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The preglacial Nysa Klodzka fluvial system in the Sudetic Foreland, southwestern Poland

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Abstract The preglacial series deposited by the Nysa Kłodzka river has a much wider extent in the Sudetic Foreland than hitherto supposed. It can be found in a 5–10 km wide belt near margin of the Sudetes Mts and an over 60 km wide belt in the Sudetic Foreland and the adjacent part of the Silesian Lowland. This series is porphyry-bearing and it is made up of four lithostratigraphic units that differ in their heavy mineral contents. The porphyry-free sediments deposited by other river systems of the Sudetic Foreland occur at the margins of the porphyry-bearing series or partially overlie it. Units I–III were deposited mainly by sinuous, suspended-load, low energy rivers and only locally by gravel-load, high energy rivers. The preglacial sediments of units I–III consist of strongly re-worked, quartz-rich material and some kaoline matrix, that most probably come from Tertiary weathering mantles of the Sudetes Mts. These fluvial sequences were deposited by rivers with widely migrating valleys and they probably reflect weak tectonic activity in the region. Unit IV was deposited by bed-load, high energy rivers which were formed during general landscape reorganisation caused by strong tectonic activity. The new valleys were incised, and as a result, local, kaolin-free material became dominant in the sequence. The vertical amplitude of tectonic movements in the Sudetic Foreland at that time was about 40–80 m, with simultaneous uplift of the Sudetes Mts of about 60–70 m. Units I–III are most probably of Late Pliocene age, whereas unit IV could have been deposited from the Early Pleistocene to the Cromerian Stage.

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INTRODUCTION

Lewiński (1928, 1929) defined a series of fluvial deposits in central Poland, mainly sand and gravel, that did not contain any Scandinavian material and lie below the glacial suites and above the Poznań Series (Clay) or its equivalents. This fluvial series was named the 'preglacial series' and it was originally suspected to be of Early Pleistocene age. The series could have been deposited on the local alluvial fans that successively filled the Poznań Clay Basin (Jahn & Turnau-Morawska, 1952; Rühle, 1955, 1973; Różycki, 1961, 1967, 1972; Baraniecka, 1975). Kosmowska-Ceranowicz (1979) suggested a Pliocene age for the preglacial series and a long-distance fluvial transport from central Belarus to at least central Poland. Mojski (1982, 1985) subdivided the preglacial series into two units, the Kozienice Formation and the Krasnystaw Formation. The Kozienice Formation lies on uplands and represents roughly the same series as that described by Kosmowska-Ceranowicz (1989). The Krasnystaw Formation fills buried valleys and was suspected to be Early Pleistocene in age. However, recent investigations, have indicated that the preglacial series of central Poland that is an equivalent to the Kozienice Formation, was deposited at least from the late Early Pliocene to the late Early Pleistocene, forming a sedimentologically uniform sequence with no distinct gap at the Pliocene/Pleistocene boundary (Stuchlik, 1987; Baraniecka, 1991; Krzyszkowski & Szuchnik, 1995; Winter, 1997).

In the Sudetic Foreland, SW Poland, gravelly fluvial sediments that did not contain Scandinavian material, namely the 'white gravels', were described for the first time at Ziębice (Münsterberg) (Jentzsch & Berg, 1913; Frech, 1915; Zeuner, 1928) (Fig. 1). These gravels lie on the top of a clayey series that contains brown coal beds and below a Quaternary series. The latter consists of local gravel series ('brown gravels'), till and loess. The coal bed

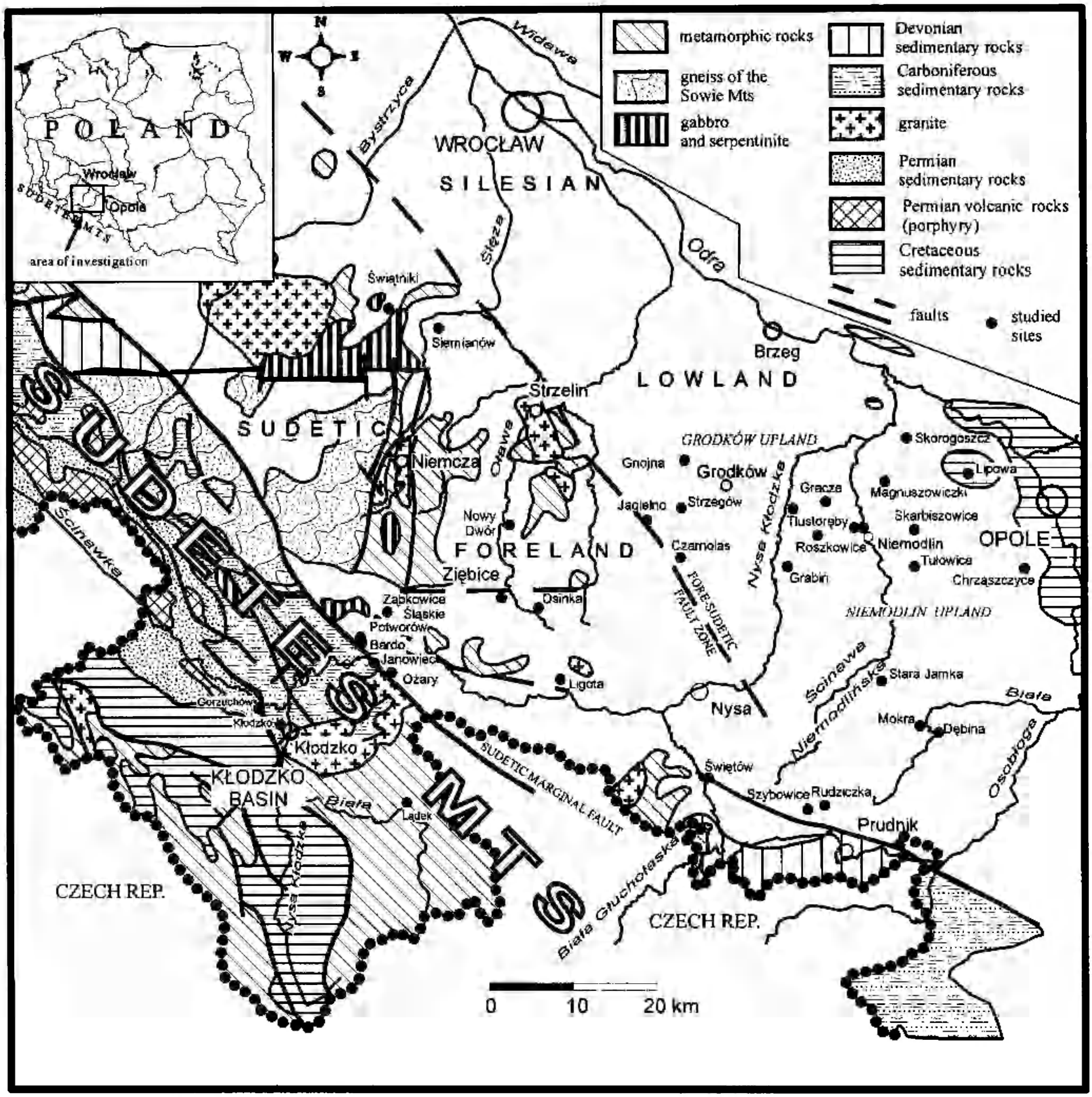

Fig. 1. Location of the studied sites and geology of the Middle Sudetes Mts and the Sudetic Foreland. Note that Permian rocks, including the porphyry, are provided to the Nysa Kłodzka river system by its mountainous tributary – the Ścinawka river.

