Polish Geological Institute Special Papers, 13 (2004): 57–64
Proceedings of the Conference "Geological heritage concept, conservation and protection policy in Central Europe"

EXCEPTIONAL GEODIVERSITY OF THE INTRA-SUDETIC BASIN WITHIN THE LANDSCAPE OF THE UPPER ŚCINAWKA RIVER DRAINAGE AREA

Andrzej KOSIÓR[1]

Abstract. The paper is focused on extremely huge geological structures and geomorphological forms present in the landscape of the Intra-Sudetic Basin which give important and clear information on the evolution of this part of Sudetes Mountains between Permian and Quaternary. The geodiversity of the geometric valley of the Upper Ścinawka River with asymmetric slopes, defined as Upper Cretaceous sandstones and Permian volcanical geotopes, is shown very picturesquely. Emphasising the didactic and tourist virtues of the north-eastern part of the Intra-Sudetic Basin, author suggests to establish there a Polish-Czech geopark.

Key words: cuesta, mega-geotop, geopark, geodiversity, landscape, Intra-Sudetic Basin.

Abstrakt. Artykuł koncentruje się na widocznych w krajobrazie niecki śródsudeckiej wyjątkowo dużych strukturach geologicznych i formach geomorfologicznych, niosących istotną informację na temat rozwoju tej części Sudetów w okresie od permu do czwartorzędu. Obrazowo pokazana została georóżnorodność geometrycznej doliny górnej Ścinawki o asymetrycznych zboczach, określonych tu jako mega-geotopy piaskowców górnokredowych i wulkanitów permskich. Akcentując walory dydaktyczne i turystyczne północno-wschodniej części niecki śródsudeckiej, autor proponuje utworzenie na tym obszarze pierwszego polsko-czeskiego geoparku.

Słowa kluczowe: kuesta, mega-geotop, geopark, georóżnorodność, krajobraz, niecka Śródsudecka.

INTRODUCTION

Within the long-term Program of Geodiversity Protection in Poland, valuable and interesting elements of abiotic environment in the Sudetes Mountains were catalogued, and the current and planned protected areas occurring there were described (Gawlikowska, 2000). The report is using the idea of geodiversity based on geotopes — interesting abiotic elements carrying clear though isolated information on the earth's crust development. In the case of the Intra-Sudetic Basin this approach is insufficient, nor is the geoconservation system for this region. Kozłowski (1997) legitimately insist to continuously refer to the current structure of the landscape while describing its geodiversity. Only with such depiction, through the general view on the landscape one can see not only the close connection between all abiotic elements but also, more than once, that they are parts of much bigger forms, for which the most suitable name would probably be — the mega-geotopes.

Such description through the entire landscape is required for the unique geological diversity of the eastern wing of the Intra-Sudetic Basin within the Upper Ścinawka river drainage area. Exceptional geological structure and fascinating morphology of this part of the Basin has not been sufficiently described and promoted as yet. Its is probably a result of the magnitude of geological forms and structures which can only be seen from bird (or hang-glider) view, and the fact that since Middle Ages the area has been twice divided by the two countries border. One can say in jest, that Czech Crown effectively cut from Silesia off one the most beautiful parts of the Ścinawka River.

Besides many German, Czech and Polish papers, not much attention was given previously to mega-elements of the abiotic environment which were created by the upper Ścinawka River and its short tributaries. When the reader looks for a world

[1] CBPM "Cuprum" Ltd., Research and Development Center, pl. 1 Maja 1/2, 50-136 Wrocław; e-mail: a.kosior@cuprum.wroc.pl

"cuesta" in written documents or on internet, one is referred to the Kraków–Częstochowa Upland only without any remark on exceptionally wide structural thresholds on the Upper Cretaceous plates of jointed sandstones reaching almost 300 m above Ścinawka valley, and unusually rare beds of Permian volcanical rocks.

