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Glacial and neotectonic constraints on the Quaternary evolution of the Fore-Sudetic reach of the Nysa Kłodzka River

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This work shows influence of the Pleistocene ice sheets and neotectonic movements on palaeogeographic evolution of the eastern part of the Sudetic Foreland during the Quaternary. Mutual relationships between glacial and fluvial series have been analysed. The preglacial fluvial deposits of the Nysa Kłodzka River are proved to have been much more widespread in the Sudetic Foreland compared with the extent that had been suggested before. A series of morphometric methods, using computer data analysis, have been applied in order to reconstruct influence of neotectonic movements on development of the river system. Influence of the Pleistocene ice sheets on palaeogeographic evolution of this region cannot be easily reconstructed in detail due to strong erosional transformations of glacial deposits. The Quaternary neotectonic movements influenced a river system stronger than it has been suggested before. They resulted in deformations of the oldest fluvial accumulation beds, being of the order of 40–50 m. Neotectonic movements are also proved by several metres high deformations at the lowest beds of river valleys.

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Key words: Sudetic Foreland, Quaternary, river valley, neotectonics.

INTRODUCTION

In the Sudetic Foreland, the Nysa Kłodzka River flows across the areas, in which occurrence of modern tectonic activity has been directly confirmed by land surveying (S. Cacoń, S. Dyjor, 1995). Moderate tectonic activity of this area is also proved by relatively frequent seismic impacts, recorded in chronicles from the early medieval times onwards (J. Pagaczewski, 1972). Many facts show that neotectonic movements have occurred throughout the whole Quaternary. During the Pleistocene, this area was simultaneously invaded by ice sheets. Both these factors strongly influenced the Quaternary palaeogeographic evolution of this region.

The studies have been basically aimed at analysis of the evolution of the Nysa Kłodzka valley since its presumable alluvial deposits have appeared in the Sudetic Foreland. Changing flow directions and character of the Nysa Kłodzka River as well as analysis of the evolution of its present valley, formed the main subject of investigations. The aim of this paper is to answer the question how far reconstruction of a river system evolution is possible for the eastern part of the Sudetic Foreland within the area of immediate proximity of ice, as well as if (and what) neotectonic movements influenced evolution of the Nysa Kłodzka valley and its tributaries in the Sudetic Foreland.

The investigations focused on mountain-foot and lowland sections of the Nysa Kłodzka valley, from Bardo at the edge of the Sudetes down to the Odra River (Fig. 1). They were also conducted in neighbouring plateaux, in order to reconstruct ancient flow directions of the Nysa Kłodzka River (different from its modern pattern) and to recognize influence of ice sheet extent on changes of the river system.

The mountain-foot section of the Nysa Kłodzka valley crosses the southeastern part of the Fore-Sudetic Block. This fragment also follows the stretch of the Neogene foredeeps, forming the Paczków Graben, in which Cainozoic deposits reach 600 m in thickness whereas they do not exceed 100 m

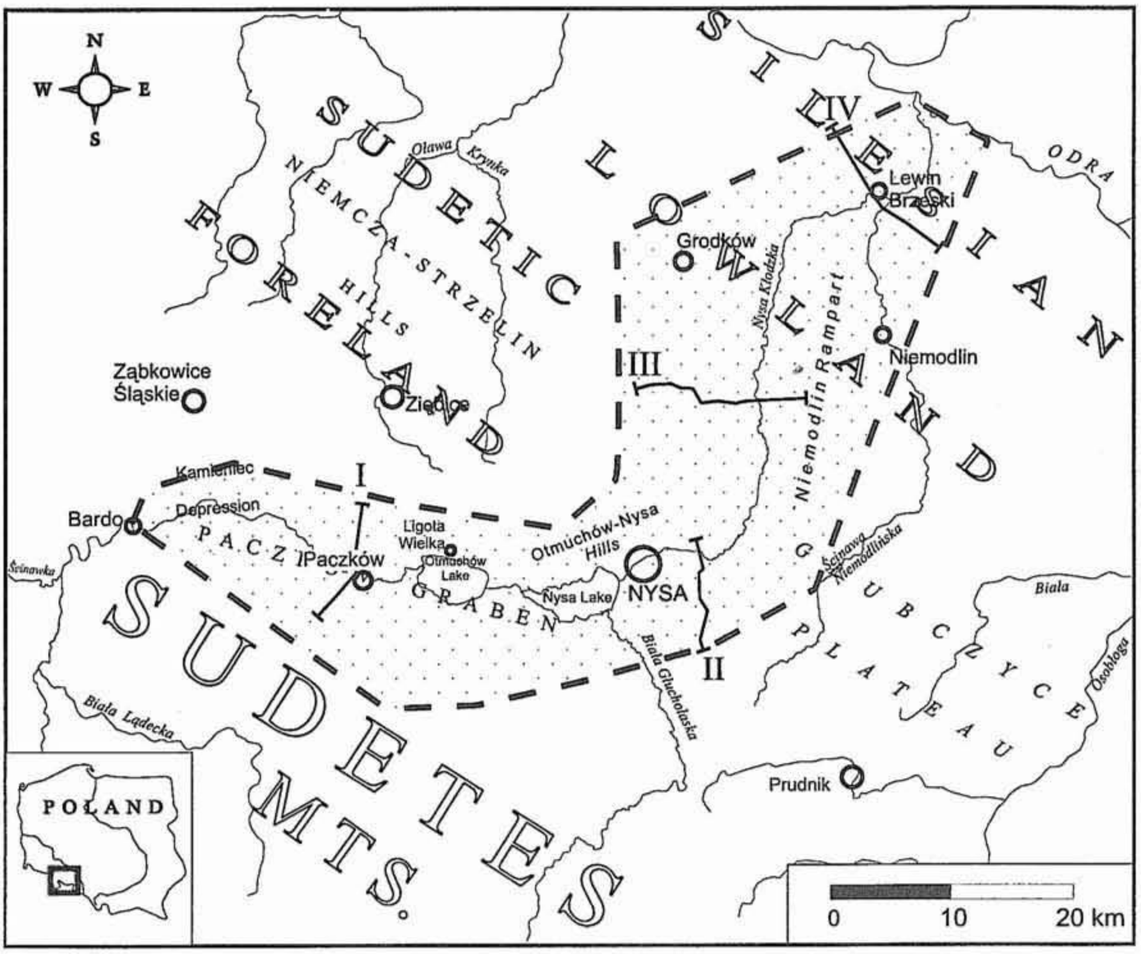


Fig. 1. Location of the studied area against background of physiographic units
I–IV — geological cross-sections (Fig. 5)

Lokalizacja obszaru badań na tle jednostek fizjograficznych
I–IV — linie przekrojów geologicznych z fig. 5

in the remaining area. The upper part of the Tertiary cover is composed of clays, silts, sands, locally with coal intercalations, referred to as the Poznań Series. Meridional section of the Nysa Kłodzka valley runs along the border between the Fore-Sudetic Block and the Silesia–Moravia unit. This is also a border line of the present extent of the Upper Cretaceous rocks. The Quaternary deposits in the Nysa Kłodzka valley and adjacent plateaux are usually 10–20 m thick but more in ancient erosional valleys (up to 110 m).

PLEISTOCENE GLACIATIONS IN THE EASTERN SUDETES FORELAND

The following questions should be answered to recognize influence of glaciations on the evolution of the Nysa Kłodzka valley:

— how many ice sheets (and when) did reach the Eastern Sudetes Foreland?

— what were the extents and directions of ice sheets advances and retreats in this area?

These are the two essential problems which Quaternary geologists have tried to solve for over eighty years. Most papers discussing this palaeogeographical and stratigraphical problem present basically a morphostratigraphical approach, with lithostratigraphy being taken into account to a smaller extent. A review of opinions on evolution of ice sheets in the Sudetic Foreland has been widely discussed by J. Badura and B. Przybylski (in press). Occurrence of positive morphological features, composed of clastic material, was a sufficient criterion in the earliest elaborations to present maximum extent of glaciations (P. Woldstedt, 1932; G. Anders, 1939). Geomorphologic traces of the Pleistocene ice sheets have been almost completely removed in the eastern part of the Sudetic Foreland by erosion and denudation, and a reduced sequence of glacial deposits makes reconstruction of extents

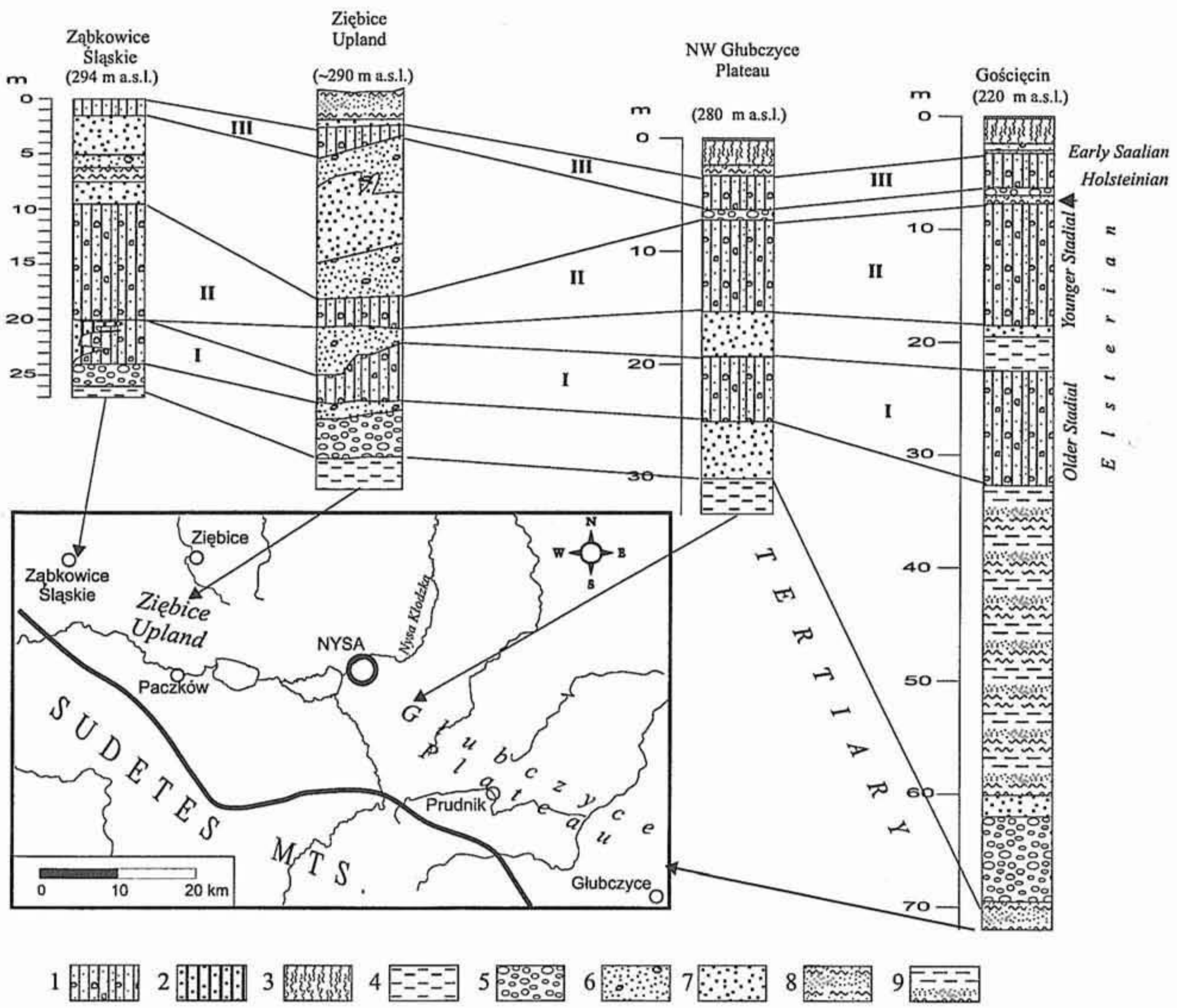


Fig. 2. Correlation of tills in the most complete sections of the Quaternary deposits in the eastern part of the Sudetic Foreland
I–III — till beds; 1 — till, 2 — sandy till, 3 — loess, 4 — clay, 5 — gravel, 6 — sand and gravel, 7 — sand, 8 — silty sand, 9 — clay, silt, sand

Próba korelacji poziomów glin zwałowych w najpełniejszych profilach osadów czwartorzędowych wschodniej części przedpola Sudetów
I–III — poziomy glin zwałowych; 1 — glina zwałowa, 2 — glina piaszczysta, 3 — less, 4 — ił, 5 — żwir, 6 — piasek ze żwirem, 7 — piasek, 8 — piasek pylasty, 9 — ił, muł, piasek

of individual glaciations impossible. The present knowledge allows to infer as follows:

1. Three Pleistocene ice sheets reached probably the northern edge of the mountain-foot section of the Nysa Kłodzka valley: two of them during the South Polish Glaciations, and the youngest one during the Odra Glaciation.

