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Tunnel valleys and alluvial fans in the western Sudetic Foreland (southwestern Poland): the lithostratigraphy of Quaternary deposits

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Abstract The western Sudetic Foreland between the Nysa Łużycka and Bóbr rivers consist of deposits of two glaciations, the Elsterian and Saalian, and the extensive fluvial sediments. The Elsterian glacial deposits (the lower glacial complex) are only preserved in deep troughs. These structures, which were formerly interpreted as buried valleys, are actually of glacial origin and represent tunnel valleys. The glacial sediments of the Odranian glaciation (the upper glacial complex) are very thin and are only represented by a single till bed which occurs throughout the area, although only in patches. In the study area there are extensive series of fluvial deposits (the lower fluvial complex) between the Elsterian and Odranian tills, which are correlated with the Holstenian to early Saalian fluvial horizon in Germany (the Middle Terrace). The Wartanian sediments are represented by another fluvial series (the middle fluvial complex) which is composed of local alluvial fans deposited by Sudetic rivers, the Wroclaw–Magdeburg Pradolina valley and the outwash plains formed at the front of the Wartanian ice sheet. The youngest sediments are represented by one Weichselian and two Holocene fluvial terraces (the Bóbr, Kwisa and Nysa Łużycka Terraces).

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INTRODUCTION

A major part of the Sudetic Foreland is occupied by the so-called Wrocław–Magdeburg Pradolina and the tributary alluvial surfaces and alluvial fans of the Sudetic rivers in the south and sandur plains in the north (Fig. 1), which are all attributed to the extraglacial Wartanian sedimentary system (Keilhack, 1920; Berg, 1936; Genieser, 1936; Schwarzbach, 1942; Grocholski & Milewicz, 1958a; Brodzikowski, 1975). There are only several isolated hills containing Pliocene and/or Middle Pleistocene deposits at their base, covered by thin glacial and fluvial sediments (Fig. 2). The southern end of the study area is a flat to slightly undulated plateau formed of Pleistocene glacial, glaciofluvial and fluvial deposits, with numerous small hillocks built of Neogene, Mesozoic and Palaeozoic rocks (Fig. 2). These surfaces are dissected by rivers down to a depth of 25 m with up to four terrace levels in the valleys.

Nosek (1966) found that the oldest Quaternary deposits in this area are pre-glacial fluvial clastic sediments. The Lower dark-grey tills occurring in erosive depressions were assigned by Nosek (1966), Milewicz (1991) and Milewicz & Wroński (1975) to the Elsterian. The Upper tills in these depressions, with thick fluvioglacial sands and gravels, were included by Nosek (1966) and Milewicz & Wroński (1975) into the Odranian. Numerous till horizons occurring in the "Czerna Wielka buried valley" were interpreted by Milewicz (1991) as redeposited tills formed during the Odranian glaciation. The tills and all the Quaternary sand-gravel deposits in the outcrops of the area under discussion were classified as Odranian glacial sediments. In the present autor's opinion (Urbański, 1995) a part of the Quaternary sand-gravel deposits in the western Sudetic Foreland has a fluvial origin.

There are a number of different opinions about the uppermost sand-gravel horizon – traditionally considered to be the Wrocław–Magdeburg Pradolina. Brodzikowski (1975) questioned the existence of the Warszawa–Berlin Pradolina. Trzepierczyński (1984) suggested that the Kwisa and Nysa Łużycka rivers during the time of the Wartanian glaciation were confluenced. In the opinions of Koźma & Przybylski (1994) and Urbański (1995) alluvial fans were formed at the front of the Warthanian ice sheet, interfering with proglacial stream valley deposits. Another problematic point is the origin of deep erosive structures in the area. Milewicz (1991) suggested that "the

Czerna Wielka buried valley" was created in the Cromer interglacial period. Milewicz & Wroński (1975) assigned part of the deep erosive structures a subglacial origin, whereas Michniewicz (1994) linked them with neotectonic activity in the discussed area. The aim of this article is to interpret the origin of the Pleistocene deposits in the deep buried structures and sand-gravel covers on the uplands. The geological information collected during this study allows for the reinterpretation of lithostratigraphical units which have been used so far.

BASEMENT OF QUATERNARY DEPOSITS

The basement of the Quaternary deposits consists of several major fault-bounded blocks exposing metamorphic rocks on highs and sedimentary rocks in depressions. The Neogene sequence of the study area consists of fluvial deposits of the Lower to Middle Miocene Żary Series and Mużaków Series, the Upper Miocene Poznań Series (clay) and the Miocene/Pliocene Gozdnica Series (Nosek, 1966). Deposits of the Żary Series, Silesian-Lusatian Series and Mużaków Series were found in boreholes situated to the norh of the Warta–Osiecznica horst (Fig. 3). Lower Miocene quartzites and deposits of the Gozdnica Series are exposed between Osiecznica and Parowa. To the north of the Warta–Osiecznica fault, gravels of the Gozdnica series and silts of the Poznań Series are situated on uplands and isolated hills.

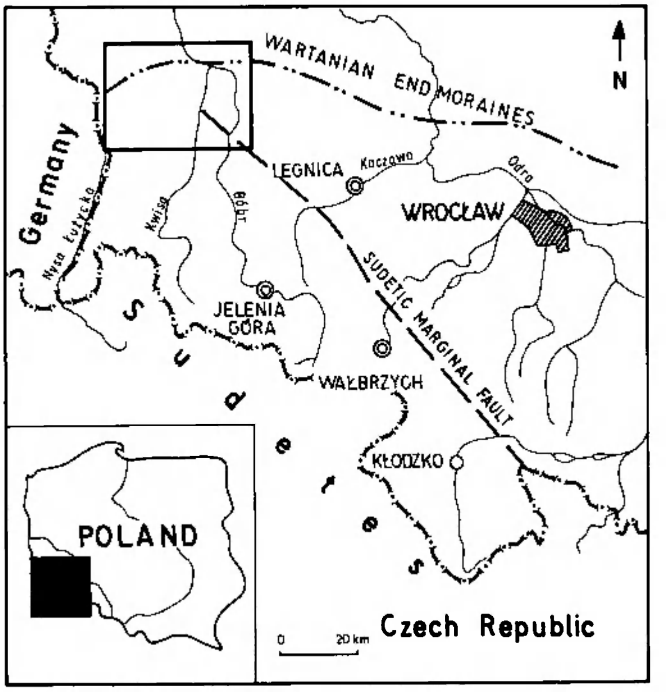

Fig. 1. Location of the study area in southwestern Poland.

THE SUB-QUATERNARY SURFACE

The sub-Quaternary surface has been described in detail only in the central part of the study area (Fig. 4) (Urbański, 1996a). It is created by the top of the Tertiary and Mesozoic deposits. This surface is generally inclined to the north, from 180–200 m a.s.l. in the southern zone to about 100 m a.s.l. near Świętoszów. This surface is incised, locally down to - 20 m, with a set of troughs with various orientations and depths (Fig. 4). The position and depth of troughs were determined based on borehole data, including two boreholes S-1 (Poświętne) and S-3 (Łąki) drilled specially for this project, and on geoelectrical investigations (Farbisz, 1993). The deepest trough, which is 150 m deep and is known as "the Czerna Wielka buried valley" (Milewicz, 1991; Kielczawa & Urbański, 1995), is located in the central part of the study area and trends roughly from the north to the south (Figs 4, 5). In this paper, this structure is named the 'Czerna Wielka Trough'. The other troughs are much shallower and have generally NE–SW and NW–SE orientations (Fig. 5). The trough bottoms are very irregular, with rapid depth changes and many isolated depressions. An especially large height difference of a trough base can be found in the southern part of the 'Czerna Wielka Trough', where it in places drops from 40 m to 170 m a.s.l. over a distance of only 2 km (Figs 4, 6).

