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Tectonic evolution of the late Cretaceous Nysa Kłodzka Graben, Sudetes, SW Poland

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Abstract The Nysa Kłodzka Graben, located in the Sudetes of SW Poland, developed as a result of Coniacian (middle Upper Cretaceous) N-trending faulting of the Variscan crystalline basement rocks that comprise the crest of the Orlica–Śnieżnik Dome. The graben was transgressed by a late Cretaceous sea that encroached during the Cenomanian from the northwest. Up to 700 m of Coniacian shales, sandstones and conglomerates were deposited in the graben, with shales (the ~500 m thick Idzików 'clays') dominating the graben's central section. On the western side of the graben, shales grade upwards to greywackes in a style that resembles a turbidite sequence; on the eastern side, shales are overlain by sandstones and conglomerates (the Idzików conglomerates) that represent extensive late Cretaceous fan deltas. These within-graben fan deltas date the onset of fault-block movements that uplifted the Sudetes region during the late Cretaceous–Cenozoic. By the end of the Cretaceous, both the sedimentary infill and the underlying Cenomanian and Turonian strata were steepened at the graben margins and were gently folded, the fold axes paralleling the graben's marginal faults. Subsequent Cretaceous–Paleocene ('Laramian') deformations resulted in NW-trending reverse faulting, which restructured the earlier N–S template of the graben, and in transcurrent faults, which cut the N-trending folds, modified the north and south ends of the graben and strongly affected the graben's western walls. The total thickness of the Upper Cretaceous strata of the Nysa Kłodzka Graben is 3 times that of the Intra-Sudetic Synclinorium, implying that the two units developed independently.

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INTRODUCTION

The Nysa Kłodzka Graben (hereafter the Nysa Graben) is one of the youngest tectonic units in the Sudetes, SW Poland. The development of the Nysa Graben postdates the Cenomanian marine transgression ('Chalk Sea'), this transgression being facilitated by what is now the Kłodzko region having a topographic relief at the time of only a few tens of metres. Because of its young age, the Nysa Gaben is easily recognised in the geomorphology of today (Fig. 1, App. 1).

The Nysa Graben is an ~55 km long, N–S trending feature that is 12 km wide near Kłodzko and Krosnowice but narrows to less than 2 km near Štity at its southern tip in the Czech Republic (Fig. 1, App. 1). The graben started to develop during the Coniacian (Don & Don, 1960), has its long axis coincident with the trend of the Orlica–Śnieżnik Dome crystalline basement (Cloos, 1922, 1936) and is bordered to the west and east by faults that control the steep marginal slopes of the exposed metamorphic basement bedrock (Figs 2, 3).

The NW part of the graben contains Cretaceous infill that passes into the Upper Cretaceous sediments of the Intra-Sudetic Synclinorium (Żelaźniewicz & Aleksandrowski, 2008). The boundary at the Cretaceous structural level between these units is rather arbitrary (Wojewoda, 2004). Some regional overviews (*e.g.*, Stupnicka, 1989) have included the Nysa Graben in the broader Intra-Sudetic Synclinorium. In the 1960s and 1970s, the lithostratigraphy that had earlier been established for the Intra-Sudetic Synclinorium was adapted to the Nysa Graben (Radwański, 1961, 1975). However, detailed studies conducted in the NE part of the graben (Don & Don, 1960; Jerzykiewicz, 1970, 1971) revealed significant differences between both the sedimentary facies and the structural development of the Intra-Sudetic Synclinorium and the Nysa Graben since Coniacian times: for example, the Coniacian deposits, especially the Idzików Beds, are nearly 3 times thicker (~1,000 m *vs.* ~370 m) than their counterparts in the synclinorium (Don & Wojewoda, 2003;

Fig. 4). Thus, lithostratigraphic correlation between the graben and the synclinorium is still a matter of considerable debate as a result of numerous on-going problems: related map sheets have been given different legends; there are apparent 'stratigraphic gaps' along boundaries of neighbouring sheets only because the rocks were mapped by different people; and that hitherto available topographic maps at the scale of 1:25,000 were purposely 'simplified' (distorted) to meet the imposed requirements on all such data in post-war Poland. All these factors have impeded making coherent tectonic reconstructions of the Nysa Graben, but the main obstacle has been from the inadequate correlation of the widespread, but poorly exposed, ~500 m thick Idzików 'clays': these clays lack any marker horizons (Don & Don, 1960).

We re-mapped the area of the Nysa Graben using the more accurate 1:10,000 topographic base maps that were published in 1976 and that were draughted using photogrammetric data. These maps accurately show the relationship between bedrock and topographic relief and, thus, have the potential to more reliably identify faults and so aid in tectonic reconstructions. Financial constraints meant that no test-pits or trenches could be dug to confirm certain lithologies or relationships, and this has undoubtedly influenced the accuracy of our maps.

Field work was conducted between Boboszów, in the south, and Krosnowice–Polanica Zdrój, in the north (App. 1). Particular attention was paid to the graben margins and the tectonics of the sedimentary infill. No new stratigraphic work was carried out because the lithostratigraphy of the area is already well established (Geinitz, 1843; Beyrich, 1849; Sturm, 1901; Pachucki, 1959; Radwańska, 1960; Teisseyre, 1975; Kędzierski, 2002). The attached map in Appendix 1 is the result of cartographic and structural observations made inside and along the margins of the Nysa Graben.