2. At least one of them crossed a meridional fragment of the Nysa Kłodzka valley and probably all of them reached the area to the south of Nysa (Fig. 2).

3. The oldest ice sheet advanced into the Ząbkowice Śląskie region from the north. The second ice sheet of the South Polish Glaciations advanced from the north-east. Such directions might have been constrained by local conditions, and little is known about directions of these advances in other study areas. Lack of local rocks in tills to the south of Nysa precludes the northwestern direction of ice sheet advance in this region.

4. Thick series of limno- and glaciofluvial deposits were formed during advance of the youngest glaciation. Their remains are the Otmuchów–Nysa Hills and their northern foreland. These deposits were deeply cut and removed by fluvial erosion of the Nysa Kłodzka River and its tributaries. So, it is difficult to declare whether there was a large ice-dammed lake in the Sudetic Foreland or waters flowed away south-eastwards. It is obvious that during ice sheet advance there were occasional local and fairly shallow periodic trans-flux lakes with deposition of fine-grained sands and silts.

5. Extent of the Odra Glaciation cannot be restored now. The Otmuchów–Nysa Hills are not a typical terminal moraine but they are rather a denudation relic, composed of glacial deposits underlain by the Miocene sediments. The ice sheet,

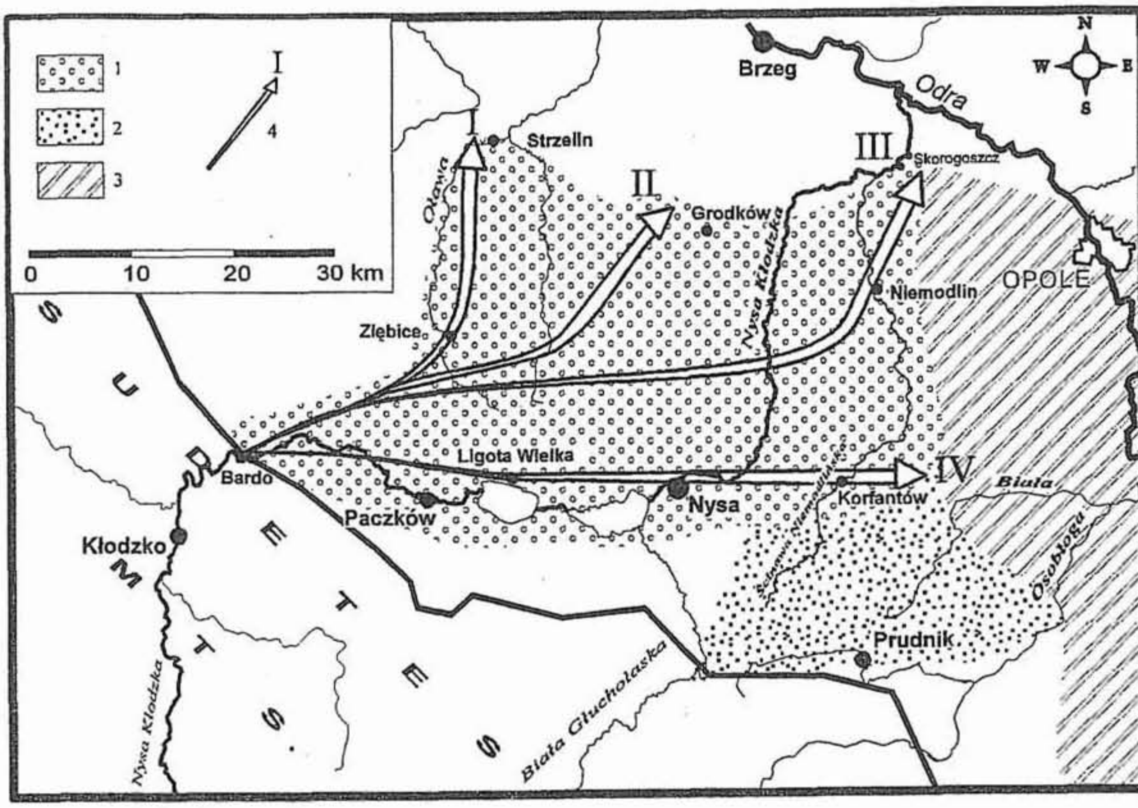


Fig. 3. Evolution of the preglacial Nysa Kłodzka valley

1 — extent of the ancient Nysa Kłodzka River deposits; 2 — extent of the ancient Biała Głuchołaska River deposits; 3 — extent of the ancient Odra River deposits; 4 — succeeding stages of the Nysa Kłodzka River flow during the Pliocene and the Early Pleistocene, from the oldest (I) to the youngest (IV)

Ewolucja rozwoju preglacjalnej doliny Nysy Kłodzkiej

1 — zasięg występowania osadów związanych z pra-Nysą Kłodzką; 2 — zasięg występowania osadów związanych z pra-Białą Głuchołaską; 3 — zasięg występowania osadów związanych z pra-Odrą; 4 — kolejne etapy przepływu Nysy Kłodzkiej w pliocenie i wczesnym plejstocenie, od najstarszego (I) do najmłodszego (IV)

a transgressive sandy-gravelly series composing the hills is related to, crossed the Otmuchów–Nysa Hills. This is indicated by glaciotectonic deformations and sedimentary structures. However, it is difficult to determine how far south of the Nysa Kłodzka valley it reached.

6. Results of lithostratigraphical analyses of glacial deposits in the eastern part of the Sudetic Foreland are not univocal. It is necessary to make some analyses of mutual relationships between fluvial and glacial series in order to reconstruct extents of glaciations and type of deglaciation in this area.

FLUVIAL SERIES IN THE EASTERN SUDETES FORELAND

PREGLACIAL SERIES

A number of investigations were conducted, aimed at reconstruction of a river system during the preglacial times, preceding an attempt to determine influence of the Pleistocene glaciations upon the evolution of the Nysa Kłodzka valley. The term Preglacial denotes here the Pliocene and the Early Pleistocene (before the first ice sheet advanced). The widespread preglacial fluvial series from the whole Sudetic Foreland have been already described for a long time. Individual stands of these deposits are preserved in the mountains (S. Dyjor, 1985, 1987*a*, *b*; S. Dyjor *et al.*, 1978; J. Oberc, S. Dyjor, 1969; A. Jahn *et al.*, 1984).

Many data have been collected during the studies and mapping in the eastern part of the Sudetic Foreland. They allow to complete a picture of preglacial deposits of the Nysa Kłodzka River and its tributaries. Collected material verifies the so far determined flow directions of the ancient Nysa Kłodzka River (F. Zeuner, 1928; J. Behr *et al.*, 1931; W. Walczak, 1954; J. Wroński, 1974; S. Dyjor, 1985, 1987*b*; S. Dyjor *et al.*, 1978). The area of scatter of preglacial material of this river considerably increased (Fig. 3). During the Preglacial, the Nysa Kłodzka River changed its routes many a time. Unfortunately, there is no evidence for precise dating of the preglacial series in the Eastern and Middle Sudetes Foreland and consequently, for their correlation with the Pliocene and the Early Pleistocene deposits from other areas. However, the northward flow along the modern Oława valley, already recognized by German geologists, seems to have been the

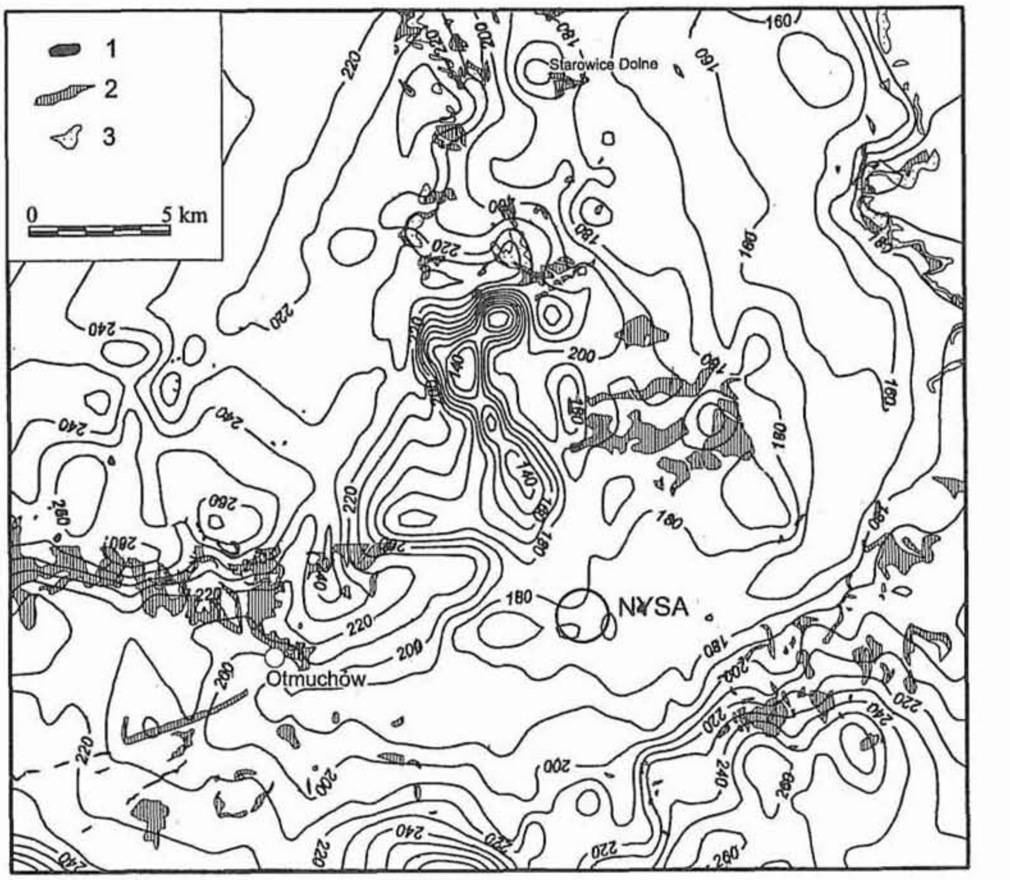


Fig. 4. Sub-Quaternary surface in the ancient erosional form north of Nysa (contour lines in m a.s.l.)
1 — outcrops of crystalline rocks; 2 — outcrops of the Poznań Series deposits; 3 — outcrops of preglacial deposits

Mapa stropu powierzchni podczwartorzędowej w rejonie kopalnej formy erozyjnej na północ od Nysy (izohipsy w m n.p.m.)
1 — wychodnie skał krystalicznych; 2 — wychodnie utworów serii poznańskiej; 3 — wychodnie utworów preglacjalnych

oldest one (Fig. 3). Later on, the Nysa Kłodzka River flowed north-eastwards, along the route recognized by J. Wroński (1974, 1975). During the next stage, keeping turning to the east, the ancient Nysa Kłodzka River was temporarily crossing the Niemodlin Rampart. The youngest flow turned to the east, across the Ligota Wielka region at the northern margin of the Paczków Graben, where fluvial gravels are most poorly weathered. It is unclear if the last mentioned change in flow direction already resulted from ice sheet advance, but a lack of erratic material from Scandinavia indicates no direct contact. This stage is related rather to constant trend of the Nysa Kłodzka River to migrate from a north-south to meridional direction during the Preglacial.

