the Magura Formation. On slabs of the wall, sole marks (Fig. 10E, F) as well as trace-fossils (Fig. 10F) can be observed. The typical Polish wooden manor house at Łopuszna (Fig. 10G) was constructed of logs at the end of the 18th century by the Lisiecki family (49°28′25.5″N, 20°07′40.1″E). Currently, the building houses a branch of the Tatra Museum. In its vicinity are remains of a stable made of the sandstones of the Magura Formation and a highlander's cottage with furnishings dating back to the turn of the 19th and 20th centuries transferred here from another location in the village.

Location 7: Łopuszna valley

The Łopuszna stream valley is an extremely picturesque, deep-cut, V-shaped valley also called "Small Kościeliska Valley" (Fig. 11A–G; 49°30′36.6″N, 20°07′36.1″E). The aesthetic qualities of the valley and the surrounding peaks were appreciated by the Polish poet and writer Seweryn Goszczyński, who described his delight over the landscape and nature of the Łopuszna valley in his book *Dziennik podróży do Tatrów* (*Diary of a trip to the Tatra Mountains*). In the Łopuszna valley, the full succession of the Magura Formation is well exposed (the Piwniczna Sandstone Member, the Kowaniec Member and the Poprad Sandstone Member).

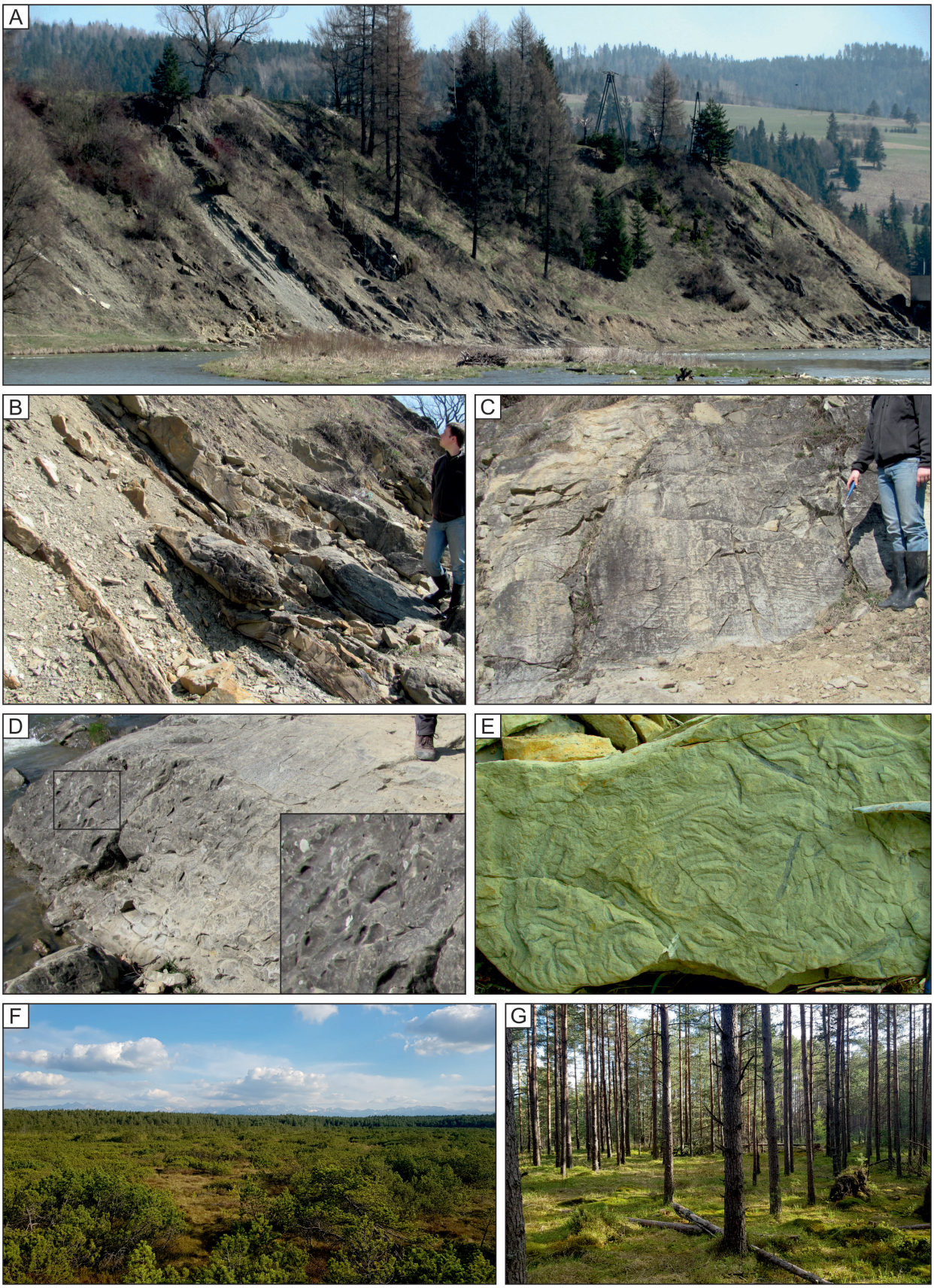

Fig. 9. Geosites in Nowy Targ town: A – Samorody nad Dunajcem Malcov Formation outcrops (Nowy Targ); B – submarine landslides with visible break layers of thick-bedded sandstone layer (Samorody, Nowy Targ); C – chatter marks in a fault zone in thick-bedded sandstones (Samorody, Nowy Trag); D – cavity after weathered shale clasts on the top of the sandstone layer (Samorody, Nowy Targ); E – *Scolicia* trace fossil (Samorody, Nowy Targ); F – raised bog – Bór na Czerwonem Nature Reserve; G – coniferous swamp – Bór na Czerwonem Nature Reserve