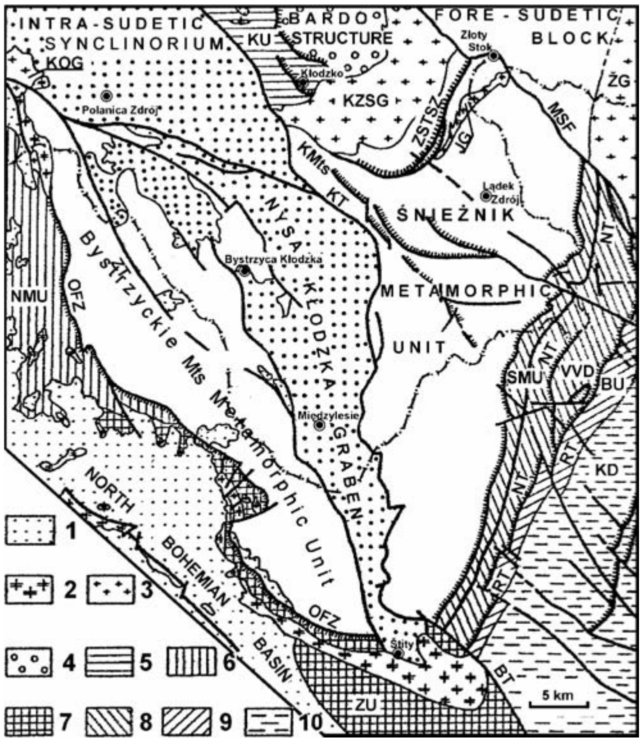

Fig. 1. Tectonic sktech of the Orlica-Śnieżnik Dome (after Cymerman (1997), corrected and supplemented). *1* – Upper Cretaceous; *2* – tonalites and granodiorites, undivided; *3* – granites and granodiorites; *4* – Upper Devonian rocks; *5* –Kłodzko Metamorphic Massif (KU); *6* – Nové Mésto Slate-Greenstone Belt (NMU); *7* – Zábřeh Schist Belt (ZU); *8* – Stáre Mésto Belt (SMU); *9* – Branna Phyllite Belt (BU); *10* – Keprnik Dome (KD). Abbreviations: BT – Bušin Fault; JG – Jawornik granitoids; KOG – Kudowa Zdrój-Olešnice granitoids; KT – Krosnowice Thrust; KZSG – Kłodzko-Złoty Stok granitoids; MSF – Marginal Sudetic Fault; NT – Nýznerov Thrust; OFZ – Orlica Fault Zone; RT – Ramzova Thrust; VVD – Velké Vrbno Dome; ZSTSZ – Złoty Stok-Trzebieszowice Shear Zone; ŽG – Žulova granitoids.

MARGINS OF THE NYSA GRABEN

Our map of the E and NE flanks of the Nysa Graben modifies earlier maps only to a minor degree. One change is the discovery of a kilometre-long fault that deflects the course of the eastern marginal fault in the Pisary–Heřmanice area. This fault is parallel to the Štity Fault and the two border the graben on its southern side (Fig. 1, App. 1).

The graben started to form during the Coniacian when synsedimentary activity on the eastern fault margin gave rise to an asymmetric subsidence of a sedimentary basin that shallowed westward. An estimated total throw on the eastern marginal fault is ~1,600 m in the area of Czarna Góra, but is even more to the north (Don & Don, 1960). The western marginal fault depressed the basin floor by some hundreds of meters in the south but by only several meters in the northwest where the Nysa Graben meets the Intra-Sudetic basin (the upper structural level of the Intra-Sudetic Synclinorium). As the graben floor steadily subsided, Cenomanian and Turonian beds were ultimately rotated into monoclines that developed very steep to vertical dips along the graben's borders. These (sub)vertically dipping beds were then displaced outwards, while remaining almost vertical, by local subhorizontal thrusts (figs 4–8 in Don, 2003). The vertical attitude of the eastern marginal fault can be observed today in deeply incised valleys in the Śnieżnik Massif area, particularly along the steep slopes of the Wilczka Valley, the Szklarka Valley and the Biała Woda Valley (Figs 5 and 6).

A second phase of tectonic activity resulted in the flanks of the Nysa Graben being disrupted by NW-trending, normal to locally reverse faults with a discrete sinistral strike-slip component. On the Polish side of the graben, the most important NW-trending fault is the ~11 km long Krowiarki Marginal Fault (App. 1): between Nowy Waliszów and Gorzanów, this fault separates metamorphic basement from graben infill. The Krowiarki Marginal Fault is a part of a regional fault structure that continues southeastward, via the Śnieżnik Massif and the Staré Město Belt, to the Keprník Dome and continues

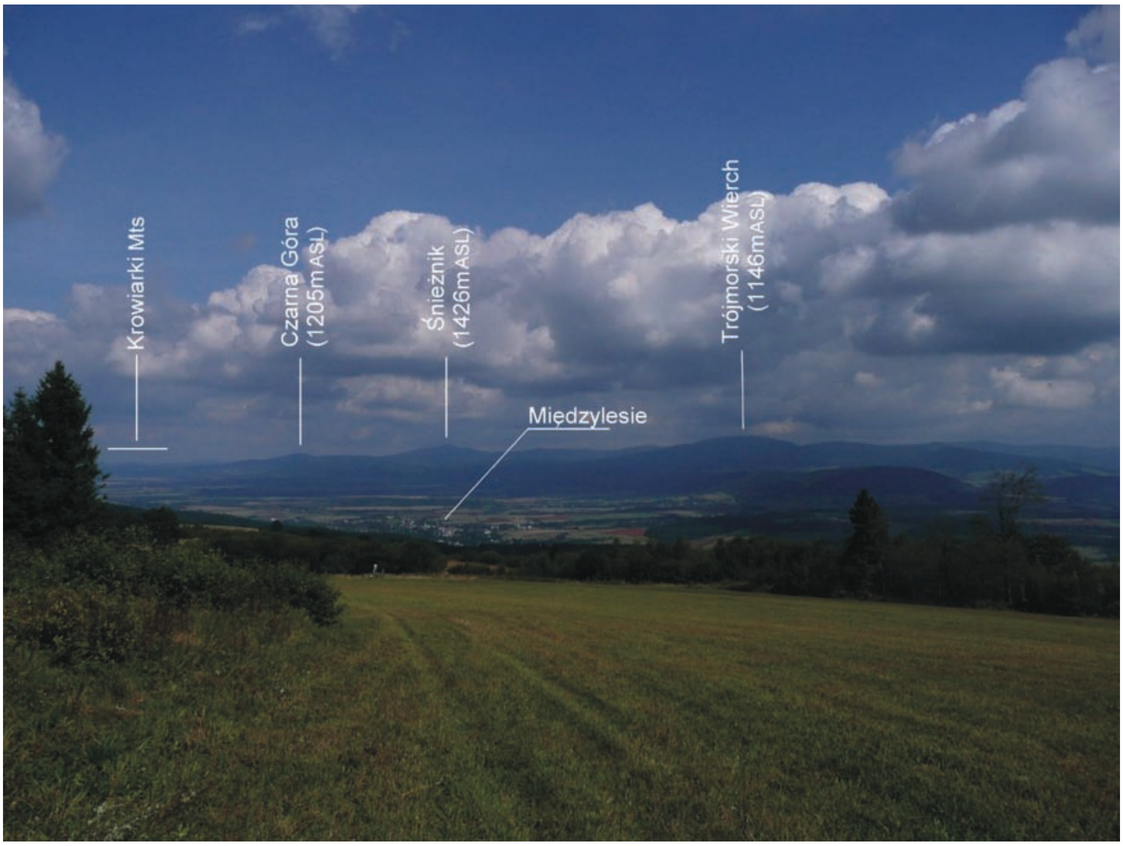

Fig. 2. The Nysa Graben and the Góry Bystrzyckie Mts. in the vicinity of Międzylesie. The Międzylesie Upland is on the right.

Fig. 3. The eastern margin of the Nysa Graben. The summit of Igliczna Mt. is on the left side.

