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Tectonics of the Upper Nysa Kłodzka Graben, the Sudetes

Janusz Badura[1] & Marta Rauch[2]

[1] *Lower Silesian Branch, Polish Geological Institute – Research National Institute,, al. Jaworowa 19, 50-122 Wrocław, Poland; e-mail: janusz.badura@pgi.gov.pl*
[2] *Institute of Geological Sciences PAS, Research Centre in Wrocław, ul. Podwale 75, 50-449 Wrocław, Poland*

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Abstract The Upper Nysa Kłodzka Graben is a geological unit well identifiable on geological, topographical and digital elevation model (DEM) maps. Tectonic activity in the area dates back to the Late Cretaceous, when the frames of the tectonic trough were formed due to the uplift of the Śnieżnik Massif Range in the east, Krowiarki Mts. Range in the north and the Bystrzyca Mts. and Orlicka Mts. ranges in the west. The total vertical displacement between the deepest locations in the graben and the highest peaks in the Śnieżnik Range varies between 1200 and 1700 m. The vertical differences in topographical relief of the graben basement exceed 500 m. Although the Upper Nysa Kłodzka Graben extends NNW–SSW, concordantly with the trend of mountain ridges in the Śnieżnik Range, subordinate tectonic structures within the graben trend N–S in its southern part near Králíky and NW–SE in the middle and northern parts. The trends of the subordinate tectonic structures are, thus, parallel to the main mountain ranges in the Orlica Mts., Bystrzyca Mts. and Krowiarki Mts. The most intensive vertical movements took place in the Late Touronian, Coniacian, at the turn of the Createaceous and Tertiary, in the Paleogene and Early Neogene. Although the Late Neogene and Quaternary activity in this area is not well documented, the vertical displacement along faults is assessed at ~70 m. The presence of volcanic rocks covering river gravels in Lądek Zdrój, thermal and mineral springs as well as the occurrence of minor earthquakes in historical times point to tectonic activity also in the Pleistocene. Recent tectonic activity in the Upper Nysa Kłodzka Graben area is evidenced by geodetic measurements and microseismicity recorded over the adjacent East Sudetes area.

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INTRODUCTION

The Upper Nysa Kłodzka Graben (= Nysa Graben, NG) occurs to the SE of the Intra-Sudetic Synclinorium (Żelaźniewicz *et al.*, 2011). It was filled with marine sediments in early Cenomanian through Coniacian to Santonian times (Teisseyre, 1975; Radwańska, 1960 a, b; Kędzierski, 2002). In the Turonian, only two islands emerged from the then shallow sea, the Eastern and Western-Sudetic Islands (Fig. 1). Variable vertical displacements along basement faults initiated local subsidence in the Coniacian, among others in the NG area (Don & Don, 1960; Jerzykiewicz, 1971). This tectonically controlled subsidence led to accumulation of over three times thicker succession of Coniacian deposits in the graben than in the adjacent areas and the vertical displacement along the border normal faults was assessed at 600 m (Rode, 1936; Pachucki, 1959; Don & Don, 1960). The subsidence in the graben ceased already in the Coniacian. In the NG, the termination of the subsidence is indicated by a shallowing- and coarsening-upward succession of marls overlain by sandstones and then by conglomerates (Jerzykiewicz, 1971; Wojewoda, 1997). Since that time, the Late Cretaceous Basin was subjected to inversion. This study presents the main events in the basin inversion and in the structural evolution of the NG.

PHYSIOGRAPHY

The NG is a distinctive topographic subunit in the Kotlina KłodzkaValley. It trends NNW–SSE, and Boboszów in the south. The NG depression is the broadest in the north, being ~12 km wide and it narrows down to ~2 km at the southern termination. Elevation difference of modern topographic surface is ~ 250 m over a distance of ~50 km. The depression separates the Bystrzyca Mts. and Orlica Mts. ranges in the west from the Śnieżnik Range in the east (Fig. 2). The Krowiarki Mts. Range terminates the depression to the north, whereas to the south, it wedges out near the town of Štíty (Czech Republic). An overall topographic surface of the depression is inclined towards the north and south respective the Międzylesie Pass.