contains floral macroremains of Late Miocene to Pliocene age, and hence the clayey series was suspected to represent the equivalent of the Poznań Series (Clay) in central Poland (Jentzsch & Berg, 1913; Friedensburg, 1914; Frech, 1915; Kräusel, 1919; Behr, 1924). The age of the white gravels was suspected to be Pliocene (Zeuner, 1928; Behr *et al.*, 1931; Behr & Mühlen, 1933). Dyjor (1966, 1987a, 1987b) found that the Pliocene fluvial deposits occur commonly all over the northern foreland of the Sudetes Mts and they consists of quartz-rich gravel or sand and gravel with a kaoline matrix. He named these sediments the Gozdnica Series, after the Gozdnica site in the western part of the Sudetic Foreland. Dyjor (1987a, 1987b) attributed the 'preglacial', *i.e.* the Early Pleistocene deposits, to deep troughs, interpreted by him as buried valleys, and correlated them with the Krasnystaw Formation in central and eastern Poland. The age of the Gozdnica Series at Gozdnica has recently been established as Late Miocene (Dyjor *et al.*, 1992), which makes it older than the top strata of the Poznań Series in the same region. The latter were dated to the Late Miocene/Early Pliocene transition or even the Early Pliocene (Stachurska *et al.*, 1971, 1973; Sadowska, 1985, 1995; Badura *et al.*, 1998a). Dyjor *et al.* (1992) explains this fact as a result of the non-synchronous initiation of the filling of the Poznań Series Basin by the alluvial fans of Sudetic rivers. However, the Gozdnica Series at

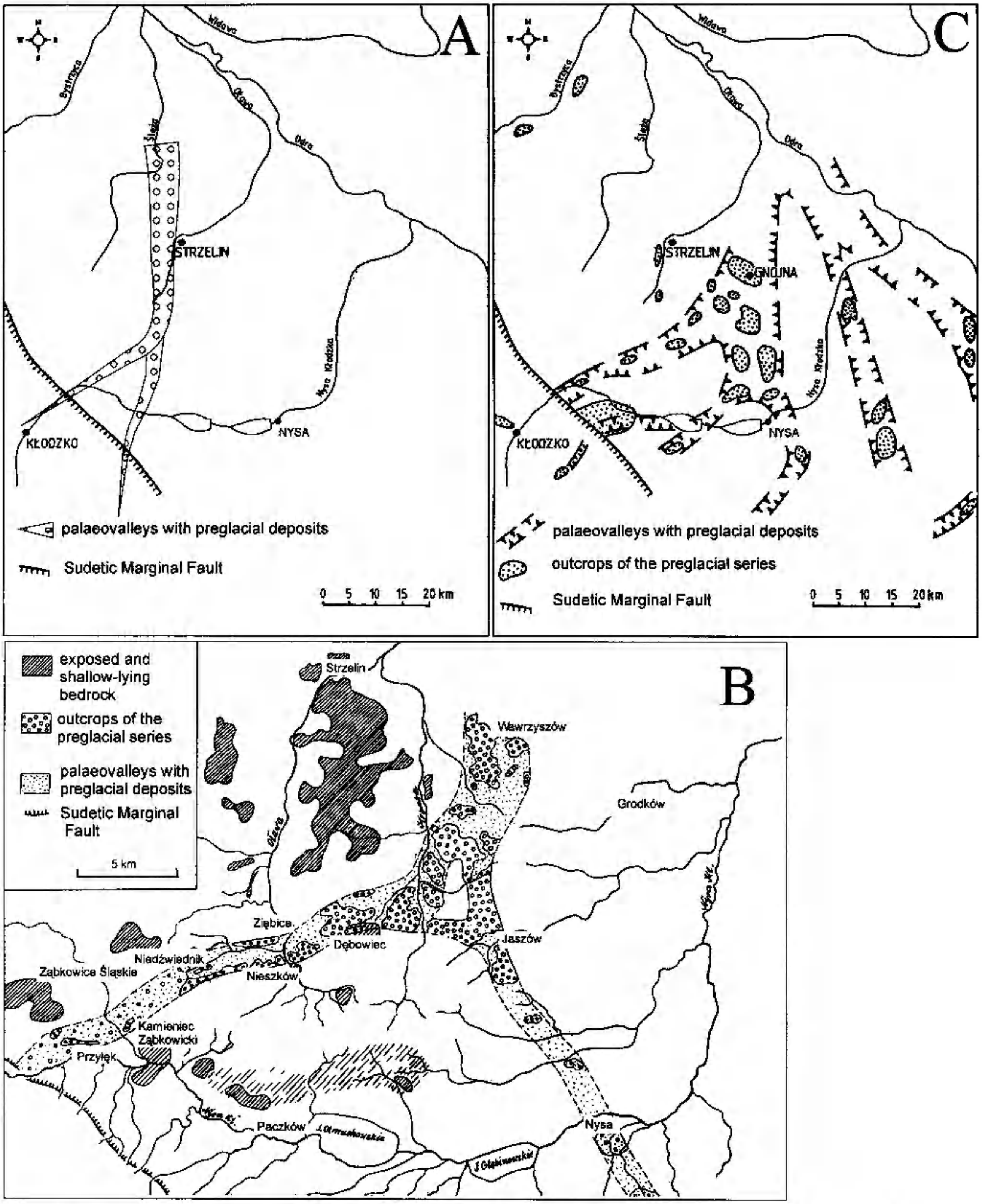

Fig. 2. Preglacial palaeovalleys of the Nysa Kłodzka river in the Sudetic Foreland: after Behr *et al.* (1931) and Walczak (1954) (A); after Wroński (1974) (B); and after Dyjor (1985) (C).

Gozdnica differs considerably from other kaolin-bearing gravel series in the Sudetic foreland. First of all, it consists of massive, fine, angular clasts with high kaoline matrix content. Moreover, the Gozdnica Series at Gozdnica contains practically only quartz grains. In contrast, other gravel series that are also named the Gozdnica Series by Dyjor (1966, 1987a, 1987b), are usually formed of well stratified deposits that consists of well-rounded to subrounded gravels of varying grain-size from cobble to granule, and that have variable, usually medium to low, kaolin content. This series, although quartz-dominated, has more variable gravel assemblages, where quartz content varies from 50% to 90%. The latter sediments are undoubtedly of fluvial origin (Krzyszkowski, 1993; Wojewoda *et al.*, 1995; August *et al.*, 1995; Przybylski, 1997). Therefore, it seems that the Gozdnica Series at Gozdnica is not the same as other quartz-rich gravel series of the Sudetic Foreland, and this fact fits well with its much older age. Consequently, the name Gozdnica Series, which might be confusing is not used in this paper. The classic, informal name, the preglacial series (Lewiński, 1928), is used instead, and the Ziębice site is accepted as the holostratotype in the Sudetic Foreland (Zeuner, 1928).