Several kilometres long gorge of Ścinawka River through volcanics of contemporary Kamienne Mountains and regular Ścinawka valley sculptured in the eastern wing of the Intra-Sudetic Basin, over 20 kilometres long and 10 km wide, is one of the biggest geological "books" of the Earth, carrying crucial and, what is more important, very clear information on forming this intermontane basin during almost 300 mln years. Broad structural thresholds of already mentioned Upper Cretaceous sandstone plates and gently dipping top of Permian volcanics on longer sides of Ścinawka valley, together with numerous attractive classical geotopes like para-volcanical fans, single rocks, scarps, slides, rock towers and mushrooms as well as whole rock walls give the exceptional geodiversity of the enormous educational and tourist importance.

Present system of the abiotic environment protection of this region, based on the Landscape Park of Wałbrzyskie Mountains on one side and the Protected Landscape Area CHKO Broumovsko on the other, passes over or treats marginally the Ścinawka valley, and the most important and interesting geological features are lost. The remedy is to form the first Polish-Czech geopark of the Intra-Sudetic Basin in the drainage area of the upper Ścinawka River, from the source near Rybnica Leśna, to Otovice. It would be the perfect completion of the mono-geological area of the National Park of Stołowe Mountains and very advisable increase of the importance of this part of the Protected Landscape Area CHKO Broumovsko, which has always been overshadowed by the Adršpašsko-Teplickie Skały Reserve. Simultaneously, it would be, due to the ere exceptional geological structures occurring there, a very good completion of the Silesian geoparks list proposed by Z. Alexandrowicz.

The issue of comprehensive description of the attractive regions of the abiotic environment, together with its mega-elements, meets the postulates of IUSG which encourages creation of general programs of protection and presentation of the landscape geodiversity and geological heritage of selected regions, shortly named geoparks. Using the formula of geopark is all the more justified, since it warrants joint of protective and tourist function with education one, which has been very much neglected there due to some objective reason — the states border. The idea of geoparks rightly gains bigger and bigger popularity in Europe. The first international geopark in Poland will probably be the planned Polish-German Muskau Arch Geopark within the borderland of Śląsk and Lausitz, which exposes unique glacitectonic structure with traces of historical coal mining. The next international geopark, Polish-Czech this time, could probably be the described there part of the Intra-Sudetic Basin with the Upper Ścinawka River drainage area, from its sources to the Otovice village in Czech Republic.

MEGA-GEOTOPES OF THE EASTERN SIDE OF MIDDLE SUDETIC BASIN

The part of the Intra-Sudetic Basin, we are especially interested in, is the area of upper Ścinawka river basin from Rybnica Leśna and Różana to Božanov and Otovice (Czech Republic). It includes the upper parts of Kamienne Mountains (Lesista Range, Dry Mountains, Javoři Hory), northern part of sandstone Stołowe Mountains (Zawory, Bukove Hory, Broumovskie Steny) and almost rectangular valley of Ścinawka River (Fig. 1), almost 20 km long and 10 km wide, situated between those mountains.

Fig. 1. Northern part of the Ścinawka river valley; in the middle – Mieroszów town; view from Broumovskie Walls

The abundance of geological forms and structures of this part of Basin is the effect of joint activity of seas, volcanoes, tectonic movements, erosion and denudation during hundreds of million years. However, the present exceptional landscape of this area, showing clearly the structure and magnitude of the Intra-Sudetic Basin, results from the activity of Ścinawka River which eroding during the Tertiary the sedimentary rocks of Rotliegendes, Zechstein and Triassic Bunter Sandstone uncovered the wide cuesta of the sandstone plate of the Stołowe Mountains on the south-west and gently dipping top of the Permian volcanics on the north-east.