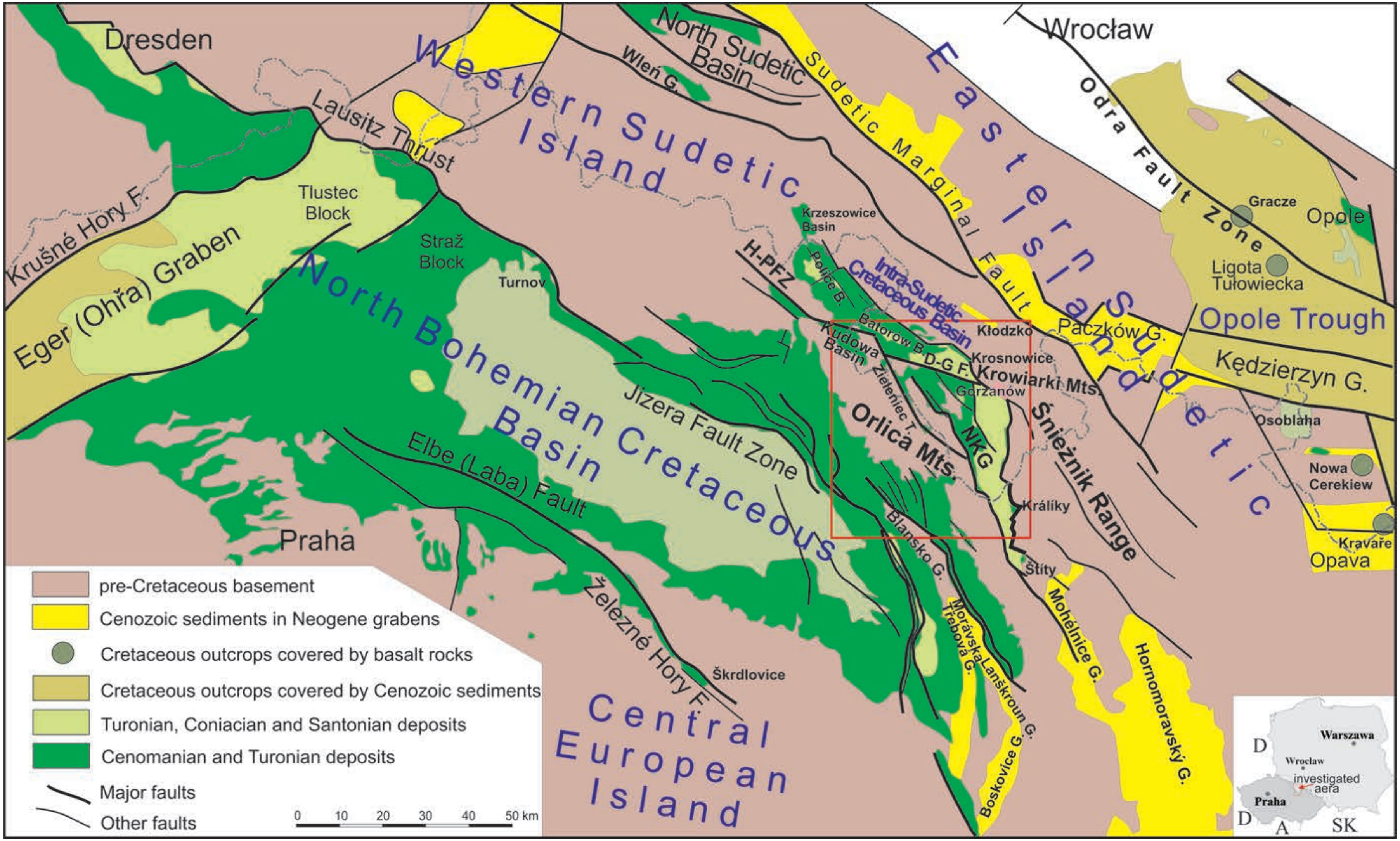

Fig. 1. Post-Alpine tectonic depressions in the Bohemian Massif area (after Ivan, 1996; Chlupáč *et al.*, 2002; Cymerman, 2004; Badura *et al.*, 2004). Abbreviations: NKG – the Upper Nysa Kłodzka Graben; H-PFZ – Hronov-Pořiči Fault Zone D-G F – Duszniki-Gorzanów Fault.

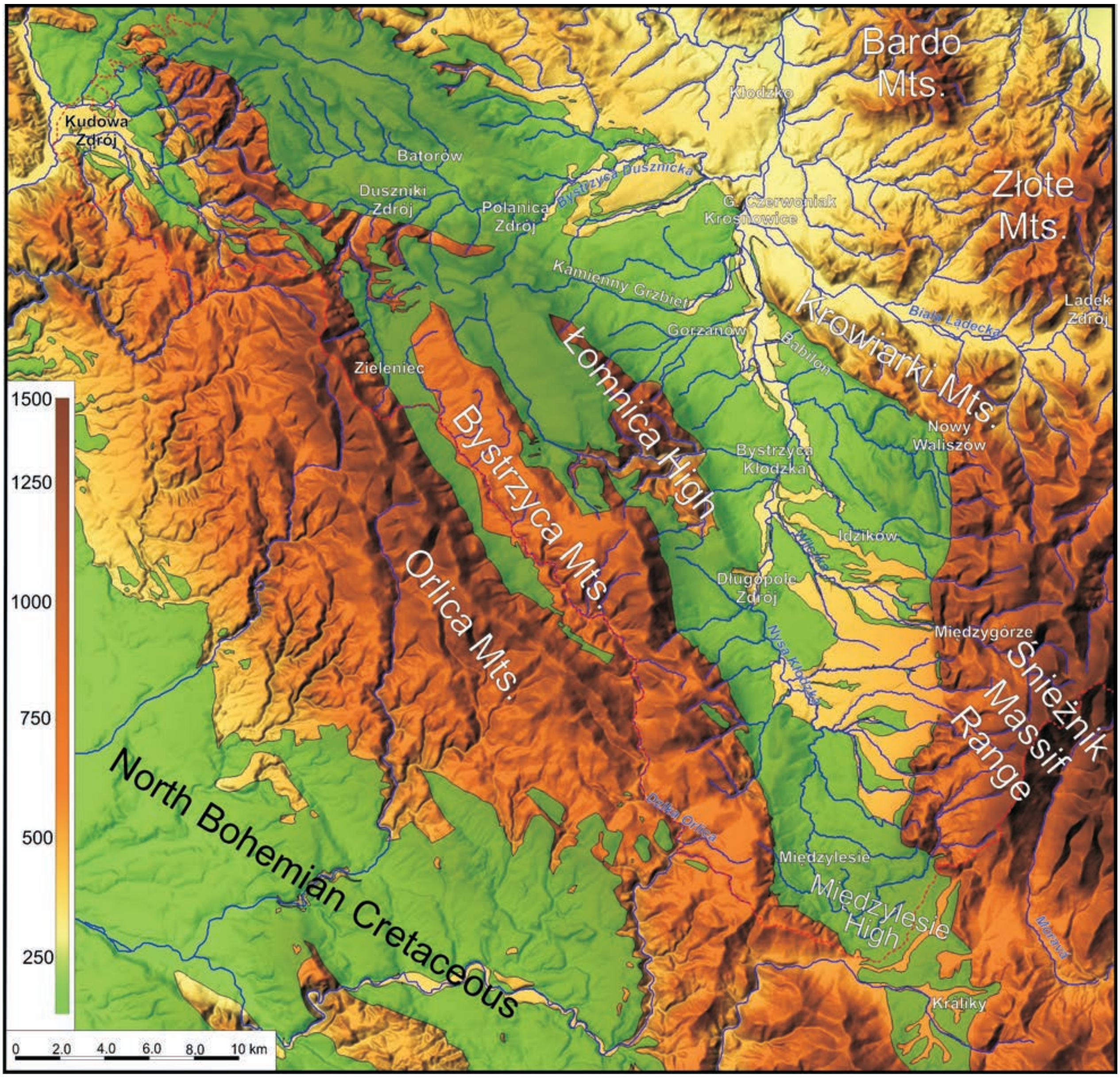

Fig. 2. Outcrops of Upper Cretaceous rocks (green) in the Upper Nysa Kłodzka Graben against the DEM model of the area. 5 times vertical exaggeration.

GEOLOGY

Graben boundaries

The NG is located in the central part of the Orlica–Śnieżnik Dome (Don *et al.* 1990). It is a narrow, wedge-shape in geometry unit that stretches over ~50 km between the village of Krosnowice in the north and the town of Králíky (Fig. 2). Its width diminishes from about 12 km in the north to ~1.3 km at the southern termination near the town of Štíty (Radwański, 1975). The maximum observed thickness of Upper Cretaceous rocks (Turonian–Santonian) in the graben is about 720 m (Radwański, 1975; Valečka, 1988). Neogene fluvial deposits occur at the Międzylesie Pass and in the area of Králíky (Žatečka, 1996; Sroka & Kowalska, 1998). The youngest infill in the NG is represented by recent fluvial and colluvial deposits.