This paper aims to present the sedimentological description, petrological properties and stratigraphy of a part of the preglacial series which was deposited by the Nysa Kłodzka river system. This series has been found throughout a large area in the southern part of the Sudetic Foreland and the adjacent Silesian Lowland (Fig. 1). The Nysa Kłodzka river deposits were easily recognizable among other preglacial sediments due to their 'porphyry' content, which significant because, besides the Bystrzyca river, the Nysa Kłodzka river is the only fluvial system with its source area in the Permian volcanic and sedimentary rocks of the Sudetes interior (Fig. 1). The Nysa Kłodzka preglacial fluvial system in the Sudetes Mts has been unambiguously documented (Jahn *et al.*, 1984; Krzyszkowski *et al.*, 1998), whereas its foreland part has been variously interpreted. Behr & Mühlen (1933) and Walczak (1954) found porphyry-bearing preglacial deposits north of Ziębice and they traced the palaeovalley to the north and northwest, along the Olawa and Ślęza river valleys (Fig. 2A). A palaeotributary river, the Biala Lądecka, was traced between Lądek and Ziębice (Behr *et al.*, 1931; Walczak, 1954). Wroński (1974) found numerous sites with porphyry-bearing preglacial deposits northeast of Ziębice and he interpreted the ancient Nysa Kłodzka river valley along the recent Krynka river valley (Fig. 2B). He also described another preglacial series in the region that did not contain porphyry and possibly represents the ancient Biala Glucholaska river valley. Dyjor (1985, 1987a, 1987b) presented a very similar preglacial fluvial pattern to Wroński (1974), adding some deposits occurring north of Ziębice as representative of another, local fluvial system, ignoring their porphyry content (Fig. 2C). Our recent investigations (Przybylski, 1997; Badura *et al.*, 1998a) suggest that the distribution of the Nysa Kłodzka river material is much wider and the stratigraphy of the preglacial series is more complex than previously thought.

MATERIALS AND METHODS

Altogether 35 sites with preglacial deposits were examined in the Sudetic Foreland, including the holostratotype Ziębice site. This includes 9 boreholes, 7 small, 1–2 m high outcrops with unknown stratigraphic context, and 19 large sections with an unambiguous stratigraphic record and/or with at least a few metre high section wall. Another three large sections with preglacial deposits are known in the adjacent region in the mountain interior (Krzyszkowski *et al.*, 1998) (Fig. 1). The boreholes and small outcrops were lithologically described and sampled for petrological investigations. Large sections were examined in more detail, which besides the petrological analyses, meant lithofacies descriptions, palaeotransport measurments, structural measurments in deformed beds and sampling for palaeobotanical studies. Petrological investigations included the determination of gravel petrography of the 5–10 mm fraction and/or heavy mineral fraction (0.1–0.25 mm) and quartz roundness (0.5–1.0 mm) analyses. Detailed description of the sample preparation can be found in Czerwonka (1994, 1996). None of the deposits investigated contained calcium carbonate, which was tested for in the field with 10% HCl and then in the laboratory using Scheibler equipment.

Altogether, there are 26 sites with gravel petrography data (Table 1) and 21 sites with heavy mineral data. Nine sites did not contain a gravel fraction available for petrographic analysis. This paper presents only a part of the data from investigated sections; others have been described in detail by August *et al.* (1995), Badura *et al.* (1998b), and Krzyszkowski *et al.* (1998).

DESCRIPTION OF SEDIMENTS

Preglacial deposits between Bardo Śląskie and Kamieniec Ząbkowicki

The preglacial deposits have generally been described from the Nysa Kłodzka river valley between Bardo Śląskie and Kamieniec Ząbkowicki. The outcrops occur at the base of the 25 m high terrace, 260–270 m a.s.l. (Zeuner, 1928; Finckh, 1929; Behr *et al.*, 1931; Behr & Mühlen, 1933; Walczak, 1954; Walczak & Rutkowski, 1974; Wroński, 1974). These deposits have not recently been available in sections, except in large outcrops at Janowiec (below 275 m a.s.l.) and Ożary (below 280 m a.s.l.) (Fig. 3) (Krzyszkowski *et al.*, 1998). New preglacial sites have been described by Badura *et al.* (1998b) at the Ząbkowice Śląskie brickyard (270–275 m a.s.l.) and by Oberc *et al.* (1996) and Przybylski (1997) from boreholes in the hills between Bardo and Potworów (280–300 m a.s.l.) (Fig. 3). Those hills were formerly interpreted as end moraines (Walczak, 1954, 1972) or kames (Gaździk, 1960; Brodzikowski,

Table 1

Percentage gravel content in the preglacial series of the southern part of the Sudetic Foreland

Site	quartz	siliceous rocks	local crystalline rocks	porphyry and other Permian rocks	local quartzites	sandstones and mudstones	other rocks
Pierwoszów (borehole 1)	60.6	3.9	7.5	19.1	1.2	5.3	2.4
Bardo (borehole 2)	78.6	5.0	2.7	–	1.4	12.3	–
Pierwoszów (borehole 3)	68.9	3.9	5.8	11.8	2.3	2.5	4.8
Bardo (borehole 4)	81.4	11.9	2.7	–	0.5	2.7	0.8
Chrząszczyce	83.3	16.3	–	–	0.4	–	–
Czarnolas	51.8	1.6	15.6	17.9	5.0	2.9	5.2
Dębina	82.0	0.8	2.7	–	11.8	–	2.7
Gnojna	86.1	2.4	4.7	6.2	0.5	0.1	–
Gorzuchów	45.1	0.8	6.5	43.4	3.2	1.0	–
Grabin	64.6	0.8	4.3	23.2	2.0	4.7	0.4
Gracze	48.1	5.9	21.6	19.8	0.8	2.3	1.5
Jagielno – lower series	66.7	3.9	9.2	18.5	1.0	0.7	–
Jagielno – upper series	67.8	4.1	4.1	13.3	4.6	6.1	–
Janowiec	16.5	3.9	27.4	16.7	–	32.9	2.6
Jordanów	85.5	12.2	0.8	1.5	–	–	–
Kłodzko	51.6	12.4	12.2	23.0	–	–	0.8
Lądek-Szary Kamień	36.2	–	62.1	–	–	–	1.7
Ligota	21.1	4.1	25.2	30.1	1.6	17.9	–
Nowy Dwór	30.6	5.1	25.8	29.0	0.6	3.4	5.5
Ożary	58.0	3.8	12.8	10.9	0.8	12.5	1.2
Roszkowice	51.6	5.5	5.9	24.4	3.8	8.0	0.8
Rudziczka	98.0	0.4	1.6	–	–	–	–
Skorogoszcz – lower series (?)	66.2	10.3	10.8	10.3	0.8	–	1.6
Skorogoszcz – upper series (?)	74.0	25.2	0.5	–	–	–	0.3
Stara Jamka	33.5	3.1	36.5	14.5	0.8	11.2	0.4
Szybowice	92.2	–	1.7	–	5.5	–	0.6
Świętów	61.8	0.7	28.4	2.1	3.5	1.4	2.1
Ząbkowice	37.5	5.2	52.1	–	–	3.1	2.1
Ziębice	70.6	3.6	11.2	9.6	1.6	2.0	1.4