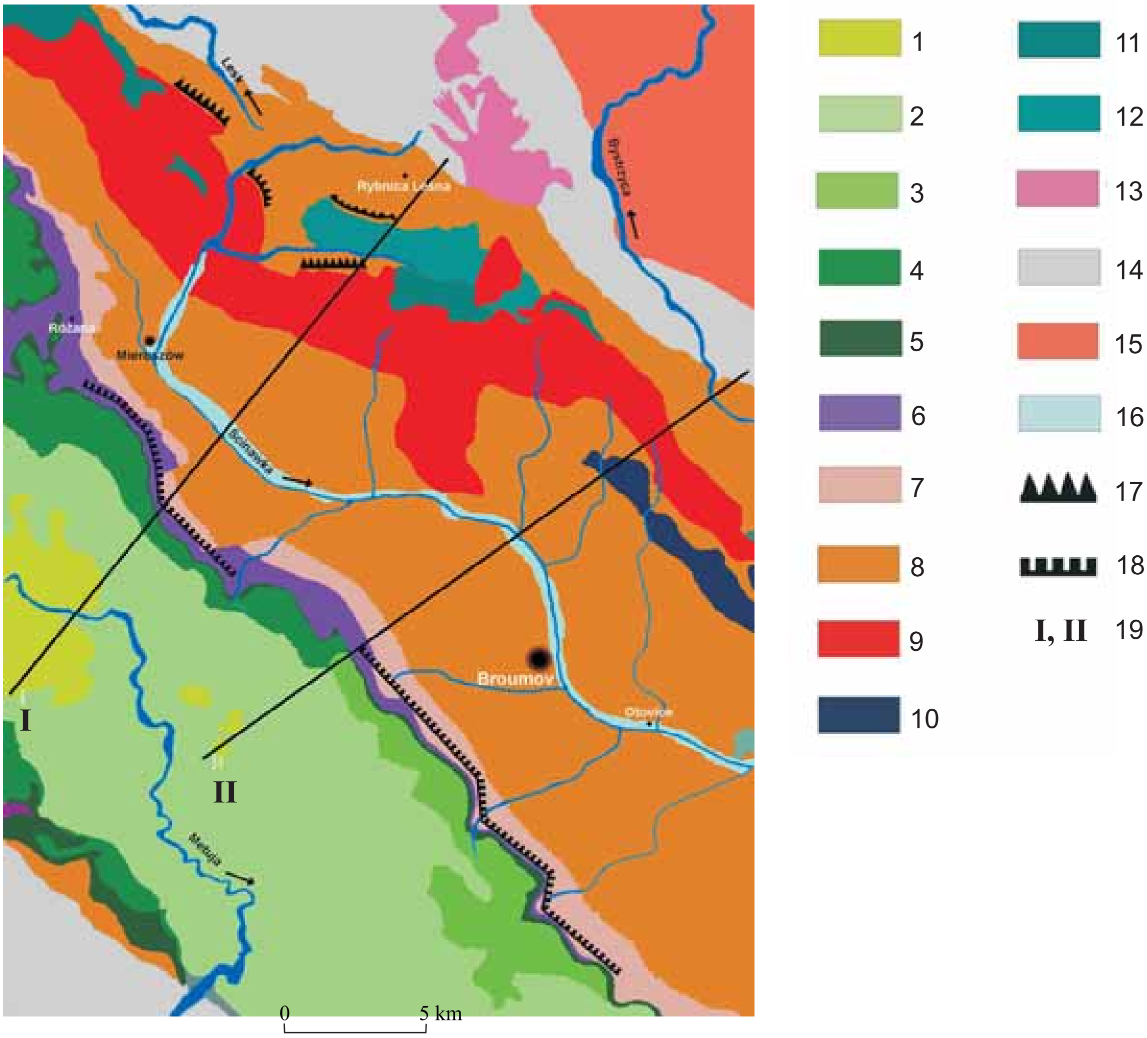

Fig. 2. Geology of the upper Ścinawka river drainage area (Kosiór, 2003), north-eastern flank of the Intra-Sudetic Basin

Upper Cretaceous: *1*, *3*, *5* — upper, middle, lower jointed sandstones; *2*, *4* — siltstones, claystones and marls; **Lower Triassic**: *6* — bunter sandstones; **Permian**: *7* — Zechstein sediments; *8* — Rotliegendes sedimentary rocks; *9* — tuffs, ignimbrites and latites of II volcanic cycle; *10*, *11*, *12* — trachybasalts of III, II, I volcanic cycle; **Carboniferous**: *13* — volcanites; *14* — sedimentary rocks; *15* — proterozoic gneisses; *16* — river sediments; *17* — cuestas on volcanic rocks; *18* — cuestas on jointed sandstones; *19* — numbers of geological cross sections

The Ścinawka valley discloses very clearly the geological history since Lower Permian through Zechstein, Triassic, Upper Cretaceous till Tertiary and Quaternary, i.e. the period of more than 260 mln years (Fig. 2).