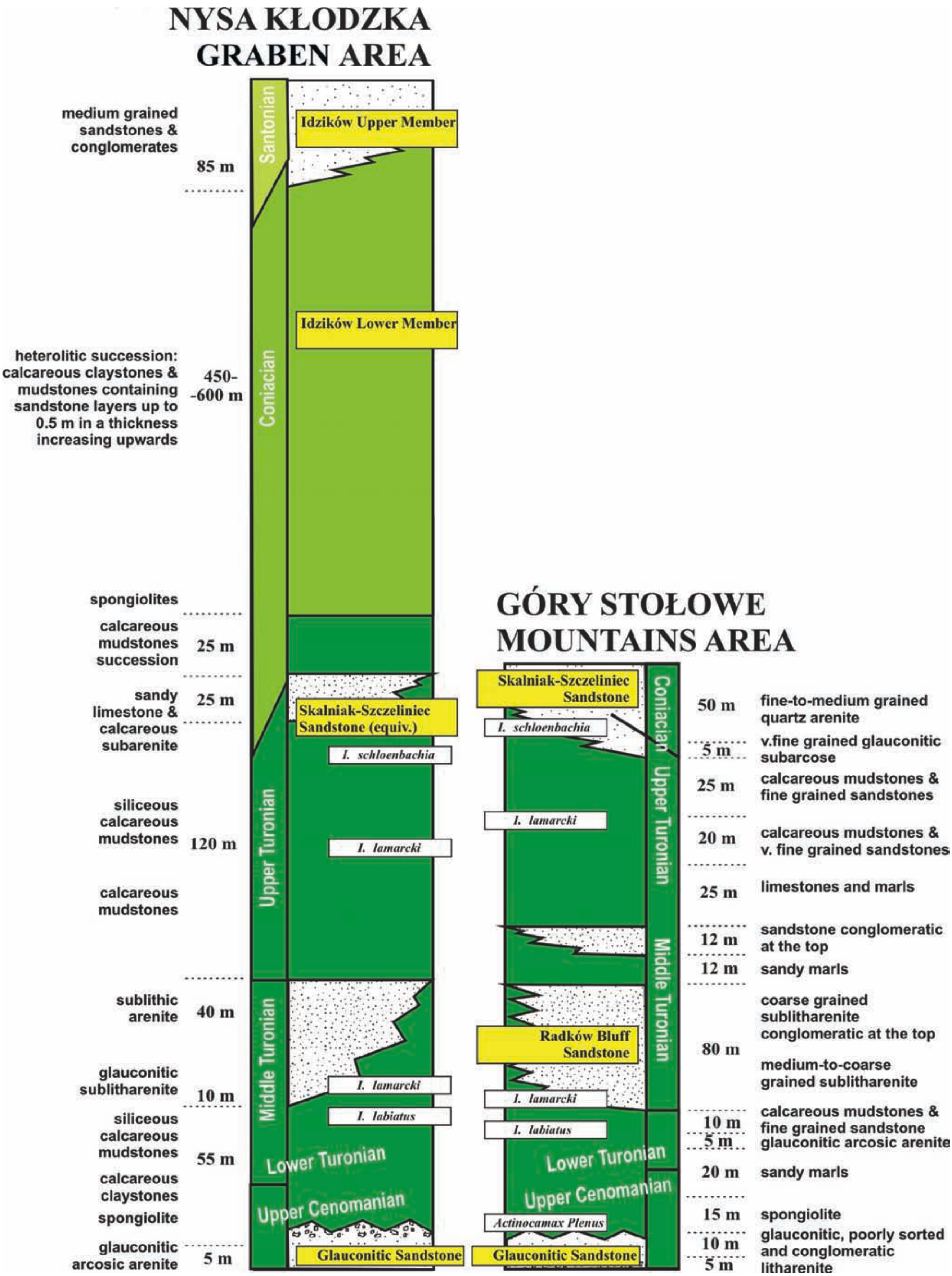

Fig. 4. Lithostratigraphic correlation of Upper Cretaceous sedimentary rocks from Góry Stołowe (Intra-Sudetic Synclinorium) and the Nysa Graben (corrected and supplemented by J. Wojewoda after Don & Wojewoda (2003)).

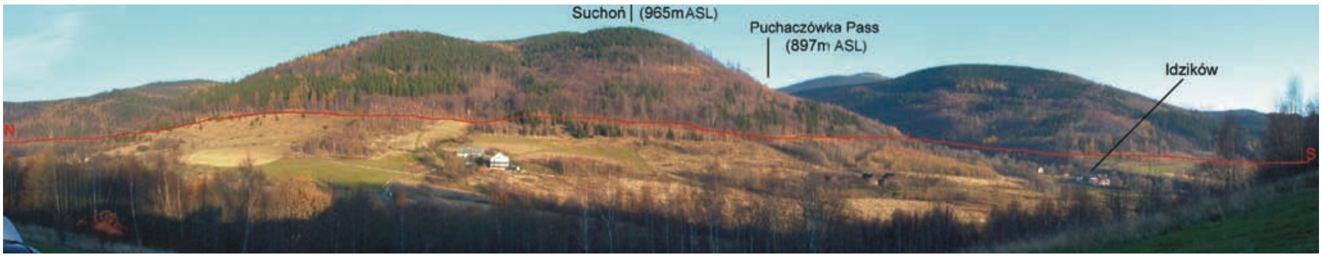

Fig. 5. Panoramic view of the eastern margin of the Upper Nysa Graben in the vicinity of Idzików, taken from the Pasterskie Skałki Rocks (Shepherds' Rocks).

northwestward as the Kamienny Grzbiet–Babilon Fault Zone (Fig. 1, App. 1). The fault contains uranium–fluorine mineralization in the vicinity of the village of Kletno (Banaś, 1965) and magnetite–hematite mineralization along the SW slopes of the Krowiarki Mts.

At the southern tip of the Nysa Graben there is the reverse, S-dipping, Štity Fault (Don *et al.*, 2003). This fault runs parallel to the Krowiarki Marginal Fault and can be taken as its regional counterpart. Between these two faults, the eastern flank of the graben is cut by several smaller faults (Don *et al.*, 2003) of which the Urwista Mountain Fault in the Pisary-Heřmanice area, with its strike-slip kinematics, appears to be the more significant because it is paralleled by three other smaller, unnamed faults that, when taken together, offset the southern part of the graben sinistrally by ~3 km (Fig. 7, App. 1). These smaller faults do not appear on earlier geological maps, despite the presence of U-mineralization in the vicinity of Kopalniana Góra, near Potoczek (Fig. 1, App. 1). The middle fault of the three has undergone neotectonic reactivation: this can be seen from the disruption of several metres in thickness of solifluction gneiss debris. During the Ice Age, this gneiss debris moved some hundreds metres down the slope of Urwista Mountain, abrading the surface of the Upper Cretaceous deposits that filled the Nysa Graben. The northern, hanging wall of this middle fault was elevated then by 4 metres. It is the only mappable evidence of neotectonic fault displacements at the eastern margin of the graben. Activity on the Urwista Fault also affected the Turonian marls on the southern slopes of Kopalniana Góra near Potoczek, causing them to reach the level of the extensive, southerly inclined, Jodłów peneplain. The latter was interpreted by Schwarzbach (1934) as a possible 'terrace' of the late Cretaceous sea. There are also some smaller reverse faults (Frąckiewicz, 1965; Frąckiewicz & Teisseyre, 1977) that cut the graben's eastern margin near the villages of Goworów and Nowa Wieś. These latter faults continue into the centre of the Nysa Graben.