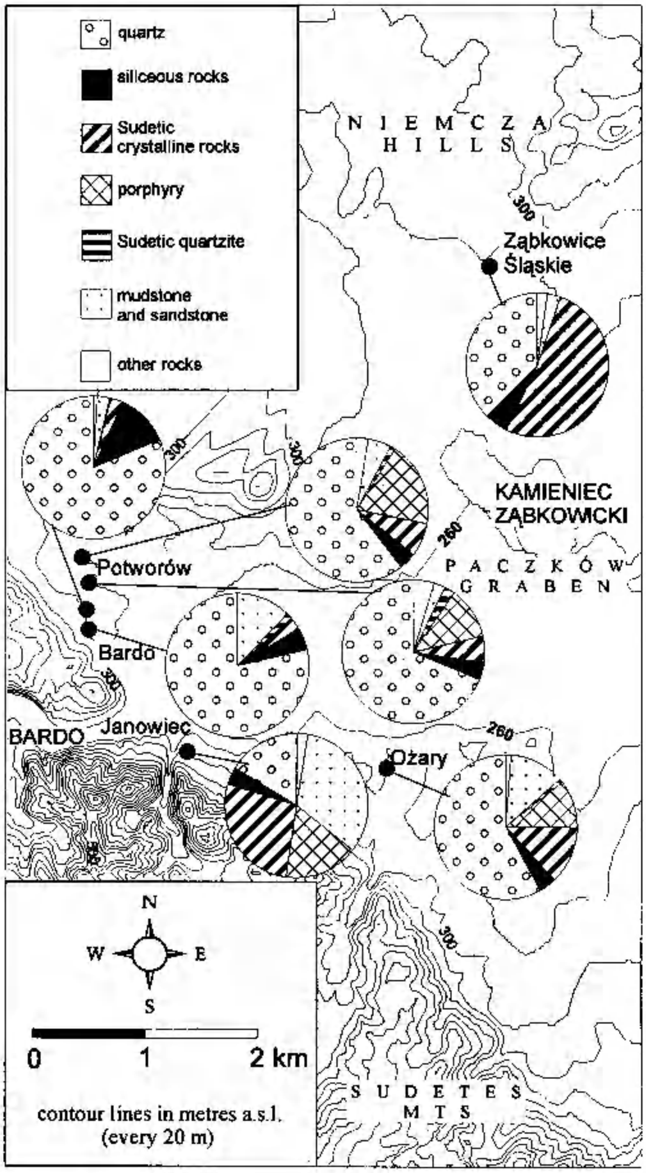

Fig. 3. Location of sites with the preglacial sediments of the Nysa Kłodzka river near the Sudetes Mts margin and petrographic composition of fluvial gravels.

1993).

After the borehole analysis Walczak (1954) suggested that the preglacial gravels fill the valley incised into the Poznań Series down to 220–225 m a.s.l. However, it seems that he incorporated all the gravel beds into the preglacial series, including those which occur within the Poznań Series, as documented by Oberc & Dyjor (1969) and Dyjor *et al.* (1978). The position of the boundary between the Poznań Series and the preglacial deposits in the region adjacent to the Sudetes Mts margin is unknown. Both series contain deposits with similar lithologies, that differ only in their clay/gravel ratio and are practically indistinguishable without detailed petrological investigations.

Petrographically, the investigated preglacial deposits can be subdivided into three series: quartz-dominated gravels with no porphyry; quartz-rich gravels with porphyry and gneiss from the Kłodzko Basin; and local rock-domi-

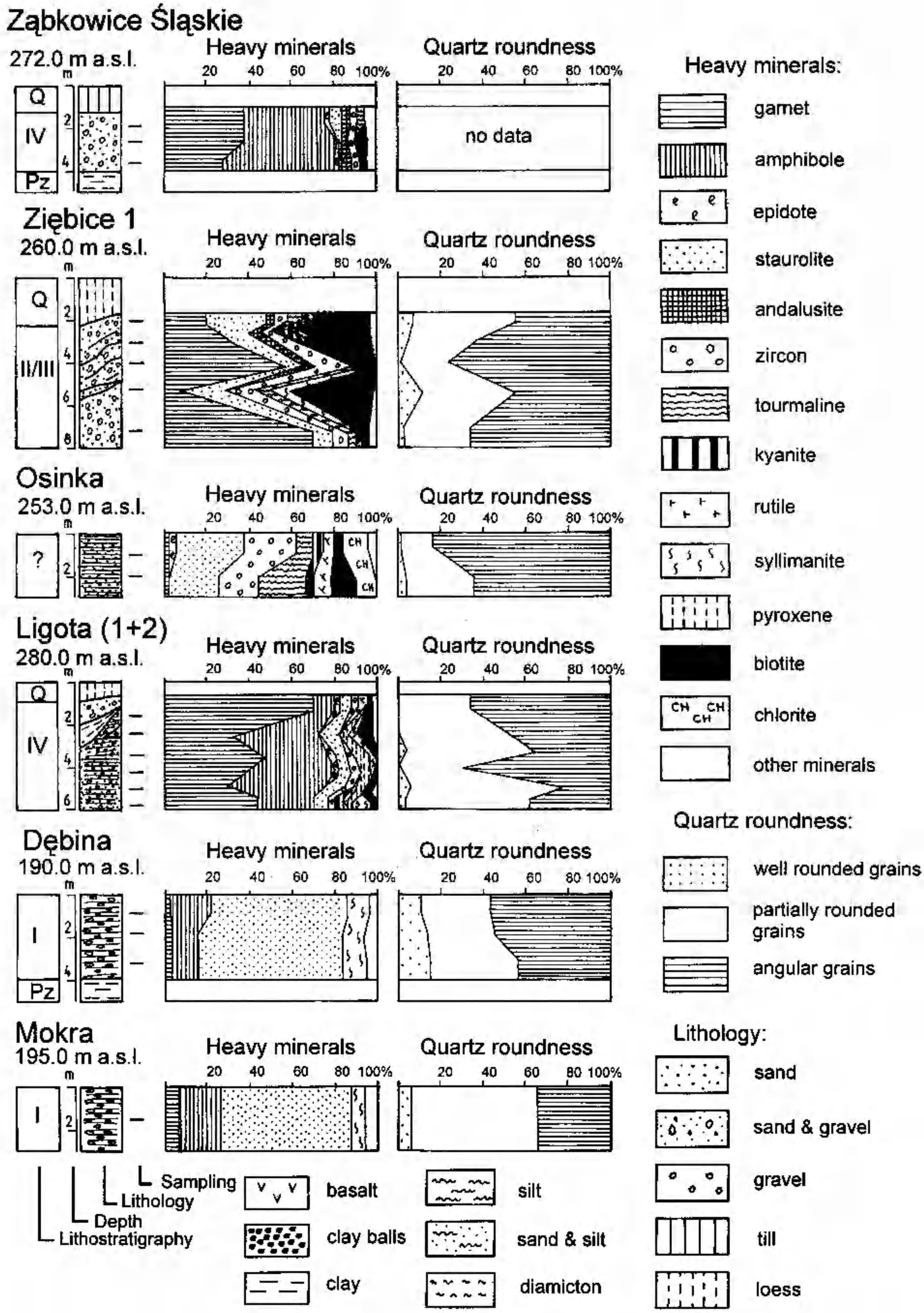

Fig. 4. Lithology, heavy minerals and quartz roundness characteristics of the preglacial series of the southern part of the Sudetic Foreland (Location of sites in Fig. 1).

nated gravels with very variable petrographic composition (Table 1; Fig. 3). The first two series have similar lithological characteristics and are kaolin-rich. The quartz-dominated deposits only occur in two boreholes between Bardo and Potworów, whereas the porphyry-bearing gravels occur in all other sections, except Janowiec and Ząbkowice Śląskie. The preglacial deposits at Janowiec and Ząbkowice Śląskie occur below the oldest till in the region (Badura *et al.*, 1998b), and they do not contain Scandinavian material or a kaoline matrix. The series at Ząbkowice Śląskie is connected with a local river, once flowing from the west or northwest, as indicated by its large Sowie Mts gneiss content (Table 1; Fig. 3). At Janowiec, the preglacial series consists of local sandstones and mudstones from the Bardo Mts, gneiss from the Kłodzko Basin and porphyry, with a quartz content of only 14–19% (Table 1; Badura *et al.*, 1998b; Krzyszkowski *et al.*, 1998). The Janowiec Gravels were deposited at least in part by the Nysa Klodzka river, as indicated by the porphyry content. Both the Ząbkowice and Janowiec gravel series are less wheathered and probably much younger than the other porphyry-bearing and quartz-rich (40–60%) preglacial deposits in the region. The kaolin-rich deposits differ also from the kaolin-free one also in their heavy mineral contents. The Ząbkowice and Janowiec Gravels practically contain only garnet and amphibole (Fig. 4) whereas the quartz-and kaoline-rich series at Ożary is garnet-dominated with a large admixture of staurolite, zircon, tourmaline, kyanite, rutile and pyroxene, and contain much less amphibole (Krzyszkowski *et al.*, 1998).