ANCIENT VALLEY OF THE NYSA KŁODZKA RIVER

The above described evolution of directions of the Nysa Kłodzka River does not exhaust the problem of the preglacial development of the river system in this part of the Sudetic Foreland. The discussed fluvial deposits are located on plateaux, whereas in the Sudetic Foreland area, the preglacial sediments have been described from bottoms of deep ancient valleys. According to S. Dyjor (1987*a*, *b*), the valley system was developed during the Early Pleistocene. Fluvial deposits of the Pliocene Gozdnica Series were cut to 80–100 m depth at that time. A series of such deeply incised valleys was recognized within the Odra River basin in the Sudetic Foreland and in the western margin of the Upper Silesia (S. Dyjor, 1987*a*, *b*; S. Dyjor *et al.*, 1978; A. Kleczkowski *et al.*, 1972; G. N. Kotlicka, 1978, 1981; J. Kryza, L. Poprawski, 1987; L. Poprawski, 1995). In these palaeogeographical reconstructions, each major tributary of the Odra River has its counterpart in an ancient valley.

Basing upon borehole sections, as well as mineralogical and petrographical analyses, the ancient erosional form located between Nysa and Grodków was considered for a fragment of the Nysa Kłodzka valley (J. Badura, B. Przybylski, 1994). The first interpretation was that the valley was formed during the Early Pleistocene and the material containing gravels of the Nysa Kłodzka River, recognized at the valley bottom, is of the same age. The valley does not continue southwards, which was interpreted as result of younger erosional processes and glaciotectonic elevation at the Otmu-

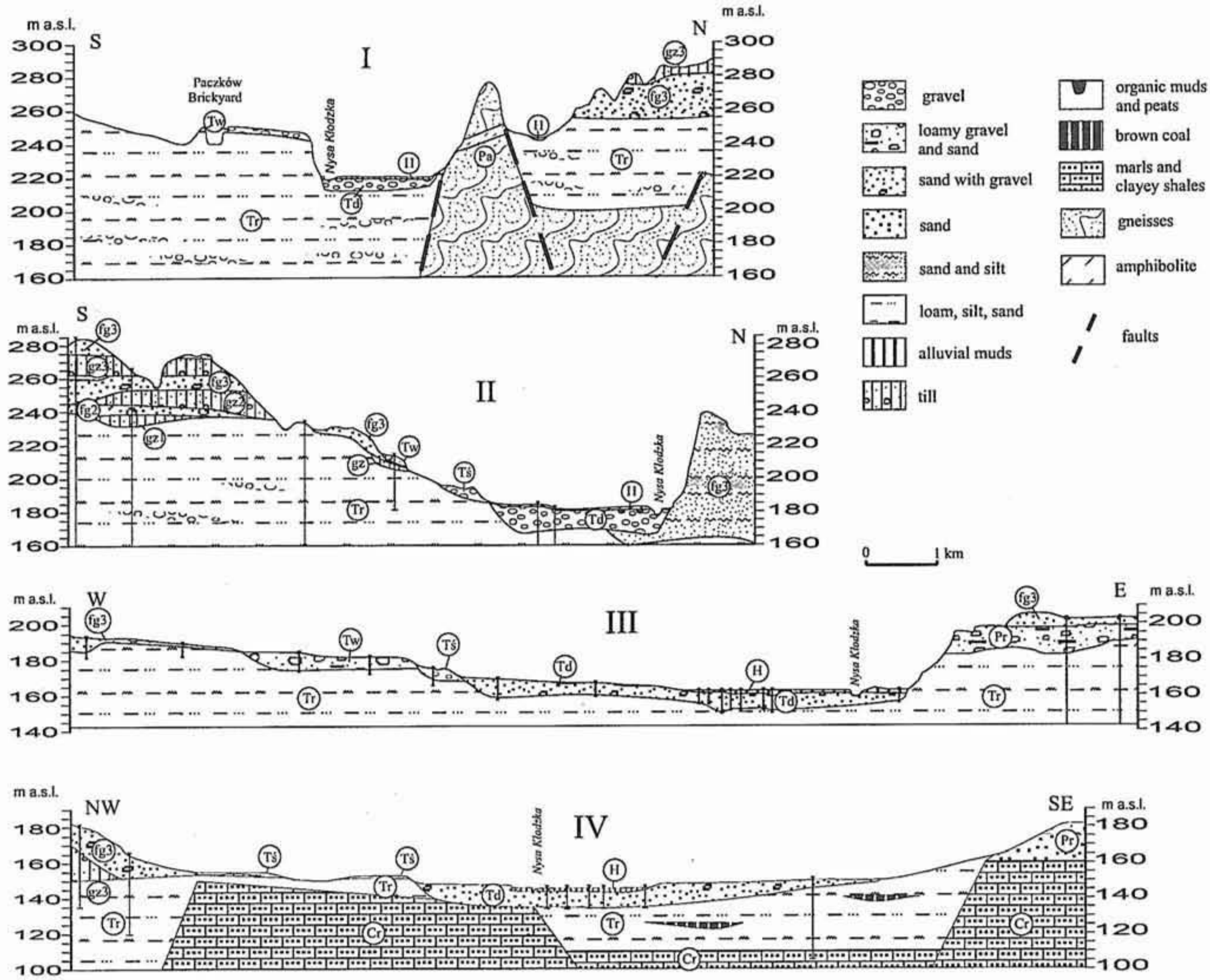


Fig. 5. Geological cross-sections (I–IV) across the Nysa Kłodzka valley (location in Fig. 1)

Holocene: fluvial deposits; **Vistulian**: Td — upper terrace deposits; **Warta Glaciation**: Tś — middle terrace deposits; **Odra Glaciation**: Tw — upper terrace deposits, fg3 — glaciofluvial deposits, gz3 — tills; **South Polish Glaciation**: gz2 — tills of the younger stadial, fg2 — glaciofluvial deposits, gz1 — tills of the older stadial; **Miocene–Late Pleistocene**: Pr — preglacial fluvial deposits; **Miocene**: Tr — Poznań Series deposits; Cr — **Upper Cretaceous; Palaeozoic**: Pa — metamorphic rocks

Poprzeczne przekroje geologiczne (I–IV) przez dolinę Nysy Kłodzkiej (lokalizacja na fig.1)

Holocen: H — utwory rzeczne; **vistulian**: Td — osady tarasu dennego wyższego; **zlodowacenie warty**: Tś — osady tarasu średniego; **zlodowacenie odry**: Tw — osady tarasu wysokiego, fg3 — osady wodnolodowcowe, gz3 — gliny zwałowe; **zlodowacenie południowopolskie**: gz2 — gliny zwałowe stadiału górnego, fg2 — osady wodnolodowcowe, gz1 — gliny zwałowe stadiału dolnego; **miocen–eoplejstocen**: Pr — rzeczne osady preglacjalne; **miocen**: Tr — osady serii poznańskiej; Cr — **kreda górna**; **paleozoik**: Pa — skały metamorficzne

ców–Nysa Hills. Young tectonic activity of this area, which could influence deformations of the primary longitudinal profile of this valley might have also been involved.

Interpretation of origin of ancient erosional feature to the north of Nysa was undertaken, taking into account new facts and reinterpretations of borehole data. Many of its features show that it is a glacial tunnel valley rather than a fragment of an ancient river valley. This feature is very narrow if compared with that of the modern Nysa Kłodzka valley or with preglacial river valleys (Fig. 4). The erosional scour does not continue anywhere. Gravel and sandy deposits in central part of this ancient tunnel valley are the redeposited preglacial sediments from the plateau basement. The assumption that the erosional scour to the north of Nysa is of fluvial origin, would require a relatively high amplitude of tectonic movements which broke a continuity of the valley. These movements would have affected a relatively narrow zone, resulting in displacements of about 100 m since the South Polish Glaciation or even the Great Interglacial. The calculations presented below prove that deformations of the preglacial series in plateaux have not exceeded 50 m and hence, a hypothesis of subglacial origin of deep scour seems to be more