Deeply under the Ścinawka valley, the Carboniferous beds with hard coal stratum occur. Below, the marine Devon sediments are presents. The bottom of the ancient sea was built of the metamorphosed crystalline rocks of Orlice–Bystrzyca and of a part of the Czech Massif. On the north-eastern side of the horizon, however, over the volcanites of the Kamienne Mountains, the archaic Sowie Mountains, still the highest in the region, can be seen.

The Intra-Sudetic Basin reaches maximum of its development in the Lower Permian. The area of Central Sudetes was a land with dry and hot climate at that time, what is documented by desert colour of the fluviatile deposits, i.e. of the then deposited Rotliegendes conglomerates and sandstones. After several subsequent volcanical cycles, those sediments were followed by porphyritic material, and today one can see it on the not very high cuesta (about 20 m), on the right side of the Ścinawka River between Mieroszów and Boumov, especially in Hyncice in the porphyry fanglomerates outcrop of saxon strata. Only drought-liking coniferous trees — walchias, debris of which are observed in the limnic walchia shales, where *nota bene* dur-

Fig. 3. East-northern slope of Stożek Massif

Fig. 4. Northern slopes of Suchawa, Kostrzyna and Włostowa

Fig. 5. South-western slope of volcanical Kamienne Mts. with cuts made by short left tributaries of Ścinawka River

ing the fifties Russians were looking for uranium ores, are worth to be mentioned.

In Permian, very intensive explosion and volcanoes eruptions took place. The volcanical deposits of big thickness formed at that time were mostly solidified lava streams, and tuff and ignimbrite covers. Permian volcanism took place in three cycles. Each cycle begun with calm effusion of trachybasalts and terminated by acid explosions of rhyolite magmas. In cycle I and III trachybasalts effusions dominated. The biggest trachybasalts massif from volcanical cycle I forms the range of contemporary Bukowiec, Klin, Turzyn and Jeleniec. Unfortunately, they are the best quality melaphyres in Poland and there is a great interest in their exploitation. The huge trachybasalt cover reaches there the thickness of over 150 m, and forms on the north a big cuesta almost 5 kilometres long. During the eruptive cycle II, after small trachybasalt effusions, the latite lavas dominated, which formed thick covers with porphyric structure, building the highest range of the Kamienne Mountains with Waligóra, Suchawa, Kostrzyna and Stożek Wlk., today. They have steep slopes and scarps, the elements of big latite cuesta visible on the northern side (Fig. 3, 4).

Today, exposures of the Permian volcanical rocks significantly differentiate topographical profile that is not always the direct result of old volcanical processes. The profile originated during the Cainozoic, as a secondary effect of the Sudetes en block uplift as well as selective erosion and denudation. Due to the hardness of some volcanical rock, they were sculptured in the form of impressive cuestas with picturesque silhouettes. On the slopes of this elevations one can observe numerous evidences of young Pleistocene land slips, for instance, large scale landslides.

Second eruptive cycle was terminated by enormous explosion of rhyolite magmas and huge amount of pyroclastic material. It resulted in formation of thick, packed banks of vitro-clastic tuffs, and covers of rhyolite ignimbrites, 700 m thick, the biggest between Kowalow and Janowiczki (Czech Republic). The top of this huge bed, dipping at the angle of 12° towards the south-west, at the distance of over one kilometre, i.e. preserving the natural dip of the sediments in that part of the Intra-Sudetic Basin, is visible from the Ścinawka valley in its whole beauty, beside overgrowing it thick spruce forest (Fig. 5).

Originally, these hard rocks formed horizontal strata covered during the next geological epochs with soft sediments of the Upper Rotliegendes, Zechstein and Triassic.

As a result of later Alpine Orogeny, those strata dipped towards south-west building gentle and wide, north-eastern flank of the main Intra-Sudetic Syncline. The thickness of the Permian volcanical cycle II beds can be guessed while looking from the Różana–Kochanów road (Fig. 6). *Nota bene*, it is one of the best scenic points, also at long and high cuestas of Upper Cretaceous jointed sandstones.