The Ziębice holostratotype section

The Ziębice section lies 2 km west of Ziębice. This section occurs in a tectonic trough, filled with a thick sequence of Cainozoic deposits. Morphologically, this is a flat to slightly undulating till plateau covered by a 2–10 m thick loess cover.

The complete stratigraphic sequence at the Ziębice section was described by Frech (1915) and Zeuner (1928) (Table 2). The 8 m thick preglacial 'white gravels' are overlain by 1–2 m thick 'brown gravels' and 6–12 m thick till. The latter two units were interpreted by Zeuner (1928) as a Saalian deposit. It is possible to interpret this section similarly to the Janowiec section (Zeuner, 1929; Krzyszkowski *et al.*, 1998), where the till would represent the oldest glaciation in the region (Elsterian). In this case the till is underlain by two types of preglacial sediments, the 'brown gravels', relatable to the Janowiec and Ząbkowice Gravels, and the 'white gravels' relatable to the quartz-rich, porphyry-bearing series.

A recently exposed section only consists of the kaolin-rich white gravels (ca 2 m thick), which are overlain by a sequence of redeposited white gravels (ca 4 m) and loess-like colluvium (ca 4–5 m). Petrographical investigations indicated mainly quartz (60–80%), which is associated with porphyry (8–17%), siliceous rocks (3–6%), quartzite (0–5%) and Cretaceous sandstones (1–3%) (Table 1), which is generally in accordance with results presented by Zeuner (1928). The heavy mineral assemblage is garnet-dominated, with a large admixture of staurolite and biotite (Fig. 4).

Table 2

Lithostratigraphic sequence and age of deposits in the Ziębice holostratotype section

Age of deposits		Lithostratigraphy		
Recent proposal	Zeuner (1928)	Western corner of the quarry after Zeuner (1928)	Main profile of the quarry after Frech (1915)	Eastern corner of the quarry after Zeuner (1928)
Weichselian	Weichselian	Humus soil Loess (decalcified) Humus soil Loess (decalcified)	Loess Ventifacts at the base	Loess
Elsterian	Saalian		Sand Till, sandy brown (6–12 m)	Till, sandy brown
Early Pleistocene (Preglacial Series – Unit IV ?)	Saalian	Gravels, with large boulders, brown	Gravels, brown (1–2 m)	Gravels, brown
Late Pliocene (Preglacial Series – Units I–III)	Pliocene	Clay, grey	Clay, blue (1.0–1.5 m)	Clay, dark grey
Late Pliocene (Preglacial Series – Units I–III)	Pliocene	Sand and Gravel, white	Sand and Gravel, white (8 m)	Sand and Gravel, white
Late Miocene (Poznań Series)	Miocene/ Pliocene	Lignite	Clay with lignite (1–2 m)	Clay

Nowy Dwór

This section is located in the Oława river valley which is part of the Niemcza–Strzelin horst (Fig. 1). On both sides of the valley, there are exposures of crystalline rocks, mainly gneiss, schists and granite. The valley is very wide, and only in part occupied by late Quaternary terraces and recent floodplains. The remainder is filled with glacigenic deposits, and, in part, with preglacial deposits.

The section is 6–8 m high and consists of a complex sequence of deposits that were examined in three exposures (Fig. 5). The sediment sequence of the eastern exposure (Fig. 5A) is formed of three distinct units. The lower one is 4–5 m thick and consists of a series of medium- to large-scale trough cross-bedded sands. The middle unit, up to 3 m thick, is formed of alternating beds of massive sandy silts or clayey silt, fine-grained sands with ripple-marks and medium-scale trough cross-bedded medium-grained sand. The upper unit is formed of medium- to large-scale trough cross-bedded sand and is separated from

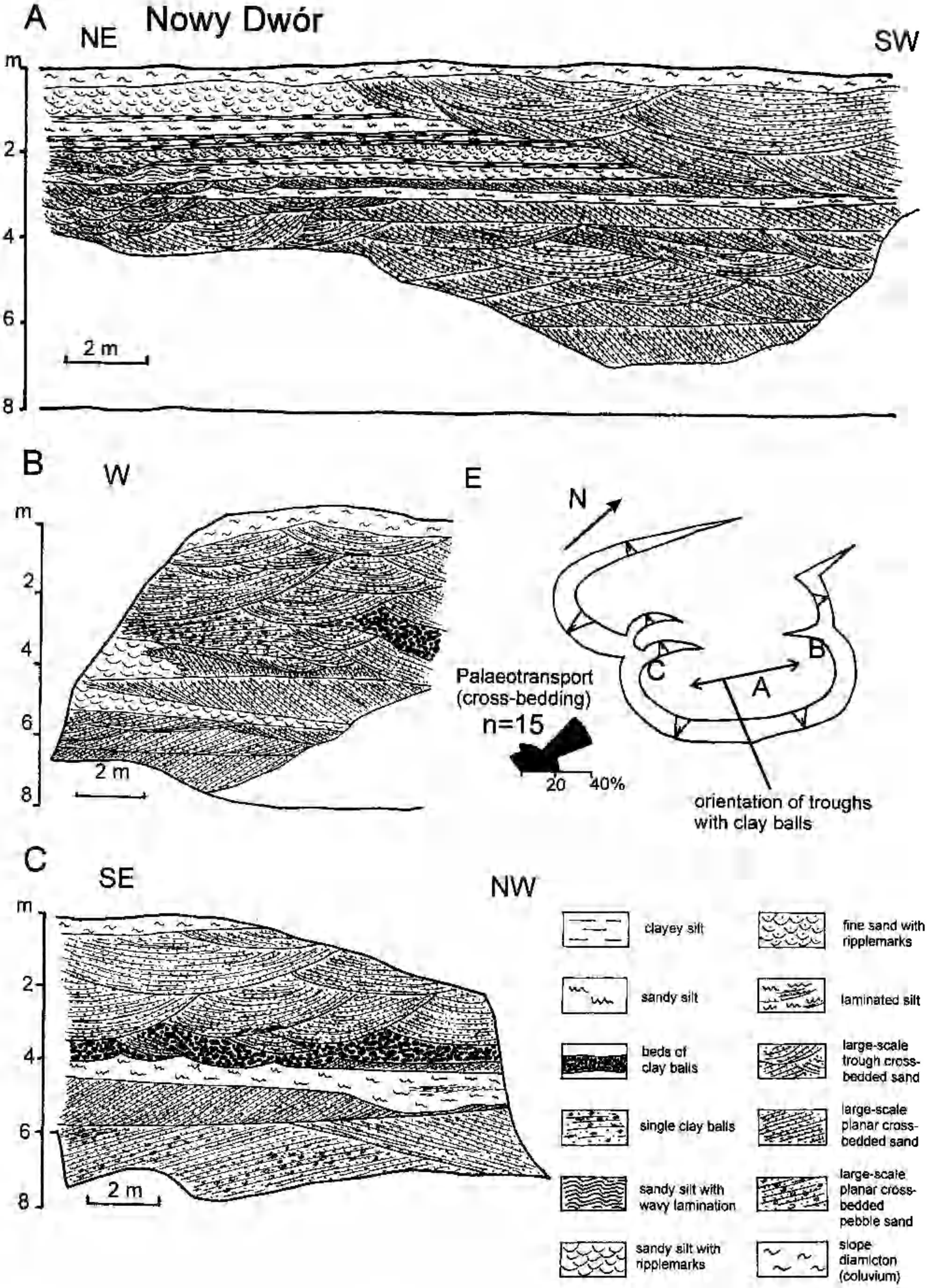

Fig. 5. A sequence of preglacial deposits at Nowy Dwor.

the middle unit by an erosional surface. The northern (Fig. 5B) and southern (Fig. 5C) exposures have a similar division, and they also contain a set of troughs filled in with clay and silt balls. The latter sometimes forms laterally continuous beds with curved bottom surfaces. This clayey sediment is macroscopically massive, although detailed study reveals that it is formed of clay/silt grains of a size varying from a few milimetres to several milimetres in diameter. The southern exposure also contains a 0.3–0.5 m thick bed of massive to laminated clayey silt that contains fragments of leaves and, at the very bottom, large-scale trough cross bedded sand with gravels. These gravels are very fine (up to 10 mm).