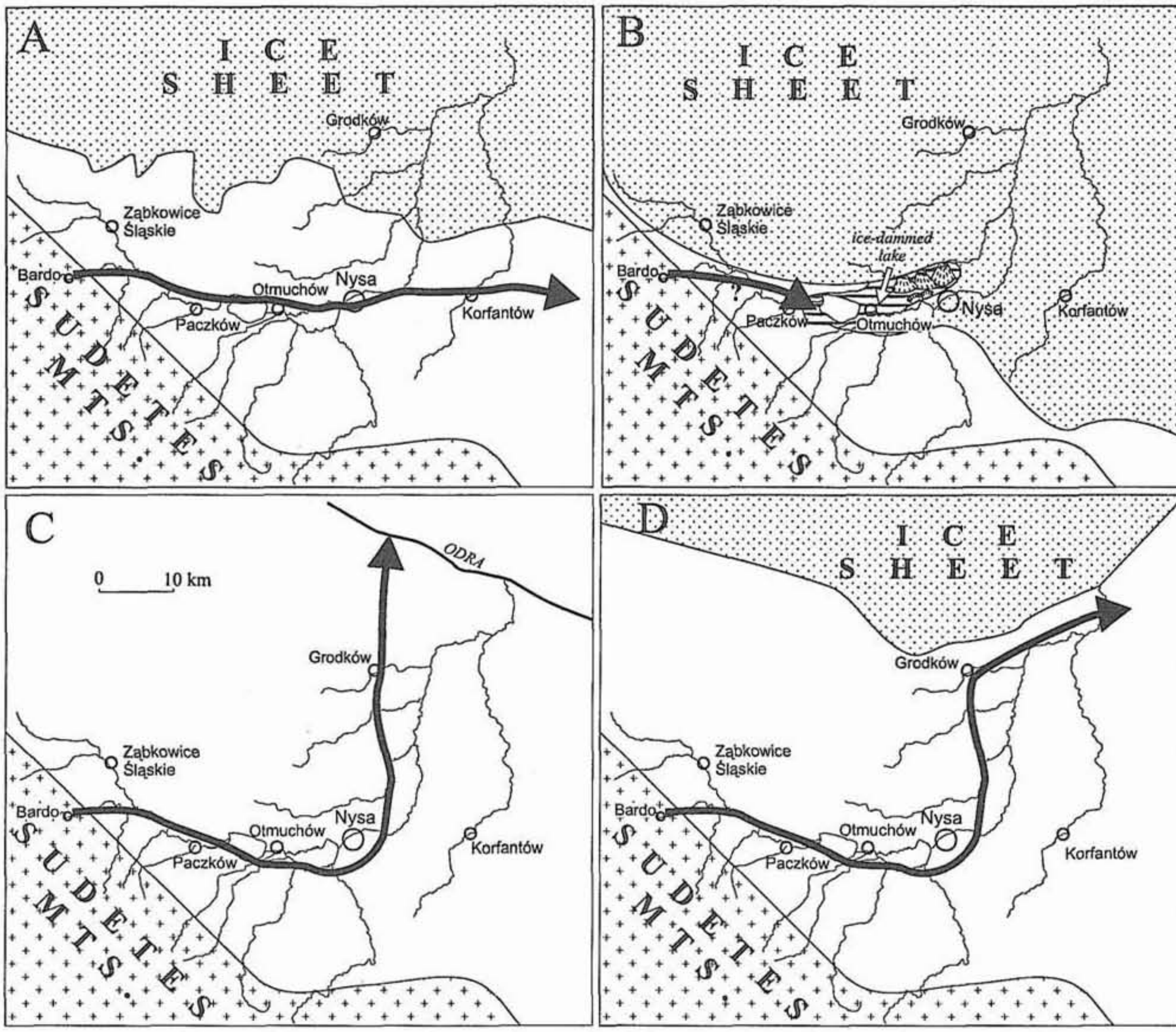


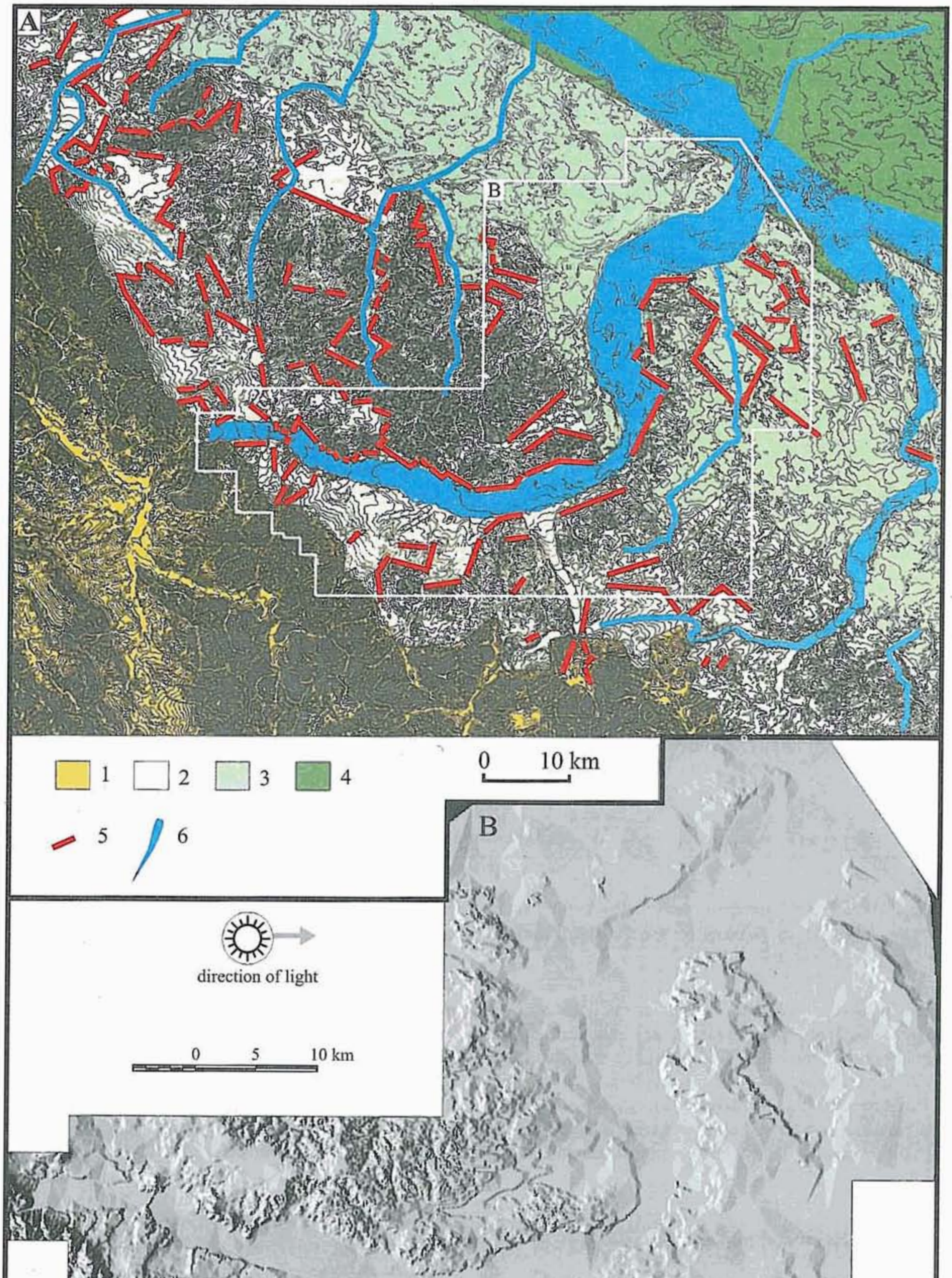
Fig. 6. Changes in flow directions of the Nysa Kłodzka River during ice sheet advance (A and B) and retreat (C and D) of the Odra Glaciation

Zmiany kierunków przepływu Nysy Kłodzkiej w czasie transgresji (A i B) oraz recesji (C i D) lądolodu zlodowacenia odry

credible. The above described verifications of opinions on a course of the ancient Nysa Kłodzka valley indicate that such a valley has never been considered for a deep erosional scour of fluvial origin. Some traces of the preglacial (and also the Early Pleistocene) Nysa Kłodzka River can be found in the present plateaux only, and their occurrence at deeper levels results from either subsidence or younger redeposition in glacial tunnel valleys.

PLEISTOCENE FLUVIAL SERIES BEFORE THE MIDDLE POLISH GLACIATION

If the fluvial series of the ancient erosional feature to the north of Nysa are redeposited, then such interpretation deprive us of the only recognized traces of a fluvial flow between the first and last ice sheet in this area. Preglacial deposits from various flow stages are relatively well preserved. The younger Pleistocene fluvial series have been either destroyed or not sufficiently recognized yet. There is a considerable gap between the preglacial deposits and the uppermost terrace in a record of fluvial deposition which should comprise fluvial deposits, particularly of the Great Interglacial. These should be gravels and sands with eratics of the northern provenance redeposited from glacial deposits of the South Polish Glaciations. No such deposits related to the Nysa Kłodzka River have been reported yet. A fluvial series of the Biała Głuchołaska gravels south-east of Nysa originates from an interglacial period. The bed of gravels, up to 10 cm in diameter, is overlain by a till. The gravels are underlain by the Poznań Clays. Content of Scandinavian pebbles indicates, however, that some older glacial deposits were incorporated.


A
B
1
2
3
4
5
6
0 10 km
B
direction of light
0 5 10 km

TERRACES IN THE NYSA KŁODZKA VALLEY

After retreat of ice sheet of the Odra Glaciation, much change took place in river systems of the Sudetic Foreland. The Nysa Kłodzka River continued flowing from Bardo along the Paczków Graben, but it changed its course farther on, beyond Nysa, from east- to northwards. It resulted from tectonic activity of the Niemodlin Rampart area. Relative downward movement of a small depression to the west of the swell contributed to the ultimate shape of the valley. The present terrace system in the Fore-Sudetic fragment of the Nysa Kłodzka River have been formed since the Odra Glaciation. It comprises three levels:

— upper terrace level, 20–30 m above river level, formed during ice sheet retreat of the Odra Glaciation;

— fragment of the middle terrace, 10–17 m above river level, related to the Warta Glaciation;

— two (occasionally only one) lower terraces, 2–8 and 1.5–5 m above river level, developed during the Vistulian and Holocene (Fig. 5).

The structure and age of the terraces in the Nysa Kłodzka valley have been comprehensively discussed in another paper (B. Przybylski, in press).

INFLUENCE OF GLACIATIONS ON EVOLUTION OF THE NYSA KŁODZKA VALLEY

The first ice sheet which invaded the Eastern Sudetes Foreland, met the eastward-flowing Nysa Kłodzka River. The preglacial series of poorly weathered fluvial gravels, stretching from the Bardo region as far as Korfantów, marks presumably a period immediately preceding the ice sheet advance. However, there is a lack of sufficient evidence to restore precisely how the river behaved during advance and retreat of ice sheets of the South Polish Glaciations. The dominant hypothesis was the existence of an ice-marginal valley flowage of the Nysa Kłodzka River along the Paczków Graben during the last glaciation in this area. This opinion was already expressed by the German geologists who considered the Otmuchów–Nysa Hills to represent the maximum extent of the Odra Glaciation (J. Behr, L. Mühlen, 1933). According to W. Walczak (1954), the Nysa ice-marginal valley had existed during the advance, and later it was crossed by the ice sheet which entered the Sudetes. This ice-marginal spillway has also existed during the older glaciations. The eastward-flowing Nysa Kłodzka River was already formed during the Preglacial without any contribution of ice sheets, probably as due to uplifting of the whole block of the Niemcza–Strzelin Hills and pushing the river towards the Paczków Graben. This direction probably existed until ice sheet retreat of the Odra Glaciation. The valley which developed in this way was an appropriate route for waters flowing during advances and retreats of ice sheets as early as during the South Polish Glaciation. After ice sheet had retreated, the Nysa Kłodzka River restored its primary flow towards the east. The next ice sheet of the Odra Glaciation (Stadial) followed partly this depression (Fig. 6). Narrow ice sheet lobes advanced from the east. It is indicated both by glaciotectonic structures in a brickyard to the south of Nysa and by reconstructed palaeodirections of transport from the south in the Otmuchów–Nysa Hills area. In front of the advancing ice sheet, ice-dammed lakes were formed. Many of them were destroyed later by erosion. The retreating ice sheet was, in turn, consecutively followed by a fluvial deposition, forming the uppermost terrace. During the first retreat stage, the Nysa Kłodzka River flowed eastwards across a depression on the Niemodlin Rampart east of Nysa, eroding glacial deposits and underlying older fluvial series. Ice sheet of the Odra Glaciation influenced the change in direction of the Nysa Kłodzka valley at its river mouth to the east of Grodków (Fig. 6). The upper terrace breaks off and fluvial sediments are overlain by glacial deposits there. Traces of fluvial gravels containing material originating from the Nysa Kłodzka River have also been found under a till on an erosive relic in the Odra valley. Such sequence of sediments proves that the ice sheet initially retreated at least as far as to the north of the Odra valley (Fig. 6C). Then the ice sheet advanced to the Grodków region, changing north- to eastward direction of the Nysa Kłodzka River (Fig. 6D). This ice sheet extent is followed by ice sheet retreat as presented by P. Woldstedt (1932). However, in this case tectonic movements could have also been involved because the Nysa Kłodzka River followed deep fracture zones in the basement (Fig. 9).

NEOTECTONIC MOVEMENTS

It is commonly accepted that both the fragment of the Sudetic Foreland crossed by the Nysa Kłodzka River was occupied during the Pleistocene by ice sheets and the area showed high tectonic activity during the Quaternary.