From exactly this point, the total beds thickness of the second volcanical cycle can be observed. A little smaller outcrops of tuffs and ignimbrites, with gently dipping top, are visible from the south-eastern side. From the north-western side, however, the higher and older stratum of latites (horizontal arrow), finished by impressive cuesta, can be seen even from that distance. The same cuesta is on the Figure 4. The third eruptive cycle occurred practically on the Czech side only and gave mainly trachybasalts and rhyolite tuffs of much smaller thickness.

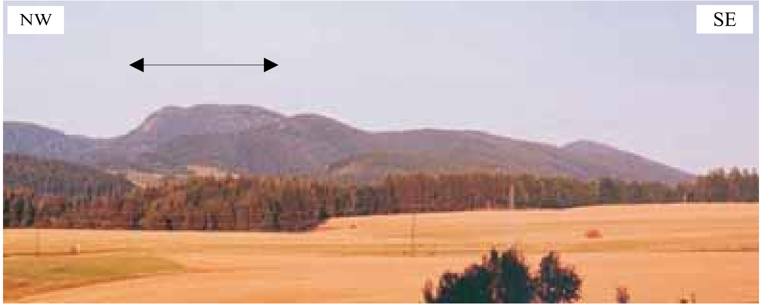

Fig. 6. Wide volcanical strata of the Permian eruptive cycle II

During the Upper Permian (Zechstein), the Intra-Sudetic Basin became a big bay of the warm southern sea, depositing limestones, sandstones and dolomites on its bottom. Variscan Sudetes had not been any longer mountains at that time due to the intensive erosion, lasting 60 million years.

In Lower Triassic, the warm sea entered again the basin leaving sediments called arkosic Bunter Sandstone. Rocks built of those sediments can be observed just at the foothills of the Cenomanian sandstone cuesta (Fig. 7).

During 100 million years, between Upper Triassic and Upper Cretaceous, lasted long period of Sudetes base-levelling but no sediments were preserved till present time. During Jurassic period, Sudetes were already almost flat land.

In the Upper Cretaceous, tectonical movements were re-activated along the old faults. About 98–100 mln years ago, the Upper Sudetic Basin submerged again, becoming once more a sedimentation area. As a result of the oceans water level rise, appeared the widespread flood of a shallow, epicontinental sea, with several islands, (western Sudetic — Karkonosze and Izerskie mountains and eastern Sudetic — Sowie Mountains and Śnieżnik Massif). Those islands were a source of sand for a sea bay which developed at the place of today's Intra-Sudetic Basin. The sand was moved by currents and deposited in form of layers. In that way, during about ten million years, the Stołowe Mountains were formed, built of three almost horizontal strata of jointed sandstones: the lower (Cenomanian), the middle (Turonian) and the upper (Coniacian) one, with a thickness of 40 to 100 m each. The sandstones are called "joint" ones because they are cut by a system of vertical fractures, perpendicular to the bedding (joint). The sandstone strata are separated by layers of fine marls, mudstones and claystones.

Marine origin of these deposits is confirmed by the presence of marine fauna (clams, ammonites, sponges and sea urchins). Densely fractured, permeable sandstones erode mechanically, and in impermeable marls the chemical erosion (dissolving and washing out of the lime binder) took place. Sandstones form steep walls and blocks, and marls — flat and gently inclined land forms. In the effect, the "table mountains" were formed, separated from the neighbouring area by distinct morphological edges: structural thresholds with relative height of up to 300 m.

The oldest Upper Cretaceous lower bed of glauconitic joint sandstones is exposed on the peripheries of the Upper Cretaceous tableland only, i.e. within the so called Mieroszów Walls, and in few erosion buttes away of the uniform tableland.

The middle bed, composed of arkosic joint sandstones and accompanying planar marls, builds the actual body of the Stołowe Mountains. Along the whole north-eastern edge, over the Ścinawka river valley, one can see head of this bed called Brounovskie Walls (Fig. 8). It is a high cuesta, locally up to 260 m (Fig. 9), which extends along nearly 25 kilometres upto Wambierzyce (Radków Walls) .