Some authors correlate the northern boundary of the graben with the Kamienna Góra Horst (Don, 1996) or Kamienny Grzbiet–Babilon Fault Zone (Don & Gotowała, 2008). This fault zone, possibly the eastern prolongation of the Hronov–Poříčí Fault Zone, is actually a horst bounded by the Duszniki–Gorzanów Fault on the southern side and the Pstrążna–Gorzanów Fault on the northern side (Figs 1–4). The northern part of the NG borders on Permian bedrock of the Intra-Sudetic Synclinorium (Fig. 3), which outcrops in the vicinity of Krosnowice on the southern slope of the Góra Czerwoniak Hill (Wojewoda & Burliga, 2008). The southern part of the graben borders on crystalline rocks from which it is separated by steep faults with an estimated throw of ~600 m (Rode, 1936; Pachucki, 1959; Don & Don, 1960). A step-like faulting is also evidenced inside the sou-

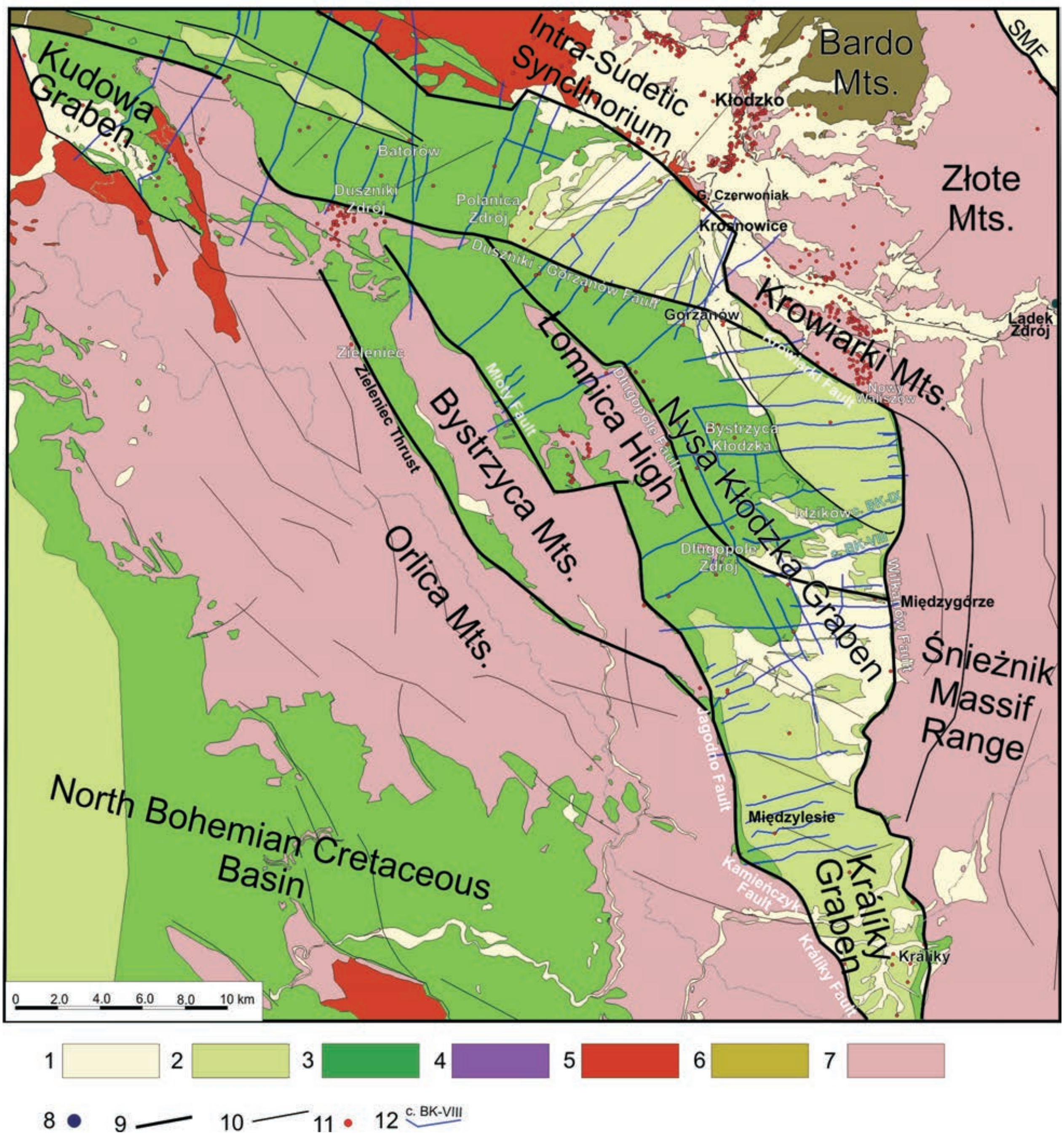

Fig. 3. Geological sketch of the Nysa Graben to show lines of geoelectrical profiles and locations of boreholes that reached the sub-Cretaceous bedrock. 1 – Cenozoic; 2 – Coniacian; 3 – Cenomanian and Turonian; 4 – Triassic; 5 – Permian; 6 – Carboniferous; 7 – metamorphic and plutonic rocks; 8 – basaltoids; 9 – faults in sub-Cretaceous basement; 10 – boreholes; 11 – electrical resistivity profiles with numbers. Abbreviations: SMF – Sudetic Marginal Fault.

thern part of the graben, where two fault-bounded blocks are distinguished: the Bystrzyca Mts. block (the most uplifted part of the graben) and the Łomnica High block. The southernmost tip of the NG is situated on the Czech Republic territory and referred to as the Králíky Graben.

Infill of the graben

The sedimentary infill of the NG represents the easternmost fragment of the formerly continuous Upper Cretaceous sedimentary cover (Fig. 1). In the area of study, the cover is dismembered into four domains located across the Polish-Czech border.

In the Cenomanian, a transgressing sea entered the area of the Kotlina Kłodzka Valley from the northwest and inundated the relatively flat sub-Cenomanian surface (Pachucki, 1959; Don & Don, 1960). The Upper Cretaceous rocks are represented by sand-clay-marl facies deposited in a shallow epicontinental sea. The sea was deepening until the Early Turonian and the sedimentary facies patterns changed in the Middle Turonian. The abundance of coarser clastic deposits