The western margin of the Nysa Graben is topographically in relief only along its meridionally trending southern sector where graben infill is in fault contact with the metamorphic rocks of the Orlické hory Mountains (App. 1). The southern part of the western margin is sinistrally offset by 3 km along the NW–SE Králiky–Kamieńczyk Fault and, further north, is displaced with similar kinematics by another 2 km along the Heřmanice–Urwista–Roztoki–Poręba Fault Zone. Still further north, most of the NW-trending faults that cut across the Góry Bystrzyckie Mountains margin of the Nysa Graben are also the result of Cenozoic-age tectonic re-structuring of the entire area, *i.e.*, the northern parts of the Intra-Sudetic Synclinorium and the Nysa Graben. The NW-trending faults all penetrate into the graben's interior and they often merge with the faults that intersect the graben's eastern margin (Domaszków–Goworów, Długopole–Nowa Wieś and Zabłocie–Idzików Faults; App. 1). Between these sets of faults synclines and anticlines emerged. The synclines, which have the Coniacian Idzików Beds in their cores, are separated by SE-plunging anticlines, which have metamorphic bedrock in their respective cores. From the south to the north, the sequence of synclines and anticlines are as follows: the Międzylesie–Roztoki Syncline; the Długopole Zdrój Anticline; the Wilkanów Syncline; the Bystrzyca Kłodzka Anticline; and the Idzików–Krosnowice Syncline (App. 1). The Długopole Zdrój and Bystrzyca Kłodzka Anticlines are separated from the graben interior by the S-trending Nysa Fault, which abruptly truncates the Krowiarki Metamorphic Belt to the north. Details of these anticline structures will be described in a paper dedicated to the tectonics of the Góry Bystrzyckie Mountains area (J. Don, in preparation).

The border between the Nysa Graben and the Intra-Sudetic Synclinorium is herein defined as coincident with the extent of the Coniacian Idzików Beds in the Krosnowice Syncline. The Idzików Beds are closely connected with the evolution of the Nysa Graben.

TECTONICS OF THE INTERIOR OF THE NYSA GRABEN

The ~500 m thick Idzików "clays" outcrop widely in the Nysa Graben but, because they lack any marker horizon, are difficult to use for tectonic reconstructions. Under such circumstances, sandstones that overlie the "clays"

Fig. 6. The eastern margin of the Nysa Graben between Idzików and Marianówka.

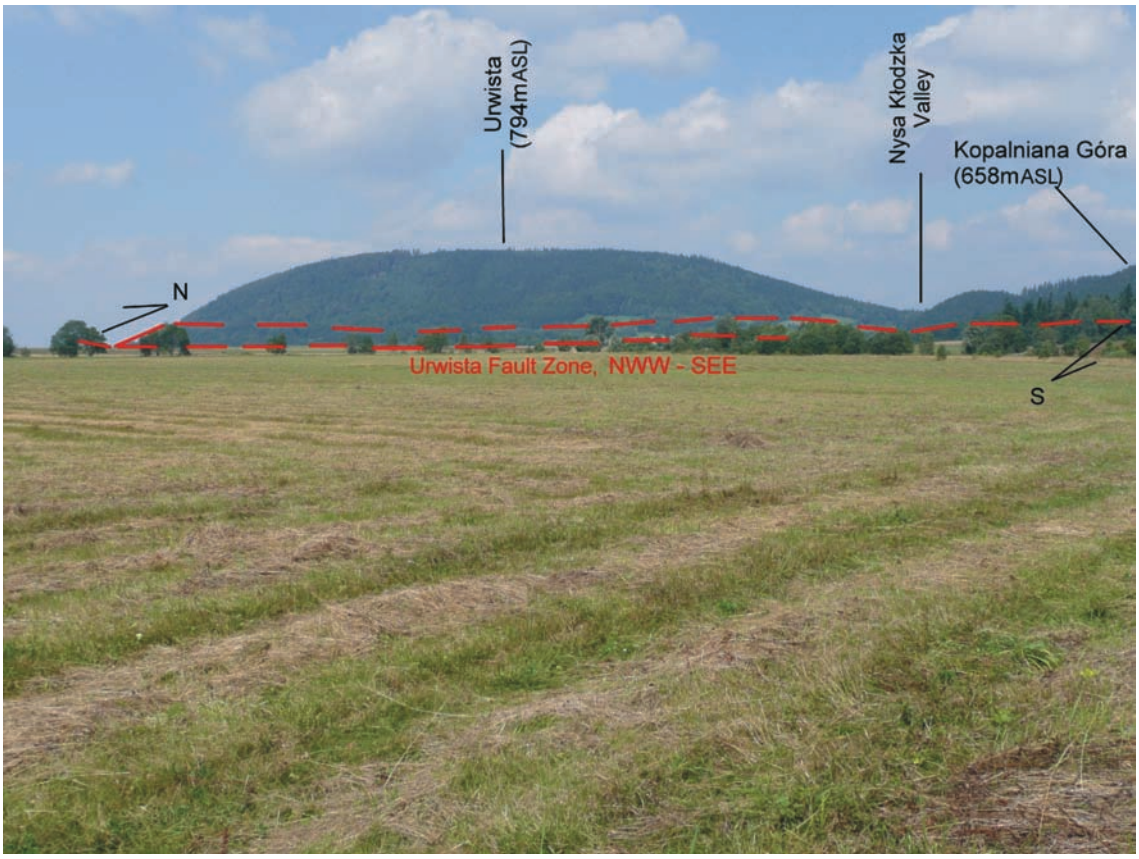

Fig. 7. The Nysa Graben south of the Urwista Mt.

and structures from the margins of the Nysa Graben become important because they can be used to solve the tectonic problems of the graben interior.