PETROGRAPHY

The lithostratigraphic subdivision of the deposits in the study area was based on the gravel petrography of the 5–10 mm fraction (Kornaś *et al.*, 1993; Urbański. 1996a). Five petrographic groups were distinguished during the analysis: (1) quartz, (2) northern, Scandinavian and Baltic rocks, (3) rocks from the Polish Lowland, (4) rocks from the Sudetes Mts and (5) undetermined rocks of either Sudetic or Scandinavian derivation.

Quartz dominates in all the analysed samples. It comes from the redeposition of Pliocene and Miocene fluvial sediments which are commonly exposed in the study area. The undoubtedly northern material only includes: red granitoids, red porphyries, red Dalarne type quartzite and Palaeozoic limestones and dolomites. Local material, derived from the adjacent part of the Sudetes, is represented by greenschists, rhyolites, tuffites, melaphyries, sandstones, claystones and epimetamorphic schists. There are probably many other Sudetic pebbles in the studied samples, but they are not characteristic enough and can be mistaken for some Scandinavian crystalline rocks. This

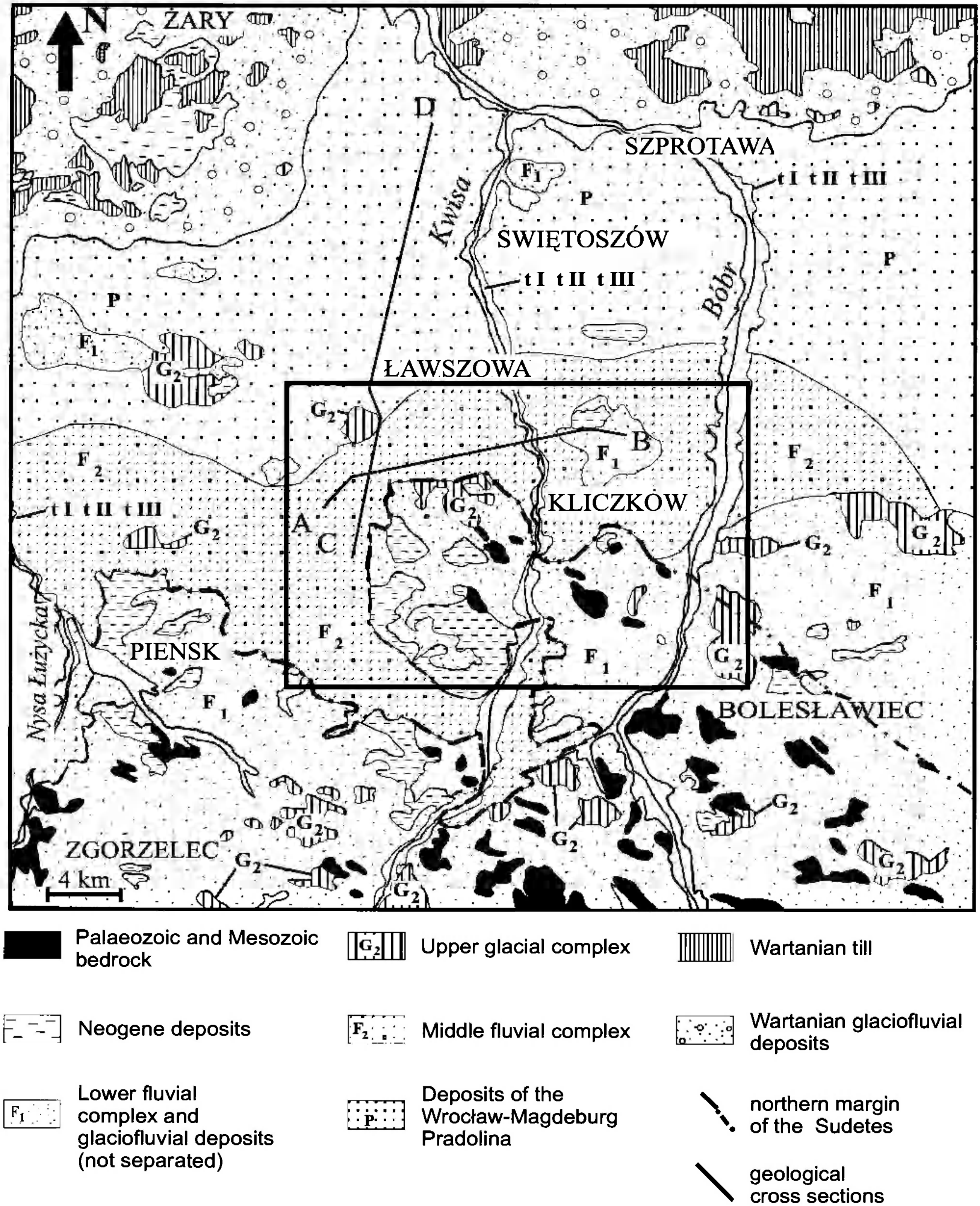

Fig. 2. Surface geology of the Sudetic Foreland between the Nysa Łużycka and Bóbr river valleys (after: Koźma & Przybylski, 1995; Urbański, 1996a; Jodłowski, 1998). The insert box shows the maps in Fig. 3 and 4.

group includes: feldspar, feldspar-quartz aggregate, grey granitoid, gneiss, amphibolite, grey porphyry, grey quartzite and siliceous rocks. Rocks from the Polish Lowland are represented by glauconite sandstone, mudstone, marl, white and porous Mesozoic limestone, flint and particles of lignite.

Petrographic analyses reveal that the if they only have one characteristic feature of the Quaternary sediments in