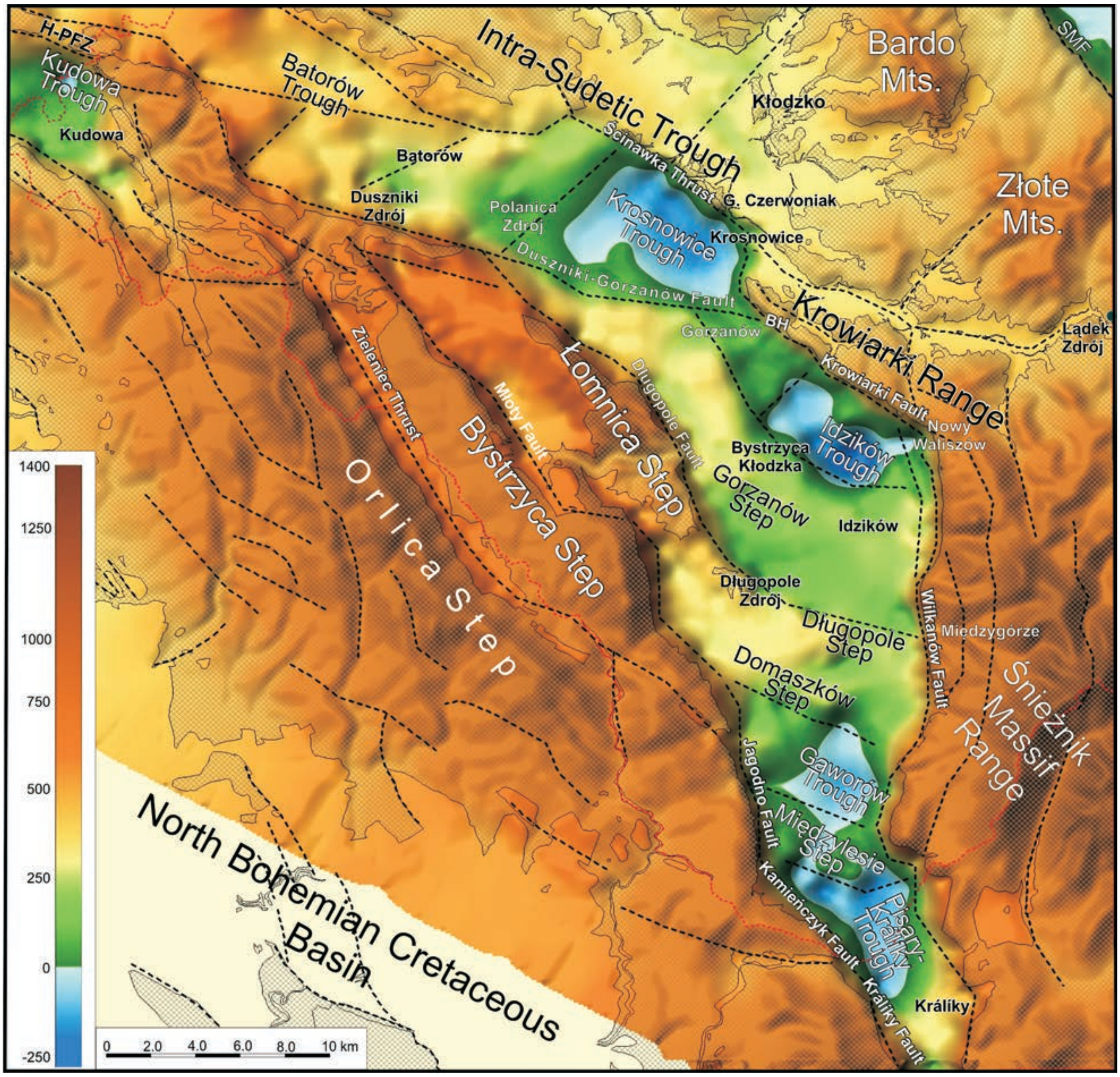

Fig. 4. Digital elevation model of the sub-Cretaceous basement. Dense grid: pre-Upper Cretaceous bedrock; thin dashed lines – faults. Abbreviations: BH – Babilon Horst; H-PT – Hronov-Poříčí Thrust; SMF – Sudetic Marginal Fault. 5 times vertical exaggeration.

suggests that the source areas were uplifted on either side of the graben and that troughs developed in the graben, in areas where thick clastic sediments were accumulated. The strongest subsidence occurred in the eastern part of the graben which abutted against the concurrently elevating Śnieżnik Range that was the main source of clastic sediments. In the NW part of the graben, the Cretaceous sediments accumulated in a broad and realtively shallower sub-basin referred to as the Batorów trough. The medium grained sandstones and conglomerates of the Idzików Beds are regarded as the youngest Cretaceous deposits in the NG (Don & Gotowała, 2008).

The thickness of the Cretaceous strata in the NG ranges between 400 and 900 m (Radwański, 1957, 1961; Pachucki, 1959; Don & Don, 1960). Jerzykiewicz (1971) estimated the total thickness at ~900 m. The Upper Cenomanian to Middle Turonian sedimentary facies and the thicknesses of deposits are similar in the Nysa Graben and in the Intra-Sudetic Synclinorium (Don & Gotowała, 2008). According to Don & Don (1960) the differences in sedimentary patterns of younger Cretaceous deposits between the graben and synclinorium indicate that since the Middle Turonian the sedimentation in the area south of Kłodzko went on under tectonic control. Since the Coniacian, the sedimentary facies in the two depocentres significantly differentiated as evidenced by the 900–1000 m thick Idzików beds in the Nysa Graben whereas their equivalents in the Intra-Sudetic basin did not exceed 370 m (Don & Wojewoda, 2003).

The thickness of Coniacian deposits in teh NG was overestimated in older analyses (Jerzykiewicz, 1971). Later boreholes provided more correct information. In two boreholes, Pisary IG1 and 7R in Stary Waliszów, the thickness of Coniacian succession was 398.3 m and 355 m, respectively (Radwański, 1975). In the narrowest part of the graben near

Králíky, the thickness of Coniacian deposits was 468.3 m in the KP-1 borehole and the apparent thickness of 553.5 m was evidenced in the KP-2 borehole (Valečka, 1988). In case of the Batorów and Police troughs, Coniacian sediments were thinner since their bedrock was elevated as evidenced in the Batorów IG-1 borehole and, thus they were entirely eroded. There is a NNE–SSW trending fault zone near Polanica Zdrój which presently separates the Krosnowice Syncline from the Bato- rów Syncline (Don & Gotowała, 2008), the latter being uplifted by ~350 m with respect to the former (Radwański, 1975).

Open synclines and anticlines in bedding of Upper Cretaceous rocks in the Nysa Graben were recognized and mapped by Don & Gotowała (2008). These tectonic structures were brought about by the NNE-SSW oriented shortening in a compressional regime. Our observations show that the present day synclines found in the outcrop pattern actually developed over former sedimentary troughs.

There are also Neogene fluvial deposits evidenced at the Międzylesie Pass and in the area of Králíky (Žatečka, 1996; Sroka & Kowalska, 1998). The youngest infill in the NG is represented by recent fluvial and colluvial deposits.

Tectonics

The NG developed in the Late Cretaceous–Tertiary (Pachucki, 1959; Don & Don, 1960; Jerzykiewicz, 1971) and was separated from surrounding metamorphic rocks by steep border faults. The vertical displacements along the individual border faults vary between 600 m (Rode, 1936; Pachucki, 1959; Don & Don, 1960) and 1600 m (Don & Gotowała, 2008).