The analysis of topography began with construction of the map with densed contour lines (Fig. 7A). Additionally, shaded

Fig. 7A. Zones of different intensity of erosional incision in the eastern part of the Sudetic Foreland and major river valleys
1 — Sudetes; 2 — inner Sudetic Foreland; 3 — Silesian Lowlands (outer Sudetic Foreland); 4 — Odra valley; 5 — major morpholineaments in the Sudetic Foreland; 6 — river valley beds
B. Shaded relief map of the Nysa Kłodzka valley and the surrounding plateaux

A. Strefy o różnej intensywności erozyjnego rozcięcia we wschodniej części przedpola Sudetów wraz z przebiegiem głównych dolin rzecznych
1 — Sudety; 2 — bliższe przedpole Sudetów; 3 — równiny Niziny Śląskiej (dalsze przedpole); 4 — dolina Odry; 5 — wyraźniejsze morfolineamenty na przedpolu Sudetów; 6 — dna dolin rzecznych
B. Mapa cieniowanego reliefu doliny Nysy Kłodzkiej i otaczających ją wysoczyzn

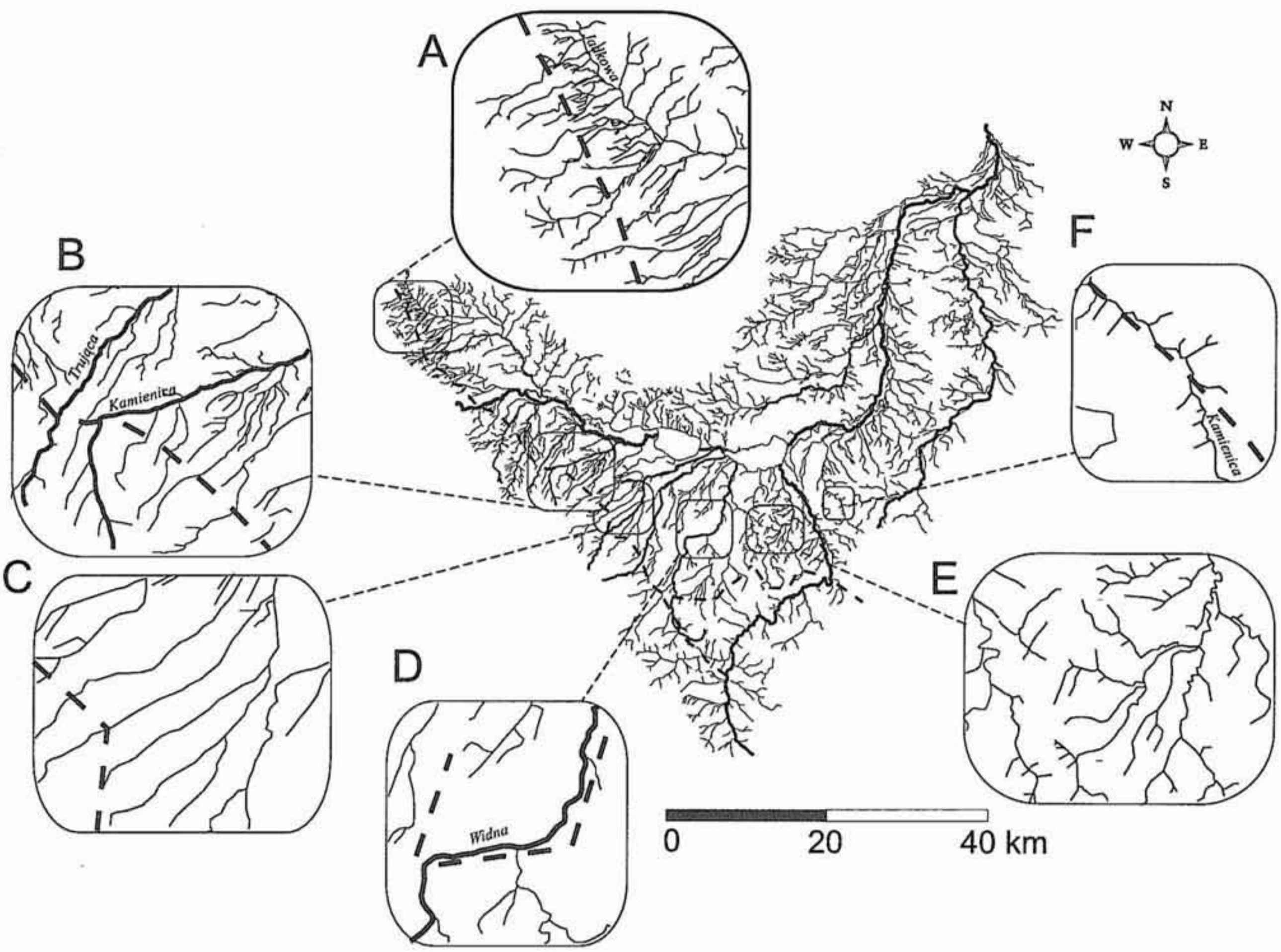


Fig. 8. Selected examples of adaptation of river systems to structures and fault zones of the basement in a mountain-foot area of the Nysa Kłodzka river-basin (description in the text)

Wybrane przykłady dostosowania się sieci rzecznej do struktur i dyslokacji podłoża w przedgórskiej części zlewni Nysy Kłodzkiej (szerszy opis w tekście)

relief maps (Fig. 7B) were prepared after digitizing the contour lines, drawn every 10 m, using the computer programme Surfer 6.1. A picture resembling a very detailed satellite or radar photograph was received. Its superiority is that such a picture shows topography, both without vegetation and anthropogenic elements. Moreover, this method allows to adjust optionally the angle and direction of light what makes erosional edges better visible. These maps clearly indicate that geomorphologic traces of the Pleistocene ice sheets in the eastern part of the Sudetic Foreland have been completely destroyed by the following erosion and denudation.

The characteristic feature, manifesting itself in the map of densed contour lines, is a zonal variability of topography (Fig. 7A). Such zones are arranged approximately parallel to the Marginal Sudetic Fault and the Middle Odra Fault Zone. The edge separating the Niemcza–Strzelin Hills and Głubczyce Plateau from Silesian Lowland is clearly marked. It seems highly probable that this line corresponds to the fault zone which is parallel to the Marginal Sudetic Fault, along which the eastern part of the Sudetic Foreland kept uplifting and therefore, more strongly eroded compared with lowland areas located to the north of this geomorphologic barrier. Strong erosional transformation which affected the landscape resulted in almost complete elimination of post-glacial topographic features in the Niemcza–Strzelin Hills and the Głubczyce Plateau. Such uplift must have taken place after the last ice sheet had retreated in this area, i.e. after the Odra Glaciation, because its sediments are eroded to a depth of 30–40 m, together with the underlying deposits.

ANALYSIS OF THE RIVER SYSTEM IN THE FORE-SUDETIC PART OF THE NYSA KŁODZKA RIVER BASIN

The river system is far from an ideal dendrite-like model (Fig. 8). A number of anomalies result presumably from the action of streams which kept matching to basement structures as well as from a young tectonic activity.

The most spectacular effect of the tectonic edge on the river system is marked in the western part of the river basin where tributaries of the Jadkowa River change their arrange-

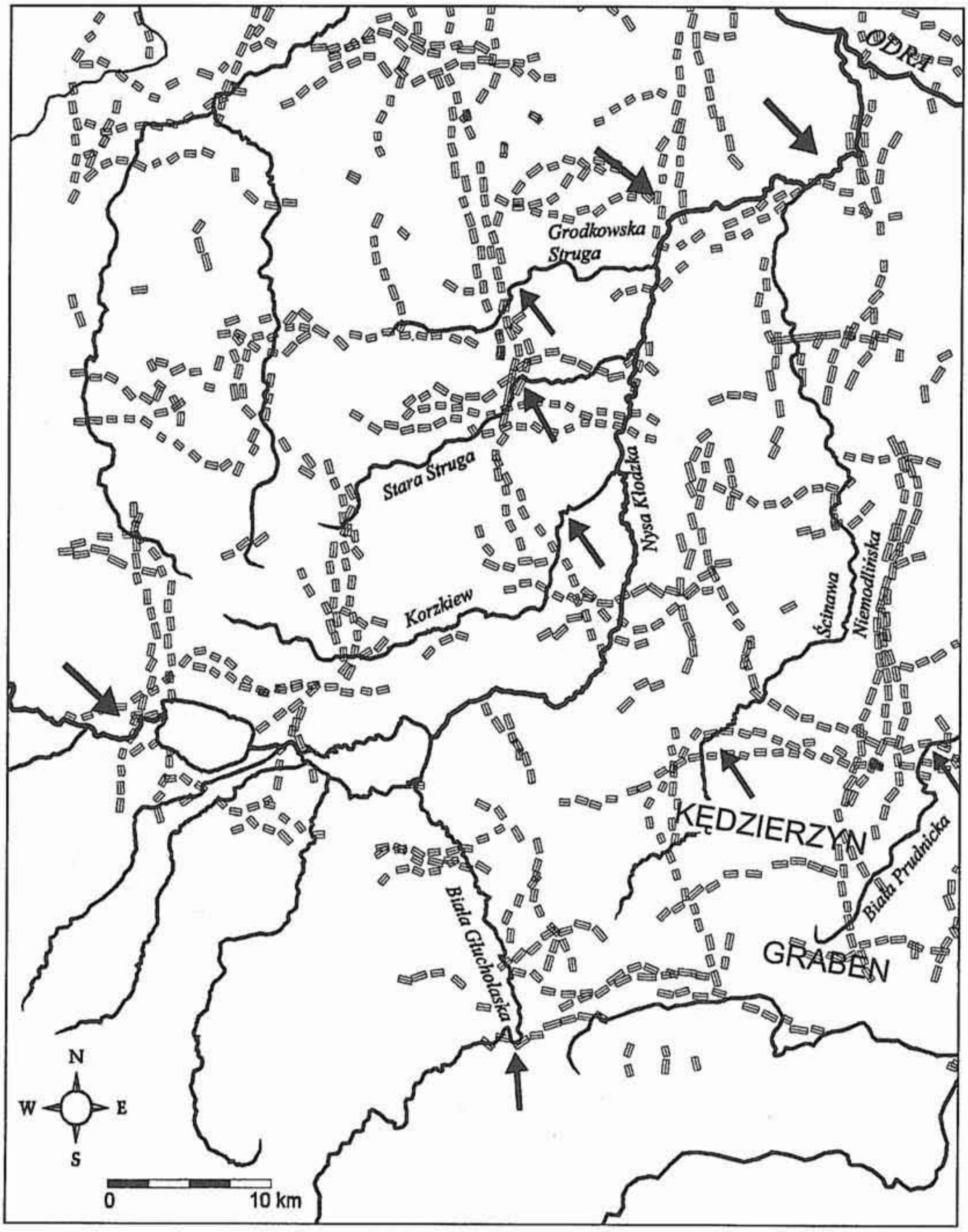


Fig. 9. Deflections of the Nysa Kłodzka River and its tributaries (arrows) against the background of zones with increased gradients of gravity anomalies (anomalies after S. Doktór *et al.*, 1988)

Defleksje Nysy Kłodzkiej i jej dopływów (strzałki) na tle stref zwiększonych gradientów anomalii grawimetrycznych (anomalie według S. Doktóra i in., 1988)

ment from a dendrite-like one up beyond the edge, into a fork-like one at a footwall of the Marginal Sudetic Fault (Fig. 8A). The Kamienica River shows distinct deflection at this fault but the neighbouring Trująca River crosses this fault perpendicularly, exhibiting no response to its potential tectonic activity (Fig. 8B). Parallelly arranged streams, flowing down across a gently sloping area of the pediment, predominate between the Kamienica and the Widna Rivers (Fig. 8C). The latter distinctly follows a young tectonic structure (Fig. 8C). Outcrops of crystalline rocks to the south of Nysa indicate perpendicular and chequered pattern of streams (Fig. 8E). A pinnate-like river system of the Kamienica River basin results from its partial adjustment to a fault zone that crosses this area (Fig. 8F).