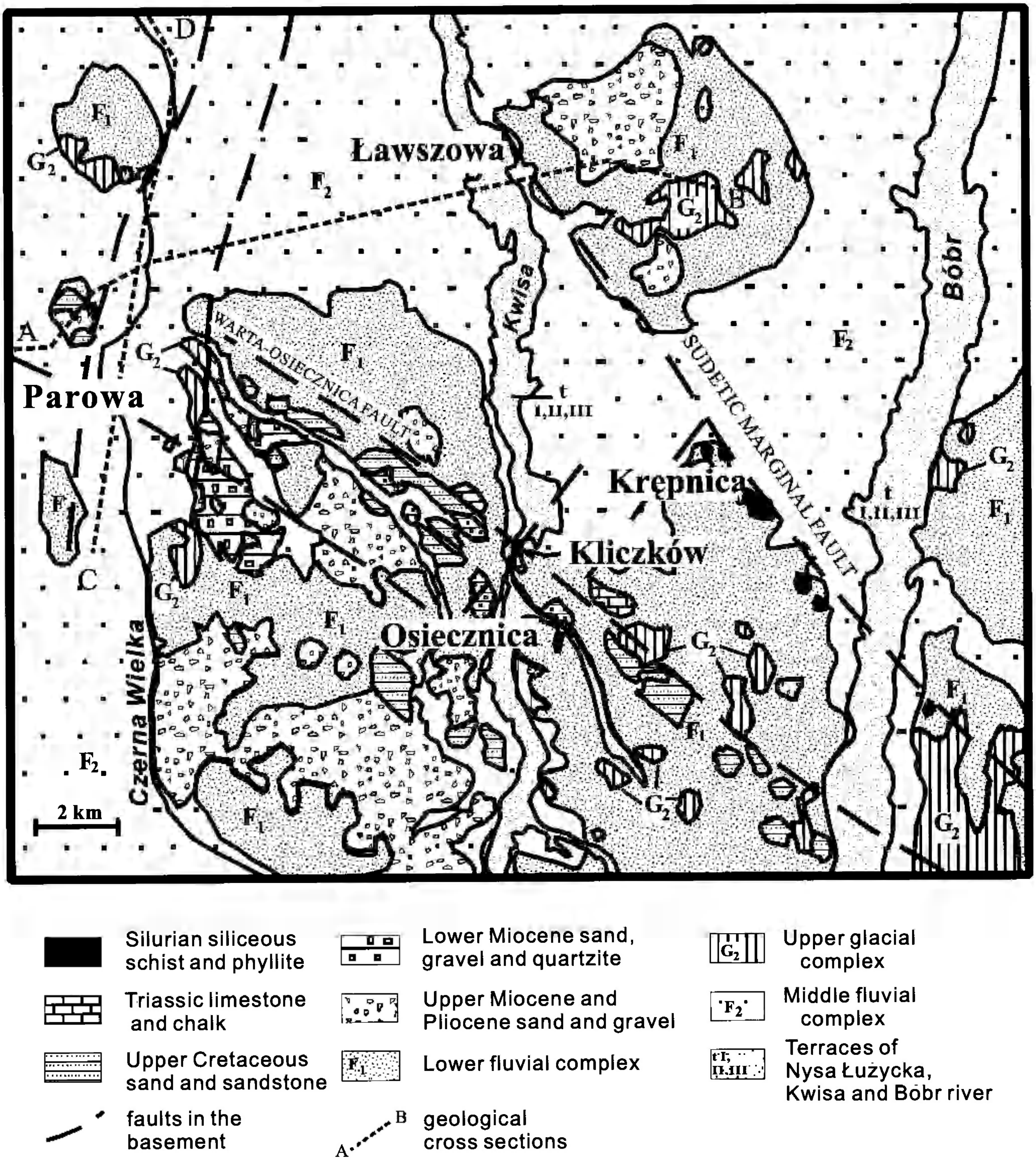

Fig. 3. Detailed geology of the Ławszowa - Osiecznica region.

the study area is the common occurrence of Sudetic material not only in fluvial suites deposited by rivers flowing from the south, but also in glacial deposits. This is due to the redeposition of the older fluvial material and mixing of local and northern components during the subsequent ice sheet advances, which entered the inner part of the Sudetes about 10–30 km southwards.

LITHOSTRATIGRAPHY

The thickness of the Quaternary deposits in the troughs is up to 150 m, while outside them is only up to 40 m (Fig. 5). The Quaternary deposits are assigned to informal lithostratigraphical units (Table 1, Fig. 9). Generally, the Quaternary sequence can be subdivided into two parts. The lower part contains mainly glacial and some fluvial deposits. The upper part consists of mainly fluvial and subordinately glaciofluvial deposits. The lower part

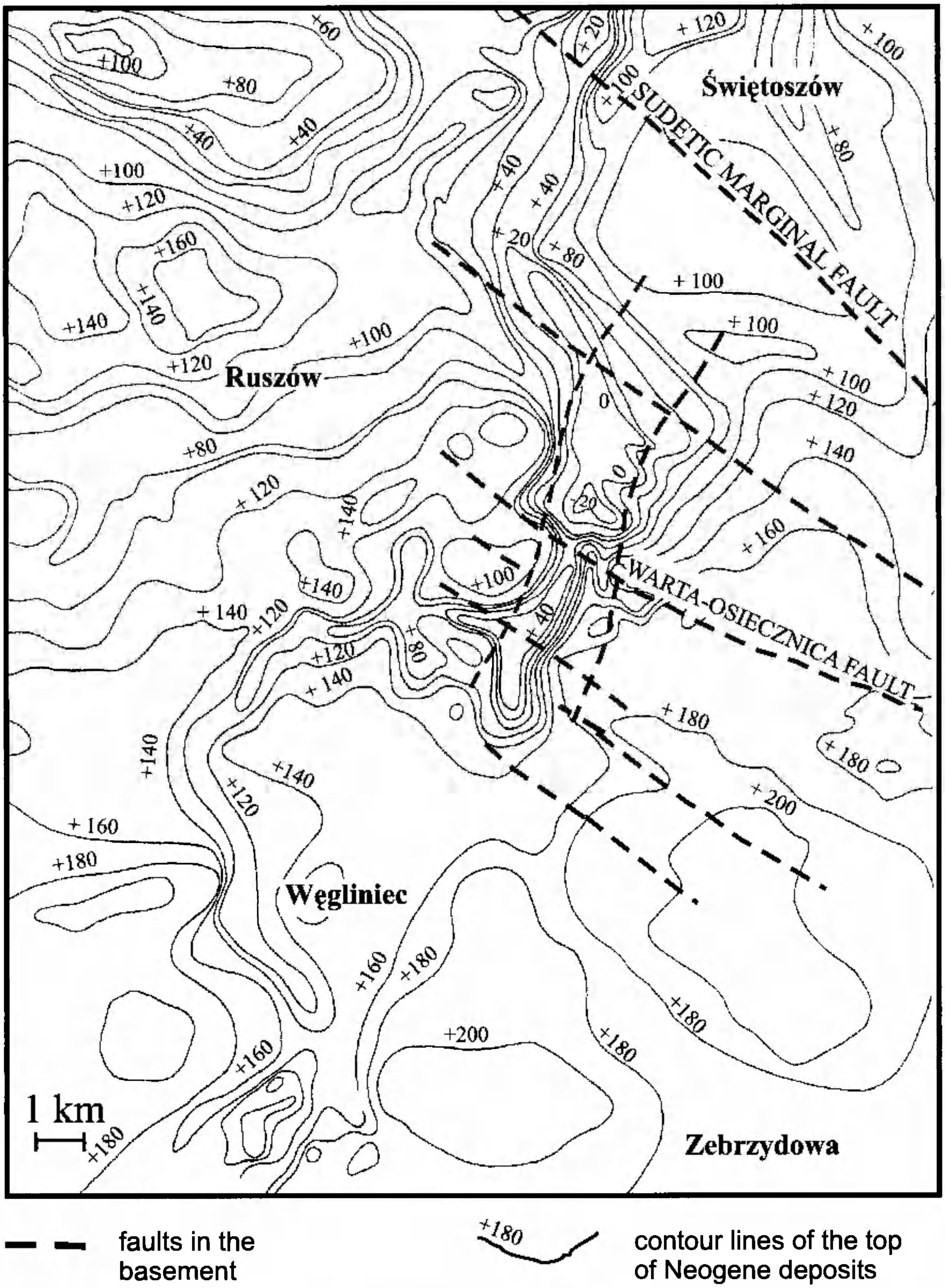

Fig. 4. The morphology of the top surface of the Neogene sediments in the central part of the study area between Węgliniec and Swiętoszów. Note a deep, N-S oriented trough, the 'Czerna Wielka Trough', in the central part of the presented area.