The Polish part of the Nysa Graben falls into three defined sectors: the Międzylesie–Roztoki sector to the south; the Krosnowice–Idzików sector to the north; and the central Domaszków sector. The Międzylesie–Roztoki and Krosnowice–Idzików sectors form secondary synclines. They are separated by the Domaszków sector, which developed as an extension of the Długopole Zdrój and Bystrzyca Kłodzka Anticlines. In the syncline sectors, the complete lithostratigraphic profiles of the Upper Cretaceous can be observed, whereas the elevated parts have the youngest members of the Idzików Beds, which are composed of sandstones and conglomerates, eroded away. These latter rock types in the synclines sectors are geomorphologically recognisable as steep slopes and kuestas because of their higher resistance to weathering. Thus, the synclines, although they are tectonically downwarped features, coincide with the positive geomorphological features of the Międzylesie Upland (Fig. 8) and the Idzików Upland (Fig. 9), respectively.

The base of the coarse clastic members act as marker horizons and prove very useful in tectonic reconstructions. On the NW side of the Nysa Graben, the sediment sequences between the underlying clays and the overlying sandstones of the Idzików Beds are graded.

MIĘDZYLESIE–ROZTOKI SYNCLINE

The Międzylesie–Roztoki Syncline is bordered by the Králiky–Kamieńczyk Fault to the south and the Domaszków–Goworów Fault to the north. The Międzylesie–Roztoki Syncline is also divided internally by the Poręba–Roztoki Fault into a northern (Roztoki) and a southern (Międzylesie) section. The border faults cut the Nysa Graben obliquely and produce sinistral strike-slip offsets of the graben's N-trending boundaries. The southern fault terminates to the north-west against a reverse fault that separates the sedimentary infill of the graben from the metamorphic bedrock exposed in the Góry Bystrzyckie Mountains up as far as Poręba (Don, 2003). We mapped the base of the Idzików sandstones in the Nysa Kłodzka valley and adjacent tributaries and recognized the presence of open upright folds with gently dipping limbs. These folds become steeper only near the graben margins and close to the transcurrent faults (App. 1). Inside the graben, a meridional fault was mapped between Boboszów and Szklarnia (App. 1) and proves to be a continuation of the Nysa Fault to the north. The western limb of the meridional fault was downthrown in Palaeogene time by ~15–20 m and this forced the Nysa Kłodzka river in the Pisary vicinity to change its course from a westerly to a southerly direction. Before its capture, the Nysa river joined the Dzika Orlica river and was then part of the North Sea river basin (Sroka & Kowalska, 1998).

A gentle folding of Cretaceous beds in the Miedzylesie part of the Międzylesie–Roztoki Syncline was followed by block tectonics. Some of our newly mapped faults obliquely cut this syncline. The fold axis in the Międzylesie part of the marginal Międzylesie–Roztoki Syncline is parallel to the western margin of the Nysa Graben between Międzylesie and Smreczyny where it is cut by the Poręba–Roztoki Fault, to the north (App. 1). Gentle dips of the limbs of this syncline can be deduced from the outcrop pattern of the basal sandstones observed in tributary valleys. In the field, apparent dips in excess of 10° can be observed, but larger dip angles often represent cross bedding and cannot be used, uncorrected, for tectonic reconstructions.

Two research boreholes in the Międzylesie vicinity reached crystalline bedrock: in Pisary at a depth of 739 m, and in Smreczyna at 737 m (Radwański, 1975). They prove that the Upper Cretaceous deposits there are much thicker than the previous estimate of only ~ 400 m).

CENTRAL ANTICLINE OF THE NYSA GRABEN

Morphologically, the N-trending Central Anticline of the Nysa Graben coincides with a lowland that separates the Międzylesie and Idzików Uplands, both of which tectonically represent synclines. Geologically, the Central Anticline is subordinate to the eastern margin of the graben and structurally bordered by the N-trending Nysa Fault and the Szklarnia– Boboszów Fault (App. 1). These faults truncate the Długopole Zdrój and Bystrzyca Anticlines with the intervening shallow Wilkanów Syncline, the three units which plunge to the SE toward the graben margin. In the Central Anticline area, only thick lower clayey members of the Idzików Beds occur, with no marker horizon, because the youngest sandstone and conglomerate members have been eroded away. The bedding planes of shales dip at 5–15° in chaotically different directions and do not match with any coherent structural unit. The presence of upper Turonian marls mapped in the border area between the Wilkanów Syncline and the Central Anticlne is difficult to explain. These marls outcrop over an area of about 1 km^2, and apparently form a 'block' that emerges from beneath the Idzików 'clays' on its southern side and that is bordered by faults on the other three sides. The eastern fault of this block is the Nysa fault which truncates the Bystrzyca Anticline and continues further north where it constitutes the western border of the Krowiarki Metamorphic Belt between Gorzanów and Krosnowice (App. 1). The northern fault of the marl block can be traced from the eastern margin of the Nysa Graben in the vicinity of Marianówka, via the Długopole Dolne area the western margin of the graben. The elevated marl block may appear in the axial portion of the Wilkanów Syncline because it constitutes a part of the SE extension of the Bystrzyca Anticline (App. 1).

IDZIKÓW–KROSNOWICE SYNCLINE

The Idzików–Krosnowice Syncline is subdivided into two parts by the NW-trending Kamienny Grzbiet–Babi-