Interesting data have been obtained from the analysis of the Nysa Kłodzka River and its major tributaries as well as

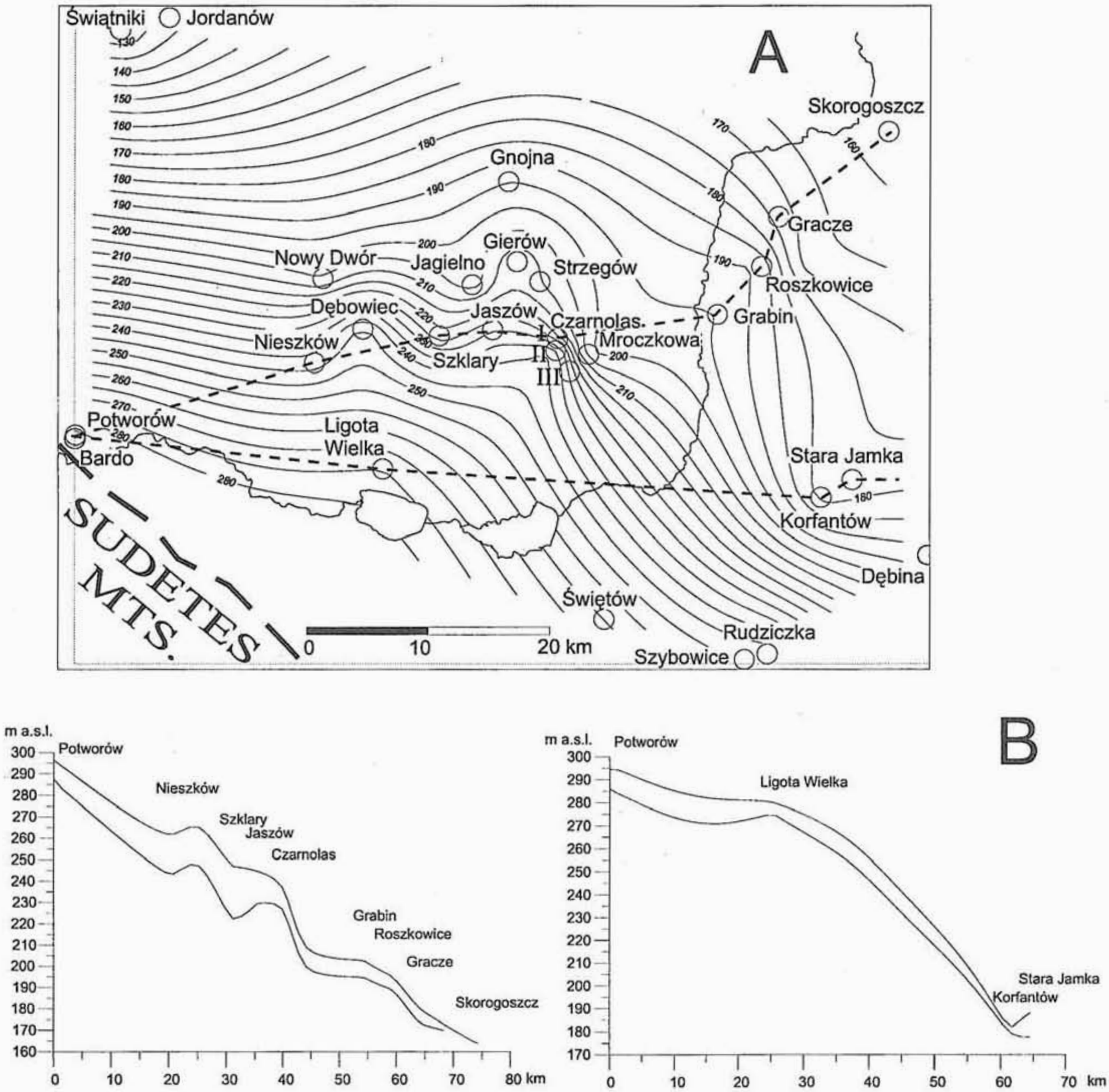


Fig. 10A. Model of surface of preglacial deposits in the eastern part of the Sudetic Foreland (contour lines in m a.s.l.)
B. Longitudinal profiles along modelled top and bottom surfaces of preglacial deposits (location in Fig. 10A — dashed line)

A. Model powierzchni cokołu serii utworów preglacjalnych we wschodniej części przedpola Sudetów (izohipsy w m n.p.m.)
B. Profile podłużne przez modelowe powierzchnie stropu i spągu utworów preglacjalnych (lokalizacja na fig. 10A — linia przerywana)

neighbouring rivers, compared with zones of increased gradients of gravity anomalies which presumably mark fault zones in a deep basement (Fig. 9). Distinct meridional anomalies delimit extent of the Kędzierzyn Graben. The Ścinawa Niemodlińska and Biała Prudnicka Rivers deflect at the northern boundary of this structure. Deflection of the major left-bank tributary rivers are characteristic for the southern reach of the Nysa Kłodzka River. The rivers Korzkiew (Cielnica), Stara Struga and Grodkowska Struga show similar double deflections there. These deformations can be related to the edge of the Nysa Kłodzka valley. However, they also follow clearly a fault zone in a deep basement, stretching NNW–SSE. The fault zone is probably a boundary of the Strzelin Hills block *sensu lato*, buried under the Cainozoic sedimentary rocks. Directions of flow of the Nysa Kłodzka River also follow discontinuity zones in a deep basement (Figs. 7A, 9).

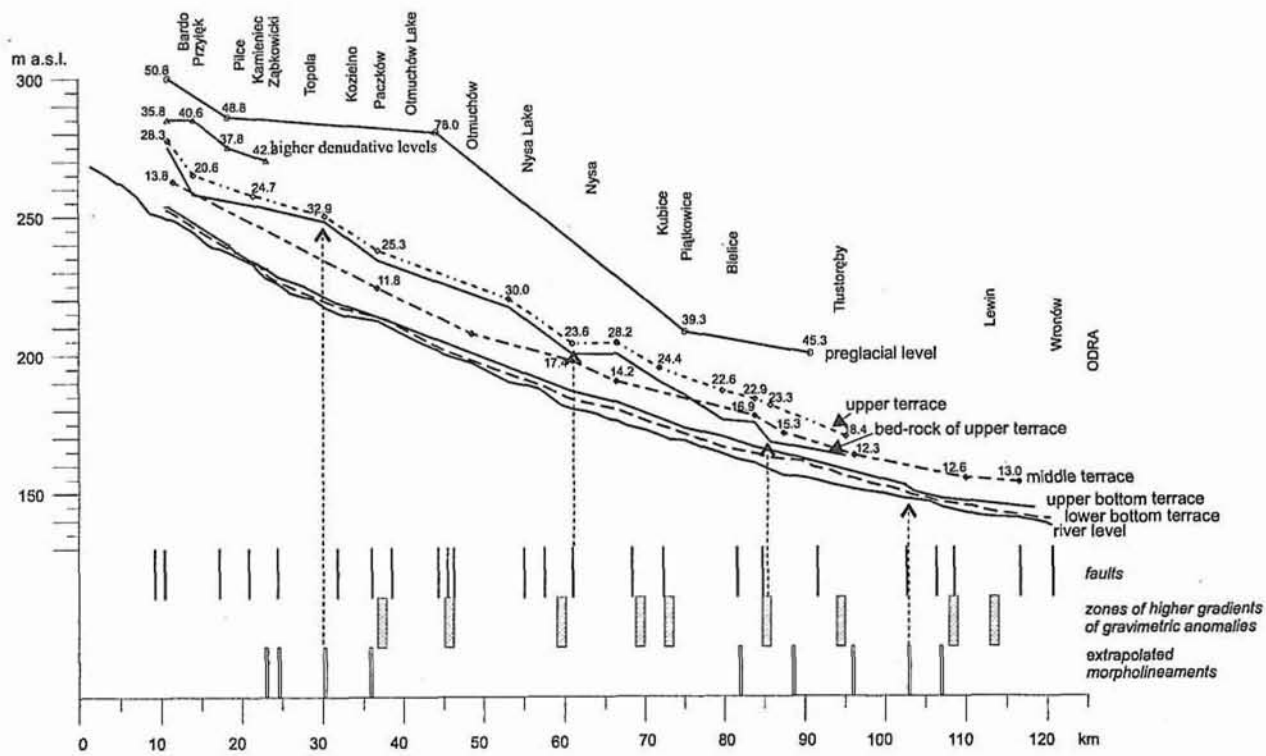


Fig. 11. Longitudinal profile of terraces in a mountain-foot area of the Nysa Kłodzka valley
Arrows denote sites of stronger deformations, resulting from activity of fault zones crossing the valley
Profil podłużny tarasów przedgórskiej części doliny Nysy Kłodzkiej
Strzałkami zaznaczono wyraźniejsze miejsca deformacji, których przyczyną mogła być aktywność dyslokacji przecinających dolinę

DISTURBANCES IN TERRACES AND FLUVIAL BEDS

Deformations of preglacial deposits of the Nysa Kłodzka fluvial series were analysed first. The constructed maps and cross-sections distinctly indicate anomalies in these sediments. Disturbances are visible in all the sections that cross the modelled socles and tops of the preglacial series (Fig. 10). Therefore, irrespectively of the subdivision into particular flowage phases, the primary deposition bed has been undoubtedly deformed. These deformations can be estimated only and their present magnitude results presumably from variously oriented tectonic movements, to which this area has been subjected since the Preglacial. Basing upon deformations of the beds in the preglacial fluvial series, the amplitude of vertical movements seems to have been of at least 40 m large since termination of the deposition. Compared with the Sudetes, its forefield got lower during the same period by at least 50 m. These displacements took place after the preglacial series had been deposited.

Deformations of the terraces (Fig. 11) were also analysed. They show certain concurrence between deformations in particular terraces and directions of some fault zones crossing the Nysa Kłodzka valley. Relationships between deformations and directions of some deep discontinuity zones recognized by gravimetric methods are also clear. The most spectacular examples of such correlations are presented (Fig. 11). Activity of the fault zones during the Early Quaternary may have been a reason why the terraces became deformed. The faults near Nysa and Tłustoręby seem to exhibit greater activity, marked by deformations in all the terraces. Less clear are disturbances in the valleys of the Paczków Graben. They may result from the Quaternary tectonic movements of individual blocks. The upper terrace has been deformed by 5–8 m, most probably at the decline of the Odra Glaciation. Local increase in thickness of sediments of this terrace is of particular importance. It indicates that tectonic movements took place as early as deposition continued. Smaller deformations of the lower level related to the Warta Glaciation prove that intensity of neotectonic movements have gradually been decreasing since ice sheet retreat during the Odra Glaciation.

