GEOTOURIST ROAD MAPS OF POLAND SCALE 1:25,000

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THE SUDETES
GEOTOURIST GUIDE

Along the road Nysa–Złoty Stok–Kłodzko–Wałbrzych –Jelenia Góra

Ministry of the Environment

Ordered by the Minister of the Environment financed by the National Fund for Environmental Protection and Water Management

Polish Geological Institute
Warsaw 2007

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STRATIGRAPHIC CHART

ERA	PERIOD	EPOCH	STAGE	AGE in Mln y	Orogeny:
CENOZOIC	QUATERNARY	Holocene		0,01	Alpine
		Pleistocene		1,8	
	NEOGENE	Pliocene		5,3	
		Miocene		23,0	
	PALEOGENE	Oligocene		33,9	
		Eocene		55,8	
		Paleocene		65,5	
MESOZOIC	CRETACEOUS	Upper		99,6	
		Lower		145,5	
	JURASSIC	Upper		161,2	
		Middle		175,6	
		Lower		199,6	
	TRIASSIC	Upper		228,0	
		Middle		245,0	
		Lower		251,0	
PALEOZOIC	PERMIAN	Upper	Zechstein	260,4	
		Middle	Rotliegend	270,6	Variscan
		Lower		299,0	
	CARBONIFEROUS	Upper	Stephanian		
			Westphalian		
			Namurian	318,1	
		Lower	Visean		
			Tournaisian	359,2	
	DEVONIAN	Upper		385,3	
		Middle		397,5	
		Lower		416,0	Caledonian
	SILURIAN	Pridoli		418,7	
		Ludlow		422,9	
		Wenlock		428,2	
		Llandover		443,7	
	ORDOVICIAN	Upper		460,9	
		Middle		471,8	
		Lower		488,3	Cadomian
	CAMBRIAN	Upper		501,0	
		Middle		513,0	
		Lower		542,0	
PROTEROZOIC	NEO-PROTERO-ZOIC				
				1000	

PLEISTOCENE GLACIATIONS	
Baltic Glaciation	
Middle Polish Glaciations	Wartanian
	Odranian
South Polish Glaciation	

Introduction

Automobile tourism becomes more popular. Travelling by car facilitates easy and comfortable access to interesting localities, tourist attractions and famous viewpoints by quick transfer from one destination to another to visit different environments and landscapes. It also enables development of a new type of tourism – roadside geotourism. The term geotourism was developed in the 1990s together with the increase of social interest in the history of our planet and geological history of visited sites, and just due to human curiosity for a single pinnacle passed by, for a roadside quarry or for an interestingly shaped hill seen in the horizon.

The growth of the interest is also fed by information broadcast by radio and TV stations about the occurrences of powerful natural phenomena such as earthquakes, tsunami waves, volcanic eruptions, increasing melting of glaciers, rapid landslides and mud avalanches. All of these phenomena are a danger to humans in far-away countries, attracting attention of many people also in Poland. They awake the interest to what there is under our feet, to the geological structure of the area and to the processes that have shaped the Earth's surface. The increasingly popular professional and amateur collecting of rock samples, minerals and fossils also promotes the attraction. Geotourism offers a combination of such interests with the need of vacation or weekend wandering. The guide we hand to geotourists is the first guide of this type produced in Poland. It corresponds to the popular "road geology" (geology seen from a car) editions published in many countries.

The guide focuses on the geology of the Sudetes Mts., proposing a travel route from the town of Nysa in the foreland of East Sudetes to the town of Jelenia Góra in the West Sudetes. The road runs through Złoty Stok, Kłodzko, Nowa Ruda, Wałbrzych, Kamienna Góra and Kowary, providing the possibility of visiting especially interesting localities. It crosses a number of Sudetic geological units worth of being acquainted with their structures and geological history, to make some observations at selected, most exciting exposures of rocks of various lithologies and ages, and to collect excellent geological samples. A number of byway routes, branching off the main guide's route, can additionally attract a motorized tourist. The choice is between short trips to the Bardo and Srebrna Góra environs, to the Stołowe Mts. National Park, to the Kamienne Mts., to the town of Krzeszów to explore the Krucze Mts., and to the Bóbr River Gorge and Sokole Mts. The trips provide the opportunity of not only to explore the landscape and geology of other geological units whose evolution has been linked to the geological history of the main route units, but also to visit interesting rock exposures, mining and post-mining objects and famous historic monuments. Duration of each trip depends mostly on tourists program chosen by guide user. It is necessery however to estimate average duration of every excursion for a half of a day.

The guide primarily encourages directing one's eyes on the landscape – the scenery shaped by the effect of external processes on rock complexes composing different geological structures. Geological knowledge is the *sine qua non* for understanding the landscape. We usually observe the scenery through the window of our running car, but the best way of admiring and understanding it is by making observations from the viewpoints proposed in this guide. Views from these sites are described with regard to the geological structure of the region and illustrated in the guide by combined geological and relief maps.

A set of such maps enables looking at the topography from the geological point of view that means that not only the overall shape of a distant landform is considered, but we also reach deep into the rock complexes composing it. The knowledge of the geological structure, in turn, helps us both reconstruct the processes which have determined the geological history of the region and identify the origin of the present-day landscape.

Another element of the guide are objects related to the ancient, full of tradition, Lower Silesian mining of metal ores and hard coal, as well as historic and present-day stone mining. Over the last years, some of the old mining objects have been adapted for tourist uses to be attractive sites of the geotourist road track.

The route presented in the guide is obviously neither the only one available nor the most interesting. The Sudetes Mts. offer to inanimate nature lovers an enormous diversity of landscapes and geological objects, which enable reconstruction of the long and exciting history of this region of Poland. I express my hope that next road guides covering other areas of the Sudetes will be produced in the future.

How do the geologists see the world?

Geology is a specific natural science – specific due to its multidimensional nature. Geologists collect direct information from the Earth's surface and locate them within a grid of surface coordinates. The third dimension – depth within the Earth's crust – is the result of direct observations in mines and wells (at present to a depth of merely 10–12 km i.e. 0.18% of the Earth's radius) and indirect geophysical data. The gradual development of nuclear physics that commenced at the turn of the 19th century enabled introduction of the absolute time scale to the geological history of the Earth. Thanks to more and more precise isotopic methods, geologists are able to move themselves relatively easy within the "fourth dimension" – the time. Determination of the absolute geological age that provides geologists with the possibility of moving within the longed-for "fourth dimension", allows for establishing the succession of geological processes reconstructed from direct geological observations, and tied to the time scale. However, the fundamental rule is the one created in the 19th century, namely the rule of uniformitarianism: the natural processes operating in the past are the same as those that can be observed operating in the present. Thanks to this rule, geologists are able to reconstruct geological processes and their consequences.

The recent geological studies also include extensively developed modern geochemical, petrological and mineralogical research methods based on the use of highly sophisticated and precise laboratory equipment. They provide information on the range of temperatures and pressures in which rock-forming processes proceeded, enable proving that different rocks can be of the same origin and, along with the radiometric age data, allow for reconstruction of the evolution of rock complexes calibrated in absolute time units. Despite huge technological progress in laboratory investigations, geological inference is always based on field observations. Quantitative results of physical and chemical research must be, however, interpreted based on hard geological evidence from direct observations in the field.

The final effect of the geologist's work in the field is a surface geological map. Such a map shows ground surface extents of rocks of various types and ages. The line along which boundaries between individual rock complexes and the ground surface intersect is called the intersection line. This is the especially important tool for interpretation of the subsurface geological structure. Intersection analysis offers a 3-dimensional insight into the geological structure to reconstruct the geometry of geological bodies, and to assess their thicknesses, shape and mutual spatial relationships in deep zones of the Earth. Depending on both the nature of geological structure and topographic variability, it is possible to decipher the geology down to a depth of even several kilometres. The higher elevation of the given area, the more accurate conclusions can be drawn about the subsurface geology around. Intersection analysis is thus easier to be made in mountainous areas. Additional information is provided by measurements of strata or various tectonic structures of preferred orientation that can be found in rocks. Along with the intersection data, they are the basis for any interpretations on the subsurface geological structure. Therefore, a geologist is not helpless in his or her insight into the third dimension, even if no well is available.

Geological maps constructed originally at the 1:25,000 scale by the Polish Geological Institute in the second half of the 20th century, have been adopted for the guide purposes. The geological contents of the maps were superimposed on a shaded relief map to create a plastic image of geological relationships along individual sectors of the guide's route. Description of the exposures and viewpoints includes explanations of the major geological structure features in relation to intersection analysis. Thereby, the reader has the opportunity for better understanding the geological structure and its relation to the ground topography.

What are the Sudetes to a geologist?

The Sudetes are a mountain range extending NW–SE along the Polish-Czech border. They are typical horst mountains. Their present-day shape developed as the result of young block-type deformation in the Neogene (23 My ago) along pre-existing faults. The deformation was followed by long-term processes of weathering, erosion and denudation of near-surface rock layers. Both variably strong tectonic movements and different resistance of rocks to destruction processes have created the diverse Sudetic topography with its picturesque, beautiful sceneries.

The Sudetes Mountains have a mosaic geological structure well visible on the geological map (Fig. 1). Igneous, metamorphic and sedimentary rocks are exposed at the ground surface. They are represented by very old Proterozoic rocks (older than 550 My), Palaeozoic (550–250 My) and Mesozoic (250–65 My) formations, as well as Cenozoic deposits (65 My until the Recent). Processes of tectonic deformation and metamorphic alteration of these rocks took place at various stages of tectonic activity: Cadomian (Late Proterozoic through Early Ordovician), Caledonian (Ordovician–Early Devonian) and Variscan (Latest Devonian–Carboniferous). Hence, there is an erroneous opinion often quoted in literature that the Sudetes are the oldest orogen in Poland; in fact, the mountains are young with deeply truncated fragments of much older orogens exposed at the Earth's surface. As the result, rocks of various ages and origin as well as interesting occurrences of minerals and fossils can be found at short distances apart, easy to travel on foot or by bike. All of these things tell us the exciting history of the region. One must only be able to read the history...

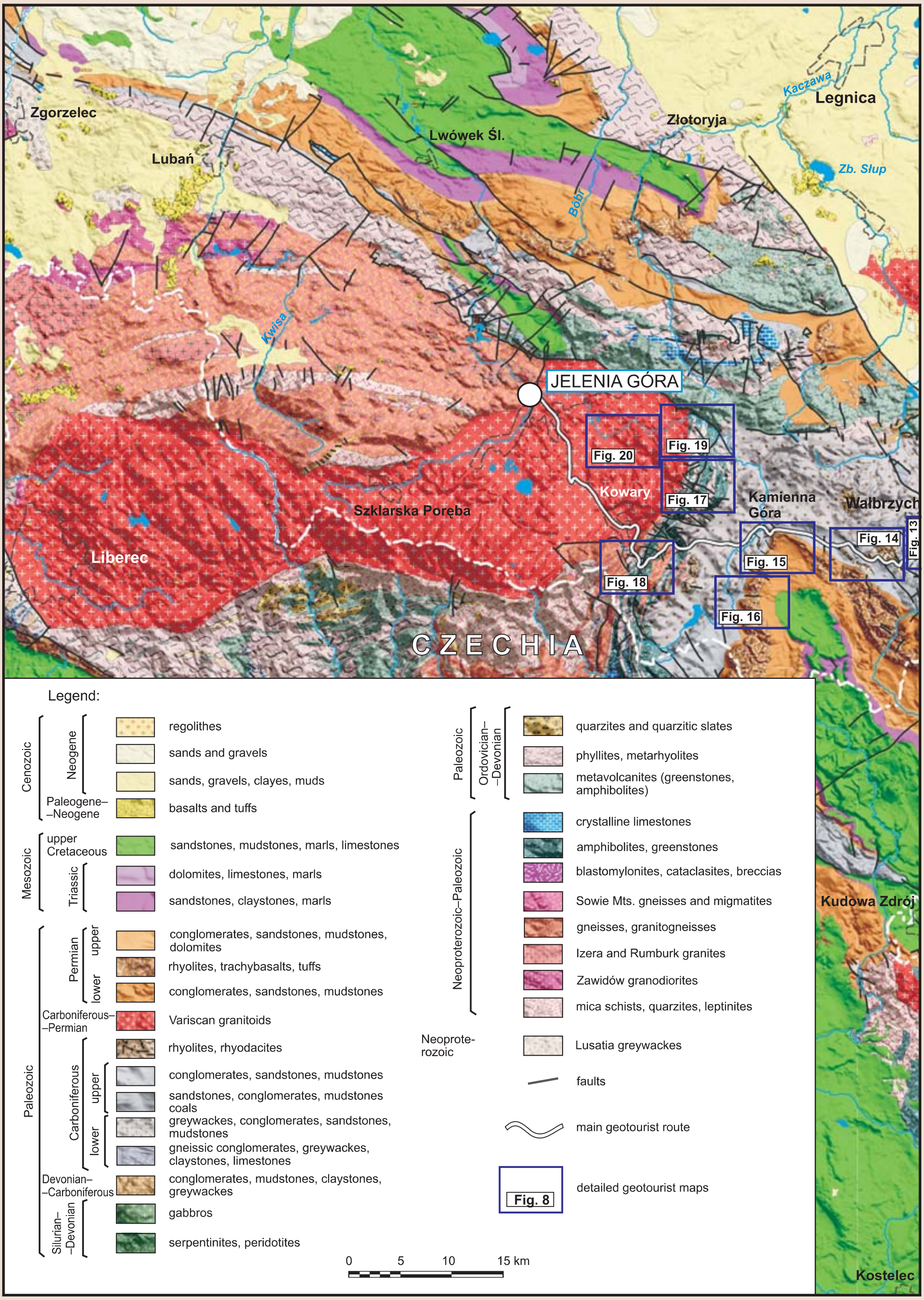
The oldest crystalline basement of the Sudetes is composed of gneisses, granitogneisses and migmatites. Together with other metamorphic rocks such as amphibolites, marbles and mica schists formed deep within the Earth's crust (at depths of 15–20 km), they occur today in the Sowie Mts., Izerskie Mts. and their foreland, in the mountains surrounding the Kłodzko Valley, and within the Strzelin and Niemcza-Kamieniec hills of the Sudetic Foreland. In the Kaczawskie Mts., near Kłodzko and north of Strzegom (in the Sudetic Foreland) there are rocks altered at much shallower depths within the so-called greenschist metamorphic zone (at depths of 10–15 km). These are various phyllites formed by alteration of mudstones and clay shales, metamorphosed sandstones, light-coloured (keratophyres) and dark (greenschists) metavolcanites, and crystalline limestones.

Sedimentary rocks of the Sudetes are represented by 2 main rock complexes. The older rocks, representing the Devonian and Carboniferous, occur in the Bardo Mts. and fill large foredeep basins surrounded by outcrops of crystalline rocks: the Intra-Sudetic Depression (Wałbrzych, Nowa Ruda and Kamienna Góra) and the Świebodzice Depression. These are conglomerates, sandstones, greywackes, mudstones and clay shales. The Intra-Sudetic Depression rocks contain hard coal seams exploited until recently in the Wałbrzych and Nowa Ruda coal mines. Palaeozoic sedimentary formations were a witness of the formation of the late Palaeozoic Variscan orogen in the Sudetes Mts. There are also two fundamental groups of igneous plutonic rocks, characteristic of this region of Poland, formed during Palaeozoic times. The older one, represented by dark green and black heavy rocks rich in dark minerals – pyroxenes and amphiboles, is called the mafic and ultramafic rocks due to high contents of magnesium and iron. These are gabbros, peridotites and serpentinites from the area of Nowa Ruda–Słupiec and the environs of Ząbkowice Śląskie (Szklary) in the Sudetic Foreland, but first of all those from Mt. Ślęża and around. The rocks contain well-known and beautiful semi-precious gemstones such as chrysoprase and nephrite, which can still be found in regions where the rocks occur. The second group of plutonic rocks is represented by light-coloured medium- and vari-grained granites. They formed in the Carboniferous period about 300–340 My ago due to intruding granitic magma into surrounding rocks, followed by gradual cooling of the magma at depths of approximately 5–10 km. Today, the rocks build variously shaped large massifs throughout the Sudetes and the Sudetic Foreland. The granites are extensively quarried near Strzegom, Strzelin and Niemcza. They also constitute the main ridge of the Karkonosze Mountains and are found in smaller massifs between Złoty Stok and Kłodzko, near Kudowa and elsewhere. The granites contain vein rocks: light-coloured pegmatites and aplites, dark lamprophyres, and various minerals very much appreciated by collectors: crystals of feldspars, smoky quartz and muscovite, as well as zeolites, berile, tourmaline, garnets and sulphides of metals.

The last stage of the evolution of the Sudetes – called the platformic period – started in the Permian (299 My ago). The rocks are unfolded; most of them lie horizontally and are cut by faults. Near-fault deformation is locally observed. The Early Permian was the period of deposition of thick sedimentary series exhibiting the characteristic red and brown colours, and containing massive complexes of volcanic rocks: light-coloured rhyolites of chemical composition corresponding to granites, grey and dark grey andesites and very dark, violet-grey trachybasalts often of specific vesicular structure.

The Permian volcanites are host rocks for the famous Lower Silesian agates. Especially spectacular, rocky forms of the volcanites can be observed in the Kamienne Mts., Wałbrzyskie Mts. and Kaczawskie Mts.

The younger sedimentary formations are represented in the Sudetes and the Sudetic Foreland by Upper Permian limestones, marls and gypsum, Triassic limestones and marls and red sandstones and mudstones, and Upper Cretaceous sandstones and marls. The Upper Cretaceous rocks form particularly beautiful isolated rocky hills and single pinnacles in the Stołowe Mts., near Lwówek Śląski, Wleń, Bystrzyca Kłodzka and Międzylesie. The Mesozoic sedimentary rocks were deposited as the result of repeated marine inundations (transgressions) interrupted by peri-


Zgorzelec
Lubań
Lwówek Śl.
Złotoryja
Legnica
Kaczawa
Zb. Słup
Bóbr
Kwisa
JELENIA GÓRA
Fig. 20
Fig. 19
Fig. 17
Kowary
Szklarska Poręba
Kamienna Góra
Wałbrzych
Fig. 15
Fig. 14
Fig. 13
Fig. 18
Fig. 16
Liberec
CZECHIA
Kudowa Zdrój
Kostelec
Legend:
Cenozoic
Neogene
regolithes
sands and gravels
sands, gravels, clayes, muds
Paleogene–Neogene
basalts and tuffs
Mesozoic
upper Cretaceous
sandstones, mudstones, marls, limestones
Triassic
dolomites, limestones, marls
sandstones, claystones, marls
Paleozoic
Permian
upper
conglomerates, sandstones, mudstones, dolomites
rhyolites, trachybasalts, tuffs
lower
conglomerates, sandstones, mudstones
Carboniferous–Permian
Variscan granitoids
Carboniferous
upper
rhyolites, rhyodacites
conglomerates, sandstones, mudstones
sandstones, conglomerates, mudstones coals
lower
greywackes, conglomerates, sandstones, mudstones
gneissic conglomerates, greywackes, claystones, limestones
Devonian–Carboniferous
conglomerates, mudstones, claystones, greywackes
Silurian–Devonian
gabbros
serpentinites, peridotites
Paleozoic
Ordovician–Devonian
quarzites and quarzitic slates
phyllites, metarhyolites
metavolcanites (greenstones, amphibolites)
Neoproterozoic–Paleozoic
crystalline limestones
amphibolites, greenstones
blastomylonites, cataclasites, breccias
Sowie Mts. gneisses and migmatites
gneisses, granitogneisses
Izera and Rumburk granites
Zawidów granodiorites
mica schists, quarzites, leptinites
Neoproterozoic
Lusatia greywackes
faults
main geotourist route
Fig. 8
detailed geotourist maps
0
5
10
15 km

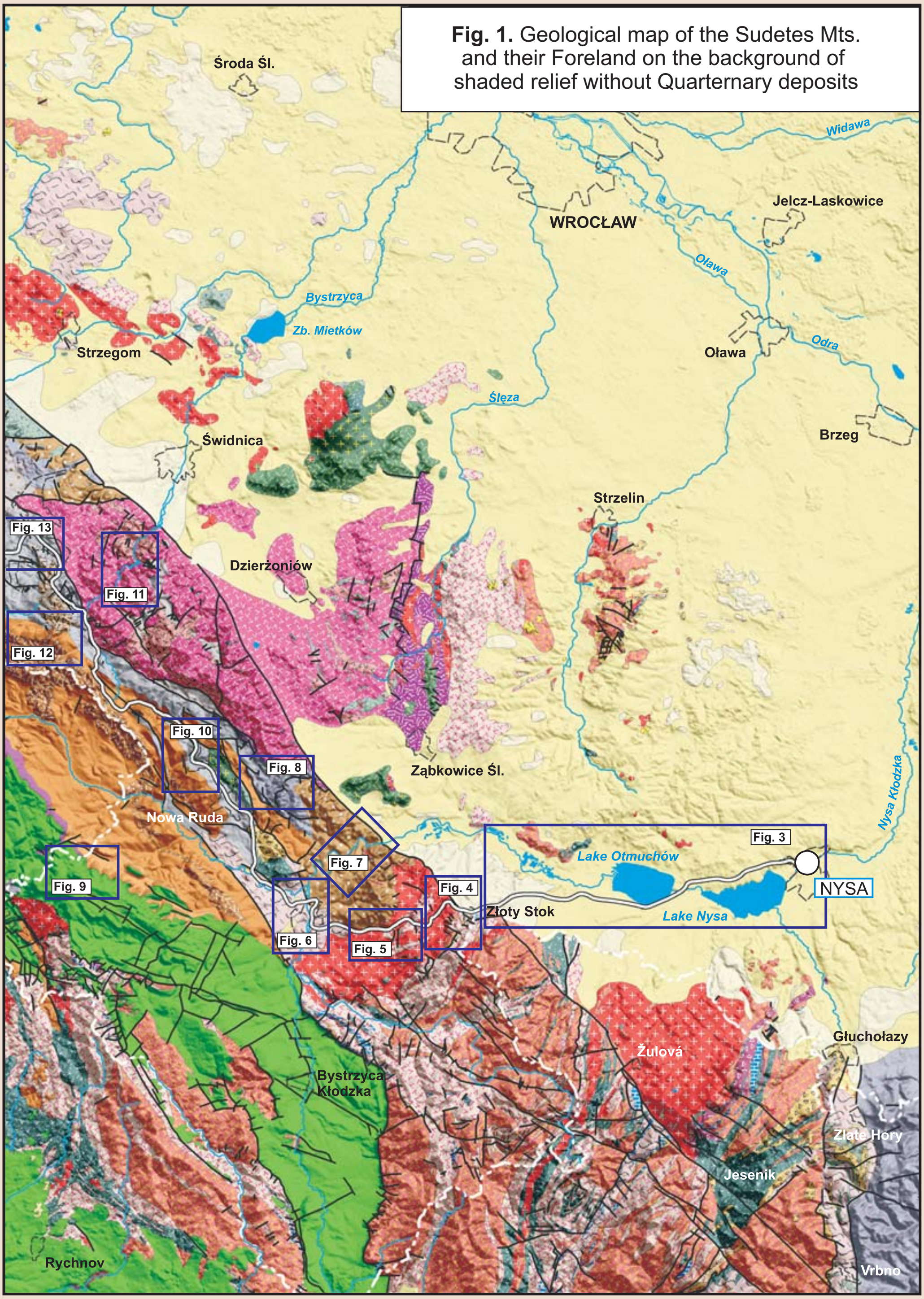


Fig. 1. Geological map of the Sudetes Mts. and their Foreland on the background of shaded relief without Quarternary deposits

ods of sea retreat (regressions), or due to inland, continental sedimentation in fluvial and desert environments under a varying climate. Finally, in the Cenozoic Era, the whole Sudetic area was uplifted in relation to the regions located to the north (Fore-Sudetic Block) and south (North Bohemian Cretaceous Basin). In recent times, during the Pleistocene, continental ice sheets invaded this area, leaving an uneven cover of glacial, fluvial, aeolian and slope deposits: a wide range of tills, sands, gravels, loesses and fen soils.

A sketch of the geological structure of the Sudetes Mts. and the Sudetic Foreland

From the geological point of view, there are two major tectonic units in Lower Silesia, developed in response to Cenozoic movements of individual tectonic blocks. These are (from the south): **the Sudetic Block** (excluding part of the East Sudetes), and the stepwise down-faulted **Fore-Sudetic Block** covered at the ground surface with Cenozoic deposits of variable thickness ranging from 250 to 300 m. Rocks of the older basement form here isolated patches of outcrops clearly marked in the topography.

The inner geological structure of the Sudetes and the Fore-Sudetic Block is very complicated (Fig. 1). It developed due to geological processes that continued from the late Proterozoic through the Quaternary. Several major evolutionary stages can be identified in this evolution: (1) Neoproterozoic–Early Ordovician (Cadomian), (2) Lower Palaeozoic (Ordovician–Devonian), (3) Late Devonian–Carboniferous–Early Permian, (4) Zechstein–Mesozoic–Tertiary and (5) Quaternary. Geological processes typical of the individual evolutionary stages interfinger both spatially and in time. The characteristic feature of the geological structure of Lower Silesia is its mosaic pattern. In the present-day intersection surface, most of individual geological units are separated from one another by faults of various natures. This makes it easier to mark the boundaries between the units, but also makes difficult the identification of their mutual spatial relationships.

However, irrespectively of the mosaic geological structure of the Sudetes Mts. and the Fore-Sudetic Block, there are rock complexes which are common for the individual geological units, despite of significant differences. These complexes are called by geologists tectonostratigraphic complexes because they are represented by sets of rocks formed due to similar tectonic and metamorphic processes that operated over the given geological time interval. Identification of such complexes is facilitated by radiometric datings based on methods related to the processes of isotope decay of various chemical elements (uranium-lead, lead-lead, argon-argon, potassium-argon methods, etc.), which enable tying the individual processes to the absolute geologic time scale.

The Cadomian complex (Neoproterozoic–Lower Palaeozoic)

Rocks of this complex form parts of the crystalline basement. They occur in the following areas of the Sudetes Mts.: the Karkonosze–Izera Block, the Orlica–Bystrzyca Crystalline Complex and the Lądek–Śnieżnik Crystalline Complex (forming altogether the so-called Orlica–Śnieżnik Dome), the Kłodzko Metamorphic Complex, as well as in areas around Wądroże Wielkie and in the crystalline complex of the Strzelin Hills of the Fore-Sudetic Block. The oldest rocks are represented by fragments of the Upper Proterozoic (supracrustal) series of sedimentary origin intruded by granitoids. Subsequently they were deformed and today form orthogneiss complexes. The supracrustal series are represented by, among others, rocks of the Izera schist belts and the Czarnów schists in the Eastern Karkonosze (the Kowary–Czarnów Unit), the Stronie Series complex within the Orlica–Śnieżnik Dome, crystalline schists of the Strzelin Hills Crystalline Complex and the schist series of the Kamieniec Metamorphic Complex in the eastern part of the Fore-Sudetic Block.

The Cadomian supracrustal series rocks were originally represented by sediments and volcanites of intracontinental or shelf sea basins. Radiometric ages determined for the volcanigenic material are 640–620 My through 560 My (Lusatian greywackes) to 520 My (some gneisses of the Stronie Series). Fossil relics from the Stronie Series rocks suggest late Proterozoic to early Cambrian age. All of these rocks underwent regional metamorphism ranging from low-grade metamorphism (Lusatian greywackes) through greenschist facies to amphibolitic facies. Basement of the Cadomian supracrustal series is unknown.

The supracrustal series rocks were intruded by granitoid bodies subsequently altered into structurally and texturally varied orthogneiss complexes due to very strong deformation processes – the so-called gneissification. The rocks are represented by the Zawidów granitogneisses (540–533 My), Rumburk and Izera granites (514–480 My) and Izera and Kowary gneisses (500 My) of the Karkonosze-Izera Block, the Wądroże Wielkie gneisses (548 My) occurring in the Fore-Sudetic Block within the Kaczawa complex rocks, ortogneisses and gneisses from the SW part of the Kłodzko Metamorphic Complex, Śnieżnik and Bystrzyca ortogneisses and the Gierałtów migmatitic gneisses (522–488 My) from the Orlica–Śnieżnik Dome, and the Strzelin gneisses (600–568 My) of the Strzelin Hills Crystalline Complex.

Currently available data about the tectonic and metamorphic evolution of these rocks do not always allow for the identification of gneissification age. Radiometric datings of the Gierałtów and Śnieżnik gneisses suggest that the age of metamorphism of the rocks is about 340 My.

The Sowie Mts. complex (Lower Palaeozoic)

The triangular Sowie Mts. Block is located in the central part of the Lower Silesian tectonic mosaic. In terms of its lithologies and geological structure, it is an alien element surrounded by metamorphic tectonic units. The block is spatially associated with the surrounding, and partly also underlying, occurrences of ultramafic-mafic rocks forming the so-called ophiolitic complex consisting of the Ślęża gabbroic massif and the Gogołów–Jordanów serpentinite massif.

The Sowie Mts. complex is composed of gneisses and migmatites with small amphibolite, granulite and serpentinized peridotite bodies. Both the age and nature of the original rocks (protoliths) are still under discussion. The light-coloured granulites and dark peridotites of the Sowie Mts. complex underwent metamorphism in the lower crust about 400 My ago. Along with the surrounding gneisses, they were subsequently metamorphosed 384–370 My ago under amphibolitic facies conditions and multiphase migmatization.

The rapid transfer of the Sowie Mts. complex towards upper parts of the crust is radiometrically documented (by Ar–Ar and Rb–Sr dating) at 370–360 My. The data do not confirm the Precambrian age of the complex, believed for a long time to be a certainty, although that age is reliable for the protolith rocks of the complex.

Along the eastern edge of the Sowie Mts. Block, there is the Niemcza Zone. The zone is dominated by mylonitized gneisses of the Sowie Mts. complex (mylonites and cataclasites). The gneisses are composed of mica schists with andalusite and cordierite, quartzites and metagreywackes (the prefix "meta" denotes a rock, which underwent metamorphism) and the Niemcza granitoids. This zone also contains serpentinites of the Szklary Massif. Both the origin of the Niemcza Zone and its significance for regional geology of Lower Silesia are still the points of controversy. Undoubtedly, its origin is strictly related to the late, Variscan evolution of the Sowie Mts. Block. The upper parts of the Sowie Mts. complex were eroded as early as the late Devonian, supplying clastic material to the Świebodzice Depression and Bardo Basin. The Visean marine transgression entered a peneplaned erosional surface of the Sowie Mts. Block.

The ultramafic-mafic ophiolitic complex (Lower Palaeozoic)

The ophiolitic complex consists of several individual elements outcropping at the ground surface within the Ślęża, Szklary, Braszowice–Brzeźnica and Nowa Ruda massifs. From the lithological point of view, it consists of the ultramafic member largely altered to serpentinites containing relict bodies of peridotites, pyroxenites and dunites, and the mafic member (gabbros, metagabbros, amphibolites and diabases).

A typically developed ophiolitic sequences occur in the Ślęża and Nowa Ruda massifs. The remaining 2 massifs are composed only of serpentinites (Szklary Massif) or serpentinites and gabbros (Braszowice–Brzeźnica Massifs). There is no unequivocal evidence that the complex is a fragment of the ancient oceanic crust. The age of the gabbros determined from zircons datings (U–Pb) is 420 My (Late Silurian–Early Devonian).

The Caledonian–Variscan complex (Lower Palaeozoic: Ordovician–Devonian)

The Lower Silesian Palaeozoic (Ordovician–Devonian) is represented by tectonic units composed of nonmetamorphosed and metamorphosed sedimentary and igneous rocks connected with the Palaeozoic Variscan history of Central Europe. Their evolution proceeded in various ways and terminated in different time periods. These rocks constitute the Leszczyniec Unit (located in the eastern aureole of the Karkonosze Massif), the Kaczawa Metamorphic Complex, part of the Kłodzko Metamorphic Complex and old-Palaeozoic lithologic elements of the Bardo tectonic unit. The rocks of these units formed in small basins developed on either the oceanic crust or thin continental crust, as evidenced by strong magmatic activity and the presence of intrusive and volcanogenic rocks of extremely contrasting chemical compositions – basic and acidic – forming the so-called bimodal series. The Caledonian–Variscan complex includes Ordovician–Silurian–Devonian sedimentary-volcanogenic sequences represented by various types of phyllites and by bimodal volcanogenic rocks. The stratigraphy of the rocks is based on palaeontological evidence (graptolites, acritarchs and foraminifers). Intense submarine volcanism of varying chemical composition through time indicates a gradual development of the basins on the oceanic crust. The rocks of these series underwent metamorphic and deformation processes associated with Variscan tectonic movements. Deformation processes within the Karkonosze–Izera Block continued from the Late Devonian through Visean. The Kaczawa Metamorphic Complex was first metamorphosed during the Late Devonian, the second metamorphic event – under greenschist facies conditions – occurred most likely only during the Early Carboniferous. The last phase of deformation was related to both the development of the orogenic relief and the formation of intramontane foredeep basins. In marine basins, it corresponded with the deposition of sedimentary breccia (so-called melanges) on slopes of uplifts. They are represented today by Lower Carboniferous weakly metamorphosed mudstones containing chaotically distributed Ordovician, Silurian and Devonian blocks (olistolites). This phase links the marine evolution of the Sudetic basins with the subsequent stage of the late Palaeozoic development of the Variscan orogen.

The synorogenic Variscan complex (Upper Palaeozoic: Upper Devonian–Lower Permian)

During the period spanning the Late Devonian and Early Carboniferous, a flysch sedimentation, contemporaneous with the onset of orogenic (i.e. synorogenic) movements, took place in the Bardo tectonic unit and Moravian–Silesian Zone (eastern part of the Sudetes). The Variscan synorogenic complex of the Bardo structure includes the typical flysch rocks of Visean age, containing olistolites of older rocks. In the Sowie Mts. Block, the synorogenic complex is represented by rocks of the culm cover. In the Świebodzice Depression these are the Upper Devonian–Lower Carboniferous sedimentary series, whereas in the Intra-Sudetic Depression – Lower Carboniferous sedimentary series.

Sedimentary complexes of the so-called molasse stage were formed somewhat later, during Late Carboniferous and Early Permian times. Their deposition was accompanied by strong volcanic activity. The complexes developed due to intense erosion in mountainous areas that came into existence at that time in the immediate proximity to the tectonic foredeep basins of the Świebodzice, Intra-Sudetic and North-Sudetic depressions.