At the edges of the middle jointed sandstones, there are numerous classical geotopes — picturesque rock forms: mushrooms, towers, walls, single rocks (Fig. 10).

The youngest, upper part of quartz jointed sandstones form famous "rock towns" — tables cut by fissures and ravines, speckled with sandstone rocks having fancy shapers. They are located out of the drainage area of Ścinawka, Adršpašsko–Teplicke Skaly, Ostaš, Kluček, Skalniak (Vicious Rocks) and the located partly there — the Szczeliniec Wielki, *nota bene* visible from almost every higher place of the region.

Fig. 7. Mieroszów Walls — Cenomanian sandstone cuesta, below — Triassic rock

Fig. 8. Broumovske Walls, view from the Mieroszów side

Fig. 9. Southern part of Broumovske Walls, 260 m above Ścinawka valley; view from the Kamienne Mts. (Javoři Hory) side

At the end of Cretaceous, 70 mln years ago, as a result of orogenic movements and uplifting of the Czech Massif, the Upper Cretaceous sea withdrawn from the area. The important tectonical stage began — the alpine orogeny, proceeding with various intensity from Tertiary to the beginning of Quaternary.

Simultaneously with the sea regression, the further deflection of the Intra-Sudetic Basin with rise of its peripheries took place. The destruction of the uplifted parts took place during the both phases of movements in the Palaeocene and Eocene leading to partial removal of the cover built of Upper Cretaceous sandstones, and to exposure of the older bedrock.

After the Laramian Phase, the whole area of Hercynian Pre-Sudetes was a land. It was the only land between the transgressive northern sea and Tethys sea in the south. The land must have been lifted up enough to become a subject of intensive erosion. In the than humid, sub-tropical climate, and with contribution of luxuriant vegetation, the strong weathering and intensive denudation by intensively running waters took place, which had deeply cut the exposures of less resistant rocks, and left more resistant beds.

At the and of old Tertiary period (Palaeogene), in the Middle Oligocene, after 40 mln years of Pre-Sudetes destruction, the widespread plain was created. The fragments of this Palaeogene surface are preserved in Sudetes until present days. In Karkonosze it is probably the plain below Śnieżka. In the Intra-Sudetic Basin the plain level of Kamienne and Stołowe Mountains, at the height of about 900 meters above the sea level, is probably a part of horizontal profile also connected with Palaeogene surface of levelling, although substantially lowered and transformed by the further degradation processes.

During the decline of Oligocene, after a long calm period, Alpine orogeny movements lifted Alps and Carpathians, and the Sudetic plate, including the Basin, was cracked (?sawijska phase). The Marginal Sudetic Fault which separates Sudetes and foreland, have risen then. A gentle folding of the Upper Cretaceous plates and then their fragmentation by numerous folds of different directions took place. The Upper Cretaceous block, like other parts of the basin, was lifted up or lowered along the faults. Pre-Ścinawka River which drained the Sudetes towards south-east was formed probably then.

Uplifting of the Stołowe Mountains intensified washing out the soft Permian sediments by Pre-Ścinawka River. The most important is that those movements did not disturb the structure of the north-eastern wing of the Basin, being as a whole characterised by gentle dipping of strata.

One of those strata — Permian volcanics were sculptured by Pre-Ścinawka River, and today, due to their hardness, we may admire the magnitude and beauty of the Intra-Sudetic Basin along 20 kilometres.

After Oligocene Sudetes uplifting, the reconstruction of the rivers network began. The valleys parallel to the mountain edges disappeared in favour of drainage carried through new troughs and gorge valleys with bigger descent.