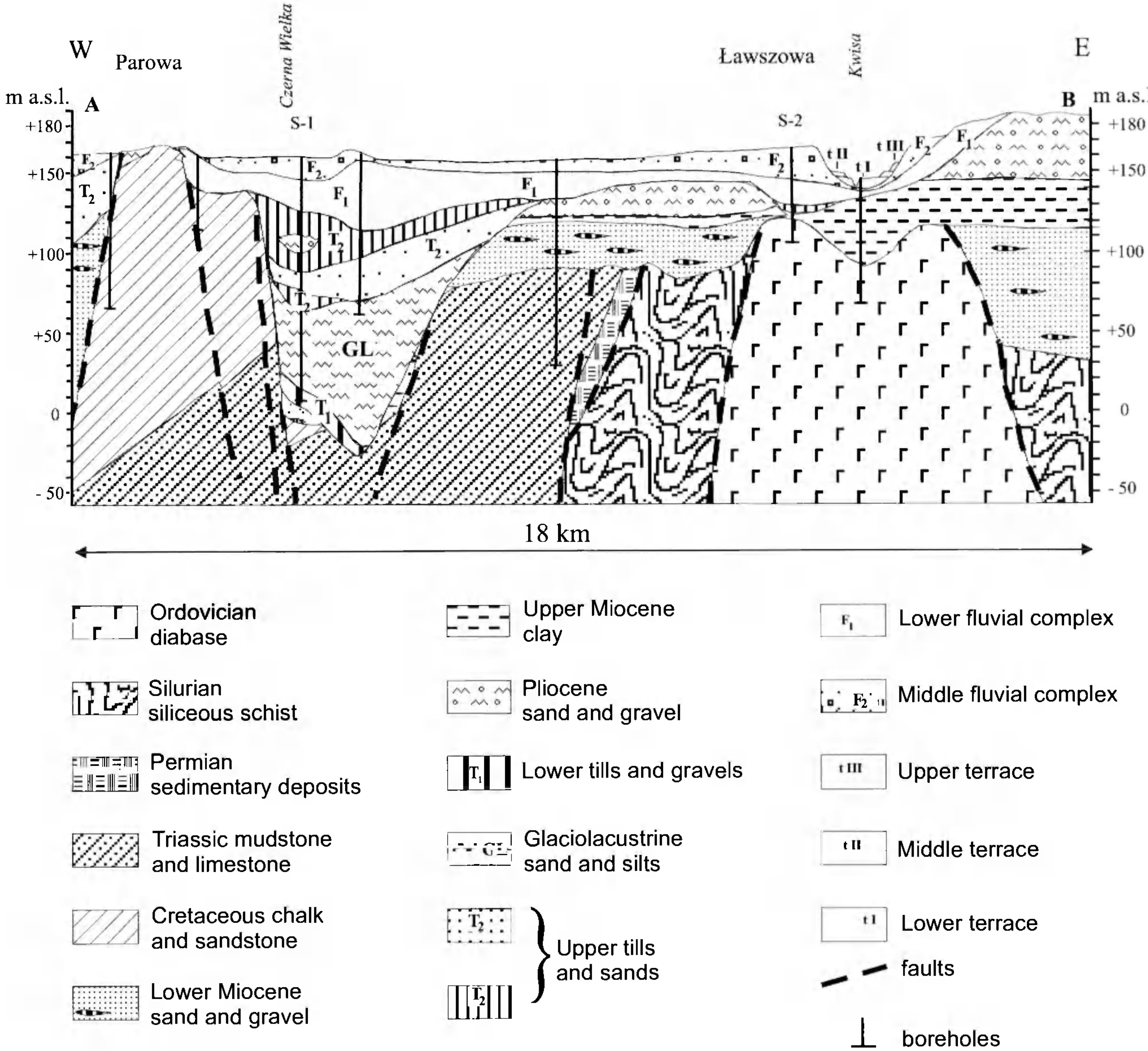

Fig. 5. Geological cross section through the 'Czerna Wielka Trough' near Ławszowa. Location in Fig. 2 and 3.

of the sequence can be subdivided into three lithostratigraphic units: the lower glacial complex, the lower fluvial complex and the upper glacial complex. The upper part of the Quaternary sequence consist of three units: the middle fluvial complex, the deposits of the Wroclaw–Magdeburg Pradolina and the Bóbr, Kwisa and Nysa Łużycka terraces. The lower glacial complex only occurs within the troughs, whereas the rocks of the lower fluvial complex, the upper glacial complex and the middle fluvial sediments are more extensive, also occurring beyond the troughs. The litostratigraphy of the Quaternary sediments is based on logs and petrographical data from boreholes S-1 and S-3, located in the 'Czerna Wielka Trough' (Figs 7, 8), with some additional data from beyond this trough for the middle glacial, upper glacial and the uppermost fluvial complexes.

THE LOWER GLACIAL COMPLEX

This complex consists of three units, namely the lower till and gravels, the glaciolacustrine sands and silts and the upper tills and sands (Table 1). The complete sequence only occurs in the borehole S-1 (Fig. 7), whereas borehole S-3 only contains the lower tills and gravels and the upper tills and sands (Fig. 8).

The till of the lower unit is grey and has a sandy matrix. It is up to 6 m thick in borehole S-3 (Fig. 8) overlying sills and sands of the Mużaków series, and its base has not been reached in borehole S-1 (Fig. 7). The lower till contains quartz (57%), red Scandinavian granitoids (2.5%), Baltic limestones (7%), lignite (up to 20%) and flint (2.5%). The gravel of the lower tills and gravels are represented by quartz (86%) red granitoids (3.9%) and local rocks (10.1%).

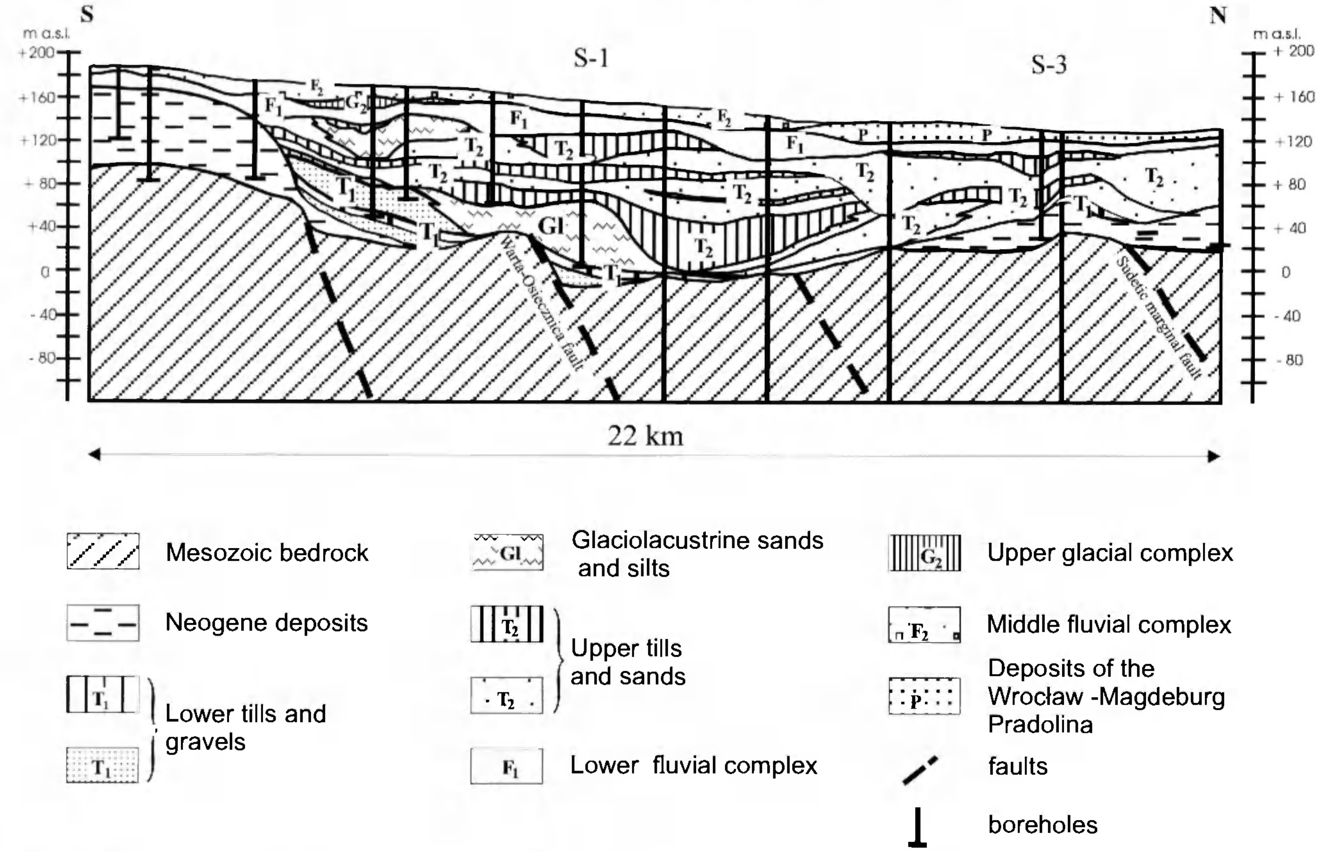

Fig. 6. Geological cross section along the 'Czerna Wielka Trough'. Location in Fig. 2 and 3.