The Carboniferous was also the period of intense granitoid plutonism responsible for the formation of both a group of intrusions occurring within all the Lower Silesian metamorphic units and a set of vein rocks represented by microgranites, aplites, pegmatites, quartz veins and various types of lamprophyres. The granitoid group includes as follows: the Karkonosze granitoid massif in the centre of the Karkonosze–Izera Block, the Strzegom–Sobótka granitoid massif intruding into the Kaczawa complex and into the Ślęża gabbros located in the Fore-Sudetic Block, granitoid bodies of the Niemcza Zone and the marginal part of the Sowie Mts. Block, the Strzelin granitoids forming (in the present-day ground surface plane) larger or smaller vein bodies in metamorphic rocks of the Strzelin Hills Crystalline Complex, the Kłodzko–Złoty Stok Massif (a crescent-shaped intrusion located at the boundary between the metamorphic complex of the eastern part of the Orlica–Śnieżnik Dome/Złote and Krowiarki Mts./, the Bardo structure and the Kłodzko Metamorphic Complex), marginal granitoid intrusions of the Orlica–Śnieżnik Dome (the Kudowa and Nowy Hradek massifs), and the Jaworniki and Biała granitoids. The Lower Silesian granitoids form both plutonic massifs (conspicuous by the presence of directional textures consistent with the trend of contact surfaces) which intruded simultaneously (synkinematically) with deformation processes of surrounding rocks, and plutons that were formed after the deformation processes (postkinematic). Within their aureole, they often produced contact metamorphism zones (hornfelses, spotted schists) whose extent is highly dependent on the lithology, intrusion size and magma temperature of aureole rocks.

The platformic complex (Zechstein–Mesozoic–Neogene)

At the end of Early Permian (Rotliegend) a change in tectonic regime occurred in Lower Silesia. The beginning of late Permian (Zechstein) was the onset of a platformic phase in the evolution Lower Silesia. Metamorphic, magmatic and folding phenomena came to their end. Shallow-marine sedimentation of the Late Permian (Zechstein), Middle Triassic (Muschelkalk) and, after a long break, of the Late Cretaceous, and continental sedimentation of the Early Triassic (Buntsandstein) was accompanied by fault deformation of variable intensity. During the Late Triassic, Jurassic and Early Cretaceous the whole region was a land area subjected to denudation processes supplying detrital material to the Mid-European Basin. The platformic complex is divided into 2 parts: the lower one comprising the Zechstein to Middle Triassic, and the upper one spanning Upper Cretaceous deposits. Rocks of the lower platformic unit of the Sudetes Mts. presently compose the Intra-Sudetic and North-Sudetic depressions.

The Late Cretaceous transgression inundated much of Lower Silesia except for several island areas. Rocks of that age occur in the Intra-Sudetic and North-Sudetic depressions and in the Upper Nysa Kłodzka Graben as the result of fault block deformations at the late Cretaceous/Paleogene transition and during the Neogene. The platformic complex also includes younger, Neogene sedimentary rocks, which form an almost continuous cover in the Fore-Sudetic Block. Numerous Neogene basalt occurrences appeared in response to a stretching of the whole area followed by the formation of deep fractures within the crust, reaching down even to the Earth's upper mantle. The youngest deposits of the area are represented by Pleistocene and Holocene sediments. The former were deposited in two glacial events of the South Polish and Middle Polish glaciations. The ice sheets overstepped the morphological edge of the Sudetes at those times. Sedimentary and erosional processes genetically related to the glaciations and warming periods gave rise to the formation of glacial covers represented by tills, glaciofluvial sands and gravels, lacustrine sediments (ice-dam clays), aeolian (loess) and fluvial (of river valley terraces) deposits, as well as slope and weathering mantles. During the Holocene (last 11 Ky), the sedimentation concentrated within river valleys. Intervalley areas are still subjected to permanent weathering and denudation processes.

The route, proposed in the guide and running from the town of Nysa in the eastern Fore-Sudetic Block to the town of Jelenia Góra through Złoty Stok, Kłodzko, Nowa Ruda, Wałbrzych and Kamienna Góra, meets many geological units, crossing some of them or touching fragments of others (Fig. 2). Beyond the town of Złoty Stok, there where the route crosses the Sudetic Marginal Fault, these are the Złoty Stok–Skrzynka Zone representing a northern continuation of the Lądek–Śnieżnik Crystalline Complex, the Kłodzko–Złoty Stok granitoid massif, the Kłodzko Metamorphic Complex,

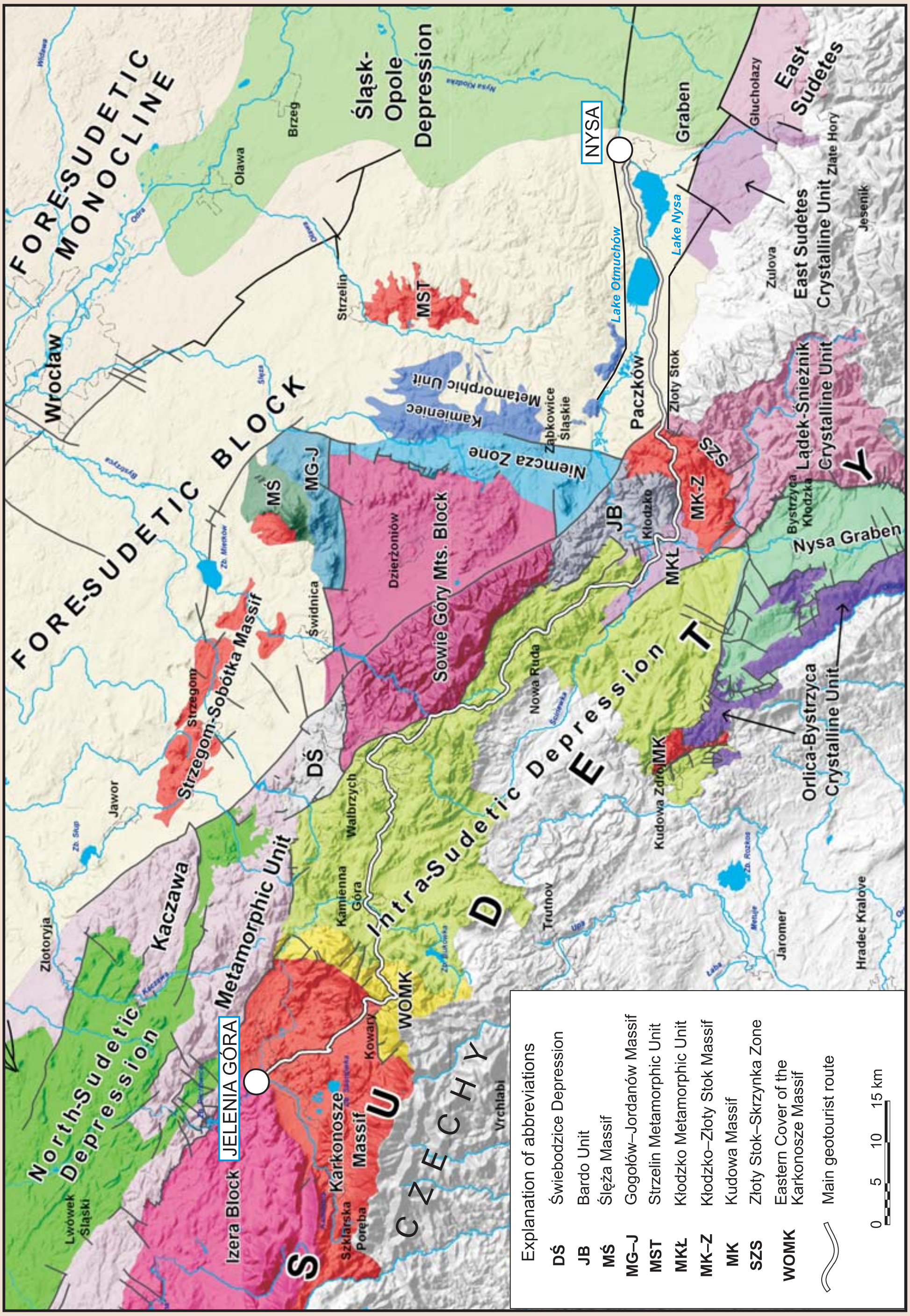


Fig. 2. Map of geological units along the geotourist route

the Intra-Sudetic Depression, eastern aureole of the Karkonosze Massif and the Karkonosze granitoid massif. The suggested side routes, branching off the main road, penetrate into the Bardo tectonic unit, Upper Cretaceous rocks of the Stołowe Mts. and into the Sowie Mts. Block. The main travel route with its side routes allows for exploring the rocks, minerals and structures typical of all of the above-described rock complexes.

Welcome to the route!

The exciting geology: between Nysa and Jelenia Góra

1 Fore-Sudetic section *(Nysa–Złoty Stok)*

Fore-Sudetic Block and the Sudetes, eastern part of Fore-Sudetic Block, Paczków–Kędzierzyn Graben, graben frames, inner structure of graben, river valley development in mountain foreland area – Nysa Kłodzka River, retention reservoirs in Nysa Kłodzka river valley

The route of our geo-travel across the Sudetes starts in Nysa – a town situated in the SW of the Opole Voivodship in the Nysa Kłodzka river valley in the East Sudetes foreland. Nysa is one of the oldest Silesian towns. A settlement probably existed here as early as the 10th century. Nysa played a more important role in the 13th century after establishing of the Duchy of Nysa and Otmuchów, belonging to Wrocław bishops. Nysa was first mentioned in 1223 when it was granted town rights under the Flemish (and later Magdeburg) law. At the beginning of the 14th century, it became the capital of the Duchy of Nysa. Favourable location of the town at the crossroads of trade routes from Prague to Kłodzko and from Opole to Cracow was conducive to its economic development. Nysa, with its population of 50,000 inhabitants is not only an important administrative and economic centre but also a town renowned for its historic monuments. It is worth heading towards the east from the town's centre to visit the Nysa dam. There is a magnificent panoramic view over the wide river valley filled with lake waters, over hilly uplands on either side, and over the forested Rychlebskie Mts. in the southwest.

In relation to the structural geological units, the foreland section of the Nysa Kłodzka river valley crosses the south-eastern part of the Fore-Sudetic Block. This fragment of the valley is also consistent with the axes of Neogene foredeep basins of the Paczków Graben. The graben is a down-faulted part of the crystalline basement of the Fore-Sudetic Block. It is filled predominantly with Neogene deposits, up to 300 m in thickness. The shape and trend of the Nysa Kłodzka valley between Nysa and Bardo strictly coincides with tectonic fault zones (dislocations) of the sub-Cenozoic basement.

The Fore-Sudetic Block is a down-thrown area in relation to the Sudetes, separated from them by the Sudetic Marginal Fault. The Nysa Kłodzka river valley runs across the Doboszowice and Kamieniec Metamorphic Complex being part of the Fore-Sudetic Block. Metamorphic rocks appear here at the ground surface in patches along the northern margin of the valley. These are metamorphic schists near the village of Kamieniec Ząbkowicki, gneisses – at Doboszowice, and gneisses with granite intrusions – in the environs of Maciejowice. Amphibolites of the so-called Niedźwiedź Massif and granitoid intrusions occur north of Paczków. The entire block is cut by faults active during Cretaceous and Neogene times when numerous basalt lava flows took place.

From Nysa we head westwards along the road to Otmuchów (road No. 46), Paczków and Złoty Stok. The most prominent element of the geological structure of this section of the tourist route is the Sudetic Foreland part of the Nysa Kłodzka valley ultimately shaped during the Pleistocene after the Odranian Glaciation. The valley's flat floor, 2.5 to 3.5 km wide, is filled with young, Holocene fluvial deposits: gravels, sands and muds overlying older, Neogene fluvial gravels, sands as well as clays and muds. There are retention reservoirs constructed within the valley: Lake Nysa (situated west of Nysa), Lake Otmuchów (between the towns of Otmuchów and Paczków), and the Kozielno and Topola reservoirs (as parts of Lake Paczków located between Paczków and Kamieniec Ząbkowicki). They are also interesting tourist attractions with their facilities for beach sunbathing, water sports and fishing. Both to the north and to south, the river valley is bounded by hilly uplands composed of Pleistocene deposits – the Nysa Upland (to the north) and the Paczków Foreland (to the south) sloping towards the valley through the Otmuchów Depression. To the far south, in the Czech Republic territory, the Rychlebskie Mts. slopes are seen in the horizon.

The Nysa Kłodzka valley extends longitudinally across the Sudetic Foreland and just after passing the Bardo Gorge it becomes very wide and follows the Paczków Graben frames along this section of the valley. The valley is accompanied by a system of fluvial terraces. These are shelf-like flattenings located at different altitudes above river level (a.r.l.), composed of fluvial sediments and separated from each other by steep edges. They represent old flood plains. The characteristic feature of deposits of all the accumulation terrace levels in the Sudetic Foreland section of the Nysa Kłodzka valley is relatively coarse-grained material, by standard of a foreland river. The travel of coarse-grained gravels transported from the Sudetes far onto the forefield required a powerful transporting force of the river and must have occurred mainly during rapid river-level rises.

There are four distinct terrace levels in the foreland section of the Nysa Kłodzka river valley (Fig. 3). The two upper terraces are associated with the Middle Polish Glaciations and occur at altitudes of 25–30 m and 12–17 m a.r.l. The 2 bottom terraces are observed down within the wide valley floor. The upper bottom terrace is at the altitude of 2–5 m a.r.l. Fluvial gravels and sands of the terrace fill a vast depression, 25–30 m deep, eroded directly into Neogene deposits represented by clays and muds of the so-called Poznań Series. The terrace was probably formed during the last Baltic Glaciation.

Deposits composing the bottom terraces are exposed in large gravel pits within the Nysa Kłodzka valley. However, the river water level limits accessibility of the section, and thus only the upper 3–4 metres of the section are available for observation. The section reveals massive gravelly deposits, non-stratified or showing planar or trough cross-bedding. The rocks are poorly sorted. The range of features indicates rather deposition by a braided river i.e. made up of branching riverbeds and carrying similar material as that forming the upper terraces.

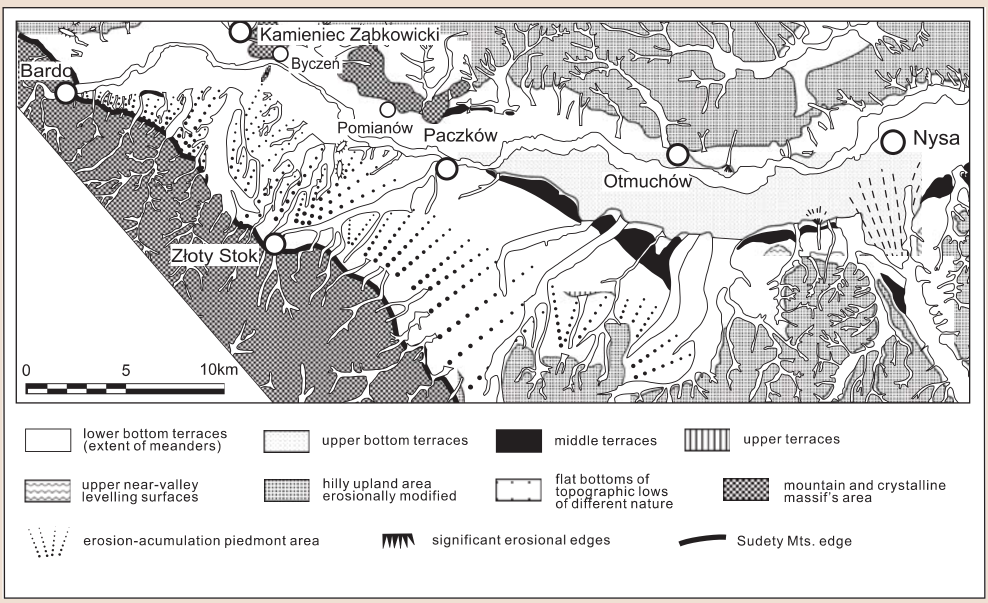


Fig. 3. Geomorphological sketch map of the Nysa Kłodzka river valley between Nysa and Złoty Stok, after B. Przybylski

Between Topola and Kozielno and west of Otmuchów, both the bottom terraces coalesce to form a wide and flat river floor. Additionally, the edges of the lower terrace are blurred by flood deposits reaching 1–2 m in thickness in the the Paczków Graben, increasing even to 5 m along the southern section of the Nysa Kłodzka valley. Thin fen soil covers and signs of flood flows are also marked on the upper bottom terrace. Data from hydrogeological annual reports and flood wave observations made in July 1997 indicate that the Nysa Kłodzka water level may rise even by 8 m during the greatest floods, resulting in flooding of the whole valley. The present-day river flows through a channel incised into the lower terrace to the depth of 1.5–2 m in the longitudinal section of the valley. A local curiosity, however of much importance in determining the age of the deposits, is the presence of fossil black oak stems within the gravel series near Topola, Kozielno and Paczków (Phot. 1). The stems are thick (up to 2 m in diameter) and they occur in this part of the valley in the gravely deposits down to the depth of even 10 m. Age determination of a wood sample recovered from underwater at the depth of 7 m, yielded the age of 7300 (± 180) years. It proves that most of the valley's fill was deposited during the last several thousand years. The fact that the stems, visible in the topmost part of the series down to the depth of 4–5 m, are embedded in coarse gravel deposits indicates a rapid deposition and catastrophic nature of river flows that flooded the whole valley. The conditions that favoured rapid deposition of gravels and tree stems, carried by strong river currents, must have existed near Kozielno.

Phot. 1. Fossil black oak stems within the gravel series. Topola. Phot. B. Przybylski

Heading westwards, we have the possibility of visiting two very interesting small towns. Otmuchów is situated on upper river terraces and on gentle slopes of the Nysa Upland on the northern bank of the Nysa Kłodzka River. This is a charming small town (population 6,000) of a long and rich history. It is worth climbing the tower of the gothic-renaissance bishop castle dominating the town for a panoramic view of the town, both the lakes and mountains.

The road runs along the southern bank of Lake Otmuchów to reach the other small town of Paczków called "Carcassonne of Poland". The town is almost entirely encircled by the medieval fortified walls with four gate towers and keeps. The town with its population of 8,000 inhabitants is situated on the upper terraces of the Nysa Kłodzka River. The beautiful Town Hall from the 16th century and renaissance St. John's Church are worth visiting here. From Paczków we can drive directly to Złoty Stok (road No. 46), or choose a roundabout road to Kamieniec Ząbkowicki through Pomianów and Byczeń. The latter road is slightly longer and runs between the northern boundary of the Nysa valley and the Pomianów Hills where crystalline rocks of the Doboszowice Metamorphic Complex, represented by the Doboszowice gneisses and amphibolites, are outcropped. We can visit a large quarry of thinly laminated fine-grained gneisses and pencil gneisses (containing quartz-feldspar aggregates forming monodirectionally oriented rods indicating direction of tectonic displacement during deformation of the rock), located near a side road between Pomianów Górny and Mrokocin (approached by a short drive off the main road).

We pass two large reservoirs extending south of the road: the Kozielno reservoir (under construction) and the Topola reservoir completed in 2002 and separated from the former by a dam. Both the reservoirs altogether form Lake Paczków (under construction). The Kozielno reservoir is the site of extensive excavation of fluvial gravels from the Nysa valley floor.

Further to the north-west, near Byczeń, the road passes a number of ponds at Bartniki (to the left) – now a tourist site for fishing, constructed in depressions after excavation of natural stone materials. Then the road reaches Kamieniec Ząbkowicki, a village situated at the foot of Mt. Zamkowa, a vast forested hill with an outstanding, although partly destroyed, Neogothic palace (Phot. 2). Close to the road, rocks composing the hill are outcropped (Phot. 3). These are grey mica schists consisting of quartz, biotite and muscovite with small admixture of feldspars and garnets, staurolite, distene and other minerals typical of high-grade metamorphism. Mica aggregates mark foliation surfaces inclined westwards at moderate angles. The outcropping rock series belongs to the Kamieniec Metamorphic Complex, one of the tectonic units of

Phot. 2. Towers of the Neogothic castle on Zamkowa Hill, Kamieniec Ząbkowicki. Phot. S. Cwojdziński

Phot. 3. Mica schists outcrop of the Kamieniec Metamorphic Complex, near the road from Byczeń to Kamieniec Ząbkowicki. Phot. S. Cwojdziński

the Fore-Sudetic Block, of unclear age. Metamorphic processes terminated here in the Early Carboniferous at the latest.

On approaching Kamieniec, we turn left on the road leading to Złoty Stok (390) through a bridge over the Nysa Kłodzka River. The road runs across a flat surface of a Pleistocene plateau covered with glacial and glaciofluvial deposits overlying Neogene clay and sand-clay rocks exposed in erosional escarpments of stream valleys. From the road, there is a magnificent panoramic view of the Złote Mts. with the town of Złoty Stok situated on their slopes, and of the Bardo Mts. to the west. The morphological edge of the Sudetes, trending in line with the Sudetic Marginal Fault, is well marked in this area.

2 Kłodzko–Złoty Stok granitoid massif and its aureole: Złoty Stok–Skrzynka Zone, Bardo Unit

(Złoty Stok–Mąkolno–Podzamek–Kłodzko)

Fragment of Cadomian metamorphic basement, gold and arsenic mineralisation at Złoty Stok, Variscan granite intrusion, roof pendants, depth of intrusions, contact metamorphism along outer and inner contacts of pluton.

The road to Paczków runs across a flat surface of the Paczków foreland plateau. To the south are seen the forested slopes of the Rychlebskie Mts. extending on the Czech side of the border. To the north are the retention reservoirs of the Nysa Kłodzka river valley. At the village of Kamienica, the road begins to ascend the northern slopes of the Złote Mts. Just close to the Czech border, the first outcrops of crystalline rocks of the Lądek–Śnieżnik Metamorphic Complex (its NE part is referred to by geologist as the Złoty Stok–Skrzynka tectonic zone) are observed (Fig. 4). Just before Złoty Stok, crystalline limestones were excavated in a large quarry – today it is a camp and bathing site (Documentation Point PD 1). Old stoves once used for lime burning from the limestones are on display here (Phot. 4). The bypassed roadside rock exposures are also interesting from another point of view. They are shifted NE'wards in relation to the main line of the Sudetic Marginal Fault which clearly cuts off the Sudetic geological structures. This shift is probably caused by the presence of NE–SW-trending transverse faults. One of the faults is followed by a beautiful valley in the north of the Złote Mts. – the so-called Złoty Jar valley.

We pass by a forester's lodge and drive down to Złoty Stok. This charming town is nestled on the slopes of the Złote Mts. and is renowned for its old, medieval tradition of

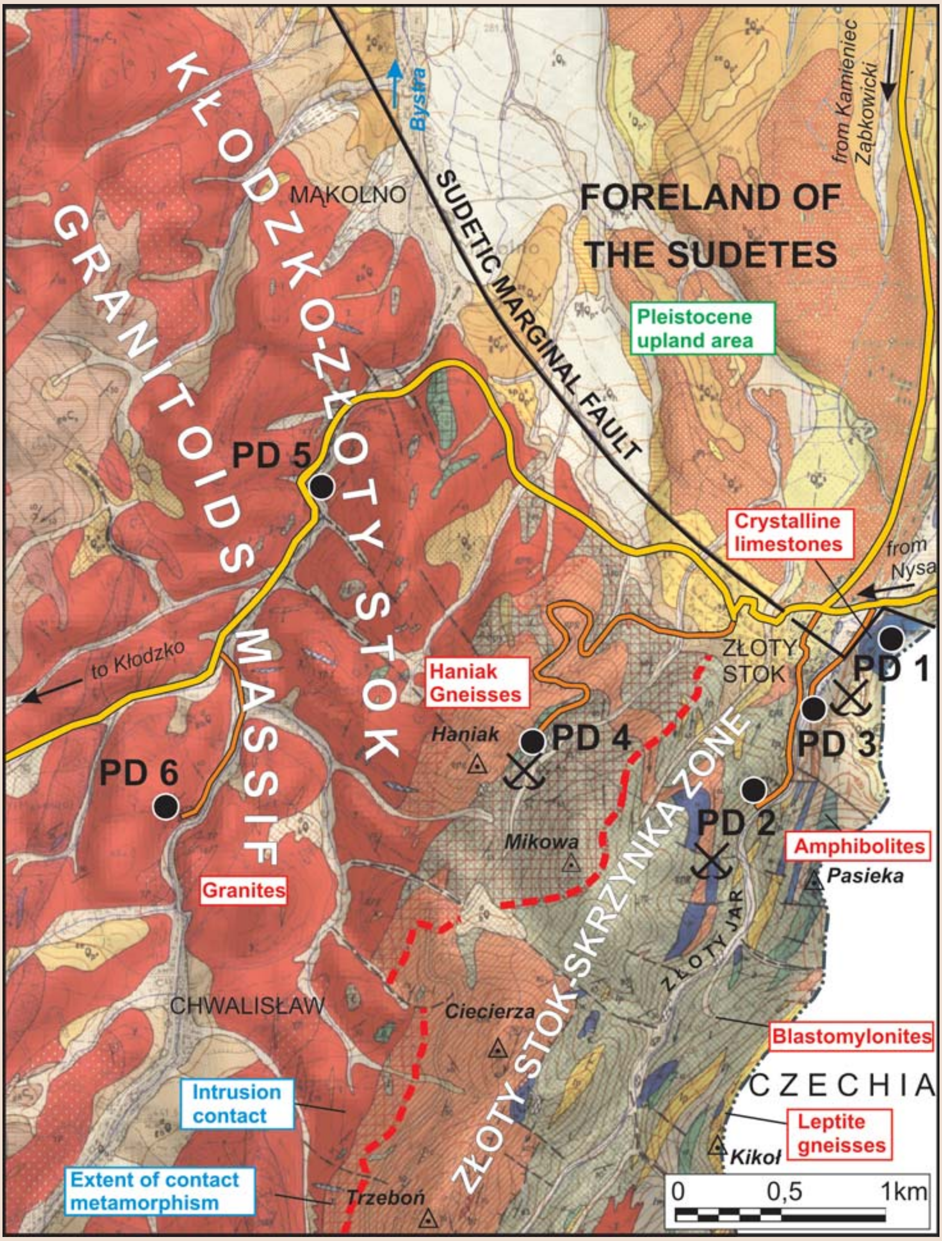


Fig. 4. Geotourist map of the Złoty Stok vicinity. Fragment of crystalline area of Lądek–Śnieżnik, Złoty Stok–Skrzynka Tectonic Zone, Variscan intrusion of Kłodzko–Złoty Stok granites, gold and arsenic mineralization in Złoty Stok, contact metamorphism along outer and inner contact surfaces of the pluton. Documentation points PD 1–6: Złoty Stok, Mąkolno, Chwalisław. Geological map after Detailed Geological Map of the Sudetes 1:25,000 (SMGS): Złoty Stok sheet

LEGEND TO GEOTOURIST MAPS (Figs. 4–20)

to Bardo ← *from Bardo* →	directions of arrivals and departures
	approaching routes to documentation points
	pedestrian approach
	tourist routes
PODZAMEK	towns and villages names
P	car parks
Ciecierza	significant peaks
Jaszkówka	streams, rivers
	mountain huts
	castle ruins
	Góry Stołowe National Park boundary
PD 1	documentation points (with succesive numbers)
	viewpoints
	old mining galleries and shafts
k	quarries

Geological data:

Granites	rocks
River terraces	elements of morphology
Intrusion contact	tectonics and geological structures
Glinik Formation	rock complexes and formations
Lower Permian	stratigraphy

MAIN ROCK TYPES

Quaternary

- River terraces – younger
- River terraces – older
- Loess
- Tills

Upper Cretaceous sediments

- Sandstones, jointed sandstones, marls

Rotliegendes volcanics

- Rhyolites
- Krucze Mts. rhyolites
- Rhyolites, latites
- Tuffs, rhyolitic tuffs
- Rhyolitic breccias
- Trachybasalts

Rotliegendes sediments

- Mudstones, sandstones
- Conglomerates
- Sub-volcanic conglomerates
- Mudstones, sandstones, conglomerates

Carboniferous plutonic rocks

- Lamprophyres
- Microgranites
- Karkonosze granites
- Other granites
- Granites of marginal facies
- Hornfelses (Bardo unit)
- Roof pendant hornfelses
- Rudawy Janowickie hornfelses

Upper Carboniferous sediments

- Glinik Formation: sandstones, mudstones, conglomerates
- Wałbrzych Formation: conglomerates, sandstones, mudstones, hard coal
- Żacler Formation: conglomerates, graywackes, mudstones, hard coal

Lower Carboniferous sediments

- Graywackes, mudstones
- Sowie Mts. Culm sediments: conglomerates, graywackes, mudstones
- Intra-Sudetic Culm sediments: conglomerates, sadnstones, mudstones

Devonian magmatic and sedimentary rocks

- Upper Devonian conglomerates
- Devonian shales: siliceous and clay shales
- Gabbros

Epimetamorphic rocks (Cambrian – Middle Devonian)

- Kaczawa phyllites
- Kłodzko and Rudawy Janowickie phyllites
- Metarhyolites
- Greenstones

Mesometamorphic rocks (Neoproterozoic – Middle Devonian)

- Gneisses cataclasites
- Haniak gneisses
- Sowie Mts. gneisses and migmatites
- Cataclastic gneisses and migmatites
- Kowary gneisses
- Blastomylonites
- Leptite gneisses
- Paczyn gneisses
- Amphibolites in northern part of the Rudawy Janowickie Mts.
- Amphibolites in southern part of the Rudawy Janowickie Mts.
- Wieściszowice amphibolites
- Sowie Mts. amphibolites
- Crystalline limestones (marbles)
- Pyrite bearing schists
- Mica schists

Phot. 4. Old stove once used for lime burning from limestones Złoty Stok. Phot. S. Cwojdziński

gold mining. Gold and later also arsenic extraction was abandoned relatively recently, in 1962. Now, the distant successor of those mining and chemical works is the Manufacturers of Plastics and Paints located in the NE of the town in the Trująca stream valley.

Present-day Złoty Stok remains faithful to its mining tradition, adapting part of the old mine pits for tourist purposes. Geotourists are welcome to visit the town and several interesting sites within its environs. These are the abandoned quarry of gneisses and blastomylonitic schists in the Złoty Jar valley (PD 2), the main tourist attraction – Gertruda Gallery and the underground tourist route along with a group of post-mining buildings (PD 3) and mine dump of the Western Field of a mine in the Kłodzko Valley (PD 4). All of the sites are easily accessible by car and offer car parks.

Złoty Stok offers a wide variety of accommodation facilities and restaurants. Numerous historic monuments, old buildings and charming nooks reveal the rich history of the town. From the southern sectors of the town, situated on the slopes of Mt. Kapliczna, is a beautiful panoramic view over the town and the Sudetic Foreland, and over the Nysa Kłodzka river valley and Kamieniec Ząbkowicki Hills. During fine weather, the horizon is closed by the Szklary and Dobrzenice hills extending north of Ząbkowice Śląskie in the Fore-Sudetic Block.

Geological structure of the Złote Mts. in the area located south of Złoty Stok is especially interesting. There is a narrow, NNE–SSW-trending zone of metamorphic rocks in this area, called the Złoty Stok–Skrzynka tectonic zone, which constitutes the northern part of the Lądek–Śnieżnik Metamorphic Complex whose rocks are exposed in the Złote and Bialskie Mts., in the Śnieżnik Massif and Krowiarki Mts. To the west, the structures of the Złoty Stok–Skrzynka Zone are truncated and they contact with much younger Carboniferous granites of the Kłodzko–Złoty Stok Massif. The massif shows a characteristic crescent shape, as seen on the present-day intersection surface, and is squeezed in between the Lądek–Śnieżnik Metamorphic Complex (to the east and south) and the Kłodzko Metamorphic Complex and Bardo Unit (to the west).

The rocks in numerous single pinnacles occurring south of Złoty Stok in the Złoty Jar valley and on the slopes of Mikowa, Trzeboń and Haniak near the road from Złoty Stok to Lądek Zdrój, are conspicuous by signs of very strong dynamic alterations. They were subject to the so-called mylonitization i.e. crushing and grinding of mineral grains, accompanied by contemporaneous or subsequent recrystallization. Due to those processes, metamorphic rocks such as mica schists and gneisses were altered into the so-called Złoty Stok blastomylonites. They form the fundamental group of rocks in the Złoty Stok zone. These are fine-grained dark-grey rocks of the characteristic platy parting due to abundant foliation surfaces composed of parallel-arranged bands of micas (biotite and muscovite) “bypassing” grainy aggregates of quartz and feldspars (plagioclases), mostly with signs of crushing (cataclasis) and recrystallization (blastesis). Typical blastomylonites can be observed in the abandoned large quarry of the Złoty Jar valley about 500 m south of the Market Square in Złoty Stok (follow Staszica Str.) (PD 2 – Phot. 5). The quarry has six exploitation levels; its walls reach 75 m in height and over 200 m in length. In the quarry and the neighbouring erosional valley of the Złoty Stream, the “Skalisko” Forest Adventure Park has been established. The park offers, among others, rope slides in the quarry from one rocky shelf to another.

Foliation in the rocks is oriented NNE–SSW to N–S and NNW–SSE, and dips at steep angles of 50°–75°. Foliation surfaces show lineation in the form of tiny rods, corrugation or monodirectionally elongated mineral aggregates. The analysis of orientation and nature of foliation and lineation in metamorphic rocks is of a great significance for geologists. It enables the reconstruction of deformation processes affecting the rocks, ages of the processes and geometry of tectonic structures. The quarry walls are cut by faults dividing them into several blocks. These fault structures are much younger than that developed during metamorphic processes that operated deep within the Earth’s crust under high pressure and temperature. The faults formed as the result of both stress relaxation in the shallow zones of the Earth’s crust and rigid deformation spatially limited to narrow zones. The zones are the sites in which some of rocks either became mechanically crushed forming tectonic breccias or smoothed and polished

Phot. 5. Abandoned large quarry of blastomylonites in the Złoty Jar. Foliation dips at steep angle to the right. Numerous faults and joints are visible (PD 2). Phot. S. Cwojdziński

forming slickensides with tectonic striae indicating movement direction of the rock mass. Numerous examples of such structures can be observed in the quarry.

The Złoty Stok blastomylonites contain many interlayers of rocks varying in composition and appearance. These are light-grey compact and thinly platy leptite gneisses, dark-green platy amphibolites, amphibolite schists, and crystalline limestones. The last mentioned are very interesting rocks. They outcrop on the western slopes of the Pasieka and Kikoł hills and near the top of the Mikowa and Ciecierza hills. They are also known from the underground mine drifts of the Złoty Stok mine. The rocks are light grey in colour, compact, fine- or medium-grained with subtle streaking. The streaking developed by the arrangement of graphite grains or sericite flakes. It probably reflects the original bedding in limestones deposited in a shallow-marine basin, preserved in the rocks despite subsequent metamorphic alteration. Limestones of that type occur in the above-mentioned old quarry above the road from Paczków to Złoty Stok (PD 1). Further westwards, the crystalline limestones are accompanied by specific green and white-green coarsely crystalline rocks called skarn rocks. They are composed of diopside, flogopite, tremolite, dolomite and quartz.