Fig. 10. Rock wall on the Broumovske Walls and mushroom on the top

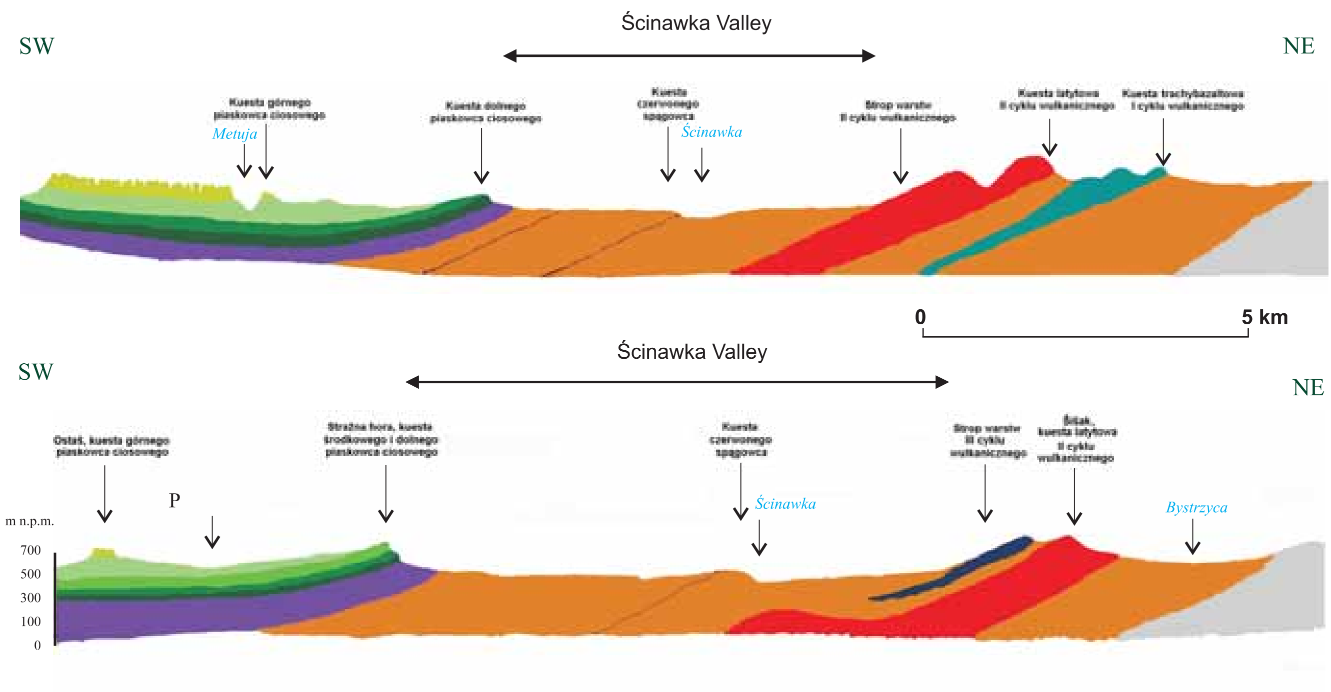

Fig. 11. Geological cross sections of the Intra-Sudetic Basin, north-eastern flank (Kosiór, 2003)

For explanations see Figure 2

In the Neogene, the progressive cooling of climate took place with changeable annual precipitation that reached periodically up to 1200 mm. It caused substantial widening of valleys in the lower Miocene. In the effect, the Pre-Ścinawka valley between Mieroszów and Otowice was becoming more and more flat-bottomed. Those processes were interrupted by revived tectonical movements occurring 13–7 million years ago. Individual parts of Sudetes were lifted up again along faults formed in the Oligocene. Therefore, erosion revived causing splitting of wide valley bottoms and lower Miocene plains.

The same situation occurred in the Pliocene. In the lower Pliocene, wide bottoms of the river valleys were formed and during the upper Pliocene the erosion deepened them. It was caused by the last tectonical movements of the Alpine Orogeny. Then fragments of the above mentioned Palaeogene plains were situated at their present heights in the Kamienne and Stołowe mountains.

The most important is, that erosion and denudation of the areas built of less resistant rocks, caused by lifting up the Sudetes in the Pliocene, have given the final shape of the exceptional edge form within the Intra-Sudetic Basin (Fig. 11).

At the end of Tertiary, one of the left tributaries of the Pre-Ścinawka River, flowing along the uncovered volcanites close to the today's Mieroszów, started splitting the volcanical Kamienne Mountains due to the fasted headway erosion, intercepting finally the upper part of the Pralesk River flowing along the northern side of those hard mountains. This pre-tributary is now an upper part of the Ścinawka River, flowing through a very beautiful gorge in the Kamienne Mountains (Fig. 12). As a result of such change of the Ścinawka course, the deep cut of the Kamienne mountains was made by several intermontane tributaries, with the longest one – Sokołowiec, flowing from under Waligóra peak, the highest of the Kamienne Mountains.