Several interpretations of tectonic evolution of the graben were proposed. The earliest concept by Cloos (1922, 1936) assumed that an extensional trough was formed in the axial part of the rising up Orlica–Śnieżnik Dome. Other authors (Don & Don, 1960; Don 1996; Don & Wojewoda, 2005; Don & Gotowała, 2008) distinguished two major stages in the evolution of the graben: (1) a synorogenic, gravitational subsidence induced by the extension of the metamorphic basement during its uplift; (2) a compressional phase at the turn of the Cretaceous and Paleogene ('Laramian' phase). Wojewoda (1997) also proposed a multiphase evolution of the NG in the Late Cretaceous with development of normal listric faults at its borders. The normal faults were then rejuvenated as dextral strike-slip faults and the extension of the basement continued in the Coniacian–Santonian through Neogene.

Tectonic activity along the eastern border normal fault enhanced subsidence in the adjacent areas of the Cretaceous basin and led to development of an asymmetric graben, deeper in the eastern part of the basin and shallower in the western one (Jerzykiewicz, 1971). An estimated throw along the eastern border fault in the vicinity of the Czarna Góra Hill was ~1600 m (Don & Don, 1960). The vertical displacement along the western border fault differed along the fault strike: hundreds of meters in its southern section and a few meters in the northern section, i.e. near the boundary between the NG and the Intra-Sudetic Synclinorium (Don & Gotowała, 2008). The difference in thickness of the Cretaceous deposits throughout the NG is due to both the asymmetry of the graben and development of subsidiary faults in the graben after the Middle Turonian.

According to Don & Gotowała (2008), the most significant event in the next stage of the NG evolution was the activity of the NW–SE trending Krowiarki Marginal Fault (KMF) which bounded the graben to the north between the villages of Nowy Waliszów and Gorzanów (Fig. 4). The Cretaceous graben infill is in contact with metamorphic basement rocks along this fault. It is a normal component fault, however, locally it appears as a reverse one with sinistral strike-slip component. The KMF constitutes a part of a regional fault zone which continues towards the southeast, across the Śnieżnik Range and the Staré Město Belt to the Keprnik Dome. Toward the northwest, the KMF extends as the Duszniki–Gorzanów Fault Zone (Fig. 4). The southern tip of the NG borders on the Štíty Fault (Don *et al.*, 2003). This is a reverse fault which trends parallel to the KMF.

Don & Gotowała (2008) indicate the importance of lateral compression in the tectonic evolution of the NG, which took place at the turn of the Cretaceous and Paleogene. The compression induced inversion of the normal faults and led to development of reverse, NW–SE trending faults in the northern and southern parts of the graben. It also resulted in large-scale, open folding of the basin infill, with the fold axes trending NW–SE, obliquely to the extent of the graben. Several folds are distinguished: Międzylesie– Roztoki Syncline, Długopole Zdrój Anticline, Wilkanów Syncline, Bystrzyca Anticline, Idzików–Krosnowice Syncline and the Domaszków–Długopole Zdrój–Bystrzyca Kłodzka Anticline. The latter extends in the central part of the graben. A bunch of faults trending WNW–ESE/NW–SE also formed during the very stage of deformation (Fig. 2).

The Krosnowice–Międzygórze Fault depicts variable displacement and geometry (Don & Don, 1960). It induced drag folding of Cretaceous beds in the vicinity of Gorzanów (Grocholska & Grocholski, 1958). The displacement on the fault significantly increases near the village of Mielnik, where the beds are down-thrown on the fault towards the southeast. Westwards, the fault plane steepens up to vertical and in the vicinity of Nowy Waliszów the fault attains a reverse geometry.

Dumicz (1964) and Frąckiewicz (1965) described evidence of thrusting of metamorphic rocks over Cretaceous deposits in several locations in the NG area. Also Dziewański (1984) reported thrusting of gneisses over Cretaceous rocks near the village of Młoty in the Bystrzyca Mts. The above evidence points to lateral compression and reverse fault development at the late stage of the NG evolution. These aspects are more thoroughly discussed by W. Kozdrój (2014) who presents the results of shallow drillings both in the graben and in the adjacent areas.

TOPOGRAPHY OF SUB-CRETACEOUS SURFACE IN THE GRABEN AND ADJACENT UNITS

The studies on the contemporary tectonics in the NG and adjacent regions were carried out with use of the digital elevation models (DEM, Fig. 4) as well as the analysis of changes in river tracts (Fig. 2), analysis of topography of depressions which are not related to the modern river system and analysis of triangular facets (Fig. 5). These analyses were correlated with the results of geophysical studies (electrical resistivity profiling) by Grzegorczyk *et al.* (1993) and Farbisz (1993) and with the data from a few boreholes which penetrated the basement rocks underlying the Cretaceous deposits in the NG. Farbisz (1993) also reinterpreted the earlier acquired resistivity profiling data.

There are numerous geophysical indications of rotation and flexural bending of Cretaceous beds in the vicinity of faults in the NG (Fig. 6). The resistivity images show an increased resistance of rocks in the vicinity of the flexural folds, for example in Pasterskie Skały (Shepherds' Rocks). Originally, this phenomenon was interpreted as a change in lithology or local uplift of the basement. However, our studies showed that the observed increase in the resistivity results from intense fracturing of the bent and dragged beds in the open flexures, as well as from steepening of beds and, thus, apparent increase of thickness of rocks with high electrical resistivity (Farbisz, 1993).

Scattered data on the depth of the sub-Cretaceous surface obtained from a few boreholes were correlated with the height at which the basement rocks outcrop on the surface at present. The 3D model of the sub-Cretaceous surface was constructed utilizing different type of software: Excel (data bases), Surfer (compilation of data bases, griding), Global Mapper (imaging, 3D projection, contour maps).

The reinterpretation of the electric resistivity profiles on a regional scale (Farbisz, 1993; Grzegorczyk, 1993) and the data obtained from boreholes in the Intra-Sudetic Synclinorium showed that the Cretaceous deposits overlay Permian deposits in the northern part of the Intra-Sudetic Synclinorium, and Carboniferous and Permian deposits in its SW part. In the area of Batorów, Duszniki Zdrój, Polanica Zdrój and Krosnowice, the Cretaceous deposits are underlain by metamorphic rocks. Several subordinate synclines and anticlines are distinguished over the area covered by Cretaceous deposits: Krzeszów, Police, Batorów, Krosnowice, Nysa Graben, and Králíky.