Some general conclusions on the Quaternary can be inferred, basing upon thickness analysis of sediments in the Nysa Kłodzka valley and the surrounding plateaux. The western part of the Paczków Graben has intensively been lowered during the Tertiary as proved by considerable thickness of the Tertiary deposits, reaching several hundred metres. The bottom of the present Nysa Kłodzka valley, broad in the Paczków Graben, consists of fluvial deposits to 15 m thick and immediately underlain by the Tertiary basement. On plateaux, adjoining the valley from the north, thickness of the Quaternary deposits is 40–50 m on the average. It indicates general decrease in activity of the Paczków Graben during the Quater-

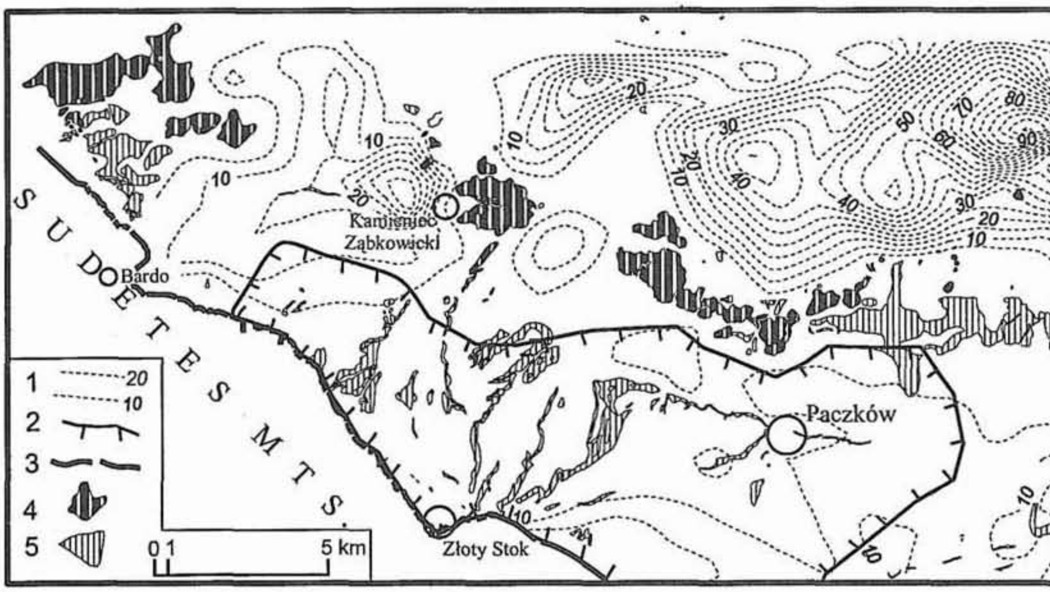


Fig. 12. Distribution of maximum thickness of the Quaternary deposits in the eastern part of the Paczków Graben and its margins
1 — thickness isolines of Quaternary deposits; 2 — zone of maximum thickness of Tertiary deposits in the Paczków Graben (200–600 m); 3 — Marginal Sudetic Fault; 4 — outcrops of crystalline rocks; 5 — outcrops of Tertiary rocks

Rozkład maksymalnych miąższości utworów czwartorzędowych we wschodniej części rowu Paczkowa i w jego obrzeżeniu
1 — izolinie miąższości osadów czwartorzędu; 2 — strefa maksymalnych miąższości osadów trzeciorzędu w rowie Paczkowa (200–600 m); 3 — sudecki uskok brzeżny; 4 — wychodnie skał krystalicznych; 5 — wychodnie utworów trzeciorzędu

nary, even with a trend to periodic shift of the maximum subsidence axis to the north of the graben (Fig. 12).

ASYMMETRY OF THE NYSA KŁODZKA VALLEY

The Nysa Kłodzka valley shows asymmetry along many stretches. The asymmetry in the south is clearly visible in the cross-section (Fig. 5 — III). Asymmetric valley terraces indicate that the river permanently migrated to the east, towards the edges of the Niemodlin Rampart. The reason was a continuous uplift of plateaux, composing the eastern margin of the Niemcza–Strzelin Hills. The Niemodlin Rampart, uplifting at the same time, was a barrier hampering its migration farther east. The swell edges are so clearly marked, just due to erosional activity of the Nysa Kłodzka River.

DISCUSSION

The studies indicate that it is difficult to answer the question which was the major factor that influenced development of the Nysa Kłodzka valley, either neotectonic movements during the Quaternary or the Pleistocene ice sheets invading the area. As it has been proved, both these factors have exerted crucial influence on palaeogeographical evolution of this area during the Quaternary. However, it is impossible to determine proper relations between them. It has been emphasized that tectonic movements influenced changes in direction of the Nysa Kłodzka valley and its evolution much more than it has been suggested before. Until now, all significant changes in flow directions in the eastern part of the Sudetic Foreland, like in the Polish Lowlands, seem to have resulted from ice sheet advances and retreats (J. Behr, L. Mühlen, 1933; G. Anders, 1939; W. Walczak, 1954, 1972; L. Baraniecki, 1975; A. Jahn, S. Szczepankiewicz, 1967; S. Szczepankiewicz, 1972; A. Szponar, 1974, 1986; M. Brykczyński, 1986; S. Dyjor, 1991). Apart from J. Wroński (1974, 1975) and some references on subsidence in the Nysa region cited by W. Walczak (1954), basically no geologist has taken into account possibilities of the evolution of Quaternary flow dependent on activity of particular basement blocks. However, it appears that traces of glaciations are now more poorly legible, compared with topographic features resulting from tectonic movements which took place in this area, mainly after the last ice sheet had retreated. The flow of the Nysa Kłodzka River took the eastward direction during the Preglacial, due to uplift of the whole Niemcza–Strzelin Hills block and pushing the river towards the Paczków Graben. This may have also been related to reactivation of subsidence in the graben during the Early Pleistocene.

A mutual relationship between glaciations and neotectonic movements is also a problem of discussion. There is no doubt that the Quaternary tectonic movements in the Sudetic Foreland resulted, to a certain extent, from glacioisostatic relaxation. These movements were especially strong after the Odra Glaciation, when the whole Sudetic Foreland, including the Głubczyce Plateau, was uplifted by 30–40 m in relation to the Silesian Lowland. It is oddly enough that the total amplitude of the tectonic movements in this area after the Preglacial, has also been evaluated at about 40 m. This means that in this region either relative tectonic stability reigned or balancing oscillatory movements took place. The youngest symptoms of tectonic movements, occurring also recently, go beyond the limits of the glacioisostatic compensation period. This undoubtedly results from some autonomous tectonic movements of the Sudetic Foreland, to which ice sheet push could have been an intensification factor only. Such suggestion was already expressed for the Middle Sudetes (D. Krzyszkowski, E. Pijet, 1993; D. Krzyszkowski, R. Stachura, 1993). A still more difficult problem to solve is the influence of tectonic movements upon behaviour of ice sheets. Different movements of particular basement blocks could result in development of cracks in marginal ice sheet zones. Spatial correlation between ice sheet retreat and direction of a fault zone in the basement is marked to the north-east of Grodków. However, it is difficult to find out if it is a fortuitous case or not.

CONCLUSIONS

A considerably broader extent of fluvial deposits related to the Nysa Kłodzka River, compared with that assumed before, has been recognized in the Sudetic Foreland. This is mainly the case with the preglacial fluvial series.

The Nysa Kłodzka River changed its course many a time when crossing the Sudetic Foreland as early as during the Preglacial (Pliocene–Early Pleistocene). These changes may have resulted from tectonic movements at that time only.

Geomorphologic traces of the Pleistocene ice sheets in the eastern part of the Sudetic Foreland have been almost completely destroyed by later erosion and denudation, and the reduced glacial sequence renders it impossible to reconstruct precise extents of individual ice sheets. Basing upon recent recognition, it seems that this area was invaded by three ice sheets and at least one of them crossed the Paczków Graben zone, reaching far into the Sudetes. Influence of the last ice sheet in this area upon changes in directions of river flow, can be inferred from distribution of fluvial series and traces of erosional scours from the time when meltwaters flowed away.

Post-glacial tectonic movements contributed to destruction of the post-glacial landscape. Tectonic movements caused by a glacioisostatic impulse after the Odra Glaciation resulted in uplifting of the Sudetic Foreland in relation to the Silesian Lowland, what in turn resulted in stronger erosion at the uplifted areas. Relative movements of smaller tectonic units (blocks and depressions) took place in these regions, contributing to general re-arrangement of the hydrographic system in the southeastern part of the Lower Silesia.

Four terraces have been recognized in the Fore-Sudetic part of the Nysa Kłodzka valley. They have been formed after ice sheet retreat of the Odra Glaciation and during the Holocene. Their longitudinal profiles show many deformations, resulting probably from activity of fault zones, crossing the valley during deposition of fluvial series and younger tectonic movements, causing the terrace profiles to be deformed. Magnitude of these deformations is more clearly visible in the uppermost terrace (8–10 m), but disturbances of 2–3 m have also been recognized within the lowermost terrace. Small anomalies following the fault zone of the deep basement (sub-Cainozoic) have also been found in a longitudinal profile of the present river bed. Research methods jointly employed allowed to find out that tectonic movements influenced development of the Fore-Sudetic part of the Nysa Kłodzka valley through the whole Quaternary, from Preglacial times until the Holocene and the present. They were particularly increased after the Odra Glaciation. Phases of glacioisostatic impulses from older glaciations are not legible now, due to lack of any fixed data. The applied research methods enabled detailed analysis of topography and the character of the river system in the eastern part of the Sudetic Foreland, in terms of probable influence of tectonic movements on evolution of this area. It seems justifiable to conduct similar studies for other fragments of the Sudetic Foreland. Especially useful are methods of topography analysis, basing on digitized densed contour lines and shaded relief maps. Not only a broader area of research but also more detailed studies are the future for these methods. They could enable recognition of more subtle features which reflect young tectonic movements.

Translated by Krzysztof Leszczyński

REFERENCES

ANDERS G. (1939) — Zur Morphologie der Ostsudeten. Veröff. Schles. Ges. Erdk., **31**.

BADURA J., PRZYBYLSKI B. (1994) — Kopalna dolina Nysy Kłodzkiej między Nysą a Grodkowem. Acta Univ. Wratisl. Pr. Inst. Geogr., Seria A, Geogr. Fiz., **7**, p. 97–110.

BADURA J., PRZYBYLSKI B. (in press) — Zasięg lądolodów plejstoceńskich i etapy recesji lądolodu zlodowacenia środkowopolskiego między Sudetami Wschodnimi i Wałem Śląskim. Biul. Państw. Inst. Geol.

BARANIECKI L. (1975) — Morfogeneza przedpola Sudetów wschodnich. In: Przewodnik Sesji Naukowej nt. „Rzeźba i czwartorzęd Polski południowo-zachodniej", p. 15–18. Wrocław.

BEHR J., MÜHLEN L. (1933) — Die Urbettung der Glätzer Neisse und Freiwaldauer Biele. Jb. Preuss. Geol. Landesanst., **53**, p. 758–765.

BEHR J., MEISTER E., GÖRZ G. (1931) — Erläuterungen zu der geologischen Karte von Preussen, Blatt Camenz in Schlesien. Preuss. Geol. Landesanst. Berlin.

BRYKCZYŃSKI M. (1986) — On the main directions of the development of the Polish Lowland river network in Quaternary (in Polish with English summary). Prz. Geogr., **58**, p. 411–440, no. 3.

CACOŃ S., DYJOR S. (1995) — Neotectonic and recent crustal movements as potential hazard to water dams in Lower Silesia, SW Poland. Folia Quaternaria, **66**, p. 59–72.