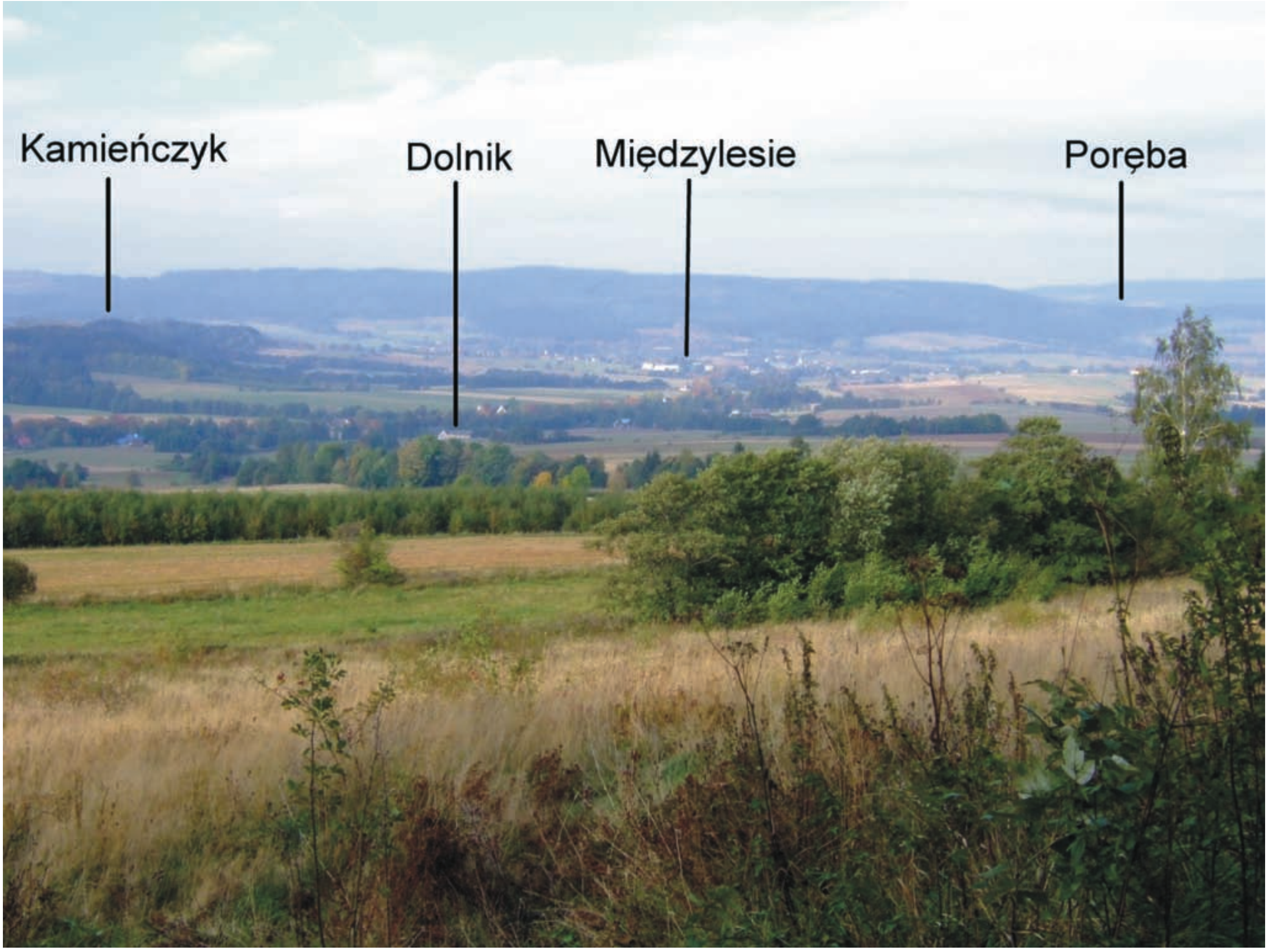

Fig. 8. The Nysa Graben and the Międzylesie Upland can be seen in the left part of the photograph. In the background are the Góry Bystrzyckie Mts., which lie to the west of Międzylesie.

lon Fault Zone. The northwestern part is referred to as the Krosnowice Syncline and the southeastern part as the Idzików Syncline (App. 1).

The Idzików Syncline has the shape of a rhomb elongated in the SE–NW direction: it is bordered by the marginal faults of the Nysa Graben to the east and northeast, but its western boundary is defined by the inner Idzików–Zabłocie and Nysa Faults that run parallel to the graben. Morphologically, the eastern part of the syncline coincides with the Idzików Upland (Fig. 9) and comprises sandstones and conglomerates surrounded on all sides by outcrops of the underlying Idzików 'clays' (shales), which appear in topographic depressions. The eastern limb of the Idzików Syncline is monoclinally tilted and attains a vertical attitude in an approximately 1 km wide zone at the contact with the eastern margin of the Nysa Graben (Fig. 10 a, b). The western limb of the syncline dips eastward at an angle of ~10° whereas the SW limb has been rotated

Fig. 9. Panorama of the Idzików Upland as viewed from the south (from Marianówka).

and attains dips of ~30° at the transcurrent Idzików–Zabłocie Fault that itself cuts the syncline obliquely and continues towards Bystrzyca Anticline. Lithologically, the syncline comprises sandstones that alternate with conglomerates in layers that gradually taper out westward over the distance of ~2 km to be lithologically replaced by finer-grained sand and clayey alternations. Seven conglomerate layers, with individual clasts up to 15 cm in diameter, were mapped. These conglomerates appear to be the eroded remains of the crystalline basement rocks of the Nysa Graben walls, although clasts of porphyry and sandstone pebbles are also present. In the Idzików–Nowy Waliszów area, conglomerates formed part of delta fans that were sourced mainly from the eastern limb of the Orlica–Śnieżnik Dome: the metamorphic basement rocks of this dome were being uplifted at the end of the Coniacian. Vertical movements during the Coniacian marked the onset of a period of 'block tectonics' in the Sudetes after a relatively long period of diastrophic quiescence during the Mesozoic.

In the Idzików Syncline, sandstones and conglomerates are underlain by the Idzików 'clays', which are widespread in the topographic depressions that surround the Idzików Upland (Fig. 9). The Idzików 'clays' are almost vertical when adjacent to the graben's eastern marginal fault and their outcrops narrow to ~500 m, which is the true orthogonal stratigraphic thickness of these rocks. To the west, in the vicinity of Stary Waliszów, where the 'clays' dip at an angle of 5–10°, their outcrops are up to 3 km wide. A set of parallel faults separate the 'clays' from upper Turonian marls of the Bystrzyca Anticline. The easternmost fault of this set likely continues into the Nysa Fault bordering in the west the Krowiarki Mountains. Nearby, at Gorzanów, all these faults intersect the sinistral, W-trending, strike-slip Kamienny Grzbiet–Babilon Fault Zone. At the junction of these faults there occur mineral water springs. Mutual relationships of the two regionally important fault zones are difficult to decipher without additional hydrogeologic and geophysical studies which would complete the field observations performed at the surface. The Kamienny Grzbiet–Babilon Fault Zone can be traced westward from the village of Piotrowice (Krowiarki Mountains) to the village of Pokrzywno (south of Polanica Zdrój; App. 1). In the vicinity of Piotrowice, it offsets the Krowiarki Marginal Fault, which was formed during the second phase of the evolution of the graben (Don, 1996).

The Krosnowice Syncline occurs north of the Kamienny Grzbiet–Babilon Fault Zone (Fig. 11). The northwestern limb of this syncline lies along the Wielisławka Valley where the Idzików 'clays' directly onlap the marls of the Upper Turonian. It is this arbitrary onlap boundary that has been assumed to distinguish the Cretaceous infill of the Nysa Graben from contemporaneous strata of the Intra-Sudetic Synclinorium. The other boundaries of the Krosnowice Syncline are tectonic.

The Kamienny Grzbiet–Babilon Fault Zone continues to the ESE across Babilon Hill in the vicinity of the village of Piotrowice, where it disrupts the Krowiarki Marginal Fault. In the Nysa Kłodzka valley near Krosnowice, the eastern boundary of the Krosnowice Syncline coincides with the Nysa Fault, which truncates the Krowiarki Metamorphic Belt. The northeastern border of the Krosnowice Syncline between Krosnowice and Wielisław Dolny is defined by the marginal Kłodzko Metamorphic Fault Zone. In this zone, the Cretaceous beds (Fig. 12) and the Rotliegend red conglomerates (Fig. 13) are rotated into the vertical.