In the NG, a sharp scarp delineates its northern boundary and separates the graben from metamorphic rocks of the Kłodzko Metamorphic Massif and the Krowiarki Metamorphic Belt (Don & Gotowała, 2008). Also the eastern edge along the contact with the Śnieżnik Metamorphic Massif is very distinctive. Only the SW boundary of the graben is less clearly expressed due to the occurrence of extensive morphotectonic flat step-like blocks, trending NW–SE, which separate the Nysa Graben from the Orlica Mts. and Bystrzyca Mts. Two broad morphological steps with steep eastern slopes and gentler western ones are distinguished in the NE part of the Orlica Mts. They are referred to as the Bystrzyca and Łomnica High steps (Fig. 4). The morphotectonic step of Gorzanów is situated in the prolongation of the Łomnica step. The asymmetric morphotectonic Bystrzyca

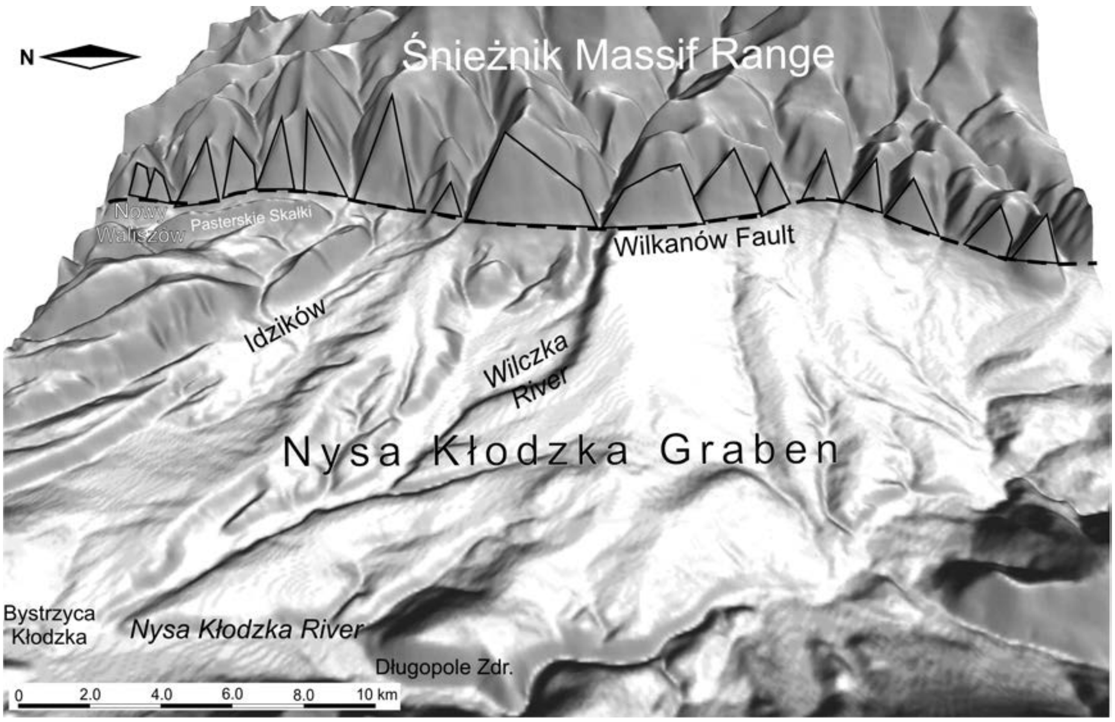

Fig. 5. Triangular facets along the Wilkanów Fault.

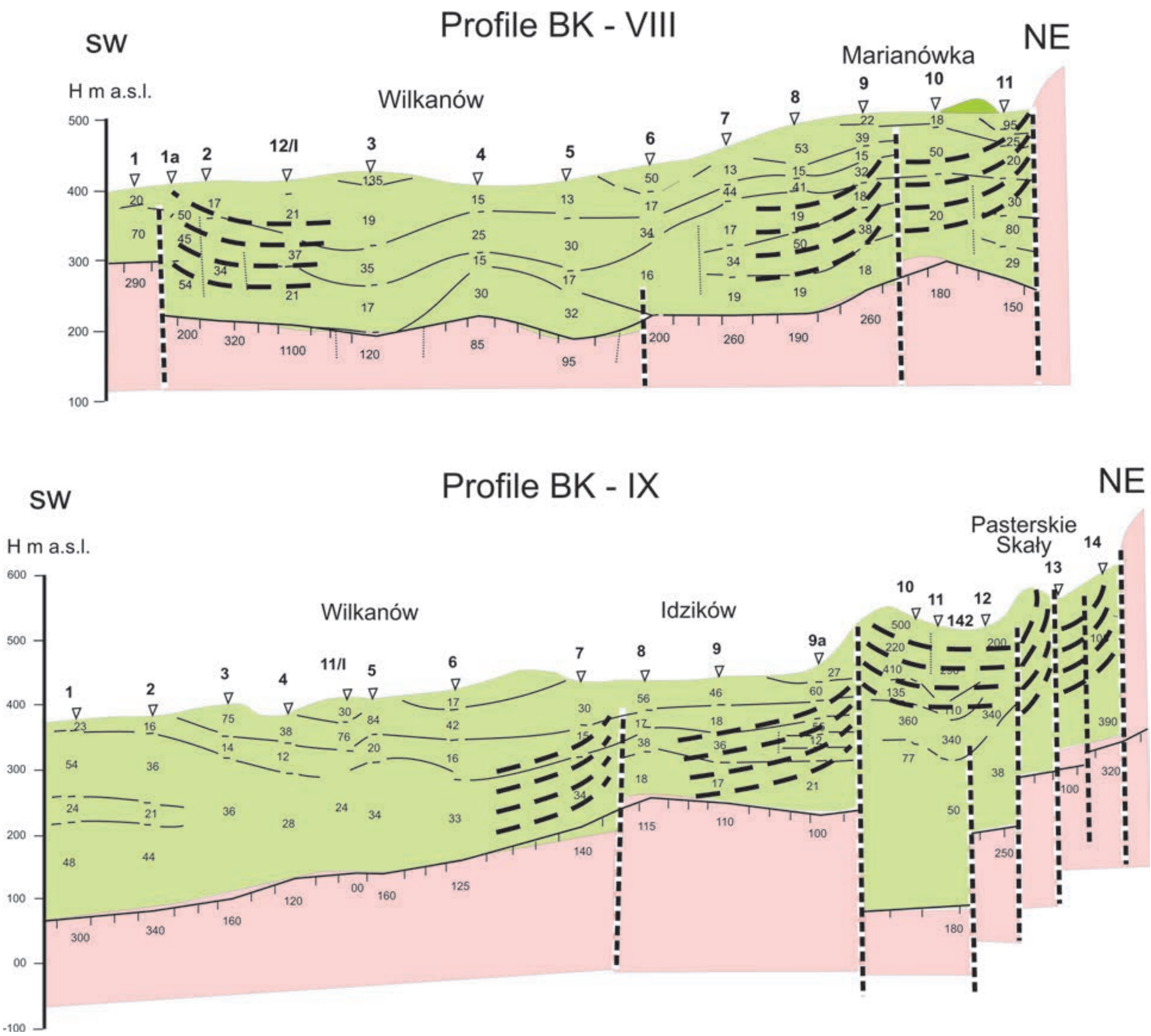

Fig. 6. Geological interpretation of the electrical resistivity profiling (thin lines and numbers at the background). For locations see Fig. 3. Pink – basement; green – Upper Cretaceous infill of the Nysa Graben; vertical dashed lines – faults; thick dashed lines – attitude of bedding planes involved in open folds, note bending of beds in the proximity of faults which recorded multiple movements with changing kinematics.