Crystalline rocks of the northern part of the Złoty Stok–Skrzynka Zone are host rocks for gold and arsenic ores well known since medieval times. During the first period, which lasted until the 17th century, only gold was obviously the object of desire. Gold exploitation started as early as the 13th century and reached its maximum level at the turn of the 15th century when the Złoty Stok mines supplied 8% of the total gold production in Europe. At the beginning of the 18th century, the mines had started to extract arsenic ores to produce arsenic trioxide, which soon became the most important product of Złoty Stok for many years. Besides arsenic, the mines also produced up to 20 kg of gold per year until the last years of production just after the Second World War.

As the mining operations expanded, the exploitation concentrated in 4 mine fields: in the field of Mt. Krzyżowa on the western slopes of the Złoty Jar valley, in the field of Mt. Sołtysia east of the valley, in the Western Field at the foot of Mt. Haniak and in the field of Mt. Biała (beneath the ridge of Mt. Ciecierza). In 1920, the 2 km-long Gertruda Gallery was built connecting all the minefields. Today it is partly adapted for tourist traffic (PD 3). Ore mineralisation is spatially associated mainly with crystalline limestones and skarn rocks. In the richest (in terms of the amount of mineralisation), Western Field of the Złoty Stok mine (situated at the eastern slopes of Mt. Haniak and in the Kłodzko Valley), crystalline limestones, amphibolites and skarn rocks are accompanied by irregular serpentinite bodies. Serpentinites are black or dark-green rocks, very compact, massif and heavy, mostly of non-directional structures, composed (as evidenced by microscopic observation) of serpentine group minerals (lizardite, chrysotile), olivine, chlorites and talc. Both the skarn rocks and the serpentinites are mineralised with loellingite ($FeAs_2$) and arsenopyrite (FeAsS) which are carriers of dispersed fine gold. The richest ore is black serpentinites. Mineralised specimens of blastomylonites, skarn rocks and serpentinites, often very attractive, can be found on mine dumps of the Western Field in the Kłodzko Valley (PD 4). Numerous small slag dumps being relics of mining and metallurgical activity can be encountered in many places in the Złoty Jar valley even 2–3 km away to the south of Złoty Stok. Gold content in the slag may be high enough for recovery using modern technologies. The gold, however, is invisible with the naked eye. Nevertheless, a slag sample from the Złoty Jar valley can be a nice souvenir and remembrance of the work of past miners and gold hunters.

After visiting Złoty Stok with its mining and geological attractions, we follow the road to Kłodzko, stepping into a quite different geological world just 0.5 km away from Złoty Stok. The road runs along the edge of the Sudetes, coincident with the Sudetic Marginal Fault. The edge of the Złote Mts. descends and the mountain slopes become gentler. We have just passed an intrusion contact between the rocks of the Złoty Stok–Skrzynka Metamorphic Complex and the Kłodzko–Złoty Stok Massif granites. The general NNE–SSW strike of the contact line is parallel to the geological structures of the metamorphic mantle rocks. The intersection line of the contact downthrows stepwise south-eastwards through a number of transverse faults parallel to the Sudetic Marginal Fault. The contact surface is inclined SE'wards at an angle of

60–65°. Contact metamorphism phenomena are observed along the line parallel to the contact within the metamorphic aureole rocks. This type of alterations is related to the high-temperature and chemical effect of igneous rocks on their aureole. The effect obviously shows a zonal pattern – it means that the effect strength decreases as moving away from the contact surface. The contact alterations refer to the Złoty Stok blastomylonites enriched in feldspars. They grade to light-grey or yellowish striated gneisses composed of alternating thin dark layers containing biotite and cordierite, and feldspar-quartz layers lighter in colour. Such rocks occur on the Mt. Haniak slopes and on the western slopes of Mt. Mikowa near PD 4. The Haniak ridge itself is composed of strongly crystallized gneisses, light in colour, called the Haniak Gneisses that locally grade into either rocks of blurred directional texture or coarse-grained pegmatites. The processes which led to the formation of the rocks are the result of contact metamorphism proceeded at high temperatures (up to 700°C) under static conditions i.e. with no effect of directional pressures. The above-described skarn rocks also belong to the rocks altered by contact metamorphism. The strongest thermal alterations of the Złoty Stok rocks are observed within the enclaves of aureole rocks, embedded within granites. The enclaves (displayed on the geological map) are commonly spherical or lenticular in outline. They occur particularly often near contacts with aureole rocks, in the area between Mąkolno and Chwalisław. They include contact metamorphic rocks of the Złoty Stok–Skrzynka Zone: blastomylonites and amphibolites. The presence of the rocks indicates that the intruding granite magma exerted a dynamic effect on the aureole, carrying its fragments upward.

The typical rocks of the Kłodzko–Złoty Stok Massif can be explored at Mąkolno – a village founded in the 13th century in the Mąkolnica valley and the Bystra Stream. Copper ore mining took place near the village in the 15th century. There was also a powder magazine nearby. Since the beginning of the 20th century until the present, a chemical plant has been in operation.

The road to Kłodzko turns south and runs across the upper flank of the village. On the left, near the bridge over the Bystra River, (PD 5), typical dark-grey and grey-yellow medium-grained, partly porphyric, granites are exposed in small steep rocky hillocks. The characteristic appearance of the porphyric granites is due to platy porphyric crystals of feldspars, up to 2 cm in length, with longer axes commonly monodirectionally arranged. The directional texture of the granites is also underlined by parallel-arranged aggregates of dark biotite and amphiboles (hornblende), and light quartz and feldspar minerals. Among feldspars, plagioclases (Na–Ca feldspars) predominate over potassium feldspars. In terms of the mineralogical classification of granites, the rocks are largely granodiorites and tonalites. All granite-like rocks belong to the same rock group called granitoids. The rocks exposed here are also cut by a vein of pink-grey fine-grained aplite. Rocks of this type fill fractures in already cooled and rigid magma bodies. Their mineral composition corresponds to granites, whereas their fine-grained structure developed due to a rapid cooling of granite magma.

Another exposure of the Kłodzko–Złoty Stok granitoids is located about 2 km to the south, on the right side of the road from Mąkolno to Chwalisław, before entering the long village of Chwalisław founded in the 13th century. Grey medium-grained granites of randomly distributed mineral grains occur here in an old forested quarry (PD 6). Dark minerals (called mafic because of Mg and Fe content) are represented by spotty and mottled aggregates of biotite and amphiboles (hornblende), light-coloured minerals are feldspars (plagioclases) and quartz. Zircon, apatite, titanite and epidote occur in small amounts – minute grains of these minerals are invisible with the naked eye. The granites are cut by 3 lamprophyre veins, 0.75 to 1.5 m thick. Lamprophyres are finely crystalline massive rocks almost black in colour (melanocratic). They commonly form during the late phase of the evolution of granite bodies through the filling of fractures in a consolidated massif by magmas genetically related to granites, but of different chemical composition enriched in iron and magnesium and depleted in silica (such rocks are called basic rocks by geologists).

From Chwalisław, the route runs back to the Złoty Stok–Kłodzko road. We drive towards Kłodzko across a hilly and partly forested land creating a distinct topographic low between the Złote Mts. ridge in the east and the outstanding Bardo Mts. ridge in the west. This topographic low developed due to processes of weathering and disintegration of the Kłodzko–Złoty Stok granitoids – less resistant rocks than those composing the aureole. As the result, the whole massif is now clearly pronounced in the topography of this region of the Sudetes Heading towards the village of Laski we cross a narrow stream valley between the Kłoda and Sokolec hills. Both the hills, well marked in the topography of the Kłodzko–Złoty Stok Lowland, are composed of various types of hornfelses and spotted schists formed as a result of strong contact metamorphism. The rocks are both underlain and penetrated by granitoids. They form part of the pre-existing top mantle of the granites, representing the so-called roof pendants. Their position within the granite body indicates, however, that they participated in magma movement. Thus, they are not typical roof pendants but fragments of the pluton mantle sunk and rotated within the granitic magma.

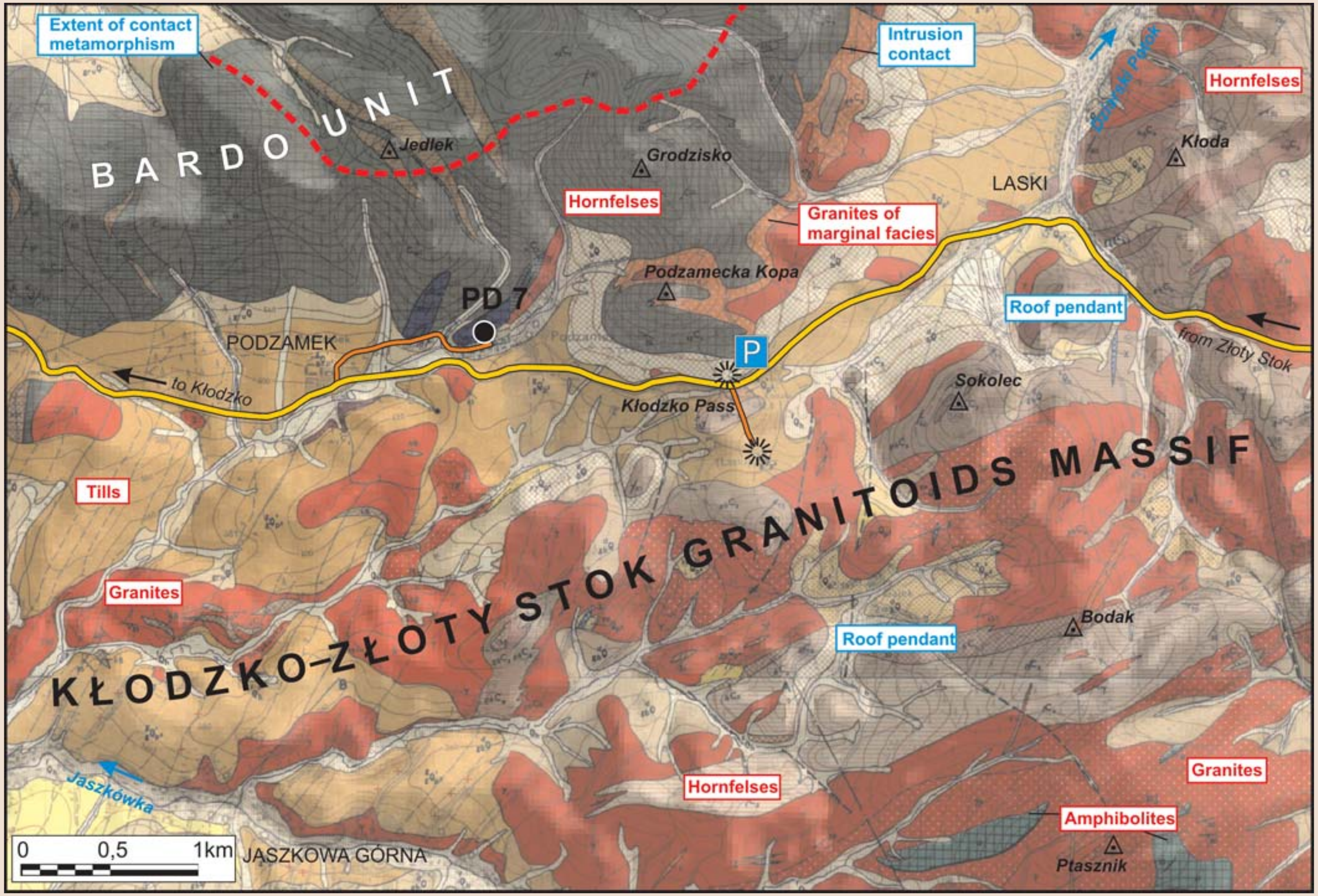


Fig. 5. Geotourist map of the Laski–Podzamek vicinity. Variscan intrusion of Kłodzko–Złoty Stok granites, roof pendants, contact metamorphism along outer contact of the pluton with Bardzkie Mts. unit: hornfelses, patchy slates. Documentation point PD 7: Podzamek. Geological map after SMGS: Złoty Stok and Kłodzko sheets

Beyond Laski, the road gradually climbs southwestwards to Kłodzko Pass (483 m a.s.l.) being a good viewpoint. There is also a car park beside the road on the southern slope of Mt. Podzamecka Kopa. We are at the foot of the Bardo Mts. forming over a long distance the western and northern aureole of the Kłodzko–Złoty Stok granitoid massif (Fig. 5). From the road to settlement Gajki, there is a nice view towards SE and E over the forested hills composed of fragments of roof mantle of the granitoids.

Just near Mt. Podzamecka Kopa and Kłodzko Pass, the intersection line between the granitoids and the Bardo Unit changes its direction from latitudinal to longitudinal. The contact line here is easy to be traced. It is clearly marked in the topography and accentuated on the mountain slopes by both a distinct change in the gradient of the slopes and the lower forest boundary in the Bardo Mts. (Phot. 6). The contact line is disturbed, especially in the south. Locally, e.g. in a topographic low between Mt. Podzamecka Kopa and Mt. Grodzisko, the granitoids enter the Bardo Unit rocks, separating at the surface a fragment of the aureole (composing the summit of Mt. Podzamecka Kopa) from the remaining part of the mantle. The contact line trend clearly indicates that the contact surface of the Kłodzko–Złoty Stok granitoids gently dips north-westwards under the Bardo aureole.

This shape of the intrusion contact at the boundary between the granitoids and the Bardo Unit rocks enables observation of endo- and exocontact alterations. The former

Phot. 6. Bardo unit contacts with Kłodzko–Złoty Stok granitoids. Contact line runs along lower forest boundary in the Bardo Mts. Phot. S. Cwojdziński

refer to the granitoids. The so-called marginal facies, represented by light-coloured fine-grained granites of non-directional structures and composed of quartz, potassium feldspars, plagioclases and small amounts of micas and chlorite, appear along the contact with the mantle. These rocks were formed as the result of mutual thermal and chemical interactions between granitoid magma and cool aureole rocks. Exocontact alterations are visible in a near-contact belt of outcrops of the Bardo Unit sedimentary rocks. The belt is up to 1 km wide at the ground surface on Mt. Podzamecka Kopa, Mt. Grodzisko, Mt. Jedlak and Mt. Obszerna. The Bardo Unit is composed dominantly of sedimentary rocks represented by Lower Carboniferous greywacke sandstones and mudstones with interbeds of limestones and various types of clay and siliceous shales. Near the contact, the rocks were subjected to local thermal alterations. Dark-grey and black very finely crystalline and compact cordierite-andalusite hornfelses, often with garnets, occur close to the contact. Biotite hornfelses, sandstones and shales in which the matrix material was slightly recrystallized (sericitization), are observed a little bit further. The dark hornfelses contain irregular feldspar-quartz augen and netted aggregates. They formed as the result of local mobilization of easily fusible light-coloured (leucocratic) fraction along the near-contact zone.

Especially interesting contact metamorphic rocks can be observed in old bush-grown quarries at Podzamek, a village situated on the southern slopes of the Eastern Ridge of the Bardo Mts. The quarries (PD 7) were established to provide stone from two NE–SW-stretching limestone layers within greywacke sandstones. The limestones are considered to be of Lower Carboniferous age, although no fossils have been found. A direct contact between the limestones and granitoids (medium crystalline granodiorites) can be observed in the pits located in the eastern part of the limestone outcrops. Limestones undergo recrystallization, assume coarsely crystalline structures, and alter into interesting skarn rocks composed of carbonate minerals (calcite) and calcium aluminosilicates. Interesting and beautiful examples of garnet (grossular), pyroxene-garnet (containing wollastonite), garnet-vesuvianite, calcite-garnet and other skarn rocks can be found here on the old dumps and in the pit walls.

Having been acquainted with the Kłodzko–Złoty Stok granites and contact metamorphic processes, we can continue our journey towards Kłodzko. The road runs westwards across the gentle southern slopes of the Bardo Mts. The slopes are covered with a mantle of Pleistocene glacial tills and slope deposits. Before the village of Paszkówka, 4 km from Kłodzko Pass, there is a narrow side road branching to the right and leading NW'wards to the Kukułka mountain hut. From the terrace in front of the building, there is a magnificent view (especially during clear weather) over the Kłodzko valley and the town of Kłodzko itself. Towards the south we can see the tectonic trough of the Upper Nysa Kłodzka Graben with the flanking mountains of the Śnieżnik Massif elevated along young frame faults in the east, and the Bystrzyckie and Orlickie mountains (seen in the background) in the west.

3 Kłodzko Metamorphic Complex – Bardo Unit
(Kłodzko–Gołogłowy–Łączna, Kłodzko–Bardo –Wojbórz–Gołogłowy)

Fragment of Kłodzko Metamorphic Complex, contact with Bardo Unit, Nysa Kłodzka River Gorge across Bardo Mts., Bardo Unit rocks

The town of Kłodzko is reached from the east following the road descending towards the Nysa Kłodzka river valley. Kłodzko is the historic capital and major administrative centre of the Kłodzko Valley. Its history dates back to the 10th century. In 1337, Kłodzko was granted town rights. The Old Town is full of historic monuments, absolutely worth visiting. The town itself is located in the river valley on Pleistocene terraces, near the two magnificent fortresses built in the mid-18th century on the Forteczna and Owcza hills separated by a narrow gorge-like valley of the Nysa Kłodzka River. The centre of Kłodzko was totally flooded by rising river waters in 1997. The floodwater level reached the first floor of houses and it is still marked on the walls of some of them (Phot. 7).

Both of the hills are composed of rocks representing another geological unit called the Kłodzko Metamorphic Complex. Patchy outcrops of this complex extend from Kłodzko towards the north-west and west as far as Ścinawka Dolna and Bożków (Fig. 6). The Kłodzko Metamorphic Complex, despite the small size of its present-day outcrops, is of a very complicated geological structure. According to the current views, it is built of a number of units which are thrust over each other and basically composed of sets of various rocks of sedimentary (phyllites, metasandstones, meta-

Phot. 7. The floodwater level in 1997 reached the second floor of houses and it is still marked on the walls of some of them at Kłodzko.
Phot. S. Cwojdziński

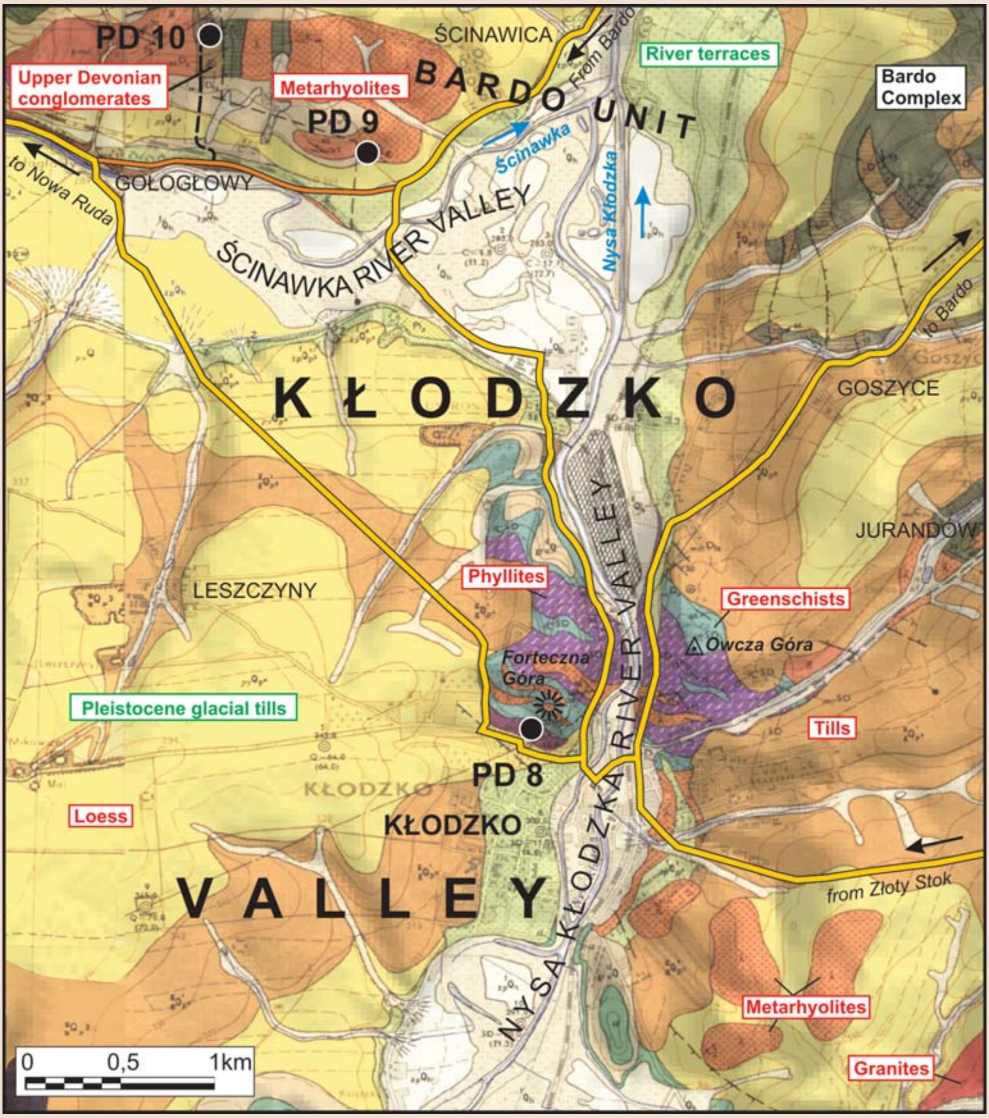


Fig. 6. Geotourist map of the Kłodzko vicinity. Fragment of the Kłodzko metamorphic unit: phyllites, greenstones, metaryolithes, Upper Devonian sedimentary cover, contact with Bardo unit. Documentation points PD 8–10: Kłodzko, Ścinawica, Gołogłowy. Geological map after SMGS: Kłodzko sheet

conglomerates, graphitic quartzites) and sedimentary-volcanic origin (greenschists, chlorite schists, metarhyolites and rhyolite metatuffs), accompanied by amphibolites, metagabbros, metagranites and orthogneisses. The prefix "meta" means that the whole Kłodzko Metamorphic Complex underwent medium- to low-grade regional metamorphism. In terms of the classification of metamorphic conditions, the rocks represent epidote-amphibolite and greenschist facies. The Kłodzko unit is a mixture of tectonic elements of various ages; Neoproterozoic (590–600 My) and early Palaeozoic (490–500 My) rocks are dominant. Middle Devonian fossils were found in some places in sedimentary rocks (phyllites with crystalline limestone interlayers, near Mały Bożków).

Very interesting exposures of the typical Kłodzko Metamorphic Complex rocks occur directly beneath the foundations of the Kłodzko Fortress, above Czeska Street close to the entrance to the forts (PD 8, Phot. 8). The rocks are represented by grey-green chlorite-epidotite schists, fine platy, fine-grained, and intensely folded in their structure. They contain lenticular blocks of a pink-grey finely crystalline rock composed of plagioclases, quartz and light-coloured micas. Small quartz crystals and subtle streaking of the groundmass can be recognized with the naked eye. This is metarhyolite – a metamorphosed volcanic rock with original composition of rhyolite. Chlorite-epidotic schists are metamorphic equivalents of volcanic rocks of basalt type. The whole rock complex of this area shows strong tectonic deformation. However, there is a distinct difference with regard to susceptibility to deformation between the schists, which are prone to plastic deformation, and metarhyolites which are more rigid and form the so-called boudins surrounded and separated by schists. The schists display NW–SE-oriented lineation manifesting itself by fine corrugation and crenulation (microfolds). Longer axes of the boudins are parallel to the lineation. For

Phot. 8. Boudins of metarhyolites surrounded by greenschists in the Kłodzko Fortress basement (PD 8). Phot. S. Cwojdziński

geologists this is the evidence that the whole complex underwent deformation at the same time. The deformation occurred under the greenschist facies conditions of regional metamorphism. It means that the original set of rocks was deformed at the temperatures of approximately 350–400°. Similar rocks and disharmonic deformations can be observed under the fortress walls in the northern flank.

Other metamorphic rocks of volcanic origin can be found north of Kłodzko, near Ścinawica. To reach PD 9 we leave Kłodzko following the road to Młynów (Łukasińskiego Street and Półwiejska Street) across the bridge over the Ścinawka River. On a hill near the Ścinawica–Gołogłowy road, about 250 m to the north of the road, grey and pink-grey massive metarhyolites occur in an old quarry. The very finely crystalline groundmass of the rock contains tiny feldspar and quartz phenocrystals, locally directionally oriented. Such orientation accentuates the fluidal texture of the rock developed due to flow of rhyolitic magma. The rocks are strongly fractured. Densely branching black manganese oxides coatings, the so-called dendrites, are observed on some of fracture surfaces.

Regardless of the age of the original rocks composing the Kłodzko Metamorphic Complex, metamorphic and deformation processes terminated in the area by the Late Devonian. Near Gołogłowy, close to the road from Kłodzko to Nowa Ruda, a very important erosional unconformity has been discovered. Upper Devonian sedimentary rocks, represented by conglomerates and basal breccias followed by limestones, unconformably overlie erosionally truncated rocks of the Kłodzko Metamorphic Complex basement. Now, they are preserved only on a local scale. The rocks contain fragments of metamorphic rocks. This geological phenomenon proves that the main deformation and metamorphic phase of the Kłodzko unit rocks occurred between the middle and latest Devonian during a relatively short period. The metamorphic basement, represented by mylonitic gneisses and amphibolites overlain by Upper Devonian calcareous conglomerates and dark limestones, is exposed in an old quarry situated north of Gołogłowy (PD 10). The sedimentary rocks strike meridionally and the strata steeply dip eastward (55–65°). Such position of the strata is due to thrusting of the Bardo Unit rocks over the Kłodzko Metamorphic Complex and its carbonate platform cover.

From Kłodzko we drive northwards (passing the railway station Kłodzko Główne) towards Wrocław through Boguszyn to Bardo Śląskie. The road runs across a broad, flat plain covered with Pleistocene glacial tills and loesses. After merging with the road No. 8 (Kudowa – Wrocław), forested ridges of the Bardo Mts. appear on its both sides. This is where the outcrops of the main rocks of the Bardo Unit begin. These are Lower Carboniferous alternating greywacke sandstones, mudstones and

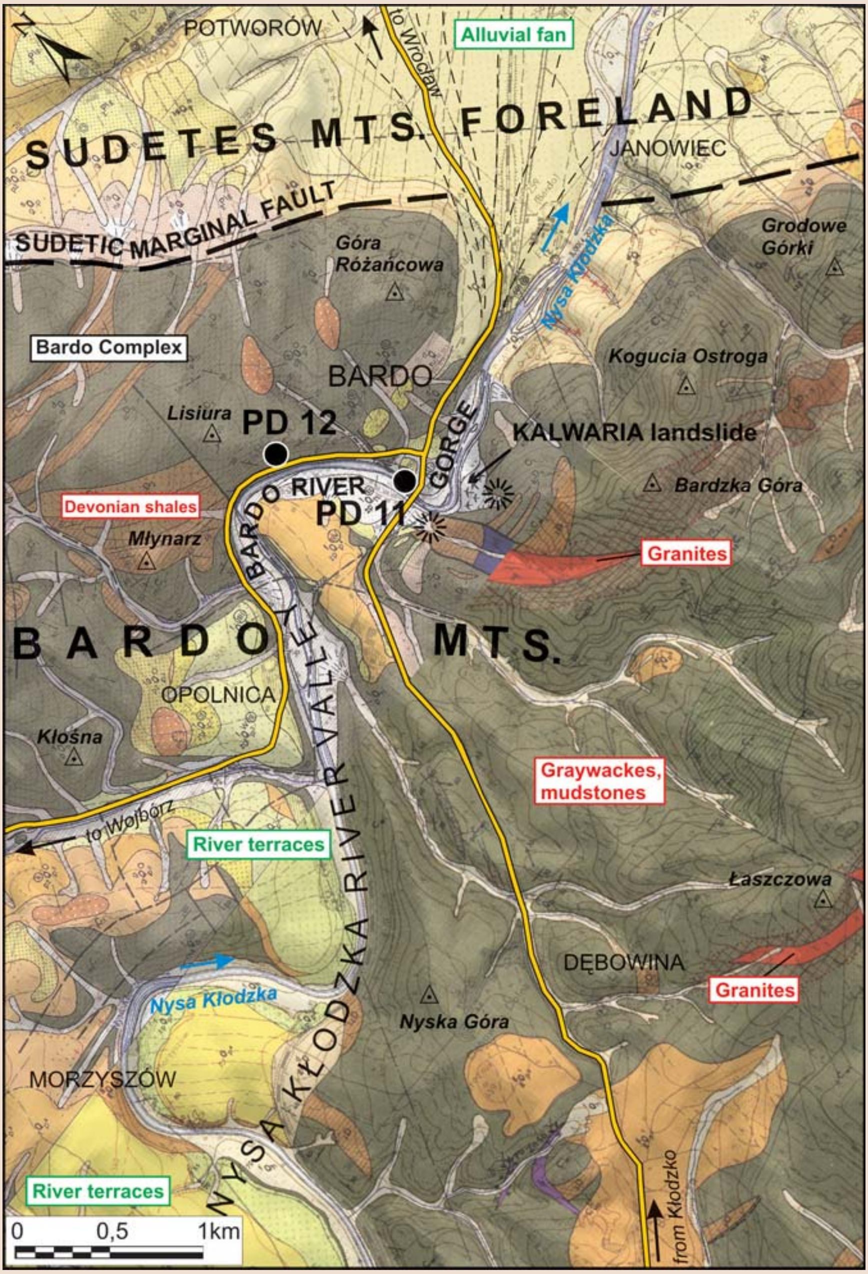


Fig. 7. Geotourist map of the Nysa Kłodzka river gorge through Bardo Mts, rocks of the Bardo unit in the Bardo vicinity: Lower Carboniferous graywecks and mudstones, olistholites. Documentation points PD 11–12: Bardo Śląskie. Geological map after SMGS: Bardo Śląskie, Kłodzko, Przyłęk sheets

clay shales. The Bardo Unit consists of a set of various non-metamorphosed (excluding the previously described contact processes) sedimentary rocks composing the Bardo Mts. cut by the famous Nysa Kłodzka river gorge between Kłodzko and Bardo Śląskie (Fig. 7). With the rocks documenting the very interesting geological history of the Bardo Mts., we will be acquainted in the middle part of the mountains in the Nysa Kłodzka river gorge and around Srebrna Góra at the contact between the Bardo Unit and Sowie Mts. gneiss block.

Bardo Śląskie is a beautiful small town (population about 4,000 inhabitants) picturesquely situated on the slope of Mt. Różańcowa dominating north of the Nysa Kłodzka river gorge. The town was founded at the beginning of the 14th century on the site of a much older settlement, at the very important trade route to Czechia. From a footbridge over the railway station is a beautiful view of the Nysa Gorge and surrounding mountains. We can see the deeply incised meanders of the river, which leaves the Sudetes 2 km to the east. Just above the valley floor is a flood terrace, up to 150 m in width. The inner banks of river meanders are gently sloping and flat, whereas the outer banks are steep and rocky. To the south-east, on the slope of Mt. Kalwaria (583 m a.s.l.) is a vast landslide scar formed in 1598, as old historical documents say. The landslide blocked the river flow, resulting in partial flooding of the

Phot. 9. Nysa Kłodzka river gorge at Bardo Śląskie. Lower Carboniferous greywacke sandstones, which contain interbeds of Late Devonian siliceous shales can be observed along the riverbed (PD 11). Phot. S. Cwojdziński

town. Rocky walls of the scar along with a landslide tongue, now partly forested, have been preserved to date. Such processes, generally called mass movements, occur on steep slopes composed of bedded rocks of different properties, e.g. sandstones and shales as in this case, dipping in the same direction as the slope. Under favourable weather conditions (after long-term rainfall) huge amounts of rocks can gravitationally slide downslope pre-existing surfaces parallel to bedding planes, to inundate the valley.

Thanks to erosional activity of the Nysa Kłodzka River, the rocks composing this part of the Bardo Unit can be observed along the riverbed immediately north of the old stony bridge (PD 11, Phot. 9). These are Lower Carboniferous greywacke sandstones, interbedded with mudstones and claystones. The rocks are grey and dark-grey in colour, medium-grained (sandstones) to very fine-grained (claystones), strongly fractured and even strongly tectonically crushed. NW–SE-striking bedding planes are parallel to the layering and they dip towards NNE at the angle of approximately 50°. These rocks, typical of the Bardo Unit, were deposited on a slope of a relatively deep marine basin close to strongly eroded coasts, partly through downslope gravity flows of sediments. The processes resulted in the formation of the so-called flysch deposits. The rocks contain interbeds of green compact siliceous shales, disintegrating into small irregular, angular pieces when hit. Microfossil investigations indicate that the rocks were deposited during the Late Devonian as the result of quiet and slow deep-marine sedimentation in a completely different, deeper sedimentary basin and at a greater distance from the coast. Their close relationship with the Lower Carboniferous flysch is explained by the concept of the so-called olistolite complex. Such complexes develop on slopes of sedimentary basins often due to rapid submarine landslides. During the process, rocks of various ages and provenance are mixed together creating a chaotic assemblage. Because of their nature, the rocks are also called wild flysch or melange rocks.

The typical Bardo flysch can be observed in the Bardo Gorge near the road from Bardo to Nowa Ruda. Dark-grey and black greywackes and mudstones are exposed here over a distance of more than 500 m in rocky walls and in an old quarry (PD 12). The rock strata strike WNW–ESE and dip northwards at the angle of 30 to 50°.

Driving on the narrow asphalt road through Opolnica to Wojbórz there is the opportunity to observe the mountain relief of the Bardo Mts. Their gentle ridges and forested domed summits reach altitudes of 450–590 m a.s.l. and are separated by the deeply incised Nysa Kłodzka river valley with its renowned gorge. The riverbed has characteristic S-shaped meanders along the gorge and is incised in many places in the basement rocks. In the gorge itself, flattenings of river terraces are visible at various altitudes. They developed from Tertiary through Pleistocene to the Holocene (the youngest terrace) times. The gorge is considered to have formed due to erosional activity of river waters flowing across the uplifting Bardo Mts. block between the Kłodzko Valley and the Sudetic Foreland. The balance between the amount of tectonic movement and river erosion continues since the late Pliocene i.e. over a period of at least two My. Such gorges are called antecedent, and the Bardo Gorge is the typical example.