The sediments of the Nowy Dwór section can be interpreted as a fragment of a meandering river sequence, where the alternating beds of silt, fine- and medium-sand were deposited on the floodplain and/or levee, and the medium- to large-scale cross bedded sediments were deposited in the laterally migrating channel. The beds with clay balls represent material transported over a short distance and redeposited, either from the floodplain or from the Tertiary Series lying in the basement. The troughs' orientation measurements show fluvial palaeotransport from SW to NE (Fig. 5).

Gravel petrographic study of one sample from the base of the southern section indicated that besides quartz, there is an abundance of porphyry (up to 30%), crystalline rocks and siliceous rocks (Table 1). Heavy mineral analysis indicated that Nowy Dwór series is almost homogeneous and garnet-dominated, with some admixtures of staurolite, tourmaline, zircon and rutile (Fig. 6). The increase of resistant minerals, such as tourmaline, zircon and rutile, in the topmost, 3 m thick, part of the sequence may be interpreted as a result of the weathering. Similar weathering has been documented in the Osinka section near Ziębice (Fig. 4).

Ligota Wielka

Behr (1929) described some Pliocene clayey deposits near Ligota and Wroński (1974) described in the same region preglacial gravels. However, location of their sites is ambiguous. Recent exposures near Ligota Wielka are located at the top of Otmuchów Rampart, 280 m a.s.l. There are two small outcrops, each 3–5 m high and with 15–20 m long sections (Przybylski, 1997). The sections consists of massive to laminated gravels interbedded with laminated pebbly sands. In one section, vague troughs can be traced in the pebbly sands, that show E–W axis orientations. In other parts of this section the sediments are deformed, generally forming wide-radius folds, but also overturned folds or diapir-like structures. In the latter zone, the gravelly sediments are interbedded with green clays that may represent the Poznań Series. In another section near Ligota Wielka, the gravelly series is overlain by Pleistocene glaciolacustrine laminated silts.

A detailed interpretation of the sedimentary environment is impossible; a fluvial origin can be presumed from the sediment lithology (gravel) and trough cross bedding. Palaeotransport was probably from E to W. The deformation was, probably, caused by glaciotectonic processes.

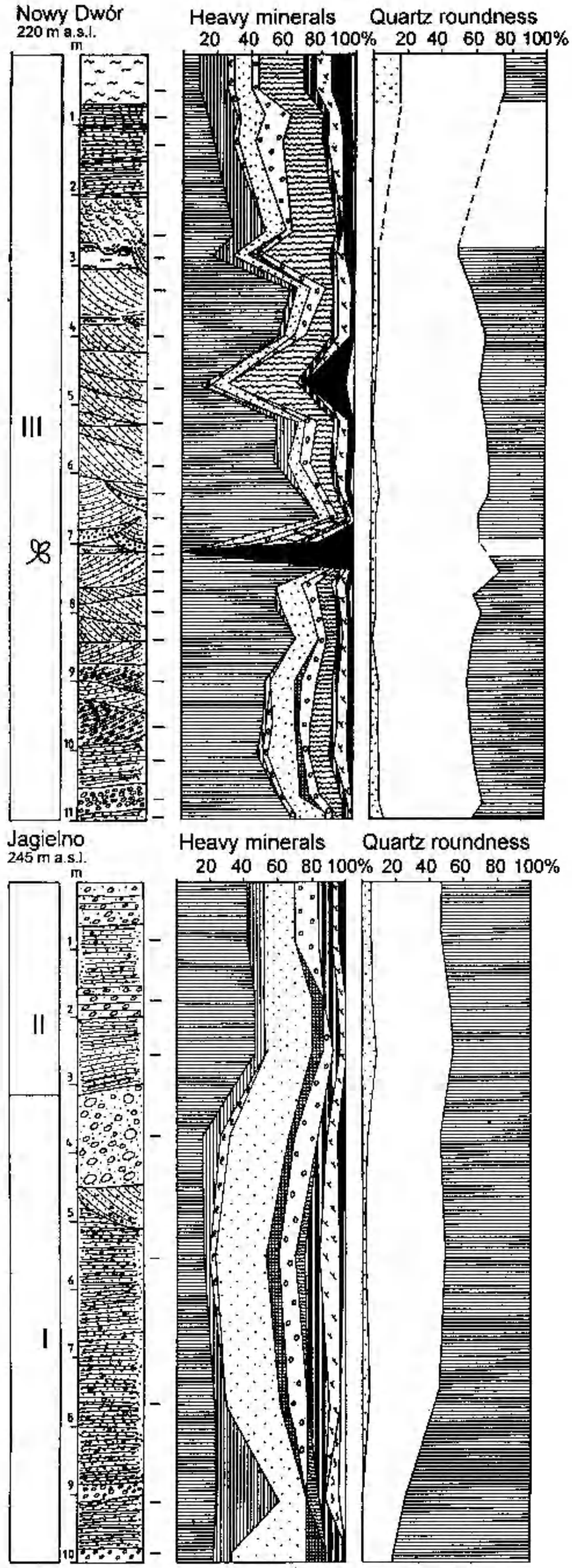

Fig. 6. Lithology, heavy minerals and quartz roundness characteristics of the preglacial series at Nowy Dwór (Oława river valley) and Jagielno (southern part of the Grodków Upland). Location of sites in Fig. 1, explanations in Fig. 4.