step trends obliquely to the graben, being partly covered by Cretaceous deposits (Fig. 4). Turonian deposits are covered by Coniacian deposits in its eastern part. The SE part of that step occurs at deeper depths and correlates with the Wilkanów Syncline distinguished by Don & Gotowała (2008).

The elevation difference between summits in the Orlica Mts. (1000–1100 m a.s.l.) and the Divoká Orlice river bed is ~350–400 m. The difference in the northern and central sections of the Bystrzycka Mts. flat step is ~150 m and over 400 m in its southern section. The Łomnica High Step is ~3 km wide and it rises ~220 m above the River Bystrzyca valley. The eastern slope of this step dips steeply towards the River Nysa Kłodzka valley, making up a 350 m high scarp. Cretaceous deposits are preserved only fragmentarily on the top of the step.

All four steps cut-off on their northern side on a tectonic zone of the Duszniki–Gorzanów Fault Zone (Radwański, 1975; Fistek, 1977; Kiełczawa & Teisseyre, 2000; Don & Gotowała, 2008). Turonian deposits are uplifted along this zone and constitute a horst which is 11 km long and 1 km high. The zone is evidenced as a scarp in a numerical model of the sub-Cretaceous basement (Fig. 6) and it extends north of the village of Gorzanów (Farbisz, 1993). The uplifted basement blocks formed ridges on the surface which shifted local stream valleys. For example, one of the streams originally flowing northeastwards changed the direction of flow to the SEE, i.e. parallel to the uplifted horst. A pass in the Kamienny Grzbiet ridge is the remnant of the former NE-trending stream valley.

A number of second-order tectonic structures can be distinguished in recent topography of the sub-Cretaceous basement (Fig. 7). These are tectonic troughs and horsts which depict high difference in elevation in places. Longitudinal scarps of the troughs, trending N–S, NNE–SSW and NE–SW, terminate on the latitudinal scarps which trend W–E, NWW–SEE and NW–SE. Therefore, the former group of scarps appear to be secondary morphological features in respect to the latter.

The sub-Cretaceous basement in the NG is asymmetrically elevated (Fig. 7). A distinct trough (~ Idzików Syncline) occurs in the northern part of the graben along the Krowiarki Marginal Fault and the other between the Nysa Fault and Szalejów–Krosnowice Fault (Krosnowice Syncline). In the Krosnowice Syncline, the basement gradually rises southwestwards, then, it is abruptly uplifted along the Kamienny Grzbiet–Babilon Horst which makes up a remarkable ramp at the SE margin of the Krosnowice Syncline. The edges of this depression outline a trapezium in a plan view. Also in the Idzików Syncline, a trapezium-shape bedrock trough is noticeable and the basement top surface gradually rises towards the Kamienny Grzbiet–Babilon Horst which is very narrow near the village of Idzików. In the central part of the NG, between the villages of Pławnica and Goworów, the basement of the graben is uplifted and bordered by WNW–ESE trending edges. The northern edge of this uplifted block is situated in the vicinity of the Zabłocie–Idzików Fault and the southern one in the vicinity of Goworów (see Tectonic Map of the Nysa Kłodzka Graben in Don & Gotowała, 2008).

There are two deep troughs or grabens in the bedrock of the southern part of the NG. These are the Králíky–Pisary trough and the Gaworów trough, both more than 700 m deep. The latter occurs below the Międzylesie Syncline. The two depressions are separated by the Międzylesie Step which rises ~200 m above the basement of the troughs and stretches along the Kamieńczyk and Králíky Fault. The elevation difference between the bottoms of both troughs and the crests of neighbouring hills is over 800–900 m.

Towards the southwest from the village of Roztoki, a triangular in shape part of the NG basement rises by ~250 m. This part of the NG is a SE prolongation of the Łomnica High Step, which was more deeply buried. Its was named the Roztoki Syncline by Don & Gotowała (2008).

Another uplifted horst extends between Długopole Zdrój and Nowa Wieś. It is a southeastward continuation of the Łomnica High Step. There are ~75 m elevation differences in the morphological surface of this buried horst. The highs and depressions may indicate that this surface evidences buried etchplain where regoliths occur.

Less variable morphology is evidenced on top of the buried extension of the Bystrzyca flat step (Bystrzyca Anticline). This step delineates the northern boundary of another deep trough referred to as the Idzików Brachysyncline (Don, 1996; Don & Gotowała, 2008). The research borehole 7R drilled to a depth of 625 m showed that Middle Turonian deposits occur at the bottom of the borehole, thus, the metamorphic basement has to occur some 20–40 m deeper (Radwański, 1975). The elevation differences between the crest of Krowiarki Mts. Range and the bottom of the crystalline basement of the trough is over 620 m and over 400 m in respect to the buried Bystrzyca step.

The resistivity profiling along lines cross-cutting the NG revealed variation in resistivity of the graben infill. Low resistivity (20–50 Ω m) rocks occur in the western part of the graben and in the proximity of tectonic borders of the Krowiarki Mts. Range and Śnieżnik massif. The resistivity of rocks sharply increases from 75 to 410 Ω m in the vicinity of the eastern border of the graben (Farbisz, 1993). Low resistivity rocks also occur at depths below 100 m. The band of high resistivity rocks is ~1300 m wide and has sharp boundaries. Therefore, it is rather unlikely to assume this feature as representing sand and gravel deltaic deposits, which interfinger with clay and sand ones. The analysis of the geophysical data is hindered due to the occurrence of several hundred meter wide tectonic steps which obscure the distribution of resistivity of rocks in the graben.