In Wojbórz, we turn left on the road towards Kłodzko. The road runs through Młynów where, driving southwards along the Nysy Kłodzka river valley, we can watch rock pinnacles above the riverbed (hardly accessible for direct observation) composed of the Bardo greywackes, and also make a closer inspection of the Bardo flysch complex in an active quarry producing crushed road stone. You must gain special permission of the management to enter the quarry (Phot. 10).

From here, we can either go back to Kłodzko or drive through Gołogłowy towards Nowa Ruda and Wałbrzych to explore another section of our geotourist route. After several kilometres, at the village of Gorzuchów, there is another very interesting side road leading towards Ścinawka Dolna and Średnia, and Radków and Karłów in the Stołowe Mts. National Park. This route will enable us to make a closer look at the geology of the Stołowe Mts. composed of Upper Cretaceous deposits.

Phot. 10. Active quarry of the Bardo greywackes at Młynów. Bedding dips to the right at the angle 45°. Phot. S. Cwojdziński

4 Sowie Mts. Block edge – Bardo Unit
(Koszyn–Srebrna Pass–Srebrna Góra–Dzikowiec –Słupiec)

Mylonitized and cataclased gneisses of Sowie Mts. Block edge, Bardo Mts. sedimentary rocks: Lower Carboniferous wild flysch, Upper Devonian carbonate platform, Nowa Ruda Massif gabbros and diabases, coal-bearing Upper Carboniferous of eastern part of Intra-Sudetic Depression

Heading towards Wałbrzych, we diverge from the main road at Koszyn and then drive to Dzikowiec and Srebrna Góra. The purpose of our trip is to get to know more about the geological structure of the area around the small town of Srebrna Góra and Srebrna Pass (586 m a.s.l.). This is a boundary zone between the Bardo Unit and the much older Sowie Mts. Block composed of quite different rocks (Fig. 8).

Srebrna Góra lies in a narrow valley sloping towards the Sudetic Foreland from Srebrna Pass, in the area of outcropping rocks of the Sowie Mts. Block. This is a town of old, medieval mining traditions. Already in the 14th century, silver-containing lead ores (galena) were mined here, peaking in the 16th century. Although the exploitation died long ago, old mineshafts and small heaps with fragments of lead ore can still be found on the valley slopes near Żdanów.

Later in the 18th century, the Prussian King Frederik the Great built a powerful fortress on the mountains surrounding the town, which blocked the passage through Srebrna Pass (Phot. 11). The fortress objects are worth visiting, especially the Donjon Fortress on Mt. Warowna and Ostróg Fort on a mount of the same name, located to the south of Srebrna Góra. The fortresses are fine viewpoints offering spectacular views toward the north over the Sudetic Foreland covered with Quaternary deposits and a number of hills composed of crystalline rocks of the Fore-Sudetic Block, towards the south-west over the Western Ridge of the Bardo Mts., and towards the south over the Żdanów Valley.

The Żdanów Valley is an oval structure situated off the main geotourist route and eroded into Lower and Middle Devonian clay shales, mudstones, sandstones and siliceous shales. The slope of the narrowed part of the Budzówka river valley also reveals exposures of Silurian black shales. Subtle imprints of graptolites – marine colonial organisms significant for the stratigraphy of the Ordovician, Silurian and Devonian periods, can be found on parting planes of the rocks. As proved by the Żdanów IG 1 deep exploratory well drilled in this area by the Polish Geological Institute at the turn of 1980s, the Sowie Mts. gneisses are overlain at the depth of 1900 m by the Bardo complex. The complex includes large blocks of Silurian (claystones and radiolarites) and

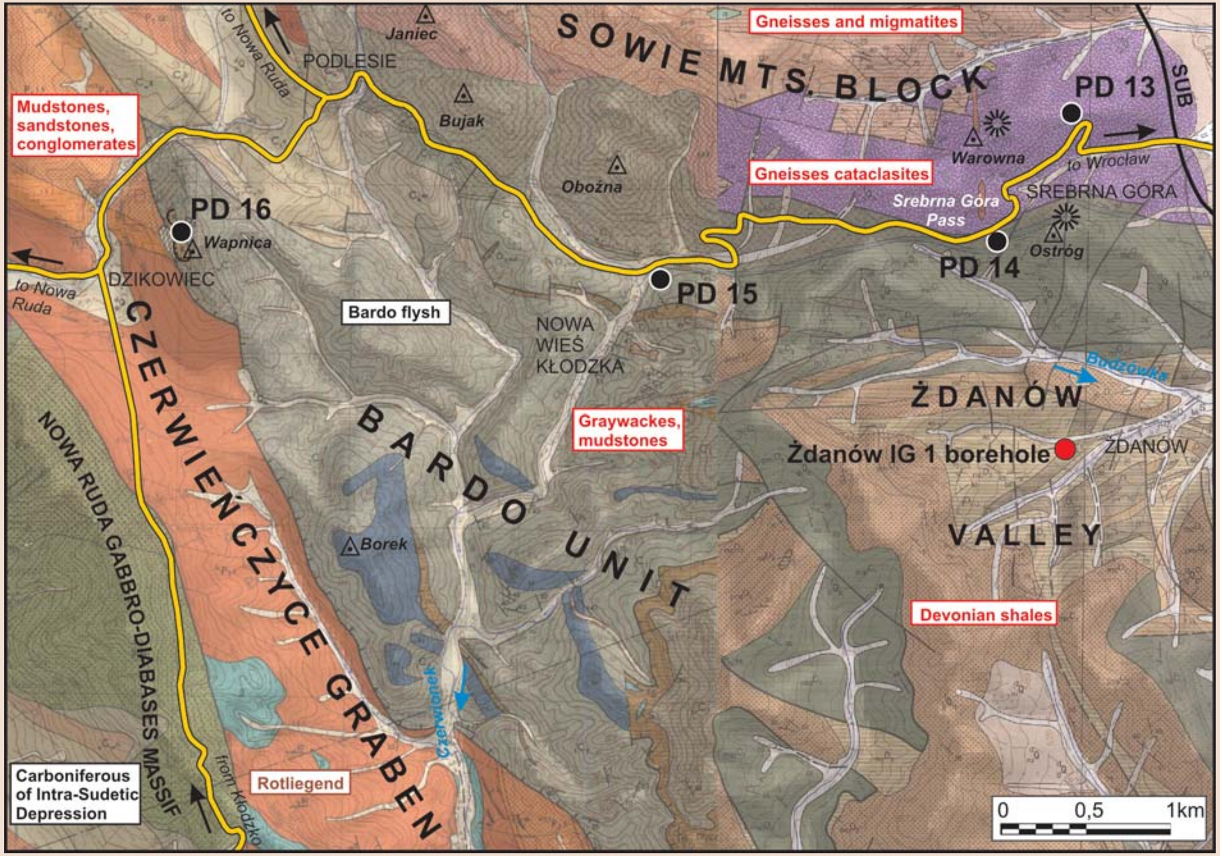


Fig. 8. Geotourist map of the Srebrna Góra vicinity (boundary between Sowie Mts and Bardo Mts). Mylonitized and cataclastic gneisses of the Sowie Mts. margin, sediments of the Bardo unit: Lower Carboniferous wild flysh, Upper Devonian carbonate platform, gabbros and diabases of the Nowa Ruda Massif. Documentation points PD 13–16: Srebrna Góra, Nowa Wieś Kłodzka, Dzikowiec. Geological map after SMGS: Nowa Ruda, Bardo Śląskie sheets

Phot. 11. Srebrna Góra on the background of Warowna Mt. Prussian Fortress on the top of mountains. The valley leading to Srebrna Pass is visible. Phot. S. Cwojdziński

Devonian (claystones with radiolarians, siliceous rocks and quartz sandstones) rocks occurring within the depth interval of 900 m up to the ground surface, and underlain by Lower Carboniferous greywacke sandstones, mudstones and claystones with interbeds of limestones and conglomerates. The blocks probably form a thick cover (nappe) of rocks that slid downslope the ancient marine basin in which the Lower Carboniferous flysch was deposited.

The Sowie Mts. Block is composed largely of various types of gneisses and migmatites with amphibolite interlayers. The rocks formed in deep zones of the Earth's crust at depths of about 20–25 km) at temperatures locally exceeding the melting point of quartz-feldspar rocks. These are conditions of migmatite formation. The gneisses and migmatites compose the whole Sowie Mts. range from Srebrna Góra nearly as far as Wałbrzych. Rocks of the marginal zone of the block, near Srebrna Góra, underwent very strong deformation; they were tectonically crushed and turned to the so-called breccias and cataclasites. This type of deformation occurs at small depths there where rocks undergo brittle deformation. The crushed and cataclased Sowie Mts. gneisses can be observed in an exposure at the road bend in the upper part of Srebrna Góra (PD 13). Similar rocks occur within a longitudinal belt along the border with the Bardo Unit. Their formation is related to tectonic movements uplifting the Sowie Mts. Block in relation to the Bardo Basin. The movements caused rapid deepening of the basin and gravitational sliding of rock masses with the subsequent development of the Bardo Mts. olistolite complex.

Sedimentary rocks of the marginal part of the Bardo Unit, bordering the Sowie Mts., are best exposed in the well-known cutting of an old cogwheel railway constructed at the turn of the 19th century. The railway cutting starts at Srebrna Pass south of the town near a tourist bridge (PD 14). It runs around the southern slope of Mt. Ostróg. It is worth to walk along the whole route of the Sowie Mts. old railway. There are 2 sites in which the route crosses mountain valleys on magnificent 20-metres high brick viaducts. Beautiful panoramic views of the Żdanów Valley and surrounding Bardo Mts. can be admired from the viaducts.

The railway cutting reveals well-exposed sedimentary rocks over long sections between Srebrna Pass and Żdanów. These are sandstones, mudstones and claystones consisting of 10–40 cm-thick layers across the whole section. They occur in a regular succession from coarser-grained rocks in the lower portions of the layers, through finer-grained deposits to very fine-grained claystones at the top. There is an upward-decrease in thickness of the layers and sandstone/mudstone ratio. In general, the dominant rocks are mudstones. This type of bedding is called graded bedding, and the sets of beds are called turbiditic layers. They are typical of flysch complexes and are well exposed also in a small exposure at the beginning of Nowa Wieś Kłodzka (PD 15). Such assemblages of rocks form as a result of gradual deposition of sand and mud from the so-called turbidity currents consisting of loose material, which is quickly transported down submarine slopes through sliding, and subsequently slowly deposited from the coarsest to finest grains at the foot of the slopes. Each successive sequence in the section represents individual turbidity current. It is easy to realize that the deposits may have formed along tectonically active coasts, i.e. in areas of high supply of material from the land, and there where earthquakes might have facilitated triggering of gravity slides towards the basin floor. Such conditions existed during the early Carboniferous at the margin of the Sowie Mts. gneiss block and the Bardo Basin. In addition, the predominance of mudstones over sandstones and commonness of parallel horizontal and graded bedding indicate that the turbidity currents travelled over a considerable distance from the seacoast. The Bardo Basin extended at that time much further than today – the Bardo Unit is only part of the basin. During the Variscan orogeny, at the Early/Late Carboniferous transition, it was subject to fold-and-thrust deformation.

Another geologically interesting sector of the railway cutting is situated north of Żdanów on the SE slope of Mt. Ostróg. Olistostrome deposits of wild flysch typical of the northern area of the Bardo Mts. are exposed here. Sandstones, mudstones and sedimentary breccias (angular rock fragments in sandy or muddy matrix) contain blocks and plates of alien rocks represented by Devonian siliceous, siliceous-clay and clay shales, green, blue-grey and black in colour, as well as sandstone blocks resembling the Lower Carboniferous flysch sandstones observed in the southern sector of the railway cutting.

Such chaotic assemblages of rocks, developed due to gravity slumping on submarine slopes, are called melange complexes. In the exposures under consideration, these deposits are typical in appearance. The overall geological setting indicates that great, several kilometres long slide structures composed of Devonian rocks, and forming extensive slump covers embedded within flysch deposits, occur also further south-eastwards within the Lower Carboniferous flysch (e.g. near Bardo Śląskie).

We leave Srebrna Góra driving back through Srebrna Pass towards Wolibórz and Nowa Ruda. In Podlesie, we turn left towards Dzikowiec, onto a narrow asphalt road. In mid-village, near a shop and a fire brigade station, the narrow road runs under a railway viaduct towards Mt. Wapienna. At the mountain top is an old limestone quarry, known already in the 19th century, currently used as a shooting ground (PD 16).

From the geological point of view, we are in the marginal south-western part of the Bardo Unit near its fault contact with the Czerwieńczyce Graben. At this place, the geological map shows an NNW–SSE elongated outcrop of Upper Devonian limestones. The western wall of the quarry offers a depositional succession, which has long been considered one of the most important sites documenting the Devonian/Carboniferous transition in Central Europe. The Upper Devonian rocks, passing into lowermost Carboniferous deposits, are represented by limestones. In the lower part, these are thickly bedded, nodular calcareous breccias composed of limestone fragments as well as gabbro clasts and rounded blocks up to 2 m in size. The rocks are overlain by thinly bedded compact dark-grey and grey-blue limestones, followed by grey and reddish nodular limestones (Phot. 12). All of the limestone types contain numerous fossils: brachiopods (including spirifers), corals, bivalves, gastropods, crinoids, trilobites and cephalopods (Clymenia).

The stratigraphic boundary between the uppermost Devonian and lowermost Carboniferous is located within the uppermost member of the carbonate formation, composed of thinly and medium bedded grey limestones. The situation observed in the quarry indicates that shallow-marine carbonate sedimentation occurred in this area of the Sudetes at the Devonian/Carboniferous transition, leading to the formation of the so-called carbonate platform. Its original extent was certainly much greater than today. There is evidence that it also extends under the Intra-Sudetic Depression.

Phot. 12. Old limestone quarry at the Wapienna mountain top at Dzikowiec (PD 16). Thinly bedded and nodular limestones of the uppermost Devonian. Phot. K. Ordzik

Rocks of a quite different formation occur up on the eastern wall of the quarry. They are unconformably underlain by limestones and are represented by Lower Carboniferous sandstones, about 10 m thick, followed by conglomerates containing pebbles and blocks of the Sowie Mts. gneisses, similar to those observed in the Srebrna Góra railway cutting. At the limestone/sandstone contact, there is a thin irregular layer of black sandy-carbonaceous shales. The limestone deposition was separated from the sandstone and conglomerate deposition by a sedimentary break lasting several million years. The younger rock formation, related to the evolution of the Bardo Basin, deposited upon the erosional surface of the carbonate platform.

From Dzikowiec we can choose between two routes. The first one leads to Słupiec and further on to Wałbrzych. The second one runs southwards to Koszyn and then back towards Kłodzko to Gorzuchów. The latter should be chosen if intend to visit the Stołowe Mts. National Park.

Whichever route is followed, we first enter the Czerwieńczyce Graben manifested as a topographic low, closed between the Bardo Mts. in the east and the Dzikowiec Ridge in the west. The NW–SE-extending Czerwieńczyce Graben is a branch of the Intra-Sudetic Depression filled with Lower Permian rocks representing a new, much younger evolutionary stage of the Sudetes Mts. The Lower Permian rocks will appear on our route several times. The characteristic feature of the Lower Permian sedimentary rocks is the red or red-brown colour, also typical of soil in areas composed of these rocks.

The forested, NW–SE-elongated Dzikowiec Ridge is composed of rocks constituting the Nowa Ruda gabbro-diabase massif. This is one of the numerous magmatic bodies of similar type surrounding the Sowie Mts. Block. The Nowa Ruda Massif consists of fine- and coarse-grained basic plutonic rocks: gabbros and diabases. The geological situation of the Dzikowiec quarry (PD 16) indicates that the gabbros are pre-Late Devonian. Absolute age determinations performed in the last years suggest that they crystallized about 420–400 My ago during the Late Silurian and Early Devonian.

The rocks from the Dzikowiec Ridge are often considered ophiolites i.e. fragments of an ancient oceanic crust incorporated in the geological structure due to deformational processes. In the NW part of the massif, the dominant rocks are typical coarse-grained gabbros. Towards the SE, there are rocks of similar chemical composition, which crystallized at much smaller depths (so-called hypabysal rocks). These are diabases of ophitic and very fine-grained structures indicating rapid magma cooling. The ophitic structure is characterized by the occurrence of 2 cm-long grey plagioclase laths randomly distributed in the dark groundmass composed of augite, hornblende, actinolite and chlorites.

Typical olivine gabbros can be observed in a large active quarry at Słupiec near the road from Dzikowiec. Special permission must be obtained from the quarry management to enter the quarry. The rocks are dark-green coarsely crystalline massive gabbros composed of plagioclases (labradorite), pyroxenes (diallage) and olivine with subordinate contribution of magnetite, ilmenite, chromite and apatite.

Diabases occur in the southern part of the Słupiec quarry. These rocks are finer-grained than gabbro and show the typical ophitic structure. Gabrros and diabases underwent later dynamic deformation in zones of mylonitization. Such zones of latitudinal trend are also visible in the Słupiec quarry. They are composed of dark-green rocks of gneissose structure. Augens of crushed plagioclases are bypassed by the indurated and oriented groundmass of amphiboles (actinolite), diallage and chlorites.

After visiting the quarry, we head towards Słupiec descending across the slopes of the Dzikowiec Ridge to the Nowa Ruda Depression. A quite different geological world awaits us here in the eastern part of the Intra-Sudetic Depression.

5 Stołowe Mts.
(Kłodzko–Ścinawka Dolna and Średnia–Radków –Karłów–Radków–Tłumaczów–Nowa Ruda)

Radków Scarp, Upper Cretaceous sandstones and marls of Eastern Sudetes, Stołowe Mts. National Park, Permian sedimentary rocks of Intra-Sudetic Depression

Driving from Kłodzko towards Wałbrzych (road No. 381), we turn in Gorzuchów to Ścinawka Dolna and Radków and follow the road running along the Ścinawka valley (road No. 386). This is a wide flat valley with a well developed system of Pleistocene terraces at the levels of 5 and 20 m a.r.l. The valley floor is composed of gravels and sands currently excavated in a number of gravel pits. Beautiful pebble specimens of Permian volcanic rocks – rhyolites and melaphyres (trachybasalts and trachyandesites), volcanic breccias, Permian red sandstones and amphibolites – can be found here.

In Ścinawka Średnia, we turn south-west towards Ratno and Radków and drive along the much narrower Pośna valley winding between gentle slopes of the Ścinawka Hills. The hills are composed of Lower Permian (Rotliegend) red sandstones interbedded with conglomerates. They are valuable building material excavated in this area and known as the building sandstone. Many buildings, especially older ones (e.g. Zwierzyniecki Bridge in Wrocław), have been built of the sandstones. The rocks gently dip SW'wards towards the Intra-Sudetic Depression axis, causing that progressively younger Permian rocks are exposed at the surface, as moving south-westwards. At Ratno, the Pośna valley changes its direction to W–E and slightly widens. Outcrops of clay shales and sandstones interbedded with limestones, representing the younger part of the Rotliegend succession, can be observed on surrounding hills.

Radków is a beautiful old town situated at the foot of the Stołowe Mts. Radków received town rights at the beginning of the 14th century as a settlement located on the trade route from Kłodzko to Broumov; Magdeburg rights were granted in 1418. The long history of Radków, like that of whole Lower Silesia, had its good and bad periods. Now, the town is absolutely worth of visiting to experience its history. This is also the centre of natural stone industry of the Cretaceous sandstones, and the important tourist centre situated close to the Stołowe Mts. National Park.

To the west of the town, above Lake Radków, is the Guzowata hill (Fig. 9). Its southern slopes expose red-brown sedimentary rocks of youngest Rotliegend age in small rocky outcroppings (PD 17). This is one of the most interesting exposures of the formation to study origin of the deposits. The rocks exposed here represent a sequence

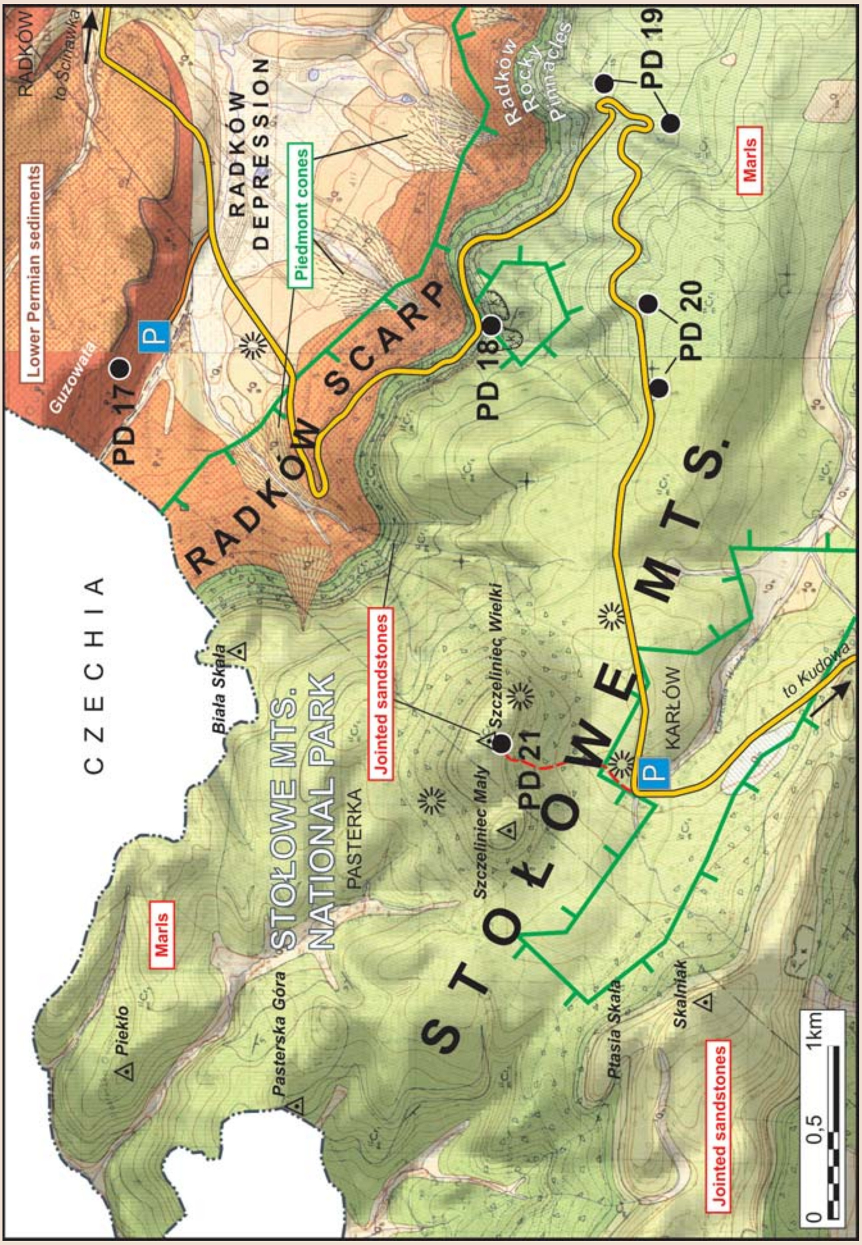


Fig. 9. Geotourist map of the Stołowe Mts. Sedimentary rocks of the Permian cover of the Intra-Sudetic depression, Upper Cretaceous jointed sandstones, mudstones and marls of the Middle Sudetes, Stołowe Mts. National Park, sandstone pinnacles. Documentation points PD 17–21: Radków, Guzowata, Radków Scarp, Karłów, Szczeliniec. Geological map after SMGS: Jeleniów, Wambierzyce, Radków sheets

Phot. 13. Northern morphological edge of the Stołowe Mts. seen from Radków. Jointed sandstones form “table-shaped” relief. Phot. S. Cwojdziński

of fluvial fans and liquefied palaeoslump deposits that slide down ancient slopes in a semi-liquid state. These are chaotically mixed rock fragments and pebbles sticking in the muddy or sandy groundmass often disturbed to form folding, irregular deformation and domed and concave features (so-called convolutions). Top parts of the slump beds contain irregular interlayers of carbonate calcarenites (ancient soil horizons) indicating time breaks between individual flows. Directional sedimentary structures document the easterly direction of the flows. The fluvial fans are inclined towards NE.

The Rotliegend (Lower Permian) sedimentation was undoubtedly associated with local graben-type basins. It took place in continental and semi-desert conditions, hence the dominant red colour of the rocks. The Lower Permian formations of the Sudetes are also accompanied by massive complexes of volcanic rocks. We will explore them further on our route.

We leave Radków following the road to Kudowa Zdrój (387) through Karłów. From the road in the middle of the Radków Depression is a magnificent view of the NW–SE-trending steep morphological edge of the Stołowe Mts. This is the so-called Radków Scarp of relative altitude of over 200 m (Phot. 13). The Upper Cretaceous sedimentary cover of the Sudetes becomes appear on the steep forested slopes above the outcropping Rotliegend conglomerates. They are represented in general by sandstones, mudstones and calcareous mudstones (marls) forming alternating layers, 30–50 m to over 100 m in thickness. The rocks lie horizontally; hence, their intersection image is relatively simple. Outcrop boundaries of individual layers are parallel to isohypses, as clearly visible in the geological map (Fig. 9). Variable resistance of Cretaceous rocks to weathering and erosion is the reason why the mountains have their characteristic “table-shaped” relief. Horizontally lying complexes of resistant quartz sandstones form flat tables rising above the gentle mountain slopes composed of soft mudstones and marls. The stratigraphy, i.e. the age succession of Upper Cretaceous strata, is based mainly on fossils of *Inoceramus* bivalves reported from the deposits. The Cretaceous rocks were deposited as the result of inundation (transgression) of a warm and shallow sea which covered much of the Sudetic area at that time leaving, however, a number of large islands (e.g. the present-day Bystrzyckie and Orlickie mountains were islands).

The winding road, called “Road of 100 Bends”, climbs the Radków Scarp. Here we step into the Stołowe Mts. National Park. The dominant lithology in the mountains is the so-called jointed sandstones of the Middle and Upper Turonian. They are best exposed in an active quarry at Radków, in beautiful small rocky crags rising above the road, and on the top of Mt. Szczeliniec Wielki near Karłów.

The excavation pits of the Radków quarry (PD 18) cut the topographic step composed of Middle Turonian jointed sandstones, approximately 50 m in thickness. These are compact medium- and coarse-grained quartz sandstones, light-yellow in colour, containing characteristic cross-bedding within horizontally lying 10–12 m-thick strata. Cross-laminae are inclined SW’wards. The deposits accumulated in a nearshore zone of an ancient sea in the area of sand bars parallel to the coast extending in the north-east. Towards the south-west there was an open sea with sandstones passing seawards into mudstones and marls. The interesting thing is that blocks of shell conglutinate – rocks consisting of *Exogyra* bivalve moulds – can be found in the quarry. The presence of these rocks indicates intense activity of sea currents, which washed away nearshore accumulations of bivalve shells and transported them to another place. The jointed sandstones are excavated in the quarry for a valuable building stone well known since a long time. The Radków natural stone deposit area has been excluded from the Stołowe Mts. National Park just to allow for further exploitation.

Similar horizontal and cross-bedded jointed sandstones compose rock pinnacles often of fantastic shapes resembling clubs, towers, tribunes and ambos occurring in the northern slopes of the Radków Scarp. Groups of crags bear local names e.g. Radkowskie Skały, Słoneczne Skały, Skalne Grzyby. Those situated close to the road immediately along the “Road of 100 Bends” (PD 19) are well exposed.

The road goes onto an undulated plateau at the altitude of about 740–780 m a.s.l. composed of Turonian marls. These dark-grey compact rocks, easily splitting into irregular thin plates, can be observed in 2 bush-grown pits near the road to Karłów

Phot. 14. Szczeliniec Wielki seen from Karłów. Beds of horizontally lying Turonian jointed sandstones form a rocky plateau (PD 21). Phot. S. Cwojdziński

(PD 20). The silt-grade rocks are composed of carbonates (carbonate clasts), fine quartz grains and clay minerals. They were deposited in a marine environment of lower energy than that of sandstone deposition, at peripheries of sand bars. The marls contain imprints and moulds of *Inoceramus lamarcki* bivalves, occasionally of large size.

The best-known exposure of the jointed sandstones, representing their uppermost portion, is the summit of Mt. Szczeliniec Wielki (919 m a.s.l.) located to the north of Karłów (PD 21). The site is reached on foot following a path from a car park in the renowned tourist resort of Karłów. Beds of horizontally lying Turonian jointed sandstone strata form here an extensive rocky plateau fractured and dismembered into individual huge rock blocks (Phot. 14). The rocky labyrinth is crossed by a red-marked tourist path bringing you also to 2 attractive viewpoints at the NW and SE edges of the Szczeliniec Wielki rocky plateau. One of the viewpoints provides a beautiful panoramic view of the Intra-Sudetic Depression, Stołowe Mts. foreland and the Bardo and Sowie Mts. closing the horizon in the north. From the south-eastern edges of the rocky plateau we can see the Stołowe Mts., the Bystrzyckie and Orlickie mountains, the Upper Nysa Kłodzka Graben filled with Upper Cretaceous deposits, and the Śnieżnik Massif in the far horizon.

From Karłów we drive back to Radków following the "Road of 100 Bends" and leaving the Stołowe Mts. In Radków we take a local narrow road along the state border to Tłumaczów (border crossing to the Czech Republic), and then along the Ścinawka river valley and its tributary Włodzica River to Nowa Ruda through Włodowice. On either side of the route, Rotliegend sedimentary rocks are seen on gentle slopes of the hills extending all along the road. The red colour of soils is indicative of their age. The rocks represent the north-eastern flank of the Intra-Sudetic Depression. Near Tłumaczów the road crosses the Ścinawka Hills where Permian volcanites occur. To the north of the Ścinawka valley in Tłumaczów, the Suche Mts. ridge begins. The mountains extend north-westwards along the border with the Czech Republic. They are composed chiefly of Lower Permian volcanites formed during one of the most intense volcanic events of the Sudetic history. There will be opportunities to examine the rocks and volcanic formations later during our visit to the area situated south of Wałbrzych.

6 Intra-Sudetic Depression – south-eastern area *(Kłodzko–Słupiec–Nowa Ruda–Ludwikowice Kłodzkie–Głuszyca–Jedlina–Wałbrzych)*

Coal-bearing Carboniferous of eastern part of Intra-Sudetic Depression, hard coal mining traditions, underground tourist route

Nowa Ruda is reached following the main road from Kłodzko through Słupiec, driving either from Srebrna Góra through Wolibórz from the north-east or from Radków through Włodowice from the south-west. Nowa Ruda lies in the wide Nowa Ruda Depression bounded by the ridges of Włodzickie Hills, Dzikowiec Ridge and part of the Wyrębińskie Hills.

Nowa Ruda was founded in the 13th century as a mining village. It was granted town rights in the 14th century. Hard coal, iron ore and tonsteins had been mined here since the end of the 15th century. In 1607, the mining of minor gold ores started at Słupiec. The 16th century was a period when a number of small textile and linen factories were set up. Damages of the Thirty Year's War and the Silesian Wars hindered the town's development. In the 19th century, coking coal deposits were discovered, and in 1879, Nowa Ruda could already be reached by rail. Thanks to the railway, the production of hard coal and red building sandstone increased. The coal mining industry boosted after the Second World War. In 1954, the town was extended by the addition of Drogosław and Słupiec. Nowa Ruda and Słupiec had been until recently associated with coal mining. There are four hard coal deposits located around the town, of which two deposits – the Piast and the Słupiec mine were mined until the 1990s. The coal is associated with Upper Carboniferous deposits of the Intra-Sudetic Depression.

The Nowa Ruda region extends in the marginal part of the NE fragment of the Intra-Sudetic Depression dismembered into several minor tectonic units composed of Upper Carboniferous and Lower Permian deposits. These are the Wolibórz Syncline (adjoining the Sowie Mts. Block), the Czerwieńczyce Graben and the Nowa Ruda Syncline. All the units are elongated in the NW–SE direction and separated by uplifted zones of basement rocks (Fig. 10). The Upper Carboniferous deposits overlie here the basement rocks consisting of weathered gabbros and diabases of the Nowa Ruda Massif. Weathering processes of the basement rocks proceeded in a warm and humid climate. They resulted in a deposition of red clay shales (called argillites), boxites (important aluminium ores) and steel-grey or bluish very fine-grained tonsteins showing conchoidal parting and composed of clay minerals of the kaolinite group and hydroxides (diaspore and bemite). Small blocks of these interesting rocks can be found on mine dumps in Nowa Ruda and Słupiec. The coal-bearing series of the Nowa Ruda–Słupiec region is represented by a complex of clay-sandy deposits, up to 180 m in thickness, belonging to the so-called Žacléř Formation considered to be of Westphalian age. These are sandstones, conglomerates and mudstones containing coal seams of maximum thickness up to 2.5 m. There were seven coal seams existed in the Piast mine of Nowa Ruda, 9 coal seams – in the Słupiec mine. Rock strata in the mines were variably dipping from 15 up to 90°; the coal seams were cut by numerous multidirectional faults. The complicated tectonic situation of this area made the coal exploitation difficult and finally became one of the reasons for closing the mines.

The coal-bearing series are overlain by uppermost Carboniferous deposits represented by the Westphalian and Stephanian Glinik Formation composed chiefly of sandstones and conglomerates with clay shale interbeds, followed by thick Rotliegend sedimentary and sedimentary-volcanic formations. Outcrops of these strata, gently dipping SW'wards, constitute the Włodzickie Hills.

From a geotourist's point of view, Nowa Ruda and Słupiec are primarily historical remnants of coal mining. Worth visiting are mine waste dumps, in particular a great dump at Słupiec near the road from Kłodzko close to old mine buildings. Another interesting mine dump is in Nowa Ruda. While visiting the dumps it is worth looking around for some specimens of Carboniferous plant imprints in carbonaceous clay shales, for argillites and tonsteins, and for silicified tree stems.