Due to those cuts we can today admire cuestas of I and II Permian volcanical cycles. Moreover, many classical geotopes like para-volcanical fans, single rocks, cliffs and numerous landslides were formed.

Quaternary during the last million years gave in the Sudetes only a touch-up to the already made model of the land topographical profile. It was done by the deep changes of the climate with several culmination during subsequent glaciations. The climate changed already at the beginning of Quaternary. The glaciations period commenced. The continental glacier was coming form the north but on this area the glacier form Scandinavia during the middle Polish glaciation reached only the Kłodzko trough and from there moved along the Ścinawka valley to the town having the same name, located at the eastern end of the area.

The glacial epoch (Pleistocene, a million years ago) was characterised by cyclic changes of climate: cool glacial periods alternated with warmer interglacial periods. In frosty and dry climate, the frost penetrated to the depth of about 100 m. The rocks were crushed and crumbled forming rock debris and accumulation of large blocks.

During that time, the unique rock forms of the Stołowe Mountains with famous "stone towns" were created. The dense network of fractures and fissures allowed the beginning of this sandstone massif erosion. Precipitation water progressively percolated through those vertical fissures in sandstone into the massif inside down to the unpermeable marl at the bottom. From there water flowed towards the peripheries and dribbled as a source. Additionally water etched the sandstones and marls binder. Progressively under the sandstone layers, the voids

Fig. 12. Mieroszów at the background of Ścinawka Gorge through Kamienne Mts.

have been washed out, what caused destruction of the sandstone plate. The isolated rock towns were formed. In the marginal parts of massif the block of rocks slid down on the plastic, marl surface and they finaly felt down. At the foothills the rock wastes accumulated. Those processes were more intensive in the periglacial climate of the last glaciation, especially during the summer snow melting, when in the marginal part the vertical fissures widen due to the more intensive underwashing the rock blocks. Additionally, in hollows and between sandstone blocks in the Broumavskie walls, the pseudo-karstic caves like for example under Lucifer and, lately discovered on the Polish-Czech border, under Božanovski Špicak, were formed.

The most interesting are, however, unusual, picturesque rock forms having the shape of mushrooms, clubs, walls, gates, animals and human figures. They were formed due to the mechanical activity of wind, frost and water and selective chemical weathering of the more susceptible sandstone binder.

Glacial epoch left gravels and sands of river terraces, lying currently on different heights, as can be seen at the Ścinawka River. At the valley outlets, the sand-gravel fluviatile fans were formed.

Fragmented area with the height difference up to 500 m, caused on the relatively small surface a substantial diversity of climate. The Ścinawka valley area has the moderate warm climate. Upper parts of the Kamienne (Javořich Hor) and Stołowe mountains are the cold regions. Exceptionally cold microclimate have the sandstone "rock towns" and deep valleys of the Ścinawka gorge, where the distinct inversion of climate is present.

CONCLUSIONS

The broadness of the cuestas observed within the basin allows to describe those geological features as the unique mega-geotopes. Impressive is not only their magnitude but also the shape. Sight of the huge geometrical valley of Ścinawka River with asymmetric slopes (steep thresholds of Upper Cretaceous sandstones and gentle top of Permian volcanics) gives unforgettable impression and clear picture of several hundred million years of the Earth history there.

Permian and Cretaceous mega-geotopes, which tower over the Ścinawka river valley, should play the substantial educational and didactical role, apart from tourist function, comparable with huge outcrops and geomorphological forms known from national parks within the drainage area of the Colorado River in USA.

Current system of exposition and protection of geodiversity in this area, based on separate Landscape Park of Wałbrzyskie Mountains on one side and Protected Landscape Area CHKO Broumovsko on the other, treats marginally the Ścinawka valley. It loses the most interesting and important geological features. The remedy is to create the first Polish-Czech geopark of the Intra-Sudetic Basin, in the upper part of Ścinawka drainage area, from its sources near Rybnica Leśna to Otovice. The area surely deserves it.

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