The glaciolacustrine sand and silt unit is composed mainly of light grey massive to laminated silts interbedded with sandy silts and diamictons. The diamictons are from a few centimetres up to 15 cm thick. The glacilacustrine sands and silts are more than 57 m thick in borehole S-1, where they are situated over the lower tills and gravels and under the upper tills and sands. They are absent from borehole S-3 (7, 8).

The upper till and sand unit contains grey brown tills beds (5 in S-1, 7 in S-3), from 0.5 to 10 m thick, alternating with sandy-silty beds. The gravel components in the tills are much richer in northern material (up to 43%, with 2–17% of Baltic limestones) but poorer in lignite (1.5–14.0%) than the lower tills. Flint is about 0.5–3.5% and quartz contents ranges from 20% to 70%.

The sandy and gravelly beds are represented by coarse- and fine-grained poorly sorted sands and gravels with clasts up to 2.5 cm in diameter. They all are quartz-rich (70–80%) and contain red granitoids (at least 11%) and/or flint 2.5%. They represent glaciofluvial deposits.

In borehole S-1 there are deposits which contain no northern material. These are Pliocene deposits of the Gozdnica series. They are not *in situ*. Their occurrence between till beds suggests an ice-raft position and derivation from the bedrock..

The direct correlation of till horizons of the upper till and sand unit, between boreholes S-1 and S-3 as well as with other borehole logs is almost impossible. Each borehole contains a different number of till beds with variable thickness, occurring at various heights. A tentative correlation is shown in Figure 6. Milewicz (1991) suggested that these till beds represent a flow till facies redeposited from a trough (valley) margin. However, these tills could have been deposited subglacially in a tunnel valley, especially during the oscillatory movements of the ice sheet margin near its southernmost extent. Glacitectonic thrusting is also possible, which is partly confirmed by the presence of ice-rafted Pliocene sediments in borehole S-1.

The lower glacial complex is probably of Elsterian age. The lower till and gravel may represent the early Elsterian and the upper tills and sands the late Elsterian stadial.

THE LOWER FLUVIAL COMPLEX

The lower fluvial complex consists of yellow to grey coarse sand or pebbly sand with gravel clasts up to 3 cm in diameter. The pebbly sand is usually massive, whereas the sandy beds are cross or horizontally bedded. The lower fluvial complex has been documented in boreholes S-1 and S-3, where it lies above the lower glacial complex (Fig. 7, 8), and it is also known from extensive surface exposures (Figs 2, 3, 6). They have also been found in several outcrops on the tops of isolated hills in the northern region (Fig. 2). Beyond the troughs, the lower fluvial complex

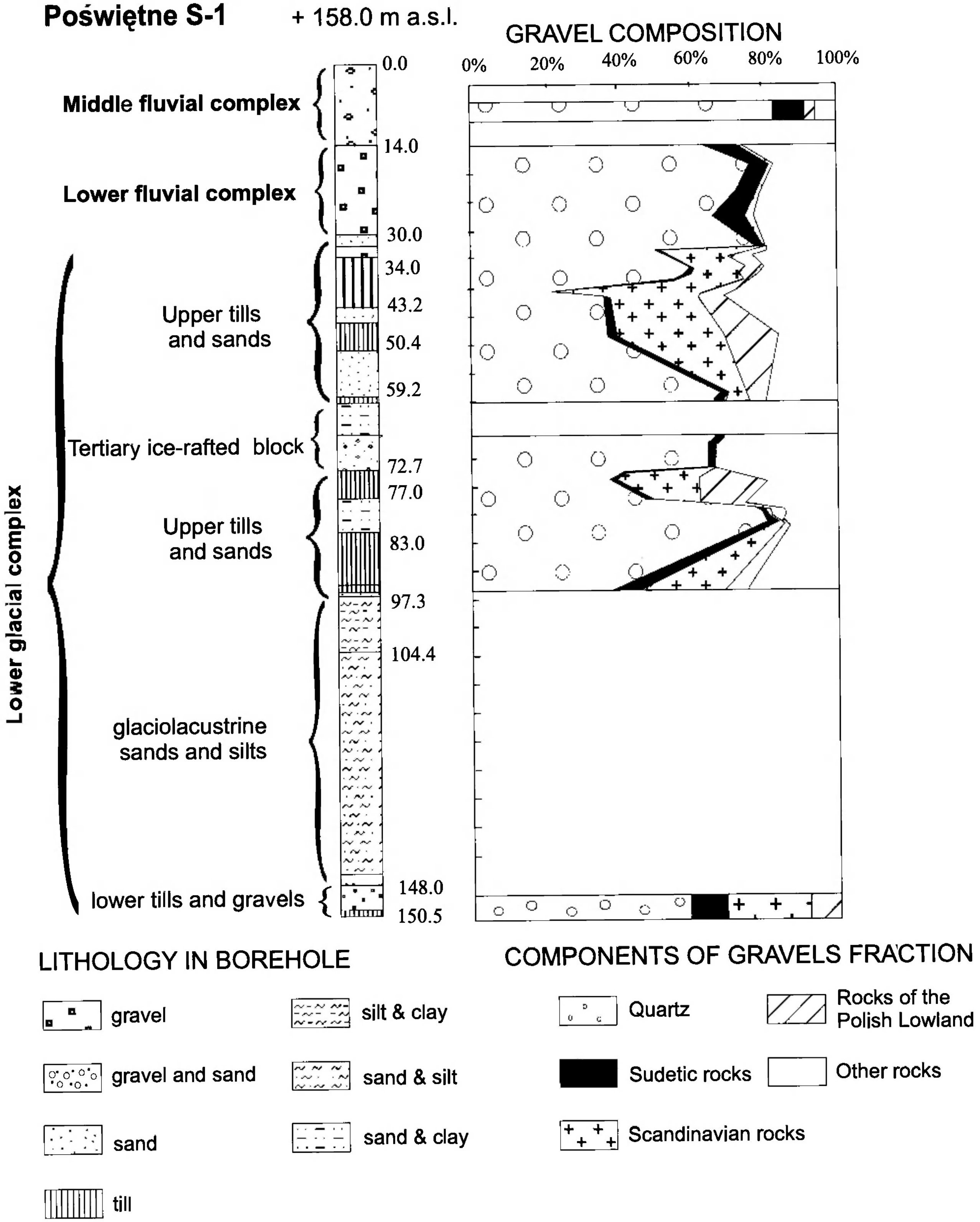

Fig. 7. Sediment succession, stratigraphy and gravel petrography in borehole (S-1) Poświętne of the 'Czerna Woda Trough' near Ławszowa.

sediments overlie the Pliocene Gozdnica Series, Poznań Series and exceptionally the lower glacial complex (Table 1). It occurs at the surface or below the till of the upper glacial complex in the southernregion, and is usually overlain by the middle fluvial complex in the northern part of study area. The thickness of the middle fluvial complex varies from 4 to 16 m.