The Žacléř beds are exposed at the ground surface near a bend of the road descending from Wolibórz to Nowa Ruda (PD 22). The rocks are represented by conglomerates of the uppermost part of the formation. Among the monotonous selection of pebbles the dominant are quartz, quartzites are rare gneisses. Fragments of silicified wood are also observed. The composition of the conglomerates indicates that they represent

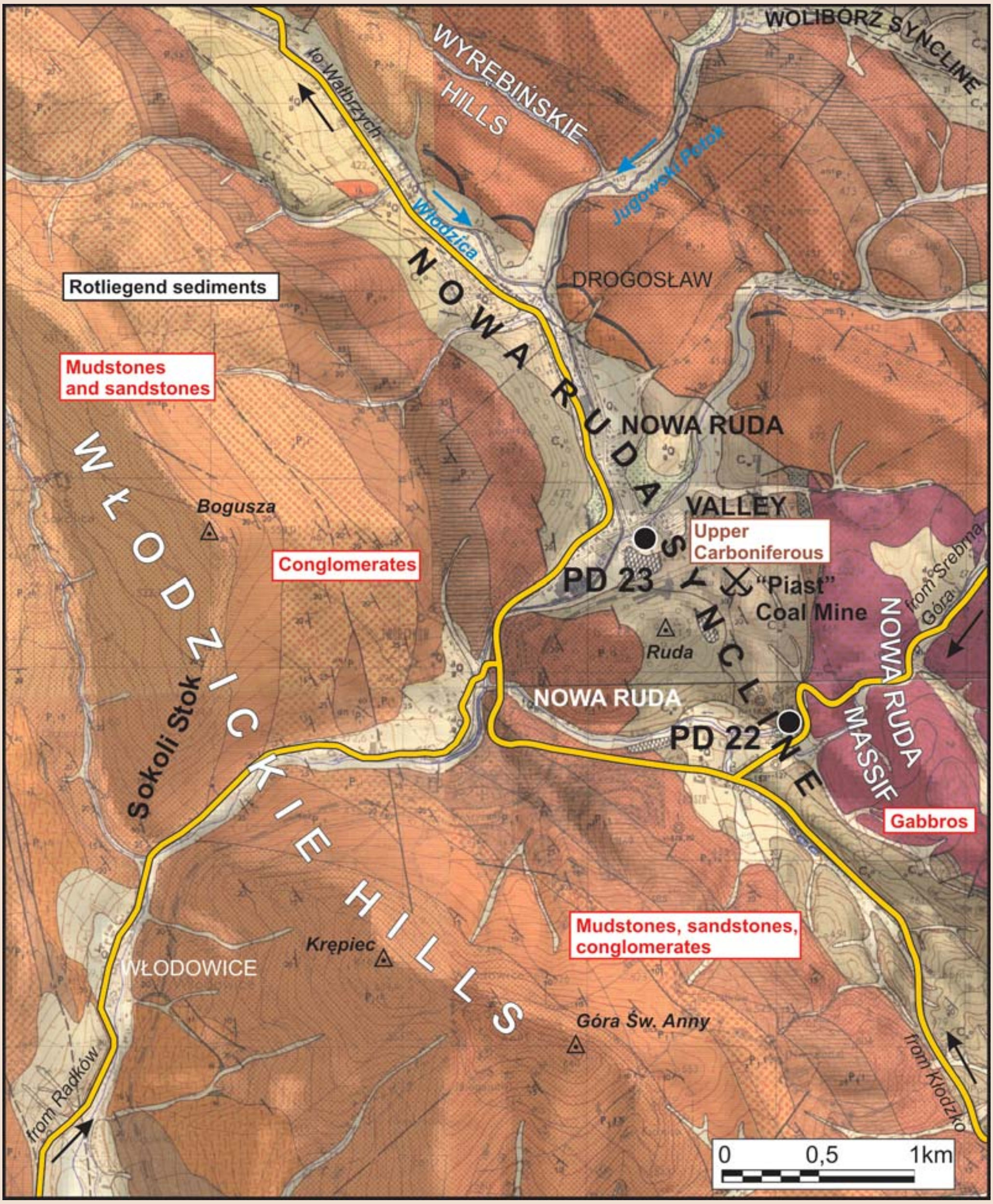


Fig. 10. Geotourist map of the Nowa Ruda vicinity. Coal-bearing Upper Carboniferous of the eastern part of Intra-Sudetic Depression, mining traditions, mining dumps, underground tourists route in former coal mine Nowa Ruda. Documentation points PD 22–23: Nowa Ruda. Geological map after SMGS: Nowa Ruda, Radków, Ludwikowice Kłodzkie, Jugów sheets

rocks deposited earlier and subsequently repeatedly reworked. Such conglomerates, consisting predominantly of components resistant to weathering and erosion, are called mature conglomerates.

While visiting the Underground Tourist Route called "Kopalnia węgla" at 4 Obozowa Street (PD 23, Phot. 15), we can discover the rich 500-year history of coal mining in the Nowa Ruda region, the oldest coal mining area in the territory of Poland. It includes 700-m long underground mine tunnels, isolated from the closed sector of the mine and supported by the lining. The tunnels were made within the orogen and all of the production operations in an underground hard coal mine are exhibited as they originally were. On the ground surface, there is an exhibition building and the original dispatcher's office as the central point of information and mine management. An underground railway operates in the mine, being the great tourist attraction.

Interesting traces of former coal-mining activity can also be observed off the route described in this guide, closer to the edge of the Sowie Mts. between Przygórze and Jugów and between Ludwikowice Kłodzkie and Jugów. The "Wacław" mineshaft was situated in this area.

Fot. 15. Shaft of the coal mine in Nowa Ruda. Museum of Mining with underground tourists railway (PD 23). Phot. K. Ordzik

We leave Nowa Ruda following the road to Wałbrzych (381) through Ludwikowice Kłodzkie, Świerki, Głuszyca and Jedlina Zdrój. First, the road runs along the Włodzica River between the Włodzica and Wyrębińskie Hills. Further, between Świerki and Głuszyca, it crosses the northern slopes of the Suche Mts. Rocks of the so-called “volcanic formation” of the Kamienne Mts. are exposed in the mountains. This massive group of igneous rocks of variable petrographical characteristics responsible for the present-day relief of the Krucze Mts., Czarny Las, Lesista Ridge and Suche Mts. included in the Kamienne Mts., was formed during Lower Permian (Rotliegend) time. The rocks form 100–200 m-thick, extensive volcanic sheets lying concordantly with the surrounding sedimentary rocks. Dark volcanic rocks of composition similar to basalts have commonly been named melaphyres. Light-coloured rocks, containing quartz, have been called quartz porphyres. Modern terminology of the volcanic formation rocks from the Kamienne Mts. is much more complicated. The rock types include trachybasalts, trachyandesites, latites and rhyolites, tuffs, tuffites and pyroclastic breccias of variable chemical composition.

A great active quarry of the volcanites is located south of Świerki village. After gaining permission from the quarry management, it is worth looking at the rocks represented by a 60 m-thick series of trachyandesites. These are compact, massive very fined-grained or aphinitic (so very fine-grained that it is impossible to recognize individual minerals with the naked eye) rocks, grey-violet and dark-grey in colour. They locally show porphyric structure – in that case, minute plagioclase crystals are visible in the aphanitic groundmass. Vesicular (with empty pores) and amygloidal varieties of the rocks are observed at the top of the unit. The latter variety shows oval pores filled with silica or carbonates (calcite and aragonite). The rocks from the Świerki quarry are composed of calcium plagioclases, pyroxenes (augite), amphiboles (hornblende), and small amounts of quartz and olivine. They are interpreted either as lava flows which poured out directly onto the ancient surface or as subvolcanic structures forming shallow-seated intrusions arranged consistently with the surrounding sedimentary rocks. The latter interpretation may be true because there are sites in the quarry where very highly ferruginous laminated rocks of sedimentary origin, thermally altered and silicified, are observed both beneath and above the volcanites. The rocks contain layers of red and green-blue jaspers – siliceous gemstones. In the volcanites themselves, chalcedony nodules can be found, reaching even 0.5 m in length.

Six km further towards Wałbrzych, 1 km west of Głuszyca Górna, is a large abandoned quarry of melaphyres located on the slopes of Mt. Ostoja (PD 24, Fig. 12). Interesting phenomena of the Lower Permian volcanism can be observed here. The excavation pit reveals a few trachyandesite bodies surrounded and separated by slate rocks resembling in appearance black phyllites, cut by numerous calcite veins and lenticular andesite blocks up to 2 m in diameter. Volcanic breccias are exposed at the top of the quarry. They are composed of spherical or angular volcanite blocks embedded in a tuff mass. Dolomitic concretions are common here. The entire volcanogenic complex formed when magma forced its way through channels created earlier by decompressing volcanic gases, which simultaneously crumbled volcanic material to form volcanic breccias.

After visiting the quarry, we head towards Wałbrzych through Głuszyca and Jedlina Zdrój. The road enters varied and highly dismembered relief of the Wałbrzych Mts. Wałbrzych, the major city of the region with the still-living coal mining tradition, lies in a trough-like Wałbrzych Valley.

7 Sowie Mts. Block
(Ludwikowice Kłodzkie–Sokola Pass–Walim –Zagórze Śląskie–Jedlina)

Gneisses and migmatites of Sowie Mts. Block, age of metamorphic and migmatization processes, Walim mineshafts, Zagórze Śląskie dam reservoir, barite veins

The trip to Zagórze Śląskie, into the heart of the Sowie Mts., starts in Ludwikowice Kłodzkie where we turn right on the road to Sokolec and Walim. The road runs along a narrow valley of the Sowi Stream across the Wyrębińskie Hills composed of Lower Permian (sandstones, conglomerates and clay shales) and Upper Carboniferous (conglomerates, sandstones and clays with hard coal layers) sedimentary rocks gently dipping SW'wards, i.e. towards the axis of the Intra-Sudetic Depression. Beyond a valley-shaped topographic low of Sowina village, where the "Kazimierz" hard coal mineshaft was once located, the route enters the area of the Sowie Mts.

Again we are in a world of quite different rocks formed at depths of about 20–25 km in the lower part of the Earth's crust where the temperature and pressure enable total recrystallization, plasticization and even liquefaction of rocks. The Sowie Mts. gneisses and migmatites were formed under such conditions.

These are medium crystalline rocks with more or less oriented structures, light-grey in colour. They are composed of light-coloured quartz-feldspar aggregates separated by thinner dark biotite laminae, with admixture of cordierite, syllimanite, hornblende and garnets. Individual exposures along the route offer various types of gneisses and migmatites – the latter are conspicuous by thicker and more irregular light-coloured laminae, locally showing non-oriented structures. Such a rock resembles a granite or a coarsely crystalline pegmatite. The Sowie Mts. pegmatites form irregular nests and veins of blurred boundaries. They contain beautiful tourmaline aggregates as well as berile and muscovite crystals. Amphibolites, ultrabasic rocks usually represented by serpentinites and granulites (rare rocks composed of quartz, feldspars, garnets and distene and related to high-pressure metamorphism) also occur in the gneisses and migmatites.

The long-term and multi-phase geological evolution of the Sowie Mts. complex had certainly terminated by the Late Devonian. Gneiss pebbles occur in conglomerates of that age in the Świebodzice Depression adjoining the NW margin of the Sowie Mts. Block. On the block itself, the gneiss basement is overlain by patches of Lower Carboniferous sedimentary rocks: conglomerates, greywacke sandstones and clay shales deposited in a shallow sea which covered the Sowie Mts. Block area at that time.

In response to the results of isotopic age determinations of metamorphic processes in gneisses and migmatites, indicating their activity 385–370 My ago (earliest Late Devonian), it is necessary to assume a rapid uplift of the Sowie Mts. Block from depths of about 10–12 km to the Earth's surface.

After crossing the edge of the Sowie Mts., we drive through Sokolec – the well-known health resort – and climb Sokola Pass (754 m a.s.l.). This broad low extends between the Sokół Massif and the main ridge of the Sowie Mts. Sokola Pass offers a beautiful panoramic view of the forested domed summits of the Sowie Mts. Slightly above is a mountain hut.

We drive down the road to the Walimka river valley, through the local ski centre in Rzeczka village. About 1 km before Walim is a car park in front of the Museum of the Walim Shafts. This is one of the most interesting and mysterious military objects of the Sowie Mts. within the so-called Rzeczka Complex.

In 1943, the Germans carried out extensive building works in the Sowie Mts. under the cryptonym called "Riese" ("The Giant"). The building objects have never been completed and there are still a number of underground construction complexes and surface buildings. Their function remains unknown. Uncommonness of these objects has attracted many researchers and adventure hunters to visit Lower Silesia. Galleries existing within Mt. Ostra belong to the best adapted for tourist uses (Phot. 16). They also offer the possibility to watch the Sowie Mts. gneisses and migmatites. The rocks are exposed in artificial rock walls close to the museum entrance and along a scarp of the road to Walim opposite the galleries. The rocks are represented by medium crystalline, flaser or laminated, dark-grey migmatitic gneisses. Close to the main entrance to the shafts, the gneisses are cut by a vein of light-coloured medium-grained granite composed of quartz, feldspars, muscovite and concentrations of a fibrous variety of syllimanite called fibrolite. All evidence indicates that the granite formed by remelting of gneisses at the temperature of approximately 650°C, and the resulting

Phot. 16. The main entrance to the Musem of Walim Galleries. Rocky walls around are built of Sowie migmatic gneisses. Phot. S. Cwojdziński

magma was injected into the overlying gneiss-migmatite complex. In a roadside rock wall we can observe fold deformation of migmatite gneisses with characteristic thickenings of light-coloured laminae in fold hinge zones. Along the hinge axes, small thin quartz-feldspar veins are visible.

The route runs through Walim, a commune village of old mining activities (silver ores), textile and clothing traditions (in particular since the 13th and in the 19th centuries), founded in 1305. We continue our travel along the Walimka river valley (road No. 383) towards Jugowice and Zagórze Śląskie. In Jugowice, we turn northwards to the Bystrzyca river valley (Fig. 11). Numerous gneiss pinnacles occur on both sides of the valley. Just before Zagórze Śląskie, the river turns NE'wards flowing around a montain with the Grodno Castle ruins, one of the oldest Silesian castles built in the 11th century. Here, in gneiss rock just beyond a bridge over the Bystrzyca River (PD 25) we meet the typical oligoclase-biotite migmatitized gneisses (oligoclase is one of the plagioclases i.e. Na-Ca-feldspars) of stromatitic textures, and locally fold textures. The main rock components are quartz, oligoclase, biotite and muscovite. They also contain microcline (K-feldspar), distene, garnet and sillimanite (Al-aluminosilicate) being considered a metamorphic equivalent of clay minerals. Rocks containing this mineral are called "para" rocks and represent metamorphic equivalents of sedimen-

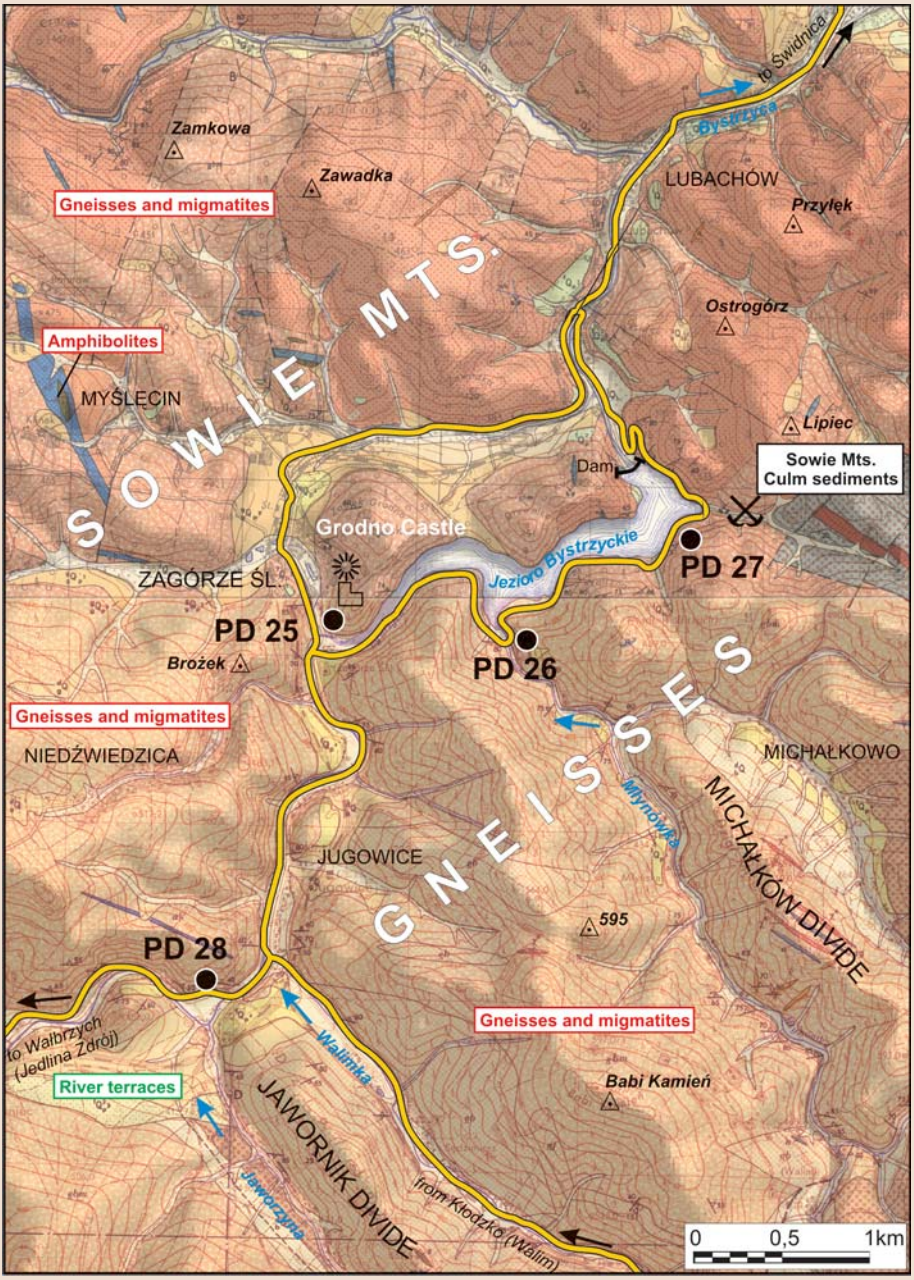


Fig. 11. Geotourist map of the Bystrzyckie Lake (Sowie Mts.) vicinity. Gneisses and migmatites of the Sowie complex, Walim galleries, dam lake in Zagórze Śląskie, barite veins. Documentation points PD 25–28: Zagórze Śląskie, Jugowice. Geological map after SMGS: Walim and Zagórze Śląskie sheets

tary rocks. That is why most of the Sowie Mts. gneisses and migmatites are considered metamorphosed Neoproterozoic to Lower Palaeozoic sedimentary rocks. However, there is also evidence indicating that the whole Sowie Mts. Complex is of "orto" origin, i.e. represents metamorphosed igneous rocks, largely of granite types. The discussion is going on.

The Grodno Castle is not only an interesting historic object, but it is also an excellent viewpoint. The castle is reached following a road from the centre of Zagórze Śląskie. The Grodno Castle ruins are situated upon a small rocky headland of Mt. Chojna rising above the Bystrzyca River in the Sowie Mts.

Tradition says that the castle was founded by Bolko I, the Świdnica-Jawor duke. The Gothic castle was built probably by Bolko II in the first half of the 14th century on a polygon-based plan with a courtyard, 2 residential buildings and 2 towers: donjon in the west and gate tower in the south. The building material was local stone blocks of the Sowie Mts. gneisses. In the 15th century it was owned by knight-highwaymen. The castle was extended in the Renaissance style in the 16th century, and after 1774, it was abandoned and gradually demolished. Today, the castle is partly reconstructed, being a tourist attraction.

From the castle tower is a panoramic view on the Wałbrzych foreland in the north and north-west, and on the forested range of the Sowie Mts. with Mt. Wielka Sowa towards NE. To the west, beyond the ridge of the Czarne Mts. composed of the Sowie Mts. gneisses and migmatites, the serrated Wałbrzych Mts. ridges are visible. They are built of Lower Permian volcanites surrounding the Wałbrzych Valley to the south and west. Note clear difference between the relief of mountains composed of volcanites and the gentle relief of domed summits of the Sowie Mts. Below the castle, Lake Bystrzyca is seen in the deeply incised Bystrzyca river valley. The lake was formed in 1912–1917 (Phot. 17) after building the Lubachów dam, 44 m in height.

Interesting occurrences of the Sowie Mts. gneisses and accompanying rocks can be observed around Lake Bystrzyca. The route follows a narrow asphalt road with nice views over the lake and surrounding forested hills of altitudes ranging from 450 to 510 m a.s.l. Rocky pinnacles and small quarry walls rising along the southern bank of the lake are composed of migmatites of stromatitic textures and irregularly veined migmatites, the so-called phlebites (Phot. 18). Near the Młynówka stream's mouth at the lake, and 300 m further, migmatites containing sillimanite concentrations are observed in an old quarry situated on the right side of the road (PD 26). About 500 m further, several tens of metres east of a dam-view restaurant on the riverbank, there is a rocky pinnacle of migmatites (PD 27) also containing granulites, lighter in colour. Pink garnet crystals and blue-greenish distene grains, up to even 1 cm in length, are visible in the light-cream-coloured quartz-feldspar groundmass. A little bit further, in a side valley, we can watch signs of old mining operations; barite fragments mineralised with zinc sulphide (sphalerite) and lead sulphide (galena) can be found on small mine dumps.

Phot. 17. View at Bystrzyca Lake at Zagórze Śląskie. Phot. S. Cwojdziński

Nice barite specimens (barium sulphate) of high specific gravity often occur in deposits of mountain stream valleys throughout the area between Zagórze and Jedlina. They are remains of abundant, NW–SE-trending barite veins in gneisses. The veins (strictly speaking the associated lead, silver and zinc minerals) have been subject of mining exploitation since the medieval period.

It is also worth stopping for a while to climb the dam to watch the view of Lubachów situated down in the Bystrzyca valley. Small shelves of Pleistocene fluvial terraces are visible in the valley.

Phot. 18. Typical Sowie Mts. migmatic gneiss. Close to the Bystrzyca Lake.
Phot. S. Cwojdziński

After making some geological observations on driving the southern banks of Lake Bystrzyca, in Lubachów we join the main road from Zagórze to Świdnica. There are two journey options now: either to go back southwards to Zagórze offering good accommodation, or to continue our trip up the Bystrzyca river valley towards Jedlina Zdrój (road No. 383).

Driving to Jedlina and further on to Wałbrzych, we can again observe the typical Sowie Mts. migmatitic gneisses composed of quartz, oligoclase, biotite and sillimanite with subordinate contribution of garnets. The rocks are exposed in the southern end of Jugowice, beyond the bridge on the Bystrzyca River, on the northern side of the road in an old quarry and nearby situated small pinnacles (PD 28). Locally, the rocks contain thicker, light-coloured feldspar-quartz veins showing characteristic irregular folding, occasional snake-like winding or lenticular thickenings and narrowings. Such migmatic structures are called ptygmatites. They are typical of the migmatization process which relies on smelting of easily fusible components out of the rock (these are usually feldspars and quartz), that proceeds simultaneously with deformation under conditions of considerable plasticization of the entire complex.

Continuing our route, in Jedlinka we meet the main road from Nowa Ruda to Wałbrzych (road No. 381) and we can either turn right towards Wałbrzych – until recently the main coal-mining centre of Lower Silesia – or turn left towards Głuszyca and then, at the beginning of the town, take the road (No. 380) towards Rybnica Leśna and Unisław Śląski. The former route leads to the centre of the Wałbrzych Trough filled with Carboniferous coal-bearing deposits; the latter moves us into the world of Lower Permian sedimentary rocks and volcanic sheets of the north-eastern flank of the Intra-Sudetic Depression.

8 Kamienne Mts. volcanic formations
(Głuszyca–Rybnica Leśna–Wałbrzych)

Lower Permian volcanism, volcanic cycles, acid and basic rocks – bimodal volcanism, various forms of volcanic bodies

The road (380) runs along a narrow, gorge-like valley of the Rybna Stream separating the Wałbrzych Mts. with the Rybnicki Range in the north, from the Suche Mts. in the south. Most of the hills throughout the area are composed of resistant volcanic rocks substantial for the topography framework. Outcropping Upper Carboniferous and Lower Permian sedimentary rocks occur in topographic lows and form belts trending from NW–SE between Łomnica and Grzmiąca (Upper Bystrzyca Depression) to WNW–ESE between Rybnica Leśna and Unisław (Unisław Upland) (Fig. 12).

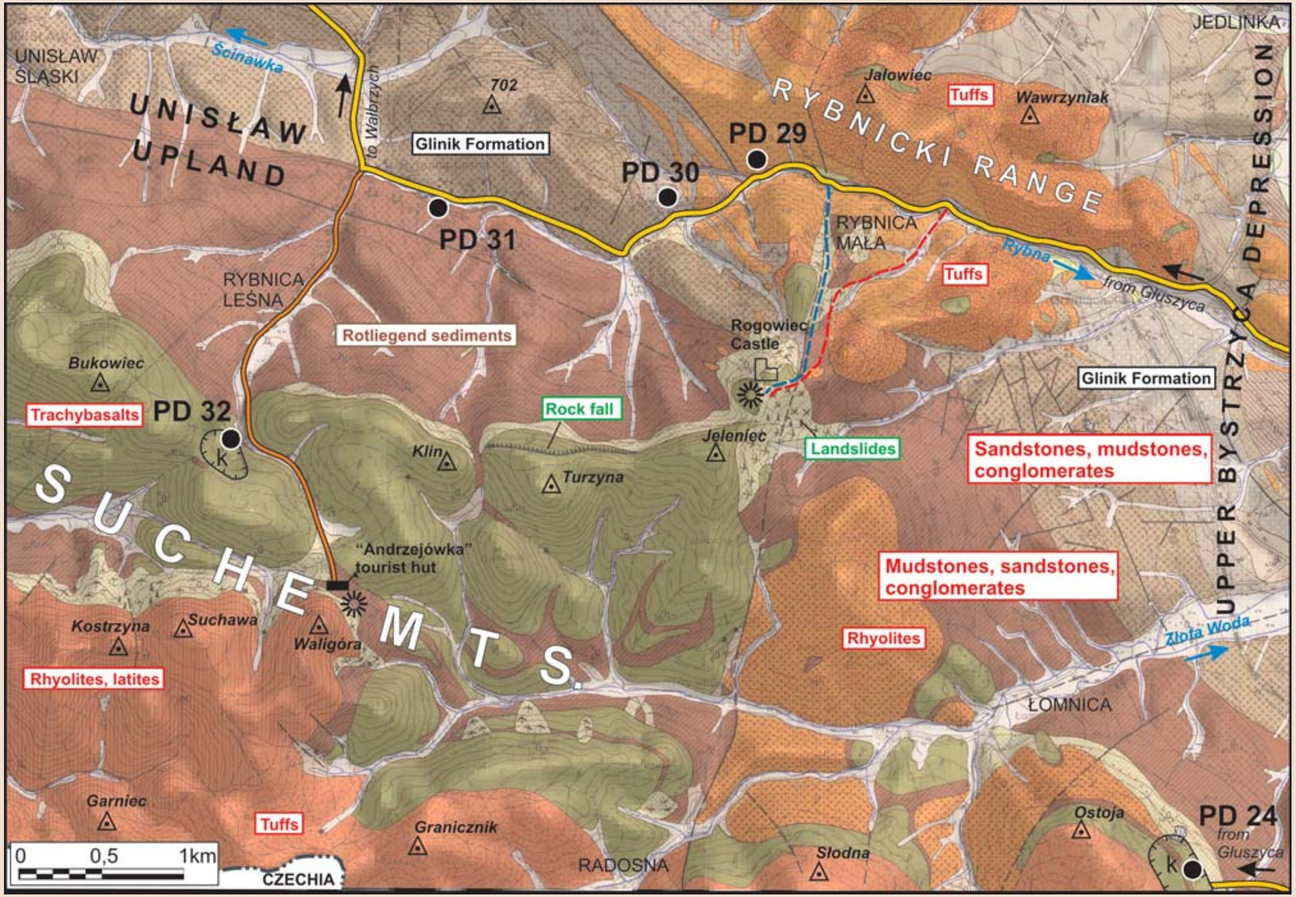


Fig. 12. Geotourist map of the Rybnica Leśna vicinity. Lower Permian volcanism, volcanic cycles, acid and basic rocks – bimodal volcanism, volcanic bodies of different shape. Documentation points PD 24, 29–32: Rybnica Mała, Rybnica Leśna, "Andrzejówka" mountain hut. Geological map after SMGS: Jedlina Zdrój sheet

Volcanite bodies of the Rybnicki Ridge and the meridionally arranged mountain ranges extending south of the Rybna gorge (Jeleniec Mały) are composed of acid volcanites of rhyolite and rhyodacite types accompanied by rhyolite tuffs and pyroclastic breccias being products of dramatic volcanic eruptions. The bodies represent a system of volcanic pipes cutting the surrounding Upper Carboniferous (Namurian and Westphalian) deposits or shallow intrusions, and hence they are considered Upper Carboniferous in age. The whole complex of volcanites is transected by a system of faults. At least part of the faults were pathways for magma rise.

Typical rhyolites can be observed near the road from Głuszyca to Rybnica Leśna along the stream gorge and slightly further westwards before Rybnica Leśna (PD 29). It is worth stopping at Rybnica Mała from where (at two different points) tourist routes (red-marked and blue-marked) run southwards to Mt. Jeleniec Mały and the Rogowiec castle ruin. The walk takes about 30 minutes one way. The castle itself is the highest situated object of its type in Poland. The summit offers a panoramic view over the whole surrounding area with the Wałbrzyskie and Kamienne mountains. A number of small pinnacles of rhyolites and rhyolite tuffs are scattered throughout the mountain ridge and its slopes. The characteristic feature of the area is remodelling of the slopes by numerous landslides.

About 750 m further westwards, sedimentary rocks of the youngest Upper Carboniferous formation (Glinik Formation) are exposed in the slopes extending north of the road (PD 30). These are uppermost Westphalian and Stephanian represented by sandstones and mudstones with conglomerate interbeds, variable in colour: red-brown, pink, grey-green, creamy and mottled. The rocks are overlain by conglomerates composed of pebbles representing various types of rocks, and hence they are called polymictic. Among the pebbles, there are also volcanic rocks.

The last section of the road to Rybnica Leśna runs parallel to the intersection boundary of the uppermost Carboniferous rocks to the right and of the lowermost Permian rocks to the left of the road. In the village of Rybnica Leśna, dark-grey lacustrine mudstones and claystones are exposed in an erosional scarp of the southern bank of the Rybna stream (PD 31). These are the so-called Anthracosia Shales, one of the important lithologic horizons of the Sudetic Lower Permian (Rotliegend), belonging to the sedimentary rock formation that formed prior to the period of strong volcanism.

In Rybnica Leśna, at the crossroads to Wałbrzych and Unisław Śląski we turn southwards across the village towards the Suche Mts. After 2-km drive among gently sloping hills composed of Lower Permian (Rotliegend) sandstones, mudstones and claystones of characteristic red and brown colours, we are between Mt. Bukowiec and Mt. Klin of the Suche Mts. ridge.

From the geological point of view, the Suche Mts. rocks represent the Lower Permian volcanic formation of the Kamienne Mts., occurring in the Intra-Sudetic Depression. The Kamienne Mts. Volcanic Formation, partly interfingering with the Lower Permian sedimentary deposits and giving with them thermal contacts, consists of a member of trachybasalt-type basic rocks and a member of neutral and acid rocks represented by latites, rhyolites, rhyodacites and rhyolite tuffs.

To the right of the road is a large active quarry of the "Rybnica I" deposit (PD 32, Phot. 19), established between Mt. Bukowiec, Mt. Klin, Mt. Gomólnik and Mt. Jeleniec within a huge sheet of massive trachybasalts overlying the Lower Rotliegend claystones and mudstones with sandstone interbeds. The volcanite complex gently dips southwards at the angle of 25–30° and attains a thickness of 80 to 120 m. It is probably a shallow-seated subvolcanic sheet intrusion within a sedimentary complex of the Słupiec Formation. There is no evidence that any volcanic vents or pipes for magma travel existed in this area. Towards the east, the subvolcanic trachybasalts gradually pass at the top into several lava flow sheets alternating with red claystones. Northern slopes of the Suche Mts. are prone both to block landsliding of volcanic rocks (by squeezing of plastic sedimentary base), e.g. northern slope of Mt. Turzyna) and to forming slumps and accumulations of blocks (e.g. in the Jeleniec–Rogowiec region).

In terms of petrography, volcanic rocks of the "Rybnica I" deposit are commonly called melaphyres represented by augite trachybasalts corresponding to andesites according to the petrographical classification of volcanic rocks. These are massive rocks of aphanitic or fine-grained, rarely vesicular, structure, dark-grey to grey-pink in colour, brown or red-grey if weathered. Their mineral composition includes plagioclases, orthoclase, pyroxene (augite), hornblende, occasionally altered olivine and small amounts of quartz. The rocks are highly fractured and cut by 2–3 m-thick fault zones of brecciated rock.

Phot. 19. Fragment of large trachybasalts active quarry of the "Rybnica I" deposit (PD 32). Phot. A. Ihnatowicz

After visiting the quarry (a permit is required), we drive to Hala (coom) beneath Mt. Klin and the well-known mountain hut “Andrzejówka”. We are in a beautiful mid-mountain planation surface with a magnificent view towards the south over the main ridge of the Suche Mts. The Waligóra and Suchawa massifs, the highest summits of the Suche Mts., are composed of rhyolites and quartz latites. Such gradual transitions are typical of igneous rocks in which even small differences in mineral composition allow for giving new names to the rocks. The elongated, 50 km-long Suche Mts. ridge extending along the Polish/Czech border, is composed of rhyolite tuffs. The tuff cover attains 300 m in thickness and gently dips SW’wards. The rocks are grey-red or red in colour, massive or bedded, frequently porous with abundant fragments of volcanic and metamorphic rocks and volcanic glass (vitroclastic tuffs). Their thickness and size of outcrops indicate that the Early Permian volcanic events were of large extent in this area of the Sudetes Mts. That ancient world of volcanoes, dramatic ash and gas eruptions, lava flows, extensive landslide processes, mud flows and strong erosion, was quite different from the present one. The Kamienne Mts., including the Suche Mts., are a distant reflection of those times.

Coming back from “Andrzejówka”, we drive again through Rybnica Leśna towards Wałbrzych. Before the crossroads with the Unisław Śląski–Glinik Stary road, there is a beautiful view from a hill at the elevation of 666 m a.s.l. To the north is the Wałbrzych Valley and the city of Wałbrzych; the Suche Mts. extend to the south. Through Glinik Nowy (road No. 377), we drive down to Wałbrzych to either have a tour round the city and its environs or drive on towards Kamienna Góra (road No. 367).