Fig. 10. Geosites in Łopuszna village: A – Church of Holy Trinity and St. Anthony the Great in Łopuszna village; B – main altar – gothic triptych with Coronation of the Virgin scene in the middle panel; C – flood plaque on the northern wall of the church in Łopuszna; D – stone holy water font; E – sole marks on the bed of sandstone; F – trace fossils and flute casts on the base of a bed of sandstone; G – manor house in Łopuszna

The outcrops also make it possible for one to observe faults with occasionally chaotic formations (Fig. 11F) and their accompanying tectonic structures e.g. tectonic striations and slickensides. This feature can enable one to determine the direction of dislocation along the fault. This valley has a remarkable wealth of geomorphological forms such as landslides (Fig. 11D), waterfalls (Fig. 11C), picturesque rock tors (Fig. 11A, B, D, E) and landscapes (Fig. 11G). The tors are represented here by all genetic types according to Alexandrowicz (1978). The most numerous group are rocks

Fig. 11. Geomorphological features in the Łopuszna valley: A – tor of Piwniczna Sandstone Member; B – cliff of thick-bedded sandstone of the Kowaniec Member of the Magura Formation in the Łopuszna stream valley; C – waterfall located on the tributary of the Łopuszna stream; D – Turniska rock formation located in the main scarp of the landslide; E – rock formation in the Łopuszna valley; F – fault zone with tectonic mélange, with sandstone clasts in fine-grained matrix; G – autumn panorama of the Łopuszna valley

associated with denudation processes (Fig. 11A, E), which are located at the ridge zones. However, there are also rock formations located along the banks of the Łopuszna stream valley (Fig. 11B), as well as tors formed by landslides (Fig. 11D). The most interesting rock tors are Turnice located in the main scarp of the landslide on the western slopes of Kiczora (Fig. 11D). In the Łopuszna valley, the rock tors are made mainly of thick-bedded sandstones of the Piwniczna Sandstone Member. However, some represent the Kowaniec Member, as well as the Poprad Sandstone Member.

Discussion

The vicinity of Nowy Targ is a unique area in the Outer Carpathians in terms of geology and landscape, with significant scientific, educational and significant geotouristic values (Cieszkowski, 2004, 2005a, 2005b, 2006a; Szczęch *et al*., 2016). The region has been the subject of geologists' interest since the 19th century. The 20th century saw the development of litho- and biostratigraphic, geological and cartographic, tectonic, seismic, and exploratory research involving several hundred to 5000 m deep parametric and exploration boreholes. The region is excellent area in which the tourist can learn about the deposits of the Krynica Subunit of the Magura Nappe, due to the presence of very good outcrops (Cieszkowski, 2005a, b, 2006a; Szczęch *et al*., 2016). The Gorce Mountains host numerous rock tors of thick-bedded sandstones often with unique vegetation. On the slopes of the Gorce ridges, numerous, sometimes wide, landslides occur, such as a landslide on the western slopes of the Kiczora Mountain.

Related to the landslides are occurrences of the crevice-type caves (about 40 in the Gorce Mountains), sometimes inhabited by bats. Moreover, the landscape beauty of the area is amplified by the picturesque waterfalls and plunge pools, e.g. in the Łopuszna stream valley. Finally, the cultural values are enriched by the wooden architecture of the old highlander houses and churches, highlander folklore, and relics of pastoral culture.

Conclusions

Nowy Targ is located in the border area between the Inner Carpathians and the Outer Carpathians. In this area, there are many valuable outcrops and geosites, including rock tors or architectural objects for the construction of which local rock material was used. These sites contribute to the great geotouristic value of this area.

The proposed bicycle route presents the most interesting geological localities in the vicinity of Nowy Targ, located in the Outer Carpathians. These geosites make it possible to trace the sedimentation conditions of the deposits that build the southernmost part of the Magura Nappe. Additionally, the route presents well the tectonics of the described area, as well as the origin and evolution of the Orawa-Nowy Targ Basin. The described route also shows the contemporary processes shaping the relief of the described terrain.

The vicinity of Nowy Targ, due to its picturesque location and rich folk culture, and the development of recreational infrastructure, is an increasingly popular place for hiking and cycling. The proposed easy bicycle route presents the most interesting places, both geologically and historically, in the vicinity of Nowy Targ, which are located at the junction of the Gorce Mountains with the Orawa-Nowy Targ Basin.

Unfortunately, the geological values, apart from the Bór na Czerwonem reserve, are not exposed or presented in any way for tourists. It is still an undeveloped area in terms of geotourism, even though the Łopuszna stream valley is located within the Gorce National Park.

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