The rocks of the Krosnowice Syncline are almost exclusively represented by the Idzików 'clays' (Fig. 14). Along the syncline axis, however, there are also some local subsidiary alternations of turbidites (Jerzykiewicz, 1970, 1971). In the vicinity of Stary Wielisław, SE of Polanica Zdrój, and in Krosnowice Dolne, in the axial part of the Krosnowice Syncline, there are easily mapped small sandstone outcrops underlain by the Idzików'clays' (App. 1). Only along the western scarp side of the Nysa river the beds dip eastward at an angle of up to 25°. The easterly plunging Krosnowice Syncline becomes wider in this direction and reaches a width of 6 km in the Nysa Kłodzka Valley where the Nysa Fault borders the metamorphic basement of the Krowiarki Mountains.

At the top of the Idzików 'clays' there are ubiquitous iron concretions (Fig. 15), which occur extensively throughout the Nysa Graben area. They formed under reducing conditions when the Cretaceous sedimentary basin narrowed and closed. At the end of the Coniacian, and possibly also during the Emsherian (late Cretaceous), a regression of the 'Chalk Sea' had started and the basin of the central Nysa Graben was steadily filled up with extensive fan deltas composed of the Idzików sandstones and conglomerates.

The Nysa Graben's tectonic evolution occurred in successive stages throughout the whole Cenozoic. This can be inferred from the succession of observable peneplains (Fig. 16) in the nearby Śnieżnik Metamorphic Massif (Don, 1989), which began uplifting during the late Cretaceous. The peneplains were formed at periods of relative tectonic quiescence, those that developed during the Miocene and Pliocene being among the most extensive, with relics of a weathered terra rossa crust occuring on the Miocene peneplain. The Mio-Pliocene peneplain, however, was accompanied by some volcanic activity, which produced a basaltic cone ~5.46 Ma old overlying the gravels of the Biała Lądecka river terrace to the NW of Lądek Zdrój (Birkenmajer *et al.*, 2002).

CONCLUSIONS

After a long period of Mesozoic quiescence, late Cretaceous block tectonics started to uplift the Sudete region and to initiate the Nysa Graben. Contrary to earlier views (Cloos, 1936), this uplift was not a single-stage event but rather a multiphase process that commenced during the Coniacian. The most important movements were probably compressional ones at the Cretaceous/Paleogene boundary ('Laramian'), which followed earlier extensional ones. Under compression, new sections of the graben fault boundaries became active and they obliquely cross-cut the

Fig. 10. The Pasterskie Skałki Rocks expose. (**A**) the polymictic Idzików conglomerates, and (**B**) form a steeply dipping monoclinal ridge that stretches north from Idzików to Nowy Waliszów in the eastern margin of the Nysa Graben (cf. Fig. 9).

Fig. 11. Tectonic breccia of the Kamienny Grzbiet–Babilon Fault Zone at Pokrzywna south of Polanica Zdrój (exposed here in house foundations).

Fig. 12. Steeply dipping Cretaceous beds on the eastern slope of the Czerwona Góra Mt. at Krosnowice.

Fig. 14. Idzików 'clays' with thin interlayers of greywacke sandstones exposed along the Mielnik–Gorzanów road.

Fig. 15. Iron concretions at the top of the Idzików 'clays'.

Fig. 13. A steep monocline of Rotliegend conglomerates on the left side of the Bystrzyca Dusznicka river between Szalejów and Wielisław Dolny.

older structures of the graben. During the compressional phase, the reverse, NW-trending faults were formed at the northern and southern boundaries of the Nysa Graben and were accompanied by minor graben-parallel and diagonal faults. Although dying out eastward, the reverse diagonal faults significantly changed the structural template of the western graben margin where a number of fold–fault blocks (Międzylesie–Roztoki Syncline, Długopole Zdrój Anticline, Wilkanów Syncline, Bystrzyca Anticline, Idzików–Krosnowice Syncline) had developed oblique to the main N–S course of the graben. Inside the Nysa Graben, we mapped several hitherto unrecognised Cenozoic faults, including the Kamienny Grzbiet–Babilon Fault Zone and a fault trending normal to this, the Nysa Fault. The Cenozoic faults are not well dated and require further study, as do a number of local faults that parallel the main tectonic trend of the Nysa Graben.

According to physiogeographical criteria, the Nysa Graben is a divide between the West Sudetes and the East Sudetes. Such a