9 Wałbrzych Coal Basin
(Wałbrzych–Boguszów and environs)

Wałbrzych Trough, Upper Carboniferous coal-bearing sedimentary formations, hard coal mining traditions, Wałbrzych mine dumps, Upper Carboniferous volcanism, Boguszów barite deposit

Wałbrzych is reached following the road descending from Jedlina Zdrój. The population of Wałbrzych is about 120,000. In 1305, a settlement was established here. In around 1400, the village was granted town rights. A rapid growth of the city, associated mainly with industrial growth in particular of mining and coking industry, took place in the 19th century. Until recently, the city was a large industrial centre, the capital of Wałbrzych voivodship and the mining centre with 3 coal mines. Nowadays, after the closure of all mines, the city gradually starts to recover its rank of a modern industrial centre as the capital of the district of Wałbrzych.

From the geological point of view, the Wałbrzych Coal Basin is situated in the centre of an oval trough being a branch of the Intra-Sudetic Depression, called the Wałbrzych Trough (Fig. 13). The trough is separated from the Sowie Mts. Block by a system of frame faults. Carboniferous sedimentary rocks form around Wałbrzych a belt of outcrops dipping at moderate angles towards the trough centre. The rocks are cut by numerous faults, which have always complicated the conditions of coal mining. The characteristic feature of the Wałbrzych Trough is the presence of numerous acid volcanic rocks along its eastern flank. These are rhyolites, tuffs and rhyolite breccias composing hills in the SE part of Wałbrzych. In addition, the Chełmiec and Trójgarb massifs, closing the trough to the west, are composed of rhyolites. Mt. Chełmiec and Mt. Mniszek rise above the town of Boguszów – the next target of our travel in the Intra-Sudetic Depression.

The oldest rocks of the Wałbrzych Trough are represented by Lower Carboniferous continental deposits of the so-called Sudetic culm facies: conglomerates, sandstones, mudstones and clay-mud shales containing abundant floral remains and displaying the characteristic grey and grey-green colours. The rocks are separated from the Sowie Mts. gneisses by faults causing their steep near-fault dips towards the centre of the trough at the angle of 60–70°. The rocks were deposited mainly during the Visean (younger stage of the Lower Carboniferous) in an intramontane foredeep basin surrounded by strongly eroded mountain ranges. That was a foreland-type sedimentation resulting in the formation of large alluvial fans deposited along the mountain margin. The fans coalesced forming an extensive cover of deposits accumulated in shallow and broad river channels. Only at the end of the Visean, a shallow sea entered the area and left sand-conglomerate and mudstone deposits. Geologists estimate that the total subsidence of the Intra-Sudetic Basin sea floor reached 5–7 km during Early Carboniferous times. Thus, it was a highly dynamic basin.

The Sudetic Culm deposits are outcropped in small rocky pinnacles along the northwestern slope of the Mt. Ptasia Kopa in the NE part of Wałbrzych (PD 33). They are reached by a blue-marked tourist route following Pocztowa Street, a side street to 11 Listopada Street, which led us to the city centre from Jedlina Zdrój (road No. 381). The valley is called Głęboki Wąwóz. The outcropping deposits – conglomerates and dominant mudstones, mud shales and claystones, represent the upper part of the Szczawno Formation. The mudstones are grey through green to brownish in colour. Harder varieties of the mudstones are characterized by much higher content of quartz and micas, whereas softer ones contain admixture of clay material.

Upper Carboniferous deposits, the most important rocks in the Wałbrzych Trough due to their coal-bearing nature, fill the trough interior. They attain here the greatest thickness in the Intra-Sudetic Depression, up to 2000 m. They are composed of continental deposits of fluvial (conglomerates, sandstones and mudstones) and swamp (hard coals and carbonaceous clay shales) origin, representing the older Wałbrzych

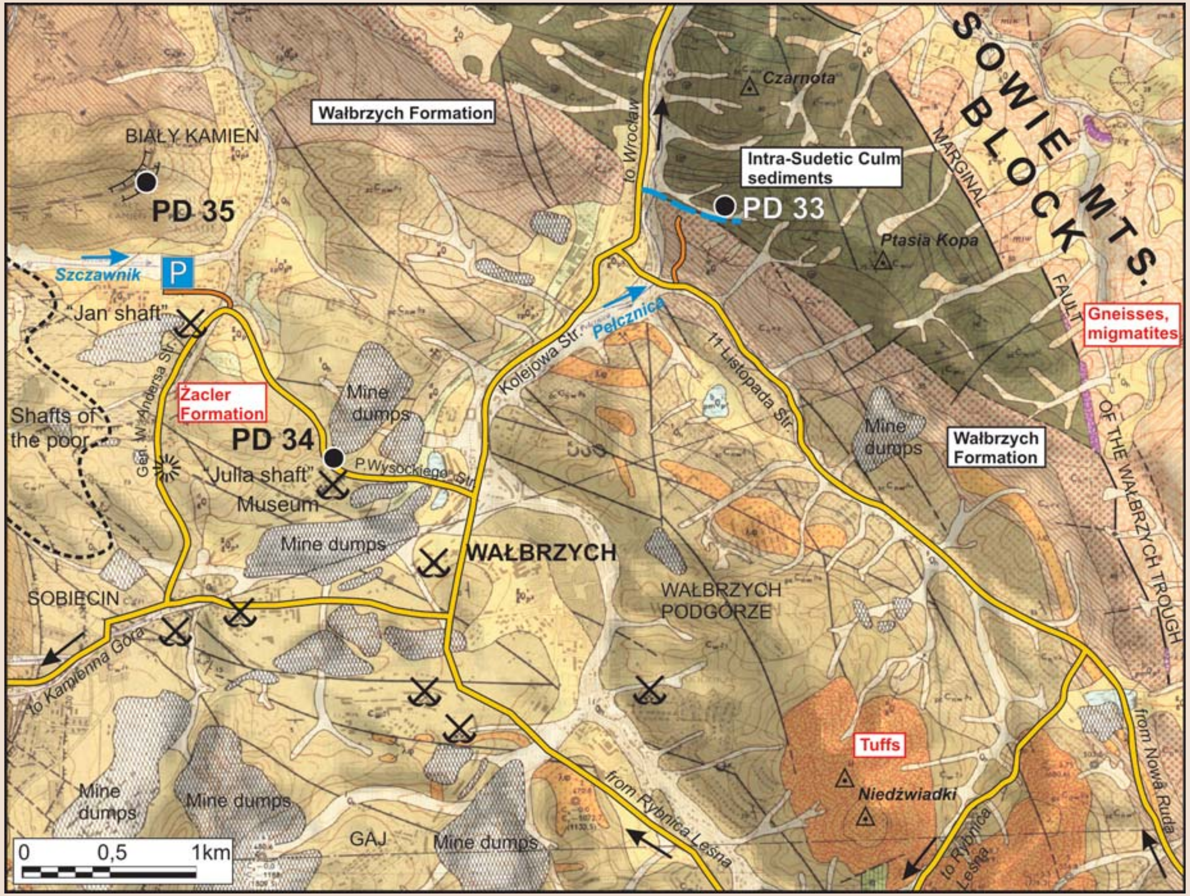


Fig. 13. Geotourist map of the Wałbrzych vicinity (Lower Silesian Coal Basin). Wałbrzych Trough, Lower Carboniferous sedimentary rocks, Upper Carboniferous coal-bearing sedimentary formations, coal mining traditions, Wałbrzych mine dumps, mineshafts of the poor. Documentation points PD 33–35: Wałbrzych, Biały Kamień. Geological map after SMGS: Wałbrzych and Boguszów sheets

Formation and the younger Žaclěř Formation. Both of them contain numerous coal seams. The last tonne of coal was mined in Wałbrzych at the end of June 1998. Since then, many mining objects have been shut down throughout the area. Most of mine derricks have been destroyed. The following mine shafts no longer exist: "Pokój" between Rusinowa and Jedlina Zdrój, "Krakus" in a forest of the Wałbrzych's Nowe Miasto quarter, "Jadwiga" between Sobięcin and Kuźnice, "Barbara" in Kuźnice and "Victoria" (main shaft). The shortest-lived "Kopernik" shaft, once located to the south of Sobięcin, and the "Wanda" shaft do not exist any longer, either.

The following shafts have happily survived: "Irena" in Emilii Plater Street (Sobięcin), "Jan" (Phot. 20), "Tytus" (Biały Kamień), "Teresa" (Rusinów), "Chwalibóg" (Stary Zdrój), "Staszic" and "Eugeniusz" (Podgórze) and "Chrobry" and "Matylda" in Beethoven Street. There are also several buildings, now reminders of the mining industry in Wałbrzych. In the former Thorez mine ("Julia" and "Sobótka" mineshafts) is the Industry and Technology Museum (PD 34) (Piotra Wysockiego Street) which, although undoubtedly worth visiting, unfortunately does not offer any underground mine tour. Another relic of the coal mining are mine dumps visible all aroud the area. Some of them have recently been reclaimed and turned into green space, the rest are still typical dumps. They are interesting for Carboniferous plant-fossil collectors, as beautiful imprints of fern leaves, lepidodendrons, sigillaria stems, and rare fragments of fossil stems can be found there.

Well-exposed rocks of the Wałbrzych and Žaclěř formations occur along the cutting of an abandoned railway line east of the city's Biały Kamień quater. The exposures are reached following 11 Listopada and Kolejowa streets across the city centre, and then along Piotra Wysockiego Street. En route, we can visit the nearby-situated Industry and Technology Museum near the "Julia" shaft, in particular its upper mining part. Having reached Generała Andersa Street, we leave our car in a car park at Piasta Street and walk up the hill above Biały Kamień.

Phot. 20. Wałbrzych. Closed mine-shaft "Jan". Phot. S. Cwojdziński

In the railway cutting (PD 35) there is about a dozen metres thick succession of repeated cycles composed of (from bottom to top) fine- or medium-grained conglomerates, sandstones, mudstones and mudstones with carbonaceous shales. This series corresponds to the top part of the Wałbrzych Formation and is overlain by coarse pebble conglomerates interbedded with sandstones, and belonging to the so-called Biały Kamień Beds representing the lowermost part of the Žacléř Formation. The boundary between these formations is concordant, although they considerably differ from each other by their petrographical compositions. The Biały Kamień conglomerates contain more pebbles of various rock types, and the sandstones include numerous feldspar fragments. Such composition of the sedimentary rocks indicates that a new evolutionary stage of the Wałbrzych Trough began at that time. It was associated with intense tectonic movements within the basin frames.

In the railway cutting, further NW'wards near Konradowo, there is another section of Wałbrzych Formation strata with an approximately 40 m-thick succession exposed. Besides the typical assemblage of conglomeratic sandstones, conglomerates, mudstones and claystones of variably thick strata, a 0.5 m-thick hard coal seam can be observed in this exposure. In the geological map, coal seams outcropping at the ground surface are marked between the arch of the old railway route and Sobięcin. The outcrops, commonly invisible directly on the surface, appear to the west and north of the city. They are illegally exploited by former Wałbrzych miners in the so-called mineshafts of the poor (Phot. 21).

Phot. 21. Mineshaft of the poor in the western part of Wałbrzych. Phot. A. Ihnatowicz

Having been acquainted with the typical section of the Wałbrzych Formation and the lower part of the Žacléř Formation, we go southwards following Generała Andersa Street towards Sobięcin (road No. 375). On the way, there is a viewpoint with a nice view of the city's industrial area with numerous dumps cones in the foreground and the high summit of Mt. Chełmiec in the west. In Sobięcin, we take 1 Maja Street (road No. 367) to drive towards Kamienna Góra.

The town of Boguszów is our next stop. This small town, situated on the southern slopes of Mt. Chełmiec, has a long history of mining traditions. By the early 1990s, hard coal (and barite) was extracted in this area in the mineshafts of "Witold" (in Gorce) and "Barbara" (in Kuźnice Świdnickie) of the "Victoria" Coal Mine. The mining traditions were continued for hundreds of years from 1499 to 1994. The period of almost uninterrupted exploitation ended when the decision to close the mines was ultimately made.

The geology of the Boguszów region is dominated by occurrences of volcanic rocks composing the Chełmiec (869 m a.s.l.) and Mniszek massifs (711) situated to the north of the town (Fig. 14). The topographic lows between volcanite outcrops consist of softer, weathering-prone Lower and Upper Carboniferous sedimentary rocks represented by the same lithological types as in the Wałbrzych region.

The most interesting geological feature in this area is the Chełmiec Massif. This strongly dismembered mountain is one of the highest summits within the Intra-Sudetic Depression. The massif is composed of rhyodacites – acid volcanic rocks of slightly higher content of plagioclases than rhyolites. The rocks form a shallow-seated, so-called hypabyssal, intrusion within Upper Carboniferous sedimentary rocks. Due to such position, the Chełmiec volcanites are also considered Upper Carboniferous in age. The rocks around the intrusion were domed by the intrusion to form a feature clearly visible in the geological map. They surround the dome core by increasingly large concentric belts. The top of the dome has been eroded away revealing at the ground surface its rhyodacite core being more resistant to erosion than the surrounding rocks. The intersection image indicates that the Chełmiec Massif forms a laccolith i.e. a mushroom-like magmatic body partly conformable with the surrounding strata. A smaller intrusion of Mt. Mniszek, of similar geometry, extends from the Chełmiec laccolith towards the south-west. Towards the south-east there is a rhyodacite dyke cutting across the Upper Carboniferous rocks.

Mt. Chełmiec is such an interesting geological feature that it is worth spending some time for climbing its summit with a view tower offering a superb panorama (PD 36). The easiest way to reach the summit is to follow a green-marked tourist route from the centre of Boguszów. There is also a route from the Grunwaldzkie housing estate. En route, the typical Chełmiec rhyodacites can be observed both in rocky blocks on the mountain slope and in several small old quarries. The very fine-grained groundmass of these pink-grey rocks contains small feldspar (orthoclase) crystals and dark biotite. The rock

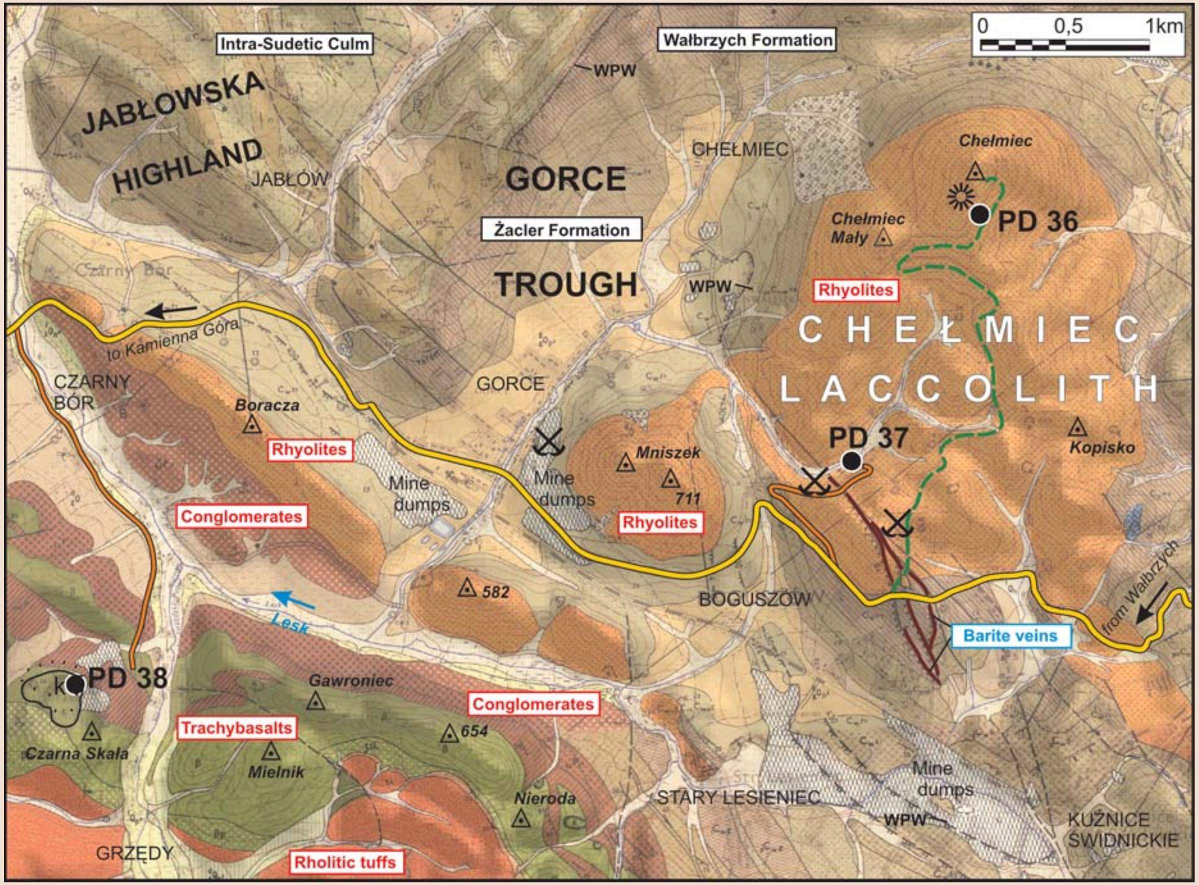


Fig. 14. Geotourist map of the Boguszów vicinity. Upper Carboniferous volcanism, Chełmiec Laccolith, Gorce Trough, barite deposits in Boguszów, Lower Permian volcanites: trachybasalts, rhyolites, tuffs. Documentation points PD 36–38: Chełmiec, Boguszów, Grzędy. Geological map after SMGS: Boguszów and Mieroszów sheets

structure indicates fast magma cooling in shallow, near-surface parts of the Earth's crust. Minute crystals, which crystallized in magma before its fast solidification, are called phenocrystals. Rhyodacites are commonly irregularly fractured.

Looking southwards from the top of Mt. Chełmiec, we can see a forested ridge of the Kamienne Mts. consisting of Lower Permian (Rotliegend) volcanic rocks. To the east, there is the Wałbrzych Valley closed in the horizon by the Sowie Mts. and in the SE by the sharp peaks of Niedźwiadki, Wołowiec and Borowa also composed of volcanic rocks, but of Upper Carboniferous age. To the NW is the vast Trójgarb Massif – a rhyolite intrusion surrounded by Lower Carboniferous rocks and resembling that of Mt. Chełmiec. In the far horizon, during fine weather, we can see the Rudawy Janowickie ridge, the target of our future journey.

To the west of Mt. Chełmiec, the Upper Carboniferous coal-bearing rocks form a local depression called the Gorce Trough. This is where the "Witold" shaft was once located. To the south of Boguszów, the geological boundary between Upper Carboniferous deposits and Rotliegend sedimentary and volcanic rocks runs to the west and south of the town across the slopes of the Boracz ridge, hill 582 and other no name hills. Still further south, beyond the Lesko stream valley, is another series of NW–SE-elongated ridges composed of trachybasalts – basic volcanic rocks. The ridges are part of the Lesista range of the Kamienne Mts.

The Chełmiec laccolith has long been renowned for its barite mineralisation. The barite deposit zone, associated with volcanite breccias, is narrow and extends from the NW towards SE over a distance of more than 2 km. The main barite vein (average thickness of 1.5 m) has been traced down to a depth of 700 m. Barite is accompanied by fluorite and sulphides of copper (chalkopyrite), zinc (sphalerite) and lead (galena) which, however, have never been of economic importance.

The barite mine was closed in the mid-1990s. Nevertheless, it is worth visiting the main mineshaft located in a valley cutting the SW slopes of Mt. Chełmiec (Młodzieży Polskiej Street) (PD 37). Today, the shaft and accompanying buildings no longer exist, but the adjacent mine dumps offer interesting specimens of barite and altered, whitened and brecciated rhyodacites.

After visiting the Chełmiec Massif and its environs, we continue our travel to the west driving the road (No. 367) towards Kamienna Góra. En route, it is worth diverting off the road in Czarny Bór to see a large active quarry at Grzędy, about 2.5 km south of the main road. In the quarry (PD 38) (permit from the quarry management is obligatory) we can observe dark-grey massive aphanitic volcanic rocks of trachyandesite chemical composition. They form here a huge 70 m-thick plate gently sloping south-westwards. The quarry reveals a conformable contact between the volcanites and the underlying sandstones and mudstones showing brecciation and whitening close to the contact surface, indicating intrusive nature of the series. Similar phenomena are observed in the top part of the volcanite series. The lower portion of the volcanite plate consists predominantly of massive lavas; in the upper portion, the lavas are vesicular and amygloidal. Vesicular lavas are full of bubbles resulting from its rapid degasification. If the bubbles are filled with secondary minerals such as calcite, zeolites, chalcedony etc. then we speak about amygdales. The volcanites are intensely fractured. Near the contact with sedimentary rocks, they show thin platy parting parallel to the contact surface. In the central parts of the plate, vertical fractures are predominant and blocky or thick platy parting is observed. The extraordinarily interesting features are vertical, volcanite-crossing sandstone and breccia "veins", up to 5 m in thickness (e.g. in the southern part of the quarry). They formed as the result of the effect of lava-heated pore waters on unconsolidated sedimentary rocks, which caused liquefaction of sand to form the "veins" in trachyandesites. From Grzędy we drive back to the main road to continue our travel towards Kamienna Góra.

10 Intra-Sudetic Depression – western part
(Wałbrzych–Kamienna Góra–Krzeszów –Lubawka–Kamienna Góra–Marciszów Górny)

Intra-Sudetic Depression axis, Krucze Mts. Volcanic Complex, sub- and supra-volcanic Rotliegend formations, Upper Cretaceous succession of the depression.

The road runs north of the Lesista and Czarny Las hills. Both of the mountain areas are composed of Rotliegend volcanic rocks represented mostly by massive trachybasalts forming extensive covers among sedimentary rocks. To the north of the road is a hilly land with gently sloping hills and broad river valleys. These are the Jabłów Highland and Lesko Lowland, whose relief is due to the occurrence of Lower and Upper Carboniferous sedimentary rocks poorly resistant to weathering. Immediately before the town of Kamienna Góra is a road bend providing a wide view of the town situated in a broad depression of the Bóbr river valley and on the slopes of the Krucze Mts. To the west is the long mountain range of Rudawy Janowickie and the huge Karkonosze Massif.

It was as early as the 13th century when a small castle was built on a hill rising at the junction of the Bóbr and Zadrna rivers. Its location was due to the trade route passing through the Lubawka Gate. At the end of the first half of the 13th century, Kamienna Góra was mentioned in the Silesian documents. Town rights were issued in 1292 during the rule of Duke Bolko I. Thanks to its long history, the town offers many historic monuments, in particular within the limits of the Old Town. There are also traditions of textile industry and the Lower Silesian Weaver`s Craft Museum. Kamienna Góra is an excellent starting point for mountain walking, cycling and car touring.

The geological structure of the Kamienna Góra–Krzeszów–Lubawka region is dominated by the characteristic arch of outcropping Carboniferous and Lower Permian rocks, manifested in the topography by the Krucze and Czarny Las Mts. composed chiefly of resistant Lower Permian volcanic rocks (Fig. 15). A change in strike of the outcrops from NW–SE to NNE–SSW, observed near Kamienna Góra, is the result of tectonic structure of the Intra-Sudetic Depression – its axis gently plunges south-eastwards and its flanks dip at the angle of about 15°. Lower Carboniferous rocks appear at the ground surface on both sides of the Bóbr valley. The Visean conglomerates and coarse-grained sandstones contain characteristic mudstone and fine-grained sandstone layers. Upper Carboniferous sedimentary rocks, conformably overlying older strata and represented by the typical conglomerates, sandstones and mudstones with hard coal seams of the Wałbrzych and Žacléř formations, are not currently available for direct field observation. The main ridge of the Krucze Mts. consists of outcropping rocks of the Kamienne Mts. volcanic complex, the same we have already explored in the Rybnica Leśna region. The complex includes both basic rocks represented largely by trachybasalts and trachyandesites, and acid rocks – rhyolites and rhyolite breccias. The contribution of acid rocks increases southwards to become dominating near Lubawka. The volcanites form a thick continuous series surrounded by Rotliegend sedimentary rocks outcropping outside (sub-volcanic complex) and inside (supra-volcanic complex) the volcanite arch.

Trachybasalts are exposed in a quarry at Borówno (PD 39). They are represented by a 50 m-thick series of massive black or dark-violet aphanitic rocks containing small plagioclase phenocrystals (labradorite). The especially complicated structure of these rocks can be observed in 3 abandoned quarries located on the slope of Mt. Łysina in Kamienna Góra (PD 40), and in the northern slope of the Zadrna river gorge (Czadrów Break) in the Krucze Mts. (Phot. 22). Rocks of three lava flows occur in this area, especially well exposed in the northern quarry. Tuffs and sandstones with mudstones separate the lava flows represented by massive, vesicular and amygloidal trachybasalts, as well as volcanic breccias composed of angular fragments and blocks of volcanites and sandstones cemented with tuff material. The typical feature of these rocks is the presence of fragments of basement sedimentary rocks within the lavas, and the so-called clastic dykes i.e. veins of indurated sand and mud in the lavas. Top parts of the lava flows contain concentrations of secondary minerals (chalcedony, carneole, calcite and

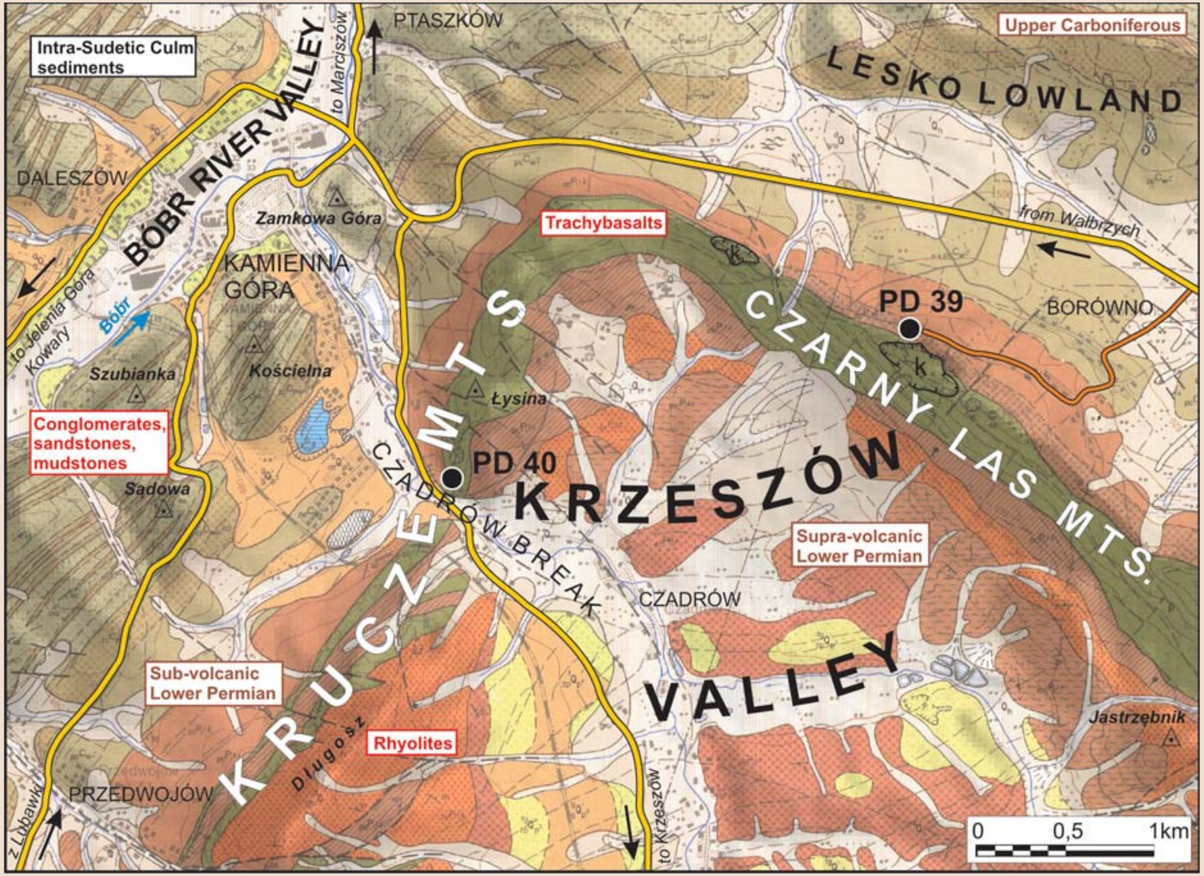
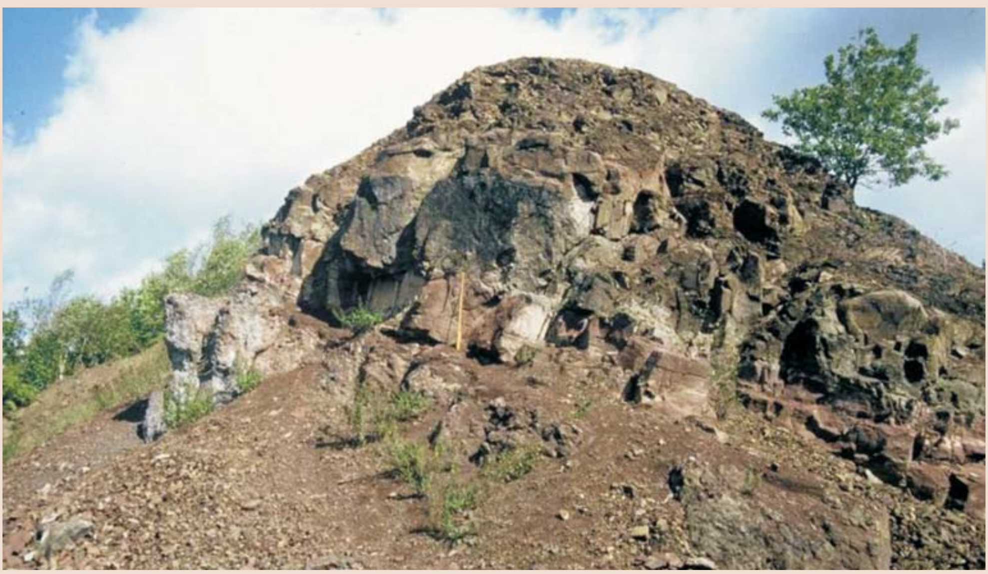


Fig. 15. Geotourist map of the Kamienna Góra vicinity (Krucze Mts., Czarny Las Mts.). Intra-Sudetic Depression axis, trachybasalts of the Czarny Las Mts., Lower Permian sedimentary formations: sub- and supravolcanic. Documentation points PD 39–40: Borówno, Czadrówek. Geological map after SMGS: Kamienna Góra and Lubawka sheets

even agates), due to the effect of hot post-volcanic solutions. The entire geological setting observed in the Łysina quarries indicates that it was a slope of an Early Permian shield volcano. Geological investigations suggest that its centre was located to the SE of the present-day exposure.

After visiting the quarries, we travel south towards Krzeszów, ascending along the Zadrna valley. Just behind the Czadrów Break, the road enters a vast depression of the Krzeszów Valley filled with sedimentary rocks of the upper part of the Rotliegend represented by mudstones, sandstones and conglomerates, as well as fanglomerates of the supra-volcanic complex. The last-mentioned are coarse-grained sedimentary rocks composed of angular and unoriented fragments of various rocks embedded within the sandy groundmass. Such rocks form within vast alluvial fans deposited near topographic highs. In this case, the fanglomerates formed due to washing away of older volcanic sheets. Extensive covers of Pleistocene deposits, represented by tills, sands and gravels of small thicknesses, are also observed in the valley.

On approaching Krzeszów, 8 km from Kamienna Góra, we can admire (even from a certain distance) the towers of the renowned Baroque Cistercian Abbey built in the first half of the 18th century. This is one of the most valuable historical complexes of



Phot. 22. Brecciated trachybasaltic lavas with tuffs and sandstones intercalations. Northern part of closed quarry in Kamienna Góra. (PD 40). Phot. M. Awdankiewicz

Baroque buildings in Poland, comprising 2 churches, Mausoleum of Lower Silesian Piast Dukes, 32 Calvary Chapels located west of Krzeszów on the gentle slopes of the Krucze Mts., and the Betlehem Palace – a small palace on the water – the summer residence of abbots. The most beautiful view of Krzeszów with the Karkonosze Mts. in the background is from the base of Mt. Święta Anna in the Krzeszów Hills – 2 km to the east.

The area situated south of Krzeszów is a quite different geological world (Fig. 16). We step into the kingdom of Upper Cretaceous outcrops of ages and lithologies similar to those observed in the Stołowe Mts. The Upper Cretaceous rocks of the Cenomanian and Turonian stages are best exposed in the Krzeszów Hills east of Krzeszów and south of the village of Zawory. The intersection image of Cretaceous deposits represented mostly by quartz and glauconitic sandstones (glauconite is mineral representing hydrated micas, it is characteristically green and forms in marine environments) differs from the image of Carboniferous and Permian rocks. The outcrop boundaries are parallel to isohypses, indicative of mostly horizontal position of strata. The Cretaceous succession was deposited upon an older basement in a shallow sea that inundated the area after a long non-deposition period spanning early Triassic through early Cretaceous times (over 140 My). They represent the youngest rock formation filling the Intra-Sudetic Depression.

From Krzeszów we go westwards following a local narrow asphalt road through Lipienica to Lubawka. Gentle slopes of the hills become steeper as we step into the Krucze Mts. The road winds up the main ridge between Lipowiec and Drążona. The whole mountain ridge is a 300 m-thick plate-shaped outcrop of the Krucze Mts. volcanic complex gently dipping eastwards (Fig. 16). Around Lubawka, there are only rhyolites represented by massive rocks, volcanic breccias and „rhyolitic" sandstones. The rocks are also referred to as trachytes, in particular when they contain a small amount of quartz and their chemical composition corresponds to rhyolites.

Typical massive rhyolites occur in several old quarries on the western slopes of Mt. Święta Góra (PD 41) in Lubawka. The rocks are grey-pink and pink-violet in colour. Irregularly dispersed platy feldspar phenocrystals of sanidine (high temperature variety of potassium feldspars) and albite are embedded in the aphanitic or very fine-grained groundmass composed of plagioclases, sanidine, quartz, biotite and hematite. The rhyolites are strongly fractured exhibiting sheet jointing, parallel to the basement of the volcanic sheet, and vertical joints. The quarries reveal a contact between the volcanites and the underlying sedimentary rocks of the sub-volcanic complex. Volcanic breccias are observed in places, composed of subrounded and angular calcite- or barite-cemented rhyolite blocks up to 50 cm in diameter. The Krucze Mts. rhyolites are a complex, asymmetric volcanic body. Its central part was probably located further to the south, west of Chełmsko Śląskie. To the north, along the mountain ridge, the amount of massive rhyolite lavas decreases in favour of tuffs.