The Krosnowice trough situated in the northern part of the graben has trapezium-shape boundaries in a plan view. It narrows eastwards, where it borders on the Krowiarki Mts. Range. Along this tectonic boundary, the easternmost occurrence of Permian deposits is evidenced in the River Biała Lądecka valley (Grocholska & Grocholski, 1958). The NW border of the trough is delineated by the Czerwoniak Thrust, whereas the western boundary corresponds to NNE–SSW trending faults, which separate the trough from the uplifted by ~300 m Batorów Basin (Radwański, 1975; Don & Gotowała, 2008). The southern boundary is outlined by the Kamienny Grzbiet–Babilon Horst. The deepest borehole drilled in that area revealed that the total thickness of Cretaceous deposits is 518 m (Grzegorczyk *et al.*, 1993). The elevation difference in respect to the Góra Czerwoniak hill is over 420 m.

CONCLUSIONS

The analysis of the sub-Cretaceous basement morphology in the NG, based on data from a few boreholes and from relatively dense network of resistivity profiling, evidenced block displacements. The most significant subsidence took place in the southern part of the graben, where the greatest thickness (~720 m) of Cretaceous deposits is documented (Fig. 4). In the northern part of the Nysa Graben, in the Idzików Trough (~Syncline), these deposits are only up to 640 m thick.

The NG is distinctly bounded by steep faults along the northern and eastern borders. The western boundary is delineated by a system of en echelon faults (Jagodna and Długopole Faults) which elevated the basement in step-like blocks up to the surface. These tectonic steps are asymmetric, being gently inclined towards SW and steeply towards NE. The steps continue further to the east where they are still recognizable in the morphology of the graben bottom which is concealed under Cretaceous strata. These tectonic steps are also asymmetric, being more gently inclined on their SW sides and more steeply on the NE sides.

The topography of the NG basement and continuation of the step-like arrangement of the fault blocks outside the western boundary of the graben indicate that the tectonic structure of the graben was modified after the Late Cretaceous–Paleogene inversion, owing to the NE–SW oriented extension. The present outline of the graben was shaped

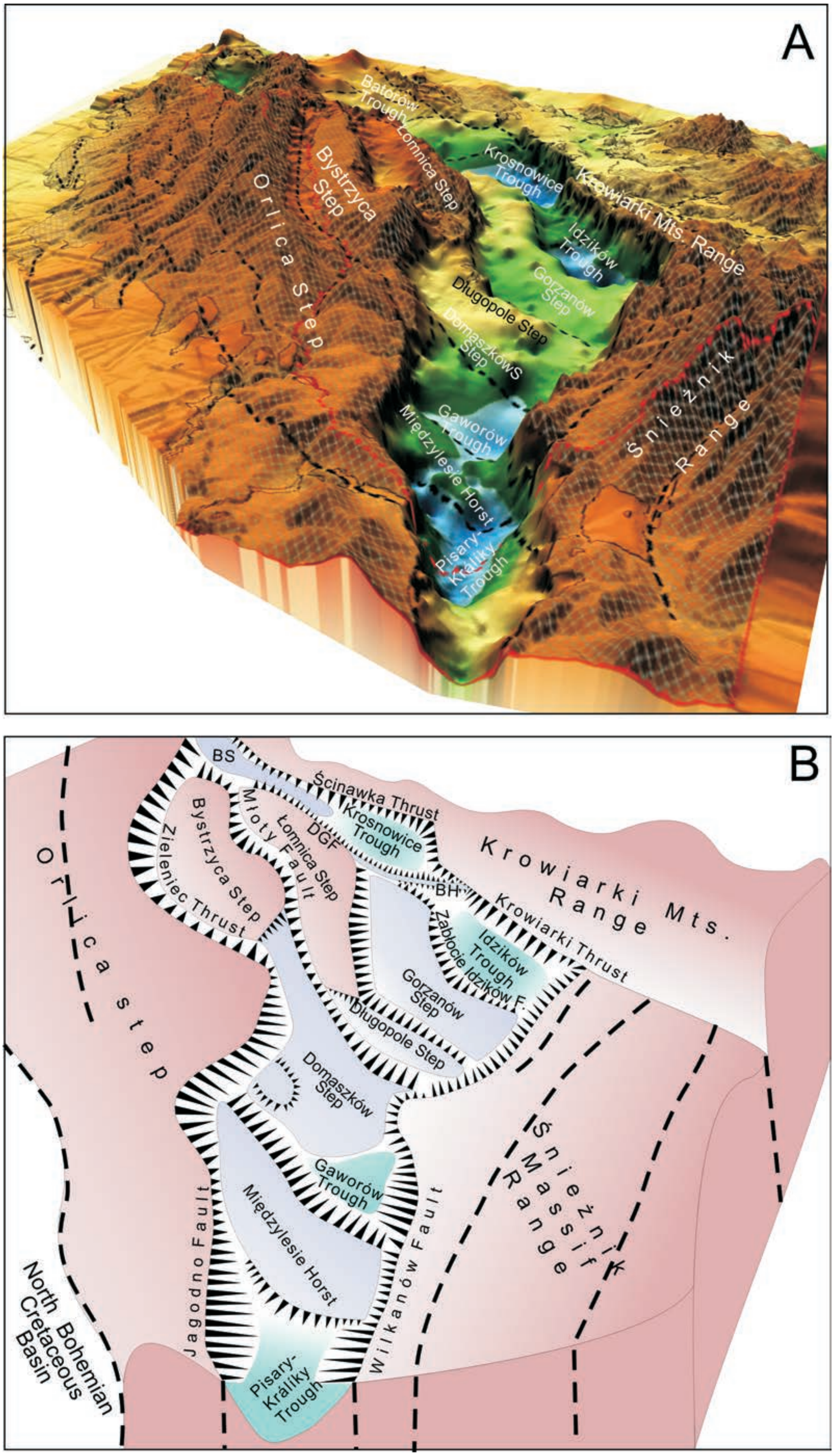

Fig. 7. A – blockdiagram showing the structure of the Nysa Graben. Grey net: pre-Upper Cretaceous bedrock, vertical exaggeration 10 times; B – tectonic sketch of the Nysa Graben. Abbreviations: BH – Babilon Horst; BS – Batorów Step; DGF – Duszniki–Gorzanów Fault.

effectively in the Miocene. Then, at the turn of the Late Miocene and Pliocene, the inversion along WNW–ESE to NW– SE trending faults elevated the graben shoulders by 70 m relative to the originally deepest areas of the graben. The resultant highs locally changed the drainage system, which is reflected by the shift of river valleys. Further subsidence continued only in the Krosnowice Syncline area.

The Nysa Graben is one of a few areas in Poland, which was vertically displaced by several hundreds metres after the basin inversion at the Cretaceous–Palaeogene turn. The estimated displacements in the Nysa Graben are likely compatible with those observed at the contact between the Eger Graben and Erzgebirge and Lausitz Massif. Strikingly, Cenozoic strata are almost missing from the Nysa Graben.

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