DOKTÓR S., GRANICZNY M., KUCHARSKI R. (1988) — Mapy liniowych elementów tektonicznych w skali 1:200 000 dla arkuszy Wałbrzych, Kłodzko, Nysa i Wrocław. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

DYJOR S. (1985) — Budowa geologiczna rejonu Gnojnej. In: Plioceńska i eoplejstoceńska sieć rzeczna i związane z nią kompleksy osadów gruboklastycznych w Polsce, p. 83–88. Krajowa Konferencja Naukowa we Wrocławiu 1985.06.18–20. Materiały do dyskusji problemowej w terenie.

DYJOR S. (1987*a*) — Młodotrzeciorzędowy i eoplejstoceński rozwój sieci kopalnych dolin w Polsce na tle ewolucji paleogeograficznej bruzdy środkowoeuropejskiej. In: Problemy młodszego neogenu i eoplejstocenu w Polsce (eds. A. Jahn, S. Dyjor), p. 13–42. Ossolineum. Wrocław.

DYJOR S. (1987*b*) — Systemy kopalnych dolin Polski Zachodniej i fazy ich rozwoju w młodszym neogenie i eoplejstocenie. In: Problemy młodszego neogenu i eoplejstocenu w Polsce (eds. A. Jahn, S. Dyjor), p. 85–101. Ossolineum. Wrocław.

DYJOR S. (1991) — Influence of the palaeogeographical evolution on the development of glaciations in western Poland. In: Geneza, litologia i stratygrafia utworów czwartorzędowych (ed. A. Kostrzewski) (in Polish with English summary). Geografia, **50**, p. 419–433. Wyd. Nauk. UAM. Poznań.

DYJOR S., DENDEWICZ A., GRODZICKI A., SADOWSKA A. (1978) — The Neogene and Old-Pleistocene sedimentation in the Paczków and Kędzierzyn Graben zones, Southern Poland (in Polish with English summary). Geol. Sudetica, **13**, p. 31–65, no. 1.

JAHN A., SZCZEPANKIEWICZ S. (1967) — Osady i formy czwartorzędowe Sudetów i ich przedpola. In: Czwartorzęd Polski (eds. R. Galon, J. Dylik), p. 397–430. PWN. Warszawa.

JAHN A., ŁAŃCUCKA-ŚRODONIOWA M., SADOWSKA A. (1984) — The site of Pliocene deposits in the Kłodzko Basin, Central Sudetes (in Polish with English summary). Geol. Sudetica, **18**, p. 7–43, no. 2.

KLECZKOWSKI A., DENDEWICZ A., DYJOR S., KOWALSKI J., MIŁKOWSKI M. (1972) — Pliocene-Quaternary Rybnik-Koźle Trough and its hydrogeological properties. Bull. Acad Pol. Sci., Ser. Sci. Terre, **20**, p. 71–83, no. 1.

KOTLICKA G. N. (1978) — Stratigraphy of Quaternary deposits in the Odra Valley near Racibórz (in Polish with English summary). Biul. Inst. Geol., **300**, p. 303–387.

KOTLICKA G. N. (1981) — The neotectonics of the valley of the Upper Odra (in Polish with English summary). Biul. Inst. Geol., **321**, p. 166–175.

KRYZA J., POPRAWSKI L. (1987) — Próba rekonstrukcji plejstoceńskiego systemu dolin kopalnych południowo-zachodniej Polski. In: Problemy młodszego neogenu i eoplejstocenu w Polsce (eds. A. Jahn, S. Dyjor), p. 137–145. Ossolineum. Wrocław.

KRZYSZKOWSKI D., PIJET E. (1993) — Morphologic and geologic effects of the neotectonic movements at the Sudetic Marginal Fault, NE Sowie Góry Mts., Middle Sudety Mts., SW Poland (in Polish with English summary). Folia Quaternaria, **64**, p. 83–99.

KRZYSZKOWSKI D., STACHURA R. (1993) — Morphologic effects of neotectonic movements in the Wałbrzych Foothils, Middle Sudety Mountains, SW Poland (in Polish with English summary). Folia Quaternaria, **64**, p. 71–82.

OBERC J., DYJOR S. (1969) — Marginal Sudetic Fault (in Polish with English summary). Biul. Inst. Geol., **236**, p. 41–142.

PAGACZEWSKI J. (1972) — Catalogue of earthquakes in 1000–1970 years. Mat. Pr. Inst. Geofiz. PAN, **51**, p. 3–36.

POPRAWSKI L. (1995) — Hydrogeology of the Odra River Valley between Krapkowice and mouth of the Nysa Kłodzka River (in Polish with English summary). Acta Univ. Wratisl., **1585**, Pr. Geol.- Miner., **42**, p. 3–81.

PRZYBYLSKI B. (in press) — The development of the Fore-Sudetic area of the Nysa Kłodzka river valley in the Neopleistocene and Holocene. Geol. Sudetica.

SZCZEPANKIEWICZ S. (1972) — Nizina Śląska. In: Geomorfologia Polski (ed. R. Galon), **2**, p. 224–239. PWN. Warszawa.

SZPONAR A. (1974) — Stages of deglaciation in a submontane zone (shown on the example of forefield of Central Sudetes) (in Polish with English summary). Acta Univ. Wratisl., **220**, Stud. Geogr., **21**.

SZPONAR A. (1986) — Chronostratigraphy and the stages of deglaciations in the Sudetes Foreland area in the period of Middle-Polish Glaciation (in Polish with English summary). Acta Univ. Wratisl., **963**, Stud. Geogr., **45**.

WALCZAK W. (1954) — The outwash of the Nysa river and the Pleistocene hydrographic changes in the foreland of the Eastern Sudetes (in Polish with English summary). Pr. Geogr. PAN, **2**.

WALCZAK W. (1972) — Sudety i Przedgórze Sudeckie. In: Geomorfologia Polski (ed. M. Klimaszewski), **1**, p. 167–231. PWN. Warszawa.

WOLDSTEDT P. (1932) — Über Endmoränen und Oser der Saale (=Riss) -Vereisung in Schlesien. Z. Dtsch. Geol. Ges., **84**, p. 78–84.

WROŃSKI J. (1974) — Plejstoceńska sedymentacja rzeczna we wschodniej części bloku przedsudeckiego jako wskaźnik młodych ruchów tektonicznych tego obszaru. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

WROŃSKI J. (1975) — Procesy endogeniczne na obszarze wschodniej części bloku przedsudeckiego. In: Mater. I Krajowego Sympozjum nt. „Współczesne i neotektoniczne ruchy skorupy ziemskiej w Polsce", **1**, p. 171–183. Wyd. Geol. Warszawa.

ZEUNER F. (1928) — Diluvialstratigraphie und Diluvialtektonik im Gebiet der Glätzer Neise. Universitätsverlag von Robert Noske. Borna–Leipzig.

GLACJALNE I NEOTEKTONICZNE UWARUNKOWANIA ROZWOJU PRZEDSUDECKIEGO ODCINKA DOLINY NYSY KŁODZKIEJ W CZWARTORZĘDZIE

Streszczenie

Badaniami objęto przedgórski i nizinny odcinek doliny Nysy Kłodzkiej (fig. 1). Rzeka ta na przedpolu Sudetów przepływa przez obszary wykazujące umiarkowaną aktywność w całym czwartorzędzie. Jednocześnie na obszar ten w plejstocenie nasuwały się lądolody (fig. 2). Obydwa te czynniki wywarły decydujący wpływ na rozwój paleogeograficzny tego obszaru w czwartorzędzie, jednak ustalenie wymiernych proporcji między nimi nie jest możliwe. Okazuje się, że ślady zlodowaceń są dzisiaj słabiej czytelne niż zarysy rzeźby uwarunkowanej ruchami tektonicznymi, które nastąpiły głównie po recesji ostatniego obecnego na tym obszarze lądolodu. Geomorfologiczne znamiona pobytu plejstoceńskich lądolodów we wschodniej części przedpola Sudetów zostały prawie całkowicie zatarte przez późniejszą erozję i denudację, a dokładne odtworzenie zasięgów poszczególnych zlodowaceń uniemożliwia zredukowana sekwencja serii glacjalnych. Na podstawie obecnego rozpoznania można wnioskować jedynie ogólnie, że na obszar ten dotarły co najmniej trzy lądolody, a co najmniej jeden z nich przekroczył strefę rowu Paczkowa, sięgając na obszar Sudetów.

Przepływ Nysy Kłodzkiej w kierunku wschodnim ukształtował się już w preglacjale w wyniku podnoszenia się całego bloku Wzgórz Niemczańsko-Strzelińskich i spychania rzeki w kierunku rowu Paczkowa. Od pliocenu do pojawienia się pierwszego lądolodu Nysa Kłodzka zmieniała stopniowo swój bieg z północnego w kierunku doliny Oławy na wschodni w kierunku pra-Odry (fig. 3). Kopalna dolina Nysy Kłodzkiej wyznaczana na północ od Nysy w świetle nowej interpretacji jest raczej rynną subglacjalną niż dawną doliną rzeczną (fig. 4). Wschodni kierunek przepływu Nysy Kłodzkiej funkcjonował prawdopodobnie aż do schyłku zlodowacenia odry. Tak ukształtowana dolina stała się dogodnym odpływem wód w okresie transgresji i recesji lądolodów poszczególnych zlodowaceń. System tarasów współczesnej doliny Nysy Kłodzkiej kształtował się od ustąpienia lądolodu zlodowacenia odry (fig. 5, 11)

Zmiana kierunku ujściowego odcinka doliny Nysy Kłodzkiej na wschód od Grodkowa mogła być spowodowana wpływem lądolodu (fig. 6). I tutaj jednak nie można wykluczyć wpływu ruchów tektonicznych, kierunek prze-

pływu Nysy Kłodzkiej pokrywa się bowiem także z przebiegiem dyslokacji podłoża (fig. 9).

Dolina Nysy Kłodzkiej wykazuje wyraźne dopasowywanie się do przebiegu stref i jednostek geomorfologicznych uwarunkowanych neotektoniką (fig. 7). Do stref nieciągłości podłoża nawiązują również anomalie sieci rzecznej w obrębie całej zlewni tej rzeki (fig. 8, 9), jak i zaburzenia profilu podłużnego oraz profilu powierzchni serii rzecznych (fig. 10, 11). Czwartorzędowe ruchy tektoniczne wpływały także na miąższość osadów akumulowanych we wschodniej części przedpola Sudetów (fig. 12). Tektonicznego uzasadnienia można doszukiwać się w zmianie kierunku doliny Nysy Kłodzkiej z równoleżnikowego na południkowy, na wschód od Nysy. Przyczyną było najprawdopodobniej uaktywnienie się tektonicznego zapadliska na wschód od wału niemodlińskiego, co spowodowało przeciągnięcie ku północy rzeki płynącej pierwotnie na wschód.

Czwartorzędowe ruchy tektoniczne, zachodzące na przedpolu Sudetów, były w pewnym stopniu wynikiem glaciizostatycznego odprężania. Szczególnie silnie zaznaczyły się po zlodowaceniu odry, kiedy całe wschodnie przedpole Sudetów, włączając Płaskowyż Głubczycki, zostało podniesione o 30–40 m w stosunku do Niziny Śląskiej. Obserwowane najmłodsze przejawy ruchów tektonicznych, które zachodzą nawet obecnie, wykraczają już poza granicę czasu glaciizostatycznej kompensacji. Jest to niewątpliwie wynik jakiś autonomicznych ruchów tektonicznych przedpola Sudetów, dla których nacisk lądolodu mógł być jedynie impulsem intensyfikującym.