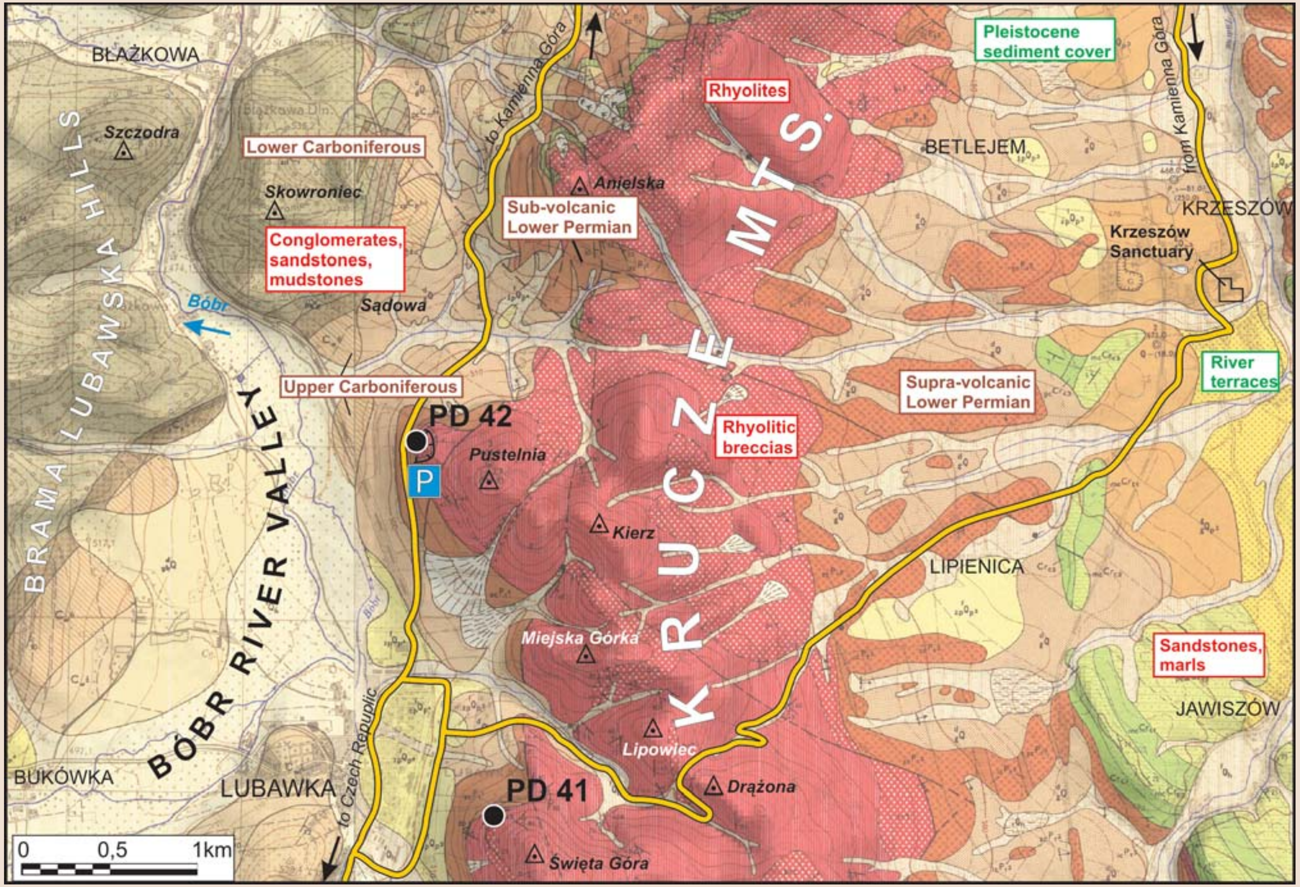


Fig. 16. Geotourist map of the Krzeszów – Lubawka vicinity (Krucze Mts., Krzeszów Valley). Krucze Mts. Volcanic Complex (rhyolites, tuffs, rhyolitic breccias), Lower Permian sedimentary formations, Upper Cretaceous of the Intra-Sudetic Depression (jointed sandstones, mudstones, marls). Documentation points PD 41–42: Lubawka. Geological map after SMGS: Lubawka, Szczepanów sheets

Driving northwards from Lubawka to Kamienna Góra (road No. 371), we stop at a roadside car park in an abandoned quarry located on the slope of Mt. Pustelnia (PD 42). Laminated rhyolites showing thin platy parting parallel to fluidal structures are exposed in the quarry. The fluidal structure developed due to lava flow during eruption. It is accentuated by directional orientation of feldspar phenocrystals and clearly visible streaking due to alternating lighter and darker laminae. From outside the quarry there is a wide view of the Rudawy Janowickie and Karkonosze mountains. In the foreground, beyond the broad flat-floor Bóbr river valley, are the low Lubawka Break Hills extending as far as the sharply outlined Rudawy Janowickie range. They accompany the western slopes of the Krucze Mts. on both sides of the Bóbr valley as far as Kamienna Góra. They are composed of conglomerates and sandstones interbedded with mudstones – the oldest Lower Carboniferous sedimentary rocks representing the early stage of the Intra-Sudetic Depression evolution in the foreland of the young Variscan orogen of the Eastern Karkonosze Mts.

11 Eastern cover of Karkonosze granites – Rudawy Janowickie and Lasocki Ridge metamorphic complexes

(Kamienna Góra–Marciszów–Wieściszowice–Rędziny –Czarnów–Pisarzowice–Leszczyniec–Ogorzelec–Kowary Pass –Okraj Pass–Kowary)

Rudawy Janowickie Metamorphic Complex: Leszczyniec Volcanite Complex (pyrite-bearing schists, amphibolites, quartz-chlorite-albite schists, Paczyn gneisses), Kowary–Czarnów Unit (mica schists, Kowary gneisses, ore-bearing formation, poly-metallic and uranium mineralisation)

The route starts in Kamienna Góra and runs northwards following the road No. 371 along the Bóbr river valley to Marciszów. Passing the railway station in Marciszów on our left, we turn south and drive under the viaduct. At the crossroads, we take a local road to Wieściszowice. The relatively low topography of the Marciszów Valley, composed of the same Lower Carboniferous sedimentary rocks as the Intra-Sudetic Depression, changes to a more hilly terrain and the road continuously climbs.

Here, we step into another geological unit composed of different rocks more resistant to erosional processes. This is the Karkonosze–Izera Block consisting of a core represented by the Upper Carboniferous Karkonosze granite, surrounded by older, Neoproterozoic and Early Palaeozoic metamorphic rocks. The eastern aureole of the granite – the goal of our travel, is the so-called Rudawy Janowickie Metamorphic Complex, also referred to in the literature as the Eastern Karkonosze Crystalline Complex. This is a submeridionally extending belt of variable width ranging from 2 to 10 km and stretching from Miedzianka in the north to Niedamirów in the south. In the south-west, the continuations of the rocks are Rychorskie Mts. and Southern Karkonosze rocks in the Czech Republic.

In Wieściszowice, we turn left near a local shop and drive up a steep narrow road to reach a nice car park after several hundred metres (Fig. 17). Following the green-marked tourist route going up to the top of Mt. Wielka Kopa (871 m a.s.l.), we reach the former pyrite-bearing schist mine, currently forested (PD 43). There is a curiosity of the region's nature – the so-called Colourful Lakes which, for their water colours, are named Purple, Blue (Azure) and Green Lakes. The first one, Purple Lake, fills the quarry pit and is seen on the left-hand side after a several tens of metres walk (Phot. 23). Its unique rust colour is due to chemical compounds formed as a result of weathering and decomposition of pyrite (iron sulphide – FeS_2), the primary mineral quarried in this site. In fact, the lake's water is a weak solution of sulphuric acid, so avoid contact with it. The extraction operations of pyrite and accompanying copper-bearing minerals of bornite and chalcopyrite started at Wieściszowice in the 17th century and continued until 1925. The technology of iron ore extraction relied on mechanical crushing of rocks in stone-crushing machines installed in the pit, and on hand separation of ore material on washing tables. Barren rock crumbs, left after the separation process, were dumped on mine waste dumps which have persisted to date and are situated to the west of the access road. Estimates say that over 200,000 tonnes of concentrate with average FeS_2 content of 13% was produced here during the period of 1852–1925. The ore concentrate was subsequently transported to processing plants, known in the 19th century as the Morgenstern Plants, situated 2 km to the north-east. Originally, the ores were used for the production of sulphur as well as iron and copper sulphides. From 1869 until the time the plants were closed, sulphuric acid was produced for further production of fertilizers (superphosphate) and paints. After the Second World War, in 1947–1954, new exploration operations for pyrite were carried out at Wieściszowice.

Though the ore reserves estimates (covering an area north of the present-day pits) were at 3.9 million tonnes, the production has not been undertaken. It was due to the discovery of large raw sulphur deposits in Poland, so that further exploration and search for the Wieściszowice pyrites were abandoned. Purple Lake is at the altitude of 560 m a.s.l. It partly fills the largest pit formerly called "Hoffnung" (Hope). The pit is on average 100 m wide and extends latitudinally over a distance of about 450 m. The consequences of the quarry location on a steep slope are that the eastern quarry wall is 150 m high, whereas the height of the western wall varies from merely 10 to 40 m.

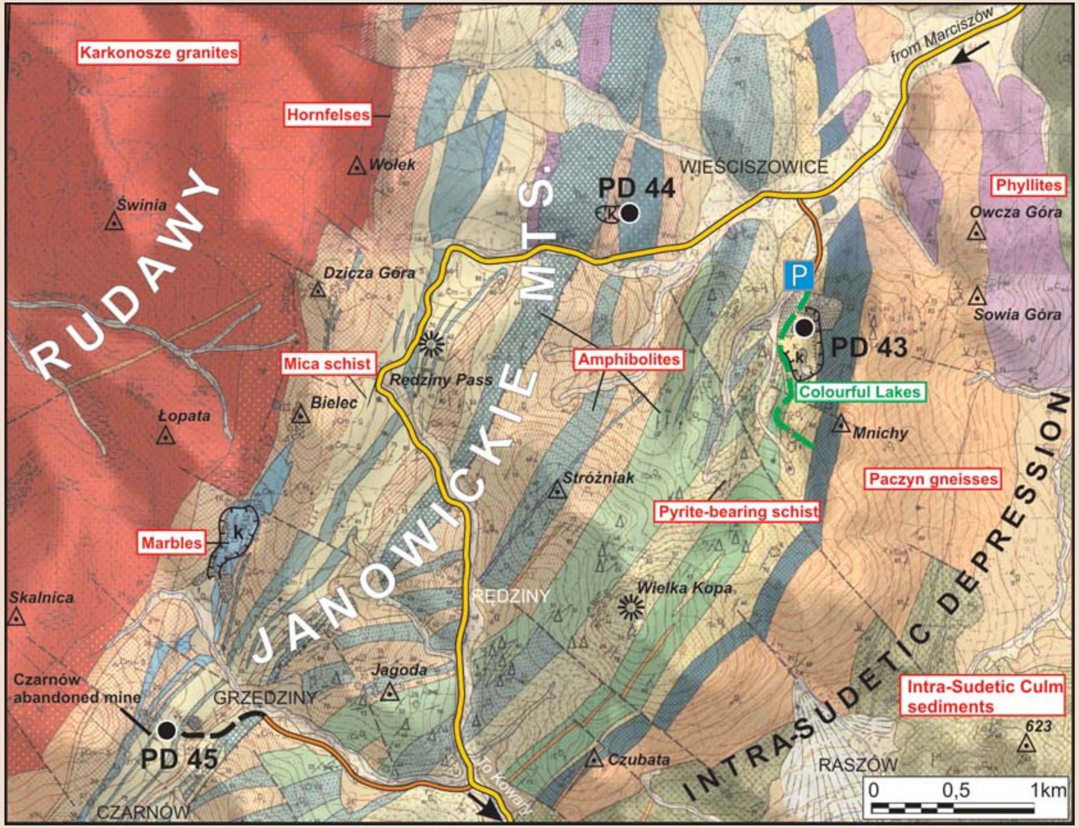


Fig. 17. Geotourist map of the Wieściszowice–Rędziny–Czarnów vicinity (middle part of the Rudawy Janowickie Range). Rudawy Janowickie Metamorphic Complex: Leszczyniec Volcanic Complex (pyrite-bearing schists, amphibolites, quartz-chlorite-albite schists, Paczyn gneisses), Kowary–Czarnów Unit (mica schists, Kowary gneisses). Documentation points PD 43–45: Wieściszowice, Czarnów. Geological map after SMGS: Janowice Wielkie and Pisarzowice sheets

Phot. 23. Wieściszowice, Purple Lake (PD 43) in the old quarry of pyrite-bearing schist. Phot. W. Kozdrój

During the last years of the quarry operations, ore extraction was carried out by boring tunnels. An outlet of such a tunnel, currently flooded, is visible in the north-eastern corner of the lake.

Pyrite-bearing schists are yellow-grey, locally rust in colour and show well developed metamorphic foliation commonly disturbed by numerous folds. In terms of petrographical composition, they represent chlorite-sericite-quartz schists. Laminae and strongly elongated lenses composed of quartz and weathered feldspars are separated by streaks of mica minerals (sericite and chlorite) which make the rocks fissile and fri able. A good site for making observations is in the northern end of the pit in a 10 m-long tunnel bored in a group of small rocks.

The characteristic feature of the schists is impregnation with dispersed pyrite whose content is variable within the rock body and varies from about 5–6% to 12–30%, in places even up to 70% in the richest parts of the ore deposit. The average pyrite content is about 16%. The name "pyrite" originates from the Greek words of *pyr* – fire and *pyrites* – sparkling. It occurs as regular golden-glistening single cubic crystals (the largest ones are 6 mm in diameter), multi-crystal intergrowths or irregular concentrations. Small glistering pyrite grains very much resemble gold hence it is popularly called "fools' gold". A simple test allows cooling down our emotions about gold: pyrite being harder than gold cannot be scratched with a knife.

The pyrite-containing chlorite-sericite-quartz schists form a few metres long layer steeply dipping eastwards. It is part of a much larger geological unit, called the Leszczyniec Volcanic Complex, which is composed almost exclusively of the so-called spilite-keratophyre series. The series was altered during metamorphic processes due to the effect of hot magmatic solutions. The spilite member of the series consists of dark-green amphibolites. They formed from basic volcanites (like e.g. basalts). The keratophyre member is made up of light-coloured, greenish-white or yellow schists originating from primary acid volcanites (e.g. rhyolites) which – being maternal for pyrite-bearing schists – are represented by acid volcanites of a tuff and tuffite type deposited in a marine environment. Submarine volcanic activity, responsible for deposition of a few kilometres thick cover of the Leszczyniec Unit rocks, continued in this area from late Cambrian through early Ordovician times i.e. approximately 510–490 My ago. Emanation of volcanic volatiles, associated with a circulation of solutions at the contact between hot volcanic rocks and seawater, favoured precipitation of sulphides of metals thus of pyrite impregnation as seen in the Wieściszowice ore deposit.

The Leszczyniec spilite-keratophyre unit was for a long time, until the Devonian/Carboniferous boundary (about 360 My ago), an ancient marine basin floor successively filled with sedimentary deposits during the Palaeozoic Era. The Early Carboniferous was the time of the so-called Variscan orogeny in the whole area of the Sudetes Mts. Both the rocks composing the basin floor and the overlying sediments underwent various deformations, folding and regional metamorphism. A stack of thrusts with tectonic units arranged one over another, developed at that time. Some of the rock complexes were deeply sunk and strongly metamorphosed resulting in changes in the appearance and mineral composition of the original rocks. These alterations, observed within the Leszczyniec Volcanic Complex, indicate that the rocks were transferred down to the depths of amphibolite facies conditions where the pressure was at about 5–7 kbar and the temperature above 550°C. A schistosity, also referred to as a metamorphic foliation, is typical of the present-day appearance of the rocks, being the effect of those transformations that relied on strong compression of the rocks that resulted in the damage of primary non-directional magmatic structures, their flattening and development of thin mica banding.

At the end of the Early Carboniferous, the Leszczyniec Unit was moved into shallow zones of the Earth's crust. During that process, the rocks became strongly folded and fractured favouring development of mineral veins in cracks. Abundant signs of the processes are also observed in the pyrite-bearing schists. In the late Carboniferous, the Karkonosze granites formed intrusions on the western side of the Rudawy Janowickie Metamorphic Complex. The intrusions penetrated and warmed the aureole rocks favouring development of post-magmatic polymetallic mineralisation. The signs of this mineralisation are observed at present near Wieściszowice as small veins (obliquely crossing schistosity planes) with Fe, Cu, Zn and Pb sulphides, or quartz and quartz-feldspar veins mineralised with the sulphides. They contain minerals such as chalkosine, bornite, sphalerite, galena, siderite, marcasite and chalcopyrite.

Among spectacular phenomena directly observable on the pyrite-bearing deposit, in particular near the above-mentioned mine tunnel, are coatings and encrustings of new hypergenic minerals that formed recently as the result of alteration of sulphides. These include white concentrations of acicular pickeringite, clustered yellow encrustings of copiapite and slavkite and red fibroferrite (please, do not damage the occurrences).

Continuing our tour, we walk a few hundred metres up the green-marked tourist route, first next to the quarry edge then along a path across a forest to reach the old pit called “Nowe Szczęście” (New Happiness). Here we find Blue Lake filling a larger pit, 150 × 40 m in size. Along its low western bank is a resting place with benches and tables, an excellent place to have a short rest. The azure colour of water seems to be caused not by chemical compounds, but by algae living in the clear, transparent water of a small stream flowing into the lake.

To reach the third lake called Green Lake, we follow on the green route to the south. After walking up about 600 m along the forest path, we turn right off the green-marked route. After next several tens of metres, we will see a flooded pit, 65 × 40 m in size and 20 m deep, located at the altitude of 560 m. a.s.l., formerly known as “Gustav Grube” (the Hole of Gustav). This lake is not as spectacular as the previous ones, so if you do not have enough time to spare you can as well end your trip at Blue Lake.

After visiting the Colourful Lakes, we return to the car park to drive back to the main road. At the crossroads, we turn left and after about 1 km is a large semicircular area with a bus stop on the right-hand side of the asphalt road. Here, we can park our car and follow the westernmost road to an abandoned amphibolite quarry at Wieściszowice (PD 44). Stone blocks, quarried here in 1971–1990, were crushed on the spot into variously sized fractions and then used as road and building aggregate.

Approximately 300 m further on we reach the middle part of a large pit. Near-vertical sets of alternating dark-green amphibolites and light-coloured, white-greenish quartz-chlorite-albite schists are visible on the southern wall of the quarry. The entire sequence is strongly fractured and cut by numerous faults. Like the previously described pyrite-bearing schist, this sequence is part of the spilite-keratophyre volcanic series of the Leszczyniec Unit. Individual layers are commonly a few centimetres to a few metres thick, although there are also millimetre-sized laminae. Their relatively constant thickness and regular, parallel arrangement resembling bedding in sedimentary rocks, allow suggesting that the rocks originate from basic and acid tuffs and tuffites. Such rocks are called volcanoclastic rocks. They were formed in a water environment through deposition of large amounts of both small volcanic material particles originally erupted by volcanoes and clastic terrigenous material formed due to erosion of other rocks. Since the rocks underwent metamorphic alteration during the Variscan orogeny, the prefix "meta-" is used to indicate their origin. Thereby, the dark amphibolites can be defined as basic meta-volcaniclastics, and the light-coloured schists – as acid meta-volcaniclastics.

The amphibolites are composed of varying proportions of chlorite, actinolite, feldspars (almost exclusively albite), epidote, clinozoisite, quartz, light-coloured micas, stilpnomelane, carbonates and ore minerals. Hornblende occurs in minor amounts. The mixed, volcanic-sedimentary origin of these rocks is indicated by, in places, both well-preserved small concentrations of plagioclases with relics of trachytic structure (typical of igneous rocks) and light-coloured particles of quartz and feldspars (typical of sedimentary rocks). Metamorphic foliation, observed in both the quartz-albite-chlorite schists and the amphibolites, developed from original sedimentary surfaces.

The quartz-albite-chlorite schists are finely laminated rocks or they form homogenous thick and massive layers lacking of any internal lamination. The main groundmass of the rock is composed of an aggregate of very fine quartz and feldspar grains. Individual laminae often contain larger feldspar grains (albite) of porphyroclast nature.

The darker mica laminae, accentuating the foliation, are composed of brown chlorite, actinolite, light-coloured mica, epidote, feldspars and abundant ore minerals. To the west of the pit, on the upper level of the quarry, is an important N–S-trending fault line separating the Leszczyniec Volcanic Complex from the Kowary–Czarnów Unit. It is manifested by a 30 m-thick zone of strongly brecciated rocks.

After returning to the place where we left our car, we can continue our travel driving steeply up to the west and then the south towards Rędziny. After about 2.5 km we reach a local topographic flat situated at the foot of Mt. Dzicza Góra (891 m a.s.l.). In clear weather, there is a magnificent view to the north on the Kaczawskie Mts., to the east on slightly lower elevated Rędziny Pass and Mt. Wielka Kopa behind. In the SE background, the Intra-Sudetic Depression and Krucze Mts. are seen.

Then the road descends to the village of Rędziny. At the end of the village, we turn to the west on a side road to Grzędziny and Czarnów. After about 1.5 km from the crossroads, we stop on the left-hand side of the road near a transformer station building. From here, we walk a dirt road westwards to reach after around 300 m a dump of the abandoned Czarnów „Evelinens Glück" (Eveline's Happiness) mine of polymetallic ores, predominantly arsenopyrite (PD 45).

Mining operations started here in the mid-18th century and continued until 1925. Like at Złoty Stok, the arsenopyrite-containing ore deposits (FeAsS) were concentrated to obtain a concentrate with 25–32% As content used for further arsenic trioxide production. Arsenic trioxide was used at those times for a production of coloured glass and paints, for leather and wood conservation and as a rodent poison. During the ore concentration process, additional by-products were isolated for Cu, Pb, Ag and Au production. It is estimated that the concentrate could contain even up to 2–4 g/t of gold and 60–80 g/t of silver. During the period of peak production at the beginning of the 20th century the Czarnów ore deposit produced on average 500 to 1000 tonnes of ore per year. The ore extraction was carried out on 10 levels of a total depth of up to 300 m. The levels were linked by a vertical mineshaft and by 2 horizontal tunnels which served for transporting the of run-of-mine material up to the ground surface. In the 1950s, the mine was dewatered and a new ore deposit documentation was produced. The arsenic ore reserves were estimated at that time at 205,000 tonnes, with pure arsenic content of 21,500 tonnes. The production, however, has not been renewed due to economic unprofitability. Nevertheless, in the 1990s, geological exploration surveys carried out at Czarnów revealed economic quantities of tin ores and the occurrence of still prospective gold deposits.

The dump is situated at the mouth of the main mineshaft which is now buried and inaccessible. The shaft dips westwards into the mountain to reach the main ore body at a distance of approximately 200 m. The body is a steeply dipping, several metres-thick and 500 metres-long quartz vein cut by transverse faults. The vein stretches NE–SW across surrounding calcareous-silicate rocks (erlanes) and mica schists. A number of ore zones within the vein, containing chiefly arsenopyrite or pyrotine, show lenticular shapes of maximum thickness up to 4 m, 40 cm average. The minerals also occur dispersed in the adjacent erlanes and schists. They are accompanied by other mineral ores such as sphalerite and galena, and subordinate chalkopyrite, pyrite, bornite, antimonite, markasite, cassiterite, raw bismuth, bismuthinite, tenantite, valeriite, cubanite, coveline, chalcosine, getite, limonite, scorodite, digenite, rutile and leucoxene. There is also gold occurring as raw metal or small electrum particles (a weak alloy of gold and silver in proportions of about 80 and 20%, respectively) dispersed as inclusions in arsenopyrite.

Although the former mine's pits are inaccessible today, many of the above-listed minerals can still be found while attentively looking through the rock material of the dump. If you are in luck, you can find nice specimen of not only polymetallic ores, mica schists and erlanes, but also crystalline dolomites and amphibolites. The rocks belong to the other part of the Rudawy Janowickie Metamorphic Complex, called the Kowary–Czarnów Unit.

Mica schists, dominant in the Kowary–Czarnów Unit, developed from sand-clay sedimentary rocks. The clastic sedimentation was accompanied by local carbonate deposition (manifested by the occurrence of white-greenish crystalline dolomites) and eruptions of basic volcanic rocks resulting in the formation of greenish streaky amphibolites. The age of this rock series can be roughly estimated at a time interval spanning the late Neoproterozoic and earliest Palaeozoic (Cambrian), i.e. about 660–500 My ago. Organic life was very poor at those times and left few faunal fossils. The exceptions are the single, millimetre-sized shells resembling Lower Cambrian *Archeocyatha* (extinct organisms transitional from corals to sponges, which lived in nearshore zones of warm seas) found in the Kowary–Czarnów Unit in the Czech Republic. The upper age limit of the sedimentary series is defined by ages of intruding igneous rocks represented by interlayers of leptites – white-yellow laminated rocks which once formed small rhyolite-type injections, and by thicker, even up to a few kilometres thick series of the Kowary Gneisses formed due to deformation of large porphyritic granite intrusions. The data obtained thanks to geochronological investigations indicate that the age of these intrusions is Late Cambrian–Early Ordovician.

The Kowary–Czarnów Unit rocks underwent strong regional metamorphic deformation under amphibolite facies conditions during the Variscan orogeny. Locally, in the southern part of the unit on the Polish-Czech borderland, there are also rocks referred to as *blueschists.* They contain minerals indicating the effect of very high pressure (up to 10 kbar) corresponding to conditions existing at depths of about 25–30 km. The rock deformation was so strong that caused the total blurring of original depositional structures such as sedimentary bedding. The orientation of mineral components, observed in the mica schists, crystalline dolomites and amphibolites, is a new foliation developed due to a directional tectonic shear called mylonitization. The process, roughly illustratable as a slide of cards within the pack, resulted in a grinding of primary components, mobilization of solutions and recrystallization of new assemblages i.e. mineral parageneses. Greenish-brown laminated erlanes are just the new rocks that formed at the contact of chemically contrasting mica schists and amphibolites with crystalline dolomites. The process occurred due to interpenetrating and exchanging of mineral solutions. The contact of such rocks, in particular the presence of mafic volcanic rocks often containing dispersed mineralisation of metal ores, favoured the formation of new ore deposits during metamorphic processes. At the end of the Early Carboniferous, the Kowary–Czarnów rock series were folded, uplifted to the Earth's surface and fractured.

The Czarnów polymetallic ore deposit formed in several phases. Although the effect of post-magmatic hydrothermal solutions of the Karkonosze granites (intruding during the late Carboniferous) is considered the crucial genetic factor, the initial stage of quartz vein formation may reach back in time to the period of early mylonitization when silica, released from mineral breakdown, syntectonically recrystallized in rock voids.

The circulation of younger post-magmatic fluids was a long-term process facilitated by strong fracturing of rocks. Absolute age determinations of galena from Czarnów yielded ages of 250–210 My suggesting that hydrothermal activity persisted here into Triassic times, at the beginning of the Mesozoic era.

After visiting the Czarnów mine dump, we go to Pisarzowice following the main road from Kamienna Góra to Kowary (367). We turn right, pass the villages of Szarocin and Leszczyniec and reach Ogorzelec (Fig. 18). On the left-hand side of the road at one of its bends is an entrance gate to the Ogorzelec amphibolite and gneiss quarry, currently in operation (PD. 46). Just behind the gate, we can park our car near the guard box and, on security staff permission, make a short reconnaissance around the pit. From the pit edge is an excellent view of the whole multi-level quarry (Phot. 24). The annual stone material production is about 350,000 tonnes. The run-of-mine is converted into crushed stone including high-quality amphibolite aggregates used for production of stone-asphalt mixes. The most interesting feature of the quarry is the presence of numerous irregular and branching interlayers of lighter-coloured, white-greenish rocks referred to as the Paczyn gneisses embedded in the dominant dark-green amphibolite rock mass.

The amphibolites represent rocks ancient basic volcanoes of the above-discussed Leszczyniec spilite-keratophyre unit, but they are of a different nature than those at Wieściszowice (see PD. 44). They are derived mainly from primary massive lava flows or basalt sheet intrusions. In places of no younger fissility, the amphibolites are massive and fine-grained and show non-directional arrangement of mineral components. Such amphibolites gradually grade into varieties of directional textures, including steaks or laminae, which mark zones of stronger tectonic deformation.

The amphibolite-cutting Paczyn gneisses from Ogorzelec are relatively weakly deformed igneous rocks. They are the spectacular example of an intrusion, the only one throughout the Sudetes, allowing for direct field observation of various forms of magma injection into aureole rocks. The thickest parts of the magma body reach up to several tens of metres in size, whereas the branching, finger-like smaller extensions of vein characteristics (so-called apophyses) range from several millimetres to around a dozen of centimetres in thickness. Geochronological determinations prove that those magmas intruded at the Cambrian/Ordovician boundary about 500 My ago, indirectly indicating that the adjacent volcanic basic rocks (amphibolites) must be older than the magmas.

Mineral composition and chemical investigations enabled identification of the protolith of the Paczyn gneisses as medium-grained high-sodium leucotonalites or plagiogranites. The original, magmatic components of the gneisses are represented chiefly by plagioclases and quartz and in minor proportions by relict hornblende, ilmenite, potassium feldspar and light-coloured mica. During Variscan metamorphic processes, foliation planes developed in some of the igneous rocks subjected to stron-

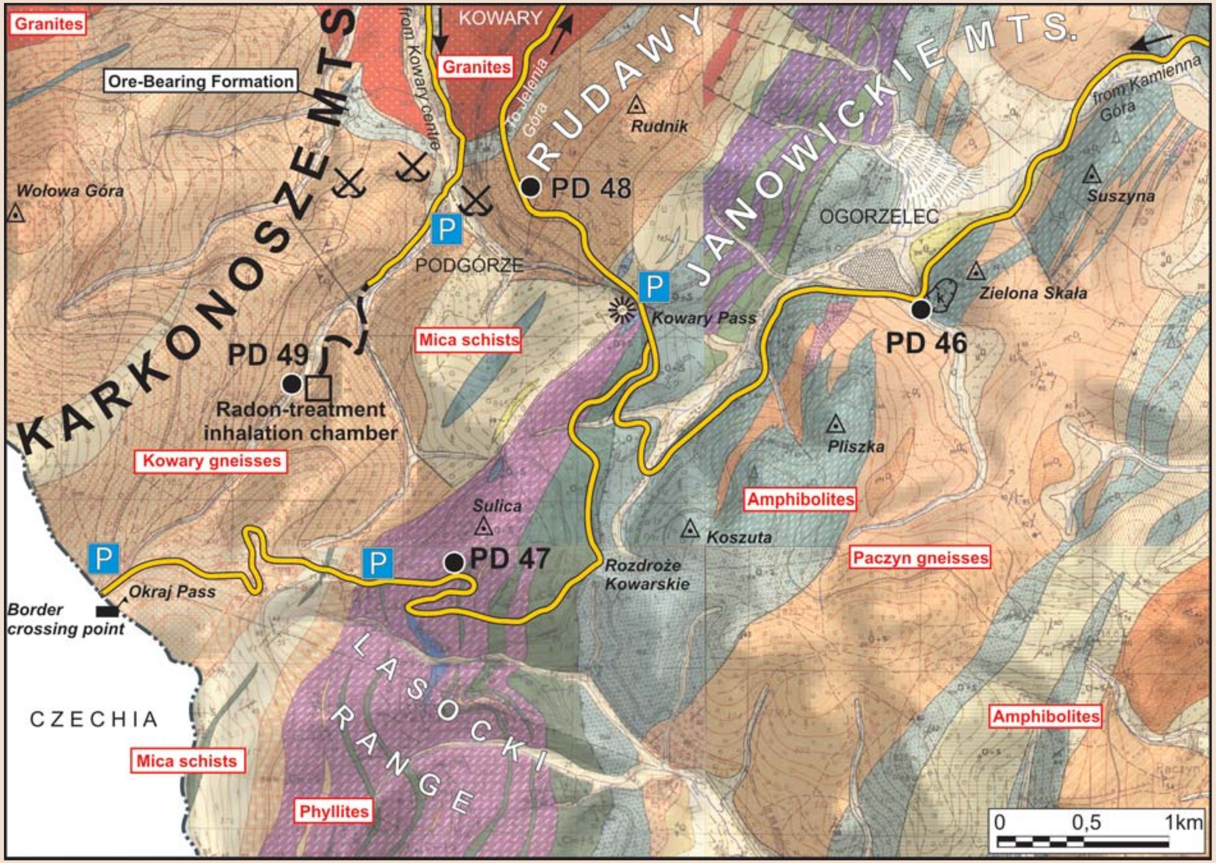


Fig. 18. Geotourist map of the Kowary vicinity (southern part of the Rudawy Janowickie Mts.). Leszczyniec Complex: amphibolites, Paczyn gneisses, Kowary–Czarnów Complex: Kowary orthogneisses, mica shists, ore-bearing formation, poly-metallic and uranium mineralisation. Documentation points PD 46–49: Ogorzelec, Rozdroże Izerskie, Kowary. Geological map after SMGS: Pisarzowice, Kowary, Czepiel, Szczepanów sheets

Phot. 24. Eastern wall of the active quarry at Ogorzelec (PD 46). Irregular interlayers of lighter-coloured rocks referred to as the Paczyn gneisses embedded in the dominant amphibolites. Phot. W. Kozdrój

ger tectonic stresses. They manifest themselves by directional flattening and stretching of older minerals, and by development of small bands composed of new components: light-coloured micas, chlorites, zoizites, actinolites and characteristic blue-green amphiboles. One of the youngest minerals is secondary calcite.

On leaving the Ogorzelec quarry, we turn left and drive towards Kowary Pass with a large car park convenient for a longer stop. The pass is a nice viewpoint for a panorama of the Kamienna Góra Depression to the east and of the eastern ends of the Karkonosze Mts. and the Jelenia Góra Valley to the north-west.

From the car park, we drive southwards following the road No. 368. A few hundred metres away, at Rozdroże Kowarskie, we turn right on the road towards the Okraj Pass border crossing. After passing the first sharp 180° bend to the right (drive carefully) we reach another road bend with a small roadside lot to the right at the mouth of a forest road on the southern slopes of Mt. Sulica. Just behind the forest road, along the northern scarp of the asphalt road, the Kowary–Czarnów mica schists are exposed over a distance of about 50 m. They form steeply arranged, meridionally striking and easterly dipping rock packets (PD 47). The exact age of the rocks is unknown; they are probably Neoproterozoic–Cambrian.