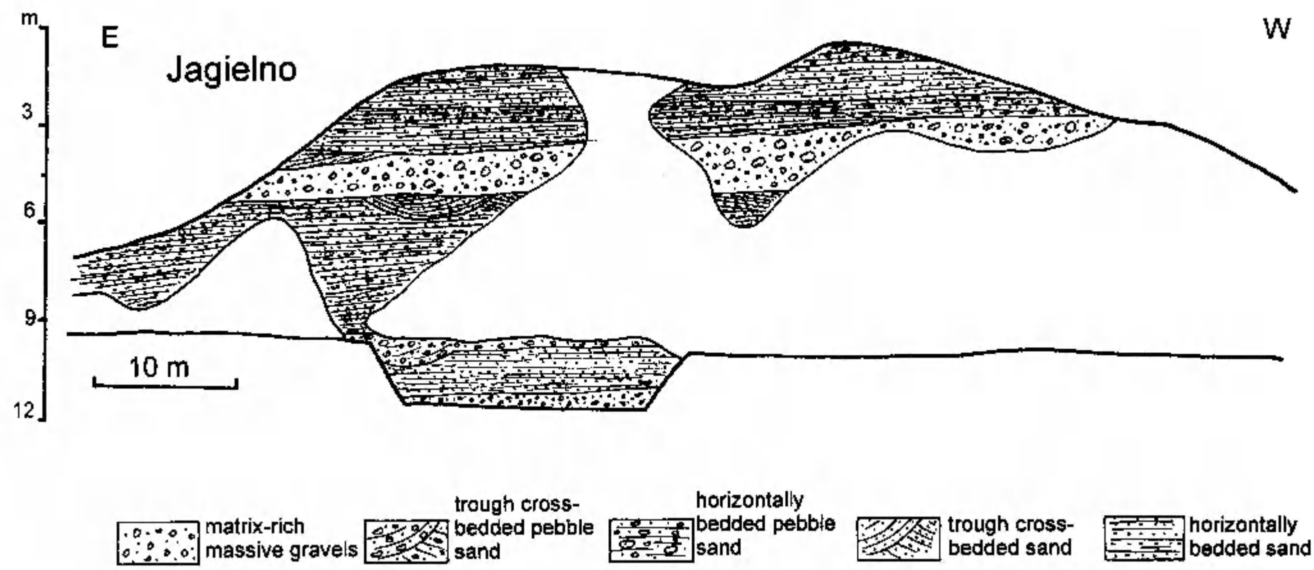

Fig. 7. A sequence of preglacial deposits at Jagielno.

Petrographically, the Ligota Wielka series differs from Ziębice and Nowy Dwór, and it mainly consists of local crystalline rocks (20–40%, mainly gneiss), sedimentary rocks of the Bardo Mts (15–20%), porphyry (15–30%) and of much less common quartz (15–33%). There are some reddish crystalline rocks (gneiss) that may come from the Klodzko Basin. The typical Scandinavian rocks and/or Mesozoic flint do not occur at all. The heavy mineral content, with garnet and amphibole as the main minerals, is similar to the Ząbkowice and Janowiec Gravels (Fig. 4). In one sample, the sediment is garnet-dominated similarly to the preglacial suites of Ziębice and Nowy Dwór (Fig. 4, 6).

Jagielno

This section is located in the southern, hilly part of the Grodków Upland (Fig. 1). The section is 12 m high and consists of to 1–2 m thick beds of massive, kaolin rich gravels and horizontally to low-angle laminated coarse- to medium-grained sand or pebbly sand (Fig. 7). The sandy deposits are kaolin-poor. The laminated sands dominate in the sequence. Only two distinct troughs were observed, one in the gravels and one in the sands. The trough axes indicate a N-S orientation. The sequence may have had fluvial origin, but the occurrence of thick, laterally extensive beds with massive and horizontally bedded sediments also suggests an alluvial fan environment. Palaeotransport was probably from S to N.

The gravel petrography shows the typical spectrum of rocks, with dominant quartz associated with porphyry, local crystalline rocks, siliceous rocks and Cretaceous sandstones. The latter, however, only occur in a large quantity (5%) in the uppermost part of the section, whereas they are almost absent in its lower part (0.1%). The heavy mineral content is variable and two distinct units can be defined (Fig. 6). The lower unit mainly consists of staurolite (20–40%) and garnet (15–23%) with a considerable admixture of zircon, tourmaline, cyanite and rutile. The upper unit is garnet-dominated (42–48%), with much less staurolite (16–28%) and less common other minerals (Fog. 6). The petrologically documented boundary between these units is at the top of the upper massive gravel bed (Fig. 6, 7). This boundary is not well marked in the sedimentary sequence, as deposits are similar below and above it, and there is no distinct erosional surface between them.

Gnojna

This site lies in the central part of the Grodków Upland (Fig. 1). The site Gnojna 1, that was supposed to represent the preglacial series, has been discussed in depth by Dyjor (1985), Teisseyre (1985) and Sadowska (1985). However, Badura *et al.* (1998a) reinterpreted the geological position of this sequence (Gnojna 1), and placed it in the Poznań Series rather than in the preglacial series. Furthermore, a new site has been found, that without doubt represents the preglacial series (Gnojna 2). It lies at the top of a hill, ca 200 m a.s.l. and consists of about 5 m thick, large-scale trough cross bedded gravels or pebble sands. The depth of individual troughs varies from 0.5 to 2.0 m and their lateral extent in the section is from 5 to 7 m. The gravel beds occasionally contain clay balls. The sequence may represent the channel zone of a river, presumably a meandering one, although this can not be proved on the basis of the data in the Gnojna section. Palaeotransport was from ESE to WNW.

Petrographically, the Gnojna preglacial sediments are identical to the lower unit of the Jagielno section. They are quartz-rich (80–90%) with some porphyry (3–12%), crystalline and siliceous rocks and are characterized by more or less equal contents of staurolite and garnet (Fig. 8).

The Dębina section and neighbouring sites

The Dębina section is located in the southernmost part of the Niemodlin Upland (Fig. 1) and is in the form of several, 3–4 m deep and 100–200 m long trenches (Fig. 9). The sequence consists of two units, the Poznań Clay at the base and gravels at the top. The major part of the sequence contains large-scale troughs formed of matrix-poor gravels. The matrix, although negligible, contains kaolin. The troughs are 2–3 m deep and form extensive structures with a length of up to 50 m. The gravels are vaguely laminated to massive, and in some exposures interbedded with layers of pebbly sands. The sequence is locally deformed, forming wide-radius anticlines and synclines (Fig. 9). The gravelly sediments probably represent a high-energy foremountain river, with troughs formed in permanently active channels. The palaeotransport was from SE to NW.

The sequence at Dębina is characterized by a specific gravel assemblage, which is quartz-dominated (80–90%). Besides quartz, it only contains local quartzites and some local crystalline rocks. There is no porphyry. Heavy minerals are also specific, with dominant staurolite (60–75%), amphibole (10–20%) and sillimanite (5–10%); the garnet content is below 5% and some other minerals are below 2% (Fig. 4). The series at Dębina certainly does not represent the Nysa Kłodzka river system, and, as series with similar characteristics have been found at Mokra, Rudziczka and Szybowice (Fig. 1), it may be interpreted as representing the Biała Głucholazka river system.

Other small outcrops in this region, Świętów and Stara Jamka (Fig. 1), represent, respectively, local river sediments with a larger admixture of crystalline rocks but with no porphyry, and Nysa Kłodzka river system sediments with common crystalline rocks and porphyry. Hence, the Stara Jamka site, although containing a large admixture of local rocks, represents the most southeastern site with the Nysa Kłodzka river material (Fig. 1).

Tłustorębу

This site is located in the northwestern part of the Niemodlin Upland (Fig. 1). It is 6–7 m high and consists of a sequence of coarse- to medium-grained sands with horizontal to low-angle bedding and medium-scale trough cross bedding. Fine sands with ripplemarks are locally present. Some troughs contain clay balls; but there is no gravel at all. The sequence is covered by till and/or slope colluvium. The preglacial series at Tłustorębу may represent a sequence of the channel zone of a sinuous river. Trough axes show palaeotransport from SSE to NNW. The heavy mineral assemblage, with dominant garnet, is similar to that of the upper unit at Jagielno as well as at Ziębice and Nowy Dwór (Fig. 8).

Gracze

The preglacial deposits near Gracze are partly exposed in the northeastern part of a basalt quarry, forming the topmost layer. The sediments are about 5 m thick and consists of horizontally to low-angle bedded medium- to fine-grained sand, and locally thin beds of pebbly sands. Detailed interpretation is impossible due to the poor exposure of the sediments. The series is quartz-dominated (50%), with some porphyry (24%) and crystalline and siliceous rocks (Table 1). It is garnet-dominated (Fig. 8). Both the lithology and sediment petrology indicate a strong similarity to the Tłustorębу sequence.