The gravels of the middle complex are represented by quartz (65–77%) with a subordinate content of Sudetic rocks (up to 21%) and a very low content of Scandinavian

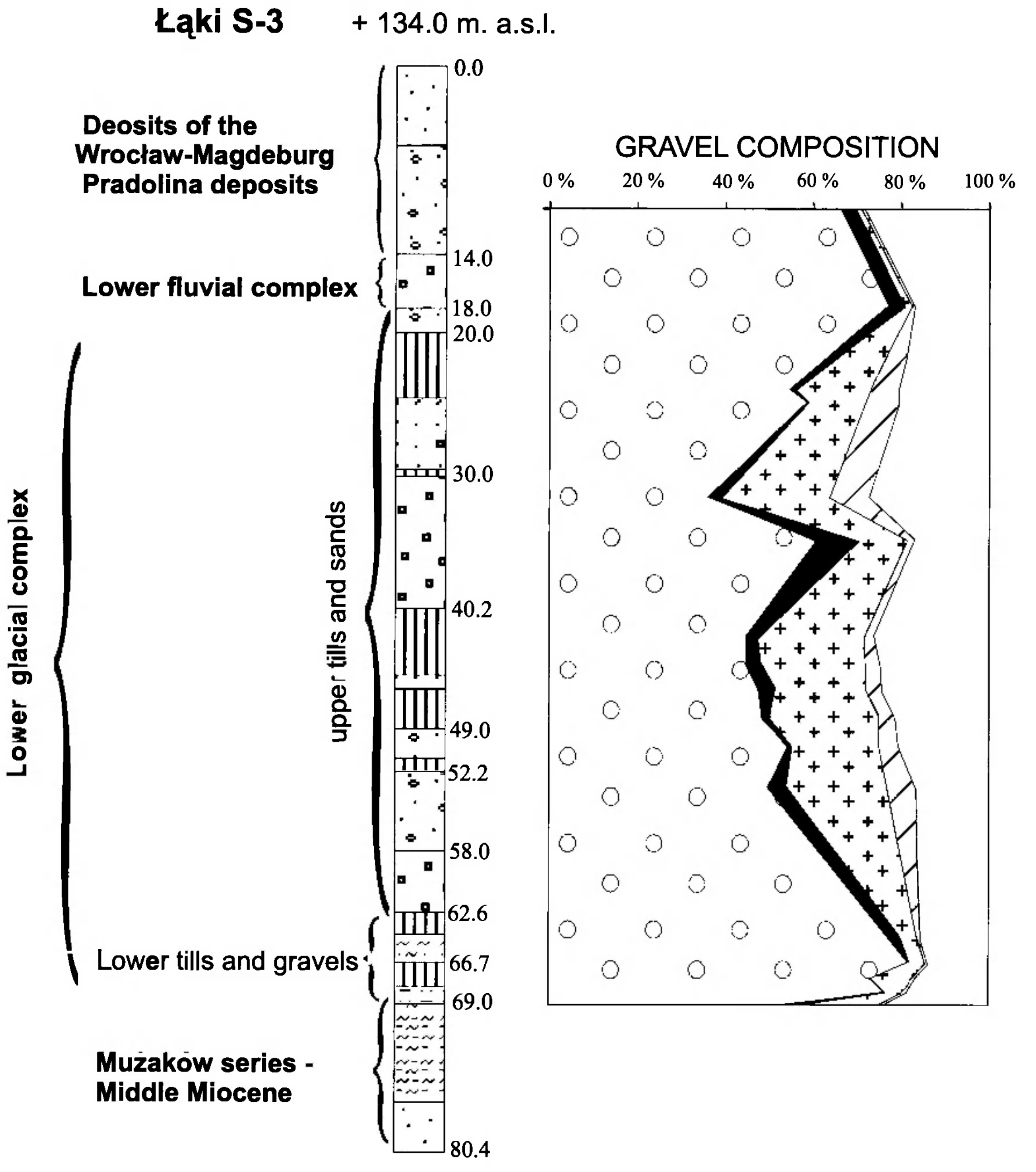

Fig. 8. Sediment succession, stratigraphy and gravel petrography in borehole Łąki (S-3) of the 'Czerna Wielka Trough' near Swiętoszów. Explanations are in Fig. 7.

rocks (1%), (single fragments of red granitoids, Dalarne quartzite and red porphyries) and Mesosoic rocks from the Polish Lowland (0.5%). It seems that most of the "other rocks" here also represent Sudetic material (Figs 7, 8). There are no limestone clasts in the lower fluvial complex.

The sediment lithology suggests that the middle fluvial complex was deposited by high energy rivers. The gravel petrography suggests that the deposits were sourced from the south, by Sudetic rivers, although with some redeposition of older glacial sediments. The crucial fact backing this interpretation is the complete lack of limestone, which should survive in glaciofluvial suites, but is usually leached in non-glacial environments. The sediments of the middle complex were probably deposited on an alluvial fan formed by Sudetic rivers at the margin of the mountain zone (Fig. 2).

The deposits of the lower fluvial complex are very common in the study area (Fig. 2) and form a good marker horizon, which can be used regionally. It separates the lower and upper glacial complexes. The inter-till position of the lower fluvial complex suggests an interglacial age. However, there are no organic deposits with interglacial pollen contents to confirm this suggestion. It seems that the lower fluvial complex could have been deposited between the late Holsteinian or early Saalian, and the first Saalian ice advance. A similar interpretation of the thick fluvial deposits which occur between Elsterian and Saalian

Table 1

Quaternary stratigraphy in the Parowa region

CHRONOSTRATIGRAPHY		LITHOSTRATIGRAPHY	
Holocene		**Terraces of Nysa Łużycka, Kwisa, and Bóbr valley**	- lower and middle terrace - middle terrace
Weichselian			- upper terrace
Eemian			
Saalian	Wartanian	**Middle fluvial complex**	**Deposits of the Pradolina Wrocław-Magdeburg**
	Odranian	**Upper glacial complex**	
		Lower fluvial complex	
Holstenian			
Elsterian		**Lower glacial complex**	- upper tills and sands - glaciolacustrine sands and silts - lower tills and gravels

tills was proposed in SE Germany. These deposits were named the Main Terrace (Hauptterrasse) in the vincinity of Leipzig (Eissmann, 1994), the 'Tannitzer Fluviatil' complex in Lausitz (Lippstreu, 1994; Schulz, 1962), or the 'Holstein-Komplex' in Brandenburg (Stendig, 1962; Cepek, 1965).

THE UPPER GLACIAL COMPLEX

The sediments of the upper glacial complex are not present in the boreholes S-1 and S-2, although they occur in patches throughout the study area (Figs 2, 6). This complex consists of only one till bed which overlies the fluvial sediments of the lower complex and usually occurs at the surface (southern region) or below the middle fluvial complex (northern region) (Table 1). The till is brown to greyish brown, very sandy, and has a thickness of up to 2 m. This till is usually strongly weathered and thus there is petrographic data available.

The upper glacial complex was probably deposited during the early Saalian (Odranian stage) glaciation, which was the last glaciation during which the ice sheet reached at least the edge of the Sudetes Mts.

THE MIDDLE FLUVIAL COMPLEX AND DEPOSITS OF THE WROCLAW - MAGDEBURG PRADOLINA

The alluvial fans of the middle fluvial complex are composed of cross- to horizontally bedded coarse-grained sand and gravel with clast up to 2 cm in diameter. The deposits of the Wrocław–Magdeburg Pradolina are composed of fine- to medium-grained sands with only rare gravel and silt beds. The gravel petrography shows that the gravels of these complexes are quartz-rich (85%), with subordinate Sudetic rocks (6%) and rare (deposits of the Wrocław–Magdeburg Pradolina) or no northern rocks (middle fluvial complex). These complexes overlie the upper glacial complex or lower fluvial complex and usually occur at the surface (Table 1; Figs 2, 5–8).