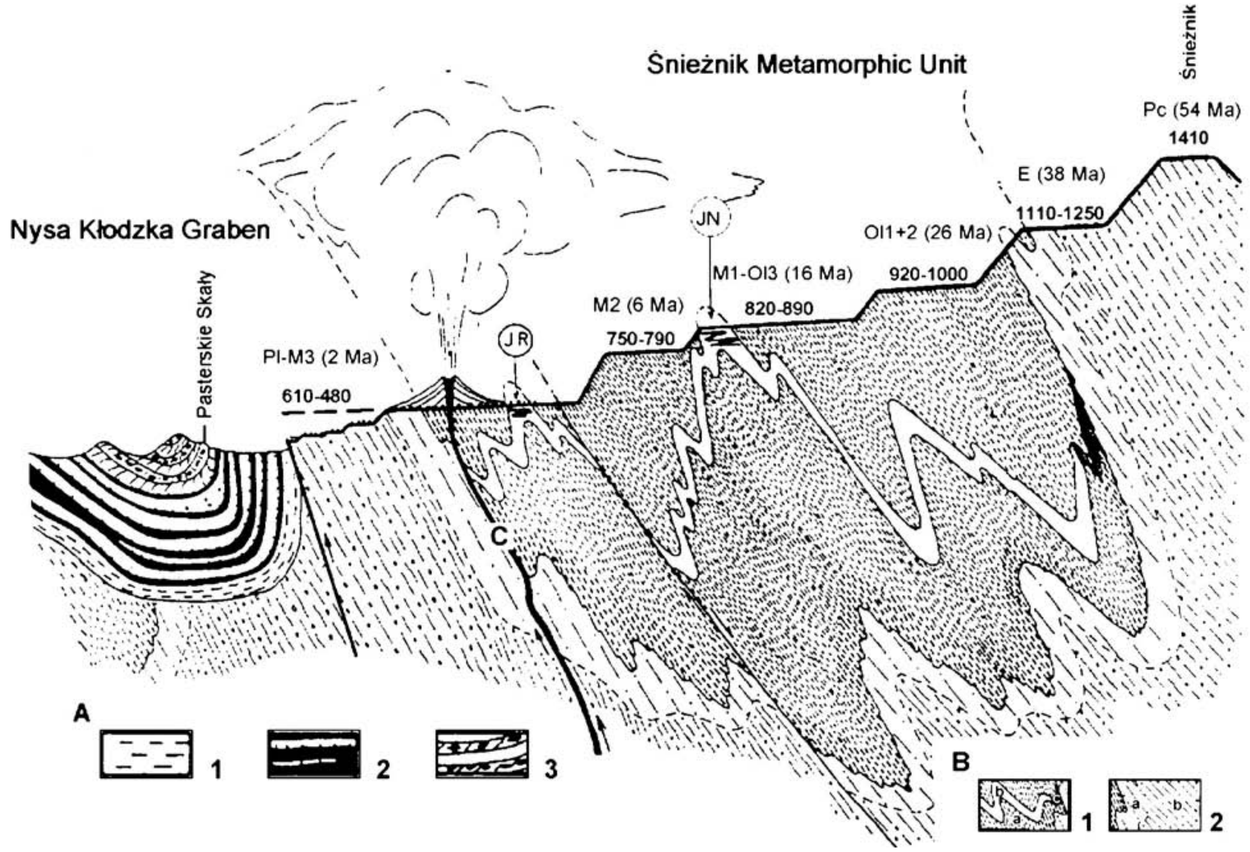

Fig. 16. Peneplains of the Śnieżnik Metamorphic Unit. (**A**)Sedimentary series of the Upper Nysa Graben composed of the following rocks: *1* – Cenomanian and Turonian marls and sandstones; *2* – shales locally interlayered with greywackes, which form part of the base of the Idzików beds; *3* – polymictic conglomerates locally interlayered with greywackes, which form the top parts of the Idzików beds. (**B**) Rocks of the Śnieżnik Metamorphic Unit. *1* – the Stronie Formation mica schist (1a) interlayered with marbles (1b) and with erlans (hornfels) (1c); *2* – Śnieżnik gneisses, which can be seen as a fine-grained aplitic variant (2a) and as a coarse augen variant (2b). (**C**) Basaltic veins and volcanogenic deposits. The peneplains are chronologically labelled as follows: Pc –Palaeocene, E – Eocene, Ol_{1+2} – Oligocene, Ol_3–M_1 – Late Oligocene–Miocene, M_2 – Middle Miocene, M_3–P_1 – Late Miocene–Pliocene. Other abbreviations are: JN – Niedźwiedzia Cave, JR – Radochowska Cave, f – phases of orogenic movements. Numbers indicate peneplains' heights above sea level.

division is not matched by the geology of the basement units, however. This is because a tectonic boundary between the West and East Sudetes coincides with the Nyznerov–Ramzova Thrust Zone (Don *et al.*, 2003), which is a part of the Moldanubian Thrust that itself is taken as the border between various Gondwana-derived terranes of the Bohemian Massif and Brunovistulia (Franke & Żelaźniewicz, 2000, 2002; Oberc-Dziedzic & Madej, 2002).

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TECTONIC MAP
OF THE NYSA KŁODZKA
GRABEN
(SUDETES)
Jerzy Don, Roman Gotowała
2008
UNIVERSITAS WRATISLAVIENSIS
Warsaw
Wrocław
Prague
Brno
KROSNOWICE SYNCLINE
KAMIENNY GRZBIET-BABILON FAULT ZONE
BYSTRZYCA ANTICLINE
WILKANÓW SYNCLINE
DŁUGOPOLE ZDRÓJ ANTICLINE
ROZTOKI SYNCLINE
MIĘDZYLESIE SYNCLINE
CENTRAL ANTICLINE
IDZIKÓW SYNCLINE
KROWIARKI METAMORPHIC BELT
KŁODZKO METAMORPHIC UNIT
BYSTRZYCKIE MTS METAMORPHIC UNIT
ŚNIEŻNIK METAMORPHIC UNIT
Nysa Fault
Krowiarki Marginal Fault
Domaszków Fault
Poręba-Roztoki Fault
Gaworów Fault
Urwista Fault
Pisary Fault
Hermanice Fault
Boboszów Fault
Zabłocie-Idzików Fault
Nowa Wieś Fault
Długopole Fault
Szklarna Fault
Międzylesie-Králíky Fault
Polanica Zdrój
Stary Wielisław
Stary Wielisław Dolny
Krosnowice Dolne
Krosnowice
Pokrzywno
Stara Łomnica
Gorzanów
Piotrowice
Stary Waliszów
Zabłocie
Nowy Waliszów
Bystrzyca Kłodzka
Pławnica
Idzików
Długopole Dolne
Marianówka
Ponikwa
Wilkanów
Szklary
Długopole Zdrój
Poręba
Międzygórze
Długopole Górne
Domaszków
Gniewoszów
Nowa Wieś
Roztoki
Różanka
Goworów
Nagodzice
Szklarnia
Jodłów
Międzylesie
Dolnik
Potoczek
Smreczyna
Pisary
Kamieńczyk
Hermanice
Boboszów
Tectonic sketch of the Orlica-Śnieżnik Dome after Cymerman (1997), corrected and supplemented. Explanations in the text (Fig. 1).
Upper Coniacian (Cr_cn2) ab. 85 m Upper Idzików Beds
Lower Coniacian ((Cr_cn1) 450 - 600 m Lower Idzików Beds
Upper Turonian (Cr_t3) 25 - 120 m
Middle Turonian (Cr_t2) 0 - 40 m
Lower Turonian (Cr_t1) 0 - 55 m
Cenomanian (Cr_c2) 0 - 5 m
Permian basement
Crystalline basement
Stratigraphic profile of the Nysa Kłodzka Graben
LEGEND:
Q Talus
pcCr_cn2-st Coarse-grained turbidites with lithic sandstone and conglomerate (Idzików and Waliszów area) - Upper Idzików Beds
icCr_cn1 Fine-grained turbidites, locally interlayered with finely granular sandstone (in top part with iron concretions) - Lower Idzików Beds
mlCr_t3 Grey calcareous siltstone (platy parting)
pcCr_t2 Arcosic sandstone
mlCr_t1 Black shale and siltstone ("ringing marls")
pcgCr_c2 Transgressive glauconite sandstone with conglomerates in bottom (Bystrzyckie Mts and Western Krowiarki Mts)
pmP1 Red beds and volcanic rocks
M Crystalline basement (Śnieżnik Metamorphic Unit, Bystrzyckie Mts Metamorphic Unit and Kłodzko Metamorphic Unit
Marginal borders and regional faults
Local faults
Primary sedimentary borders of the Nysa Kłodzka Graben
Main foliation in crystalline basement rocks
Bedding in sedimentary rocks
590.6 Top with altitude asl
Town or village
0 1000 2000 3000 4000 5000 m
Geographic Coordinates - WGS84. Planar Coordinate System (Gauss-Krüger; 6 degree) - Pulkovo42, Zone3.
Contours 5 m spacing, generated from SRTM DTED 2, 3"; 2005.