Niemodlin 2

This site is located in the central part of the Niemodlin Upland (Fig. 1). The section is 10 m high and consists of

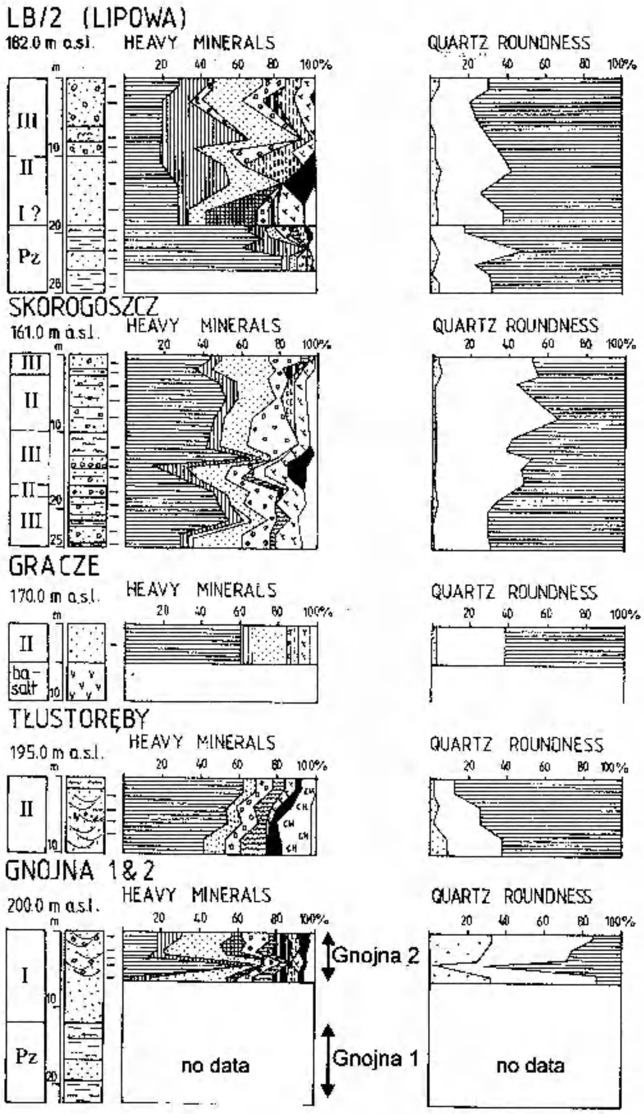

Fig. 8. Lithology, heavy minerals and quartz roundness characteristics of the preglacial series of the Grodków Upland and the northern part of the Niemodlin Upland. Location of sites in Fig. 1, explanations in Fig. 4.

two sedimentary units separated by a distinct erosional boundary. The lower belongs to the preglacial series and the upper is a Pleistocene glaciofluvial deposit that contains Scandinavian red granitoids (Fig. 10). The preglacial series mainly consists of medium- to large-scale trough and planar cross-bedded sands. The planar sets are from 0.3 to 0.6 m thick and the troughs are 0.3 to 1.0 m deep. Fine sands with small-scale trough cross-bedded sands also occur in the upper part of the sequence where they form a laterally continuous bed up to 2 m thick. A 0.15–0.20 m thick clay bed has been also recorded from the lowest part of the sequence. It is formed of partly homogenized clay balls from a few millimetres to a few centimetres in diameter (Fig. 10).

This sequence may represent the channel zone of a sandy, sinuous river. The bed with clay balls may come from the redeposition of fine-grained floodplain sequences during floods. Palaeotransport of these fluvial deposits was from SE to NW. The preglacial series at Niemodlin 2 is

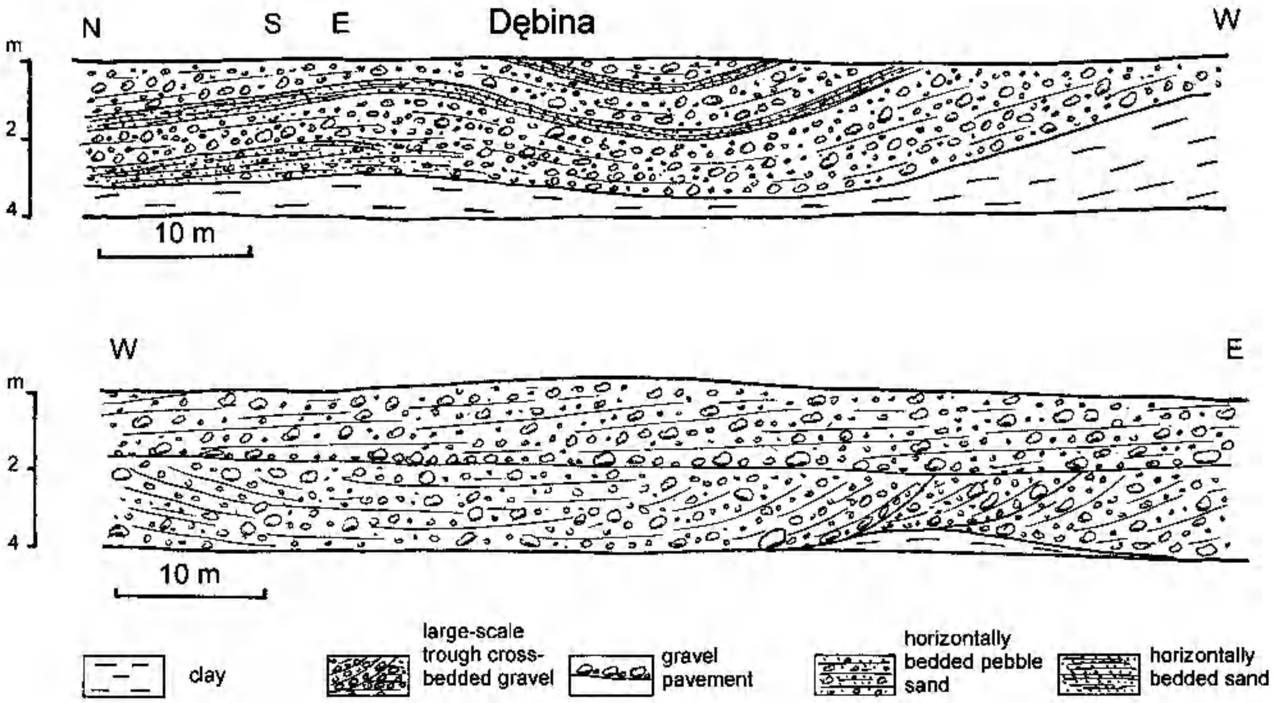

Fig. 9. A sequence of preglacial deposits at Dębina.

garnet-dominated, with an abundant admixture of staurolite, zircon, tourmaline and rutile throughout the profile (Fig. 11).

Niemodlin 1 (Wesele)

This site is located near the previously described section. It consists of 6–8 m high section of only preglacial deposits. The series is very uniform, consisting of medium-scale trough cross-bedded sands throughout the exposure. It may represent the channel zone of a sinuous river, similarly to Niemodlin 2. However, the heavy mineral content is slightly different. At Niemodlin 1, besides the dominant garnet, zircon and rutile are the major minerals whereas staurolite is less frequent (Fig. 11).

Skarbiszowice

This is a poorly exposed section that occurs 5 km southeast of Niemodlin (Fig. 1). It consists of a 6 m thick sequence with mainly sand and sand with fine gravel, but also locally containing a 0.3 m thick, laminated dark brown silt and grey, laminated sandy silt and fine sand. The sequence may represent the channel (sand) and floodplain (silt) deposits of a sinuous river. The sediments are slighty folded and faulted, probably due to glaciotectonic