The schists exhibit excellent mylonitic foliation accentuated by silvery-greenish laminae of glittering flaky minerals: muscovite and chlorite, separating laminae composed predominantly of quartz and feldspars. In places, in particular in the western part, the foliation is distinctly deformed by younger asymmetric folds of steeply dipping axes.

The directional structure of the rock (foliation) can be mistakenly taken for lamination inherited from sedimentary bedding, if roughly examined. Even with use of a magnifying lens, it is noticeable that the laminae are in fact discontinuous and form strongly stretched mineral concentrations typical of mylonitization under plastic (ductile) deformation conditions. It proves that the rocks underwent very strong dynamic deformation. The schists contain white-yellow spherical or lenticular feldspar (albite) particles of blast nature, often visible even with the naked eye. Such feldspars form through growth in metamorphic conditions under high temperature, but prior to the main deformation phase.

Foliation planes of the schists locally show parallel-arranged mica bands and stretched quartz or feldspar rows marking lineation of mineral grains. By the identification of strike and dip angles of the lineation and by examining other structures called kinematic indicators, we can infer that tectonic transport in this exposure occurred through a movement of rock masses from the west to the east. Due to modern geochronological research on micas from the rocks we can also determine relatively precisely the timing of their crystallization and cooling i.e. the age of metamorphism and foliation. Rb–Sr and Ar isotope datings of micas from the Kowary–Czarnów schist samples yielded ages of 345 and 320 My, indicating the maximum activity of tectonic movements during the Visean (late Early Carboniferous).

After exploring the mica schists, there is an option to walk several hundred metres further west to a forest car park, convenient for a short rest, or even to climb to a tourist mountain hut at Okraj Pass (2.5 km distance).

To reach the next point of our geological journey we must return by the road No. 368. About 1.5 km beyond Kowary Pass, we stop at a small car park aside the road on the left. The exposure of interest (PD 48) is exactly on the opposite side. The old excavation is a 50 m long and 5 m high wall quarried for roadstone material. This is also one of the best exposures of the Kowary gneisses forming a large, dozen kilometres long body belonging, like the mica schists, to the Kowary–Czarnów Unit. The gneisses make up the highest parts of the southern Rudawy Janowickie (e.g. Mt. Rudnik) and eastern ends of Karkonosze (Mt. Wołowa Góra and Mt. Izbica).

The Kowary gneisses are of magmatic origin. They formed due to alteration of coarse-grained granites that intruded into a shale series at the Cambrian/Ordovician boundary. Watching the pit walls, we can see some varieties of gneisses differing in their textures that reflect different degree of deformation of the same original granite. The southern end of the pit reveals the most poorly deformed granitogneisses. The presence of large light-coloured potassium feldspar specimens, up to a few cm in size, indicates that the granitogneisses were derived from a coare-grained porphytitic granite precursor. The remaining area of the pit offers granite varieties illustrating later stages of the gradually proceeding deformation process. These are augen, augen-lensoidal and laminated gneisses. The last variety represents the rock that underwent the strongest mylonitization. The deformation process in granites under metamorphic conditions resulted in destruction of older mineral grains, their recrystallization and development of foliation planes accentuated by thin bands of newly formed micas. Mineral composition of the Kowary gneisses includes mainly quartz, potassium feldspar (ortoclase, microcline), plagioclase, albite, muscovite and biotite. Apatite, tourmaline, magnetite, zircon and garnet occur in minor proportions. Light-coloured fine-grained laminae are quartz-feldspar in composition and contain lenticular potassium feldspar porphyroclasts. Darker mica laminae are composed largely of light-coloured mica flakes (muscovite) with rare black biotite being under the process of chloritization.

Foliation planes exhibit clear lineation manifested by linear, parallel traces of feldspar, quartz and mica grains ground due to tectonic stresses. Spatial orientation of the steeply eastward-dipping foliation and lineation, and asymmetry of feldspar augens (indicating movement of rock masses during Variscan deformation) we can infer that the movement was from the west to the east, like that interpreted for the mica schists from the previous locality (PD 47).

The middle part of the excavation, near its upper edge, contains a small interbed of dark-green fine-grained biotite amphibolites originating from pre-existing basic veins. Closer observation reveals that the amphibolites also show thin cleavage indicating that, together with the gneisses, they underwent similar deformation.

We continue out travel driving the main road down to Kowary over a distance of 5 km. About halfway we can stop for a short rest at a car park. The site hereabout is an old quarry of the Karkonosze granites with a perennial fissure spring offering tasty drinking water.

In Kowary, it is worth visiting the Old Town with its numerous historic tenements, the classicistic Town Hall and parish Gothic Holy Mother Church. The history of Kowary dates back to the 12th century. Its dynamic medieval growth was due to mining and processing industry of iron ores (magnetite). The peak production period took place in the 16th century when Kowary became one of the major iron metallurgy, smithing and gunsmithing centres of Lower Silesia. In the 17th century, following the Thirty Year's War, mining activity had died out and afterwards the town grew due mainly to weaver and textile's craft. The 18th and 19th centuries' attempts of reactivation of the mining industry, including exploitation of silver-containing lead ores, did not bring prosperity to the town. Only after World War One, richer polymetallic ores were explored and mined, out of which iron, silver as well as arsenic, nickel and cobalt were produced. In addition, at the end of 1920s, uranium ores were discovered in this area. Soon later, they became the raw material of strategic significance. In 1935, Nazi Germany increased production of iron and uranium ores in Kowary. During the “Cold War” of 1947–1956, the uranium ores were mined for Soviet military purposes. That secret production proceeded parallel to official iron ore production conducted by a Polish company named “Kowarskie Kopalnie” later renamed to “Zakłady Przemysłowe R1”. Because of economic reasons, the iron ore exploitation was ultimately abandoned in 1960. It is estimated that a total amount of about 3 million tonnes of Fe ore and about 90 tonnes of uranium ore were produced over the whole period of mining activity in Kowary.

The magnetite and polymetallic mineralisation of the Kowary ore deposit is located within the so-called Ore-Bearing Formation extending over 2 km. It is an almost horizontally positioned lens occurring at the contact of the Kowary gneisses and Karkonosze granite. The formation attains up to 200 m in thickness and includes a wide variety of rock types. The main body is composed of metamorphic rocks: limestones (marbles), calcareous-silica rocks (erlanes), garnet-epidotic gneisses, mica schists, amphibole schists and chlorite schists. Like the ore-bearing rocks of the Czarnów region, the rocks belong to the Kowary–Czarnów Unit. As the result of thermal effect of the Karkonosze granite, part of the Ore-Bearing Formation was additionally altered to hornfelses and skarn rocks.

Origin of the ore mineralisation itself is both highly complicated and multi-stage. Its most important mineral, magnetite (iron oxide Fe_3O_4), forms lenticular bodies within the Ore-Bearing Formation. The bodies are elongated parallel to the foliation of metamorphic rocks, suggesting that magnetite formed as the result of alteration of Fe concentrations in the pre-existing sedimentary-volcanic series. A certain ore-forming role was also played by the Kowary pra-granite intrusions. The second generation of ore mineralisation (Fe, U, As, Cu, Pb, Zn, Bi, Ni, Co and Ag,) in the Ore-Bearing Formation is represented by sulphide and arsenic ores forming lenses, nests and veins, which were partly involved in fold deformation during the Variscan orogeny. The youngest mineralisation is contact-metasomatic polymetallic and uranium mineralisation related to the Karkonosze granite intrusion and post-magmatic emanations. This mineralisation follows a system of fractures and faults. It concentrates in quartz and carbonate veins and barite-fluorite-calcite breccias crossing both the Ore-Bearing Formation and Kowary gneisses.

From the centre of Kowary, we head southwards to Podgórze district. En route, behind a bridge on the Jedlica Stream, bush-grown dumps of the old mines of “Wolność” and “Wulkan” are seen on both sides of the road. In Podgórze, to the left of the road, there are car parks – a good place to leave our car and walk on across the forest to the “Sztolnie Kowarskie” mineshafts offering a nice underground route (PD 49). The entrance is situated near the “Jelenia Struga” hotel. There is a resting room and a waiting hall for those who wait for the underground tour.

The 1200 m-long route was made accessible for tourists in 2000. This is part of a system of underground mine tunnels drilled within the „Podgórze" mine field exploited for uraninite by the "Zakłady R-1" company. Good technical conditions of the mineshaft are due to the maintenance of a radon-treatment inhalation chamber that existed here for purposes of the Cieplice health resort after the closure of mine works. While visiting the chamber, note the Kowary gneisses and accompanied dark amphibolite interlayers, perfectly exposed in the wall. The unique occurrences of uranium mineralisation veins, presented by a guide, are also very interesting.

After visiting the mineshaft, we drive back through Kowary to the main road (367) and go towards Jelenia Góra through Mysłakowice along the Jedlica valley, passing the Karpnickie Hills seen on the right. In Mysłakowice, we enter the Jelenia Góra Valley. The road is accompanied by the outcropping Karkonosze granites seen to both sides of the valley.

12 Northern part of the Rudawy Janowickie metamorphic complex, Karkonosze granite massif

(Marciszów–Miedzianka–Janowice Wielkie–Karpniki –Jelenia Góra)

Bóbr River Gorge, Intra-Sudetic Fault, contact between Rudawy Janowickie Metamorphic Complex and Karkonosze granites, polymetallic mineralisation at Miedzianka, Karkonosze granites, small pinnacles, Jelenia Góra Valley

In Marciszów, behind a bridge on the Bóbr River, we have a choice between the above-described route towards Wieściszowice across Rudawy Janowickie Mts., and a journey to the west towards Janowice Wielkie and Jelenia Góra. The road runs across the northern slopes of the Rudawy Janowickie Mts. parallel to the Bóbr River gorge (Phot. 25).

This typical antecedent gorge, similar in origin to the Nysa Kłodzka river gorge at Bardo, follows one of the major Sudetic faults – the so-called Intra-Sudetic Fault. This is a complex, WNW–ESE-trending fault zone separating at the surface the Karkonosze–Izera Block in the south from the Kaczawa tectonic unit in the north. Between Marciszów and Janowice Wielkie is the Janowice Gorge separating the Ołowiane Mts., composed of the Kaczawa greenschists (basalt-type rocks metamorphosed under the greenschist facies conditions), from the meridionally extending outcrops of

Phot. 25. View from the Marciszów–Miedzianka road towards Bóbr river gorge and Ołowiane Mts. Phot. S. Cwojdziński

Rudawy Janowickie rocks (Fig. 19). Metamorphic rocks of the Rudawy Janowickie Mts. (represented here by the Paczyn gneisses, various types of amphibolites of the Leszczyniec Unit and mica schists of the Kowary–Czarnów Unit) are in contact with the Karkonosze granites along a meridionally oriented line trending between Miedzianka and Janowice Wielkie.

The granites are part of the largest Sudetic granite massif of the Karkonosze Mts., formed due to Late Carboniferous plutonic magmatism. The process led to the formation of both a group of granite intrusions occurring within all the metamorphic units of Lower Silesia and a set of vein rocks represented by microgranites, aplites, pegmatites, quartz veins and lamprophyres of various types. Granite magmas of the Karkonosze Massif solidified in general at depths of 5–10 km. The age of the Sudetic granites is determined by isotopic methods to be about 330–325 My. The initial locating of the main pluton body occurred during the early Late Carboniferous, although some of stratigraphic schemes suggest that it began as early as the Early Carboniferous, during the Visean. Southern part of the Karkonosze pluton makes up the highest Sudetic mountain range of Karkonosze, whereas its NE part is tectonically lowered and constitutes the basement of the broad Jelenia Góra Valley. The latter part underwent the most intense weathering and erosion, in particular during the Neogene. In Pleistocene times the area was covered by glacial, slope and fluvial deposits.

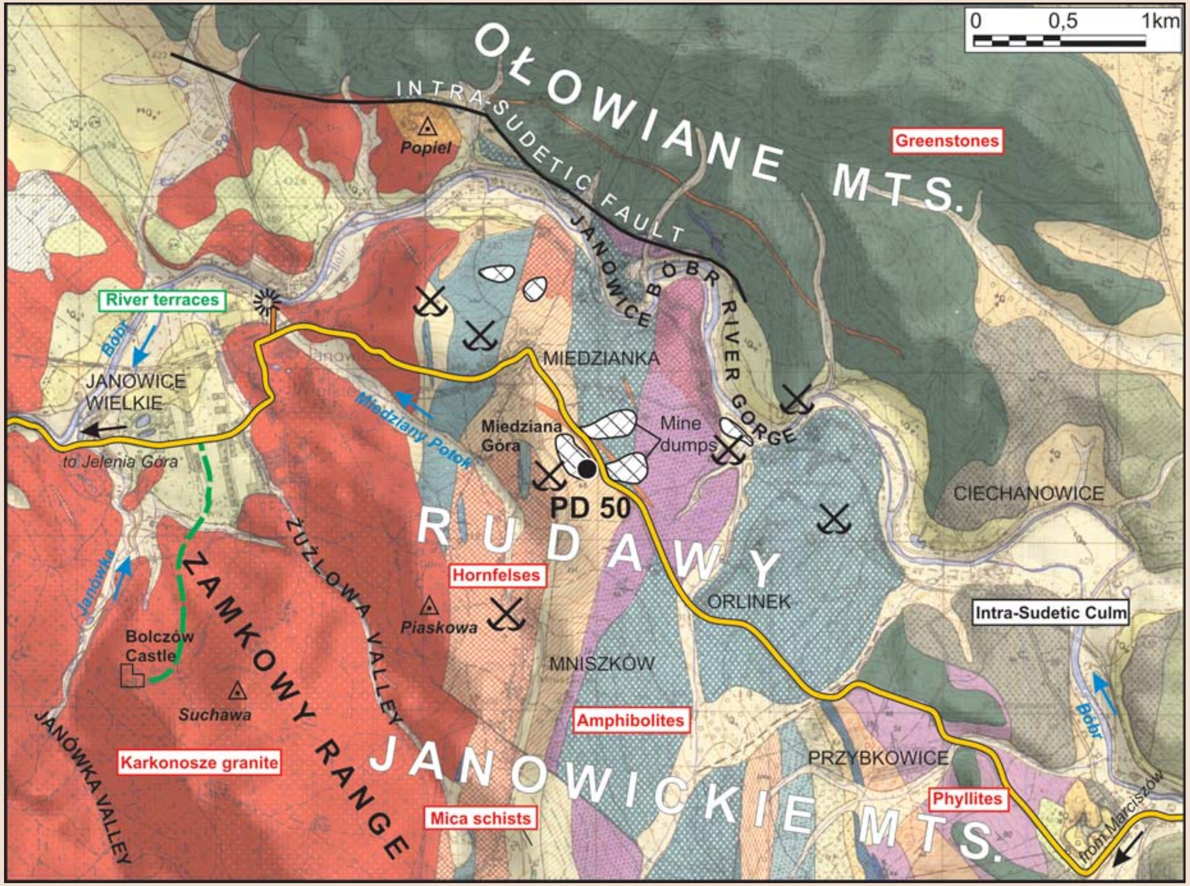


Fig. 19. Geotourist map of the Miedzianka–Janowice Wielkie vicinity (northern part of the Rudawy Janowickie Mts.). Bóbr River Gorge, Intra-Sudetic Fault, contact between Rudawy Janowickie Metamorphic Complex and Karkonosze granites, poly-metallic mineralisation at Miedzianka. Documentation point PD 50: Miedzianka. Geological map after SMGS: Janowice Wielkie sheet

The characteristic feature of the Karkonosze granites composing the basement of the Jelenia Góra Valley is the presence of weathering mantles (regoliths) in the near-surface layer. Such deposits occur at the topmost portion of weathered granites. They locally form a profile of continuous transitions from a hard, unweathered granite through a strongly weathered rock to a loose granular sediment called granite grit. Only locally, there are topographic highs with numerous pinnacles and rock towers preserved due to increased resistance to weathering, of which the most spectacular are Zamkowy Ridge, Janowickie Garby Hills, Karpnickie Hills, and first of all the Sokole Mts.

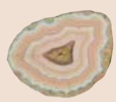
The contact surface between the granites and their aureole in the Rudawy Janowickie Mts. is nearly concordant with foliation planes in metamorphic rocks. However, details of the intersection image indicate that the granites truncate the aureole rocks. In the Janowice Wielkie region and to the south of it, the contact surface dips eastwards at the angle of 40–45°, whereas foliation in the aureole rocks dips eastwards at 60–70°. While intruding, the granites affected the aureole rocks by both high temperature of 700–750° C and chemical reactions through the action of hot vapours and mineral solutions. The effects of the contact process are observed throughout the entire area of the Rudawy Janowickie Mts. Within the exocontact zone, towards the outside of the granites, hornfelses are observed. Their pre-existing metamorphic structures were blurred by recrystallization of feldspars and quartz. As a result, new minerals appeared instead. These are cordierite and andalusite, minerals typical of high-temperature alterations proceeding however in much lower pressures. Nevertheless, the aureole rocks also affect intruding hot granite magmas, resulting in endocontact alterations within them, at least by making the magma cooler to freeze faster and form finer-grained granite varieties of the so-called marginal facies. Such granites show characteristic quartz-feldspar intergrowths and are called granophyric granites. They occur along the contact zone at Janowice Wielkie and in the Bóbr Gorge.

Apparently, the contact effect of the Karkonosze granites on the aureole of the Rudawy Janowickie Metamorphic Complex reflects itself in ore mineralisation zones. Earlier during our travel, we were acquainted with the Czarnów and Kowary ore deposits, on the route through the northern part of the mountains we cross the Miedzianka–Ciechanowice zone known since medieval times. The zone is composed of three orefields: the western orefield near Miedzianka, the central orefield between Miedzianka and Mniszków and the eastern orefield between Ciechanowice and Orlik. All the ore fields were once connected by a system of underground tunnels and excavations. Ore veins, 0.1 to 3 m thick, are composed predominantly of amphiboles and chlorites, sporadically of calcite. They occur mainly in amphibolites, locally in mica schists. The major ore-forming mineral is chalcopyrite (copper sulphide) accompanied by chalcosine, bornite, coveline, tetraedrite, magnetite (Fe oxide), sphalerite, galena, arsenopyrite, pyrite and pirotine. Copper and, subordinately, arsenic and silver have been the most important metals produced over historical times. It is reflected in the geographical names in the region: Miedzianka, Miedziana Góra and Miedziany Potok – derived from copper, Hutniczy Grzbiet and Żużlowa Dolina – derived from metallurgy, Góry Ołowiane – derived from lead, etc. Ore mining and metallurgy reached its peak development in the 16th century. After the decline period in the 17th century, it revived for a short time in the mid-18th century. Excavations reached the depth of 80–110 m at that time. Unsuccessful attempts of economic production were later undertaken several times during the 19th and 20th centuries.

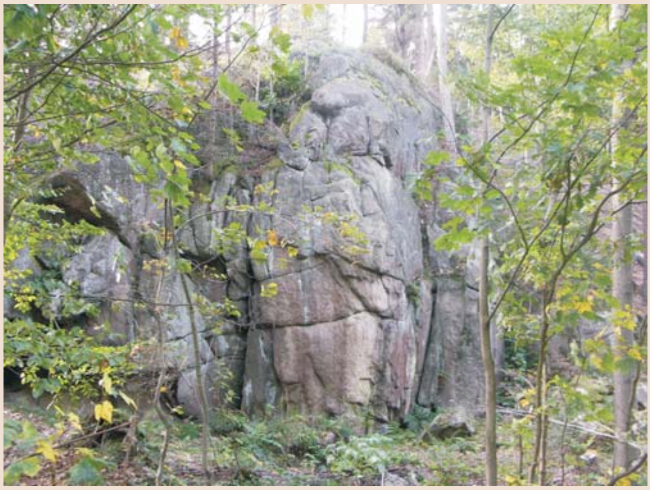
At present, abundant signs of ancient mining and metallurgical activity can be observed all over the region. These are old, already collapsed mineshafts, numerous usually bush-grown mine dumps and smelting slime dumps. Underground excavation sites are inaccessible. The most interesting mine dumps in terms of mineralogical content are clusters on both sides of the road to Miedzianka, about 500 m before the village (PD 50). Both small barren non-mineralised rock blocks (amphibolites, mica schists, hornfelses, porphyries, quartz) and sulphide-mineralised rocks can be found here. Near tiny inclusions of copper sulphides, green and blue concentrations of weathering minerals of malachite and azurite are observed.

From the Miedzianka ore zone, we drive to Janowice Wielkie. This is a picturesque commune village situated to the south of the Bóbr Gorge. There is a bridge on the river in the centre of Janowice, offering a nice view over part of the gorge. Janowice Wielkie itself is located on the Karkonosze granite massif, strictly in its eastern, near-contact part.

The road runs westwards along the Bóbr river valley across the hills of Hutniczy Grzbiet, Zamkowy Grzbiet and Janowickie Garby ridges composed of granites. Small rocky pinnacles are very picturesque elements of the area's landscape (Phot. 26). Worth visiting is also a ruin of the Bolczów castle built in the 14th century on the western slope of Mt. Sucha. It is accessible from the centre of Janowice following the green-marked tourist route. The castle is excellently built-in among surrounding granite rocks. It is also a good viewpoint of the Rudawy Janowickie Mts.



The winding road heads southwards to Karpnicka Pass situated between Janowickie Garby Hills and Sokole Mts. (Fig. 20). There is a forest car park on the pass. Following the green-marked tourist route, we can reach after a 20-minute walk the "Szwajcarka" mountain hut located on SE slopes of the Sokole Mts. From the hut is a 20–30-minute walk to the peaks of Mt. Krzyżna and Mt. Sokolik offering beautiful



Phot. 26. Karpnicka Pass – typical rocky pinnacle built of Karkonosze granite with rounded edges due to weathering (PD 51).
Phot. S. Cwojdziński

views over the whole area with the Rudawy Janowickie and Karkonosze mountains, and the Jelenia Góra Valley. Along the route and around the peaks there is a possibility to make a closer inspection of the Karkonosze granites that form numerous pinnacles in this area. The Sokole Mts. rocky pinnacles are typical granite peaks, often steep and craggy. The rock walls range from several to 60 m in height, some of them even up to 90 m. The walls are good paths for rock climbing training.

In terms of petrography, the Karkonosze granite is represented by biotite granite included in monzogranites, to a lesser extent in granodiorites. As regards the rock structure, the Karkonosze granites are categorized into 3 main types: coarsely and medium porphyritic granites, equigranular, fine- and medium-grained granites, and granophyric granites.

The typical granites are massive rocks, grey, grey-pink, beige or pink in colour, and show blocky or rarely cubic parting. Their mineral composition includes quartz, plagioclases, alkali feldspars, biotite, sporadic chlorite and iron oxides. Large potassium feldspar phenocrystals contain small inclusions of quartz and plagioclases.

Fine-grained porphyritic granites, locally coarse- and medium-grained, occur along the western slopes of the Rudawy Janowickie within the Janowickie Garby Ridge, Starościńskie Skały and Świnia Mt. Apart from the typical porphyritic granite, there are also finer-grained varieties containing small amount of pink platy feldspar porphyrocrystals, up to 1.5 cm in size. It is often difficult to put a clear boundary between the typical coarse-grained porphyritic granites and the fine-grained granites containing sporadic porphyrocrystals. Grains in the groundmass are also variable in size ranging from coarse to fine. There can be either a remarkable difference or gradual transition in grain size between groundmass grains and porphyrocrystals. Coarse-grained porphyritic granites of the area occur together with fine-grained gran-

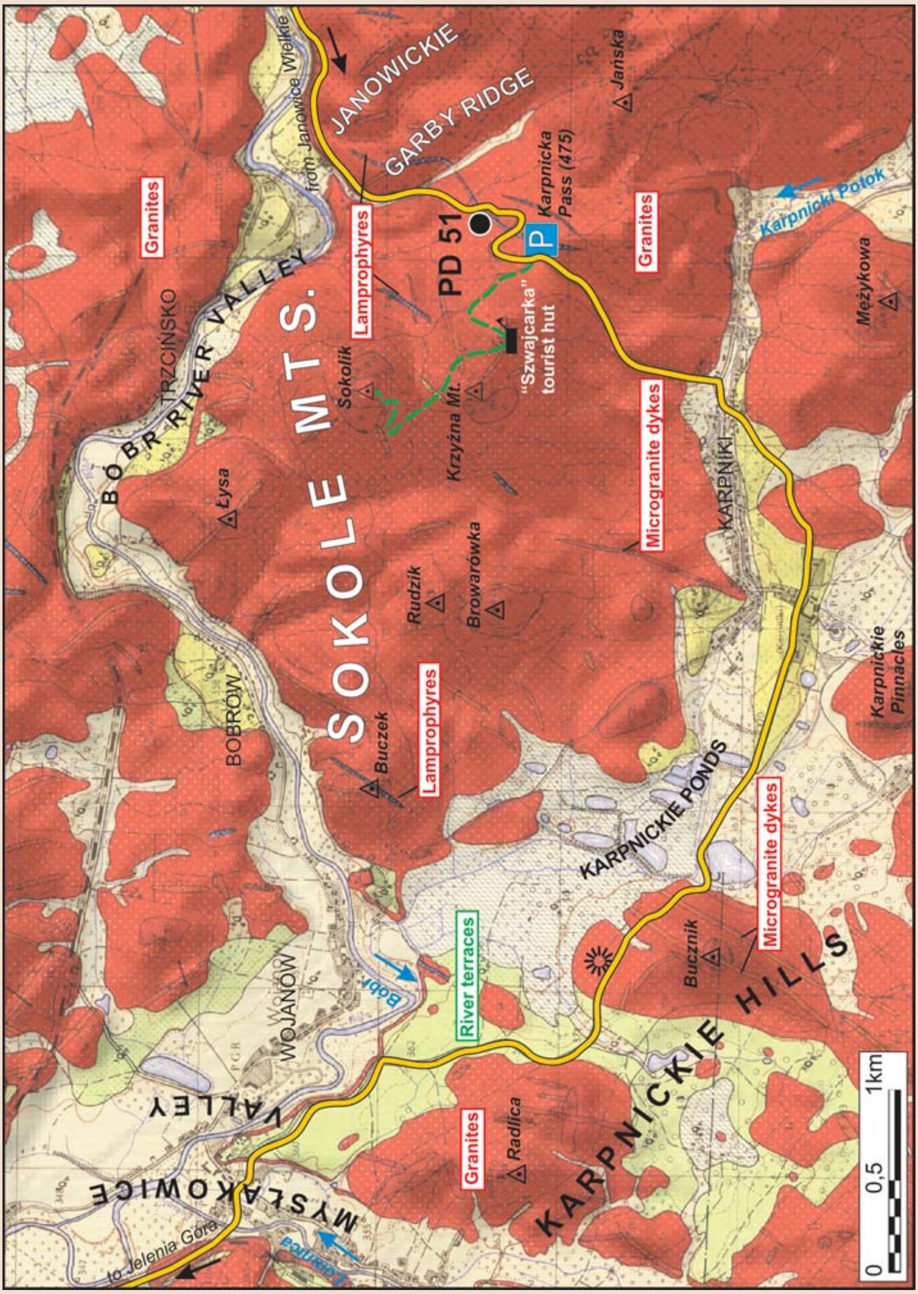


Fig. 20. Geotourist map of the Janowice Wielkie–Karpniki vicinity (Sokole Mts.). Karkonosze granites, granitic pinnacles, Jelenia Góra Valley. Documentation point PD 51: Karpnicka Pass. Geological map after SMGS: Janowice Wielkie and Jelenia Góra–East sheets

ites forming a latitudinally oriented outcrop, 1.5 to 2 km wide, arranged parallel to the intrusive contact between the Karkonosze Massif and the metamorphic aureole of the Rudawy Janowickie.

Numerous single rocks and old quarries reveal structural and petrographical variability, typical of these rocks. For example, there are fine-grained granites with rare, single large platy automorphic feldspar grains at contacts with coarse-grained porphyritic granites. In places, the granites contain intensive accumulations of feldspar porphyrocrystals in parts separated by porphyrocryst-free zones, of aplite schlieren nature.

The granites, in particular porphyritic varieties, contain biotite schlieren often co-occurring with endogenic enclaves and xenoliths. The term schlieren refers to darker finer-grained, often wavy or folded-like bands grading into surrounding granite. They are commonly spatially associated with dark spherical or oval enclaves displaying different resistance to weathering than the parent rock. Endogenic enclaves are rock bodies, which are older than the main granite body, but they originate from deeper zones of a magma storage or from igneous rocks formed by earlier solidification of the same magma. These are microgranitoid enclaves with high biotite contribution. Due to magma flow, the enclaves were melted and mechanically crumbled forming banded schlieren. Xenoliths are fragments of aureole rocks torn and transported by magma. These are e.g. hornfels xenoliths with clearly preserved schistosity. In both these cases, the enclave size ranges from 0.20 to 0.70 m. Enclaves can be oval, spherical or irregular, however they always have rounded edges and corners. It indicates strong chemical and mechanical effect of granite magma while it flowed.

Analysis of orientation of structures that developed in granites at time of the intrusion process (i.e. synintrusion structures) enables reconstruction of the internal structure of the intrusion, as well as drawing conclusions about magma flow directions, sites of its outflow from the Earth's crust, and the mode of mechanical effect on the aureole rocks. The internal structure of the Karkonosze granite massif, reconstructed in this way, is very complex. The granites form, among others, a large dome stretching NNE–SSW along the present-day Rudawy Janowickie range. The dome forms the core of intrusion extending in similar direction, and is enveloped by schlieren coats. The inner coat is composed predominantly of biotite schlieren; the outer one consists of aplite schlieren. Obviously, such large structures cannot be directly observed in exposures. They are reconstructible based on a regional analysis.

Post-intrusive elements of the massif's tectonic structure are represented by magmatic vein systems, fractures and mylonitic-cataclastic zones. Traditionally, there are three major fracture systems categorized with reference to the orientation of longer axes of feldspar grains and schlierens in granite: (1) vertical, transverse, NNE–SSW-trending fractures perpendicular to the magma flow direction (subsequently followed by vein rocks); (2) vertical, longitudinal, NW–SE-trending fractures; and (3) horizontal schlieren-related fractures.

Vertical or steeply dipping aplite veins are very commonly observed in the Sokole Mts. pinnacles. The veins are 0.5–0.7 m thick and most frequently trend NNE–SSW, N–S, NW–SE and NE–SW. The occurrence of some of the aplite veins is accentuated at the ground surface topography. Aplites, as more resistant to weathering, usually form topographic ridges. They can also be responsible for the presence of granite pinnacles. Lamprophyre veins are also numerous there.

There is also a regional system of vertical NE–SW and NW–SE-trending shear fractures, covering the whole Karkonosze–Izera Block. Rock blocks were displaced along these surfaces. Systems of slickensides are associated with such displacements occurring within near-surface zones of the Earth's crust. They are frequently observed on granite rocks. The orientation of the striae unambiguously indicates the movement direction of rock blocks in relation to one another. Most of them are horizontally oriented. All the types of fractures affect the shapes of granite pinnacles, as can be easily observed in Sokole Mts.

After visiting Sokole Mts., we drive down from Karpnicka Pass and then to Karpniki – an old, 13th-century village situated at the foot of Krzyżna Góra. In the 18th century, the village was owned by the Hohenzollerns. During the times of Prussian King Frederic Wilhelm III, the village was a place of blooming social life. Members of the Prussian aristocracy and artists from all over Europe often visited Karpniki. The estate was well known for its spectacularly rich facilities, decorations and park grounds. Little has remained after prosperity of Karpniki. The castle was plundered and destroyed after the Second World War.

From Karpniki, we head towards Jelenia Góra across a broad, valley-like topographic low between the Wzgórzami Karpnickimi and the Sokole Mts. The low is drained by the Karpnicki Stream and filled with muds, aggregated peaty muds and peats. There are fishponds in this topographic low, well known for a long time. Passing Łomnica Dolna, we drive along the Bóbr river valley with a system of fluvial terraces, and near an aerodrome we arrive in Jelenia Góra. This is a beautiful city, capital of the local administrative district, situated on both riverbanks of the Bóbr, in the centre of the Jelenia Góra Valley at the foot of the Karkonosze Mts. There are many sites in the city and its environs, offering nice views of the mountains. Jelenia Góra is also the major tourist centre for the Karkonosze region, Izerskie Mts., Kaczawskie Mts. and Southern Karkonosze of the Czech Republic. This is also the place where we must say good-bye to our geo-travel across the Sudetes Mts.

Closing remarks

The route we covered from Nysa to Jelenia Góra led us across different geological units of the Sudetes Mts.: Fore-Sudetic Block with the foreland section of the Nysa Kłodzka river valley, northern part of the Złote Mts. Metamorphic Complex, Kłodzko–Złoty Stok granitoid intrusion, Kłodzko Metamorphic Complex, Bardo Unit, Upper Cretaceous cover of the Stołowe Mts., Sowie Mts. gneisses and migmatites Block, Intra-Sudetic Depression with the Wałbrzych Trough and Nowa Ruda coal-bearing foredeeps, volcanic formations of the Kamienne Mts., Rudawy Janowickie Metamorphic Complex and Karkonosze granite massif. Each of these units and rock formations is tied to a specific, complex and exciting geological history. However, the evolution of the individual units occurred in close spatial and casual relationships between one another.

One of the guide's goals was to make the geotourists realize these relationships with regard to the wealth of rock types, minerals and structures observed in the exposures. Last but not least was the attempt to show the close relationship between the ground topography and the geological structure of the area, in particular with resistance of rocks. The diversity of the Sudetic landscapes results from a wide range of rock types and geological structures. Human civilisation and history have existed within the landscape and among these rocks. Therefore, the guide also briefly refers to some of more interesting localities we pass by, historic monuments and mining traditions. Obviously, the knowledge about these issues should be extended by referring to normal tourist guides. I express my hope that the present geological publication will bring the reader to a closer knowledge about the beauty of geology and the profound need for exploration of the Earth's history.

Acknowledgements. The authors would like to express their gratitude to Andrzej Biel and Magdalena Czyżowska for computer graphics of the geotourist maps. Special thanks are also due to the authors of photographs: Adam Ihnatowicz, Karolina Ordzik, Bogusław Przybylski and Marek Awdankiewicz. Bogusław Przybylski is thanked for permission to use data from his doctoral thesis in describing geological setting of the Nysa Kłodzka river valley in the Sudetic Foreland.

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