The middle fluvial complex occupies an extensive area (Fig. 2). The alluvial surface lies at 175 m a.s.l. near the margin of the Sudetes Mts (wide valleys) and is gently inclined to the north. The inclined alluvial surfaces represent the alluvial fans formed by the Sudetic rivers at the mountain margin (Koźma & Przybylski, 1995; Urbański, 1996a). The flat, alluvial surface, which lies in the north at 130 m a.s.l., represents the Pradolina ice marginal system (deposits of the Wrocław–Magdeburg Pradolina) (Grocholski & Milewicz, 1958; Berezowska & Berezowski, 1979, 1982; Berezowski, 1977; Buksiński, 1975; Milewicz, 1976). The deposits of the Wroclaw–Magdeburg Pradolina are interdigitated with outwash sediments deposited directly at the front of the Wartanian ice sheet (sandurs) (Fig. 2) (Brodzikowski 1975).

The middle fluvial complex and deposits of the Wrocław–Magdeburg Pradolina form a single stratigraphic horizon connected with fluvial activity at the front of the Wartanian ice sheet (Keilhack, 1920; Berg, 1936; Genieser, 1936; Schwarzbach, 1942; Grocholski & Milewicz, 1958; Buksiński, 1975; Milewicz, 1976). During the period of maximum extent of the Wartanian ice sheet, Sudetic rivers accumulated alluvial fans in the Wrocław–Magdeburg Pradolina and to the south of the ice margin sandurs were created. A similar interpretation of these complexes was presented for SE Germany (Stendig, 1962; Cepek, 1965).

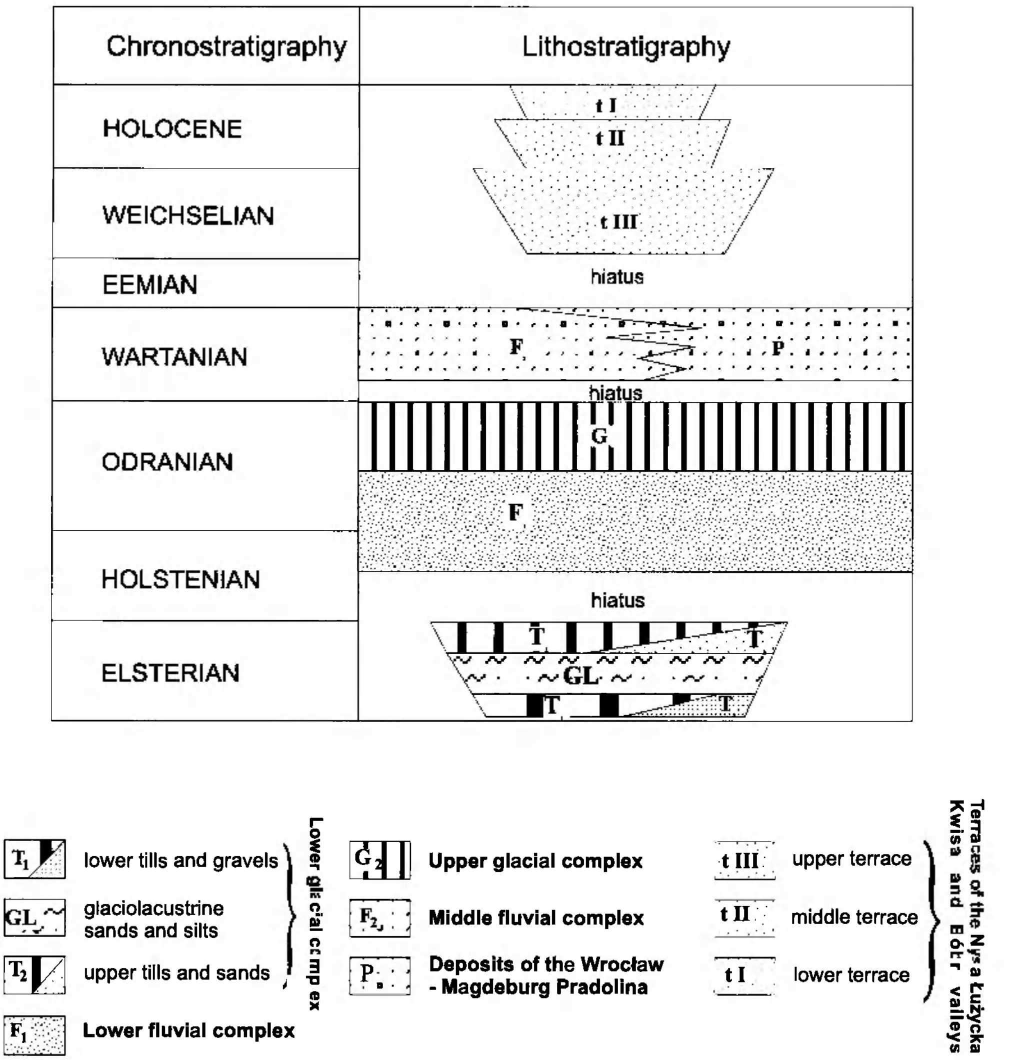

Fig. 9. Stratigraphy of the Quaternary deposits in the western Sudetic Foreland.

THE BÓBR, KWISA AND NYSA ŁUŻYCKA RIVER TERRACES

The middle fluvial complex and Wrocław–Magdeburg Pradolina deposits are strongly incised, with a set of younger terraces (Table 1, Fig. 9). The highest of them, the Upper Terrace, is from 5.0–7.0 m high (Bóbr valley) to 12–13.5 m high (Nysa Łużycka and Kwisa valleys). This terrace is composed of sands and gravels which are poorly preserved as small benches on the valley sides. It is usually interpreted as the Weichselian alluvial surface. The Middle Terrace deposits are more extensive and occur at heights of 5.5–7.5 m and 7.5–11.0 m in the Kwisa river valley, 4.0–8.0 in the Nysa Łużycka valley and 3.0 m in the Bóbr river valley.

The lower terrace is 0.5–4.0 m high. This terrace is composed of coarse-grained sands with gravel lenses. These deposits are covered by alluvial mud. The Middle Terrace and Lower Terrace are represent the Holocene (Grocholski & Milewicz, 1958a; Koźma & Przybylski, 1995; Urbański, 1996a; Jodłowski, in press).

ORIGIN OF DEEP TROUGHS

The deep troughs, and especially the "Czerna Wielka Trough", were interpreted as buried fluvial valleys (Milewicz, 1991). The occurrence of till/diamicton beds in such valleys was explained as redeposition from the valley sides. This interpretation may be challenged. Similar troughs in SE Germany are interpreted as glacial tunnel valleys (Alexovsky, 1996; Kupetz *et al.*, 1989). These thick glacial deposits filling the studied troughs are also interpreted as sequences deposited at the time of tunnel valley formation; in the case of SE Germany during the Elsterian glaciation. These deposits are highly variable, both vertically and laterally, and are represented by tills, glaciofluvial sands and gravels and glaciolacustrine laminated sediments. Other features that confirm a glacial origin of the troughs are: (1) their deep incision, locally below sea level, which is much deeper than any river valley base level in the region; (2) their irregular bottoms with many isolated depressions and heights, which cannot be explained by fluvial erosion; (3) their relatively low width (up to 1 km) in comparison to their depth (up to 150 m); (4) the occurrence of Neogene rafts within glacial sequences, which suggests glaciotectonics and/or glacial transport.

The troughs could have originated along fault zones, as their NE–SW and NW–SE orientations well coincide with the deep fault pattern in the region. Such a location can be assumed at least for the 'Czerna Wielka Trough' (Figs 3, 5). Similar trough orientations were described in SE Germany by Eissmann *et al.* (1995). However, ice rafting and possible sediment deformation in the 'Czerna Wielka Trough' are entirely of glacial origin. Glaciotectonic thrusting could have occurred at the margin of the Sudetes (scarp) (Fig. 6).

QUATERNARY MORPHOLOGY AND NEOTECTONIC ACTIVITY

The study area contains numerous tectonic blocks and fault zones. The main tectonic activity was during the Laramian Phase (Grocholski & Milewicz, 1958b; Milewicz, 1980), although its pronounced presence in recent morphology may also suggest some minor activity during the Neogene or Pleistocene. Several authors recently documented quite young, Middle to Late Pleistocene, tectonic activity in the Sudetes (Krzyszkowski, 1990; Krzyszkowski *et al.*, 1995, 1998; Dyjor, 1993b; Cacoń & Dyjor, 1995; Michniewicz *et al.*, 1996) and north of the Sudetes (Brause *et al.*, 1964; Dyjor, 1993a). The fresh structural morphology, possibly of tectonic origin, has been de-

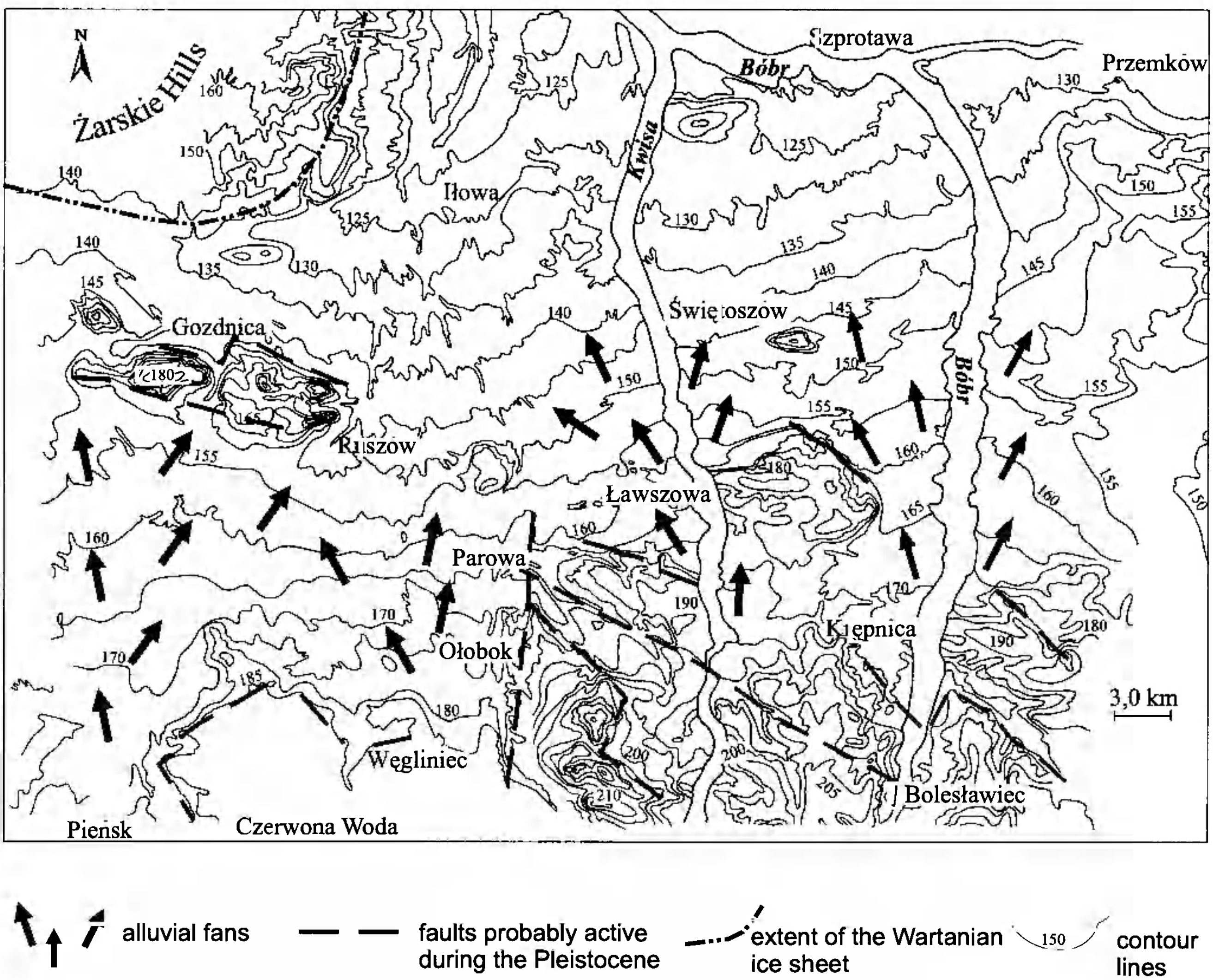

Fig. 10. The dense contour map of the area between the Nysa Łużycka and Bóbr river valleys and faults probably active during the Pleistocene.

scribed in many regions of the Sudetes and their foreland using dense contour maps (Badura & Przybylski, 1995; Badura, 1996; Migoń, 1996). This method was also used for the study area (Urbański, 1996b; Fig. 10).

The dense contour map reveals the presence of several distinct straight scarps which correlate with some fault lines. These are especially scarps along the Sudetic Marginal Fault (its southernmost fragment), the Warta-Osiecznica Fault and the Ołobok-Parowa Fault (Fig. 10). The latter fault zone coincides subsurface with the 'Czerna Wielka Trough'. Moreover, some hills which overlie the basement horsts (Koźma & Przybylski, 1995), such as the hill near Gozdnica, indicate very distinct marginal scarps (Fig. 10).

From the above it follows that some fault lines could also have been active during the Pleistocene or even until the Recent, but this activity was rather of low order. It seems that the occurrence of hills with distinct scarps played much greater role during the glaciations, when they formed passive obstacles against the advancing ice sheets. In several zones, such as on the northern slopes of Gozdnica hill there are strongly glaciotectonically deformed sequences, which could have been extensively formed due to these scarps (Koźma & Przybylski, 1995). These deformations are not continous and they are formed as overthrusted slices.

CONCLUSIONS

1. In this paper a new lithostratigraphical subdivision of Quaternary deposits for the western Sudetic Foreland is proposed. The Pleistocene deposits were divided into six units: the lower glacial complex, the lower fluvial complex, the upper glacial complex, the middle fluvial complex, The Wroclaw–Magdeburg Pradolina deposits and the Nysa Łużycka, Kwisa and Bóbr valley terraces.

2. The Elsterian glacial deposits in the western Sudetic Foreland are only preserved in deep troughs; they are represented by two glacial horizons separated by glaciolacustrine and/or glaciofluvial deposits. These glacial sediments are 60 to 100 m thick.

3. Deep troughs, formerly interpreted as buried fluvial valleys, are of glacial origin (tunnel valleys). These troughs often coincide with fault lines in the basement.

4. The glacial sediments of the early Saalian (Odranian) glaciation are very thin, being represented only by a single till bed which occurs throughout the area although only in patches.

5. The glacial sediments are very rich in milk quartz (20–70%), which probably comes from the redeposition of the Upper Miocene–Pliocene Gozdnica Series. Other than quartz they contain up to 45% northern rocks, including Baltic limestones, and numerous local (Sudetic) rocks.

6. The thick and extensive fluvial deposits between the Elsterian and early Saalian tills, are correlated with the Holsteinian to early Saalian Main Terrace fluvial horizon in Germany. These deposits practically only contain only local material from the Sudetes Mts, with the admixture of northern rocks below 2% and no limestones at all.

7. The late Saalian (Wartanian) sediments are represented by local alluvial fans deposited by the Sudetic rivers, the E–W trending Wrocław–Magdeburg Pradolina valley and the outwash plains formed at the front of the Wartanian ice sheet, all of which form one extensive fluvial system. The local alluvial fans only contain Sudetic material whereas the Pradolina sediments also contain rare northern rocks.

8. The youngest sediments are represented by one Weichselian (Upper Terrace) and two Holocene (Middle and Lower Terraces) fluvial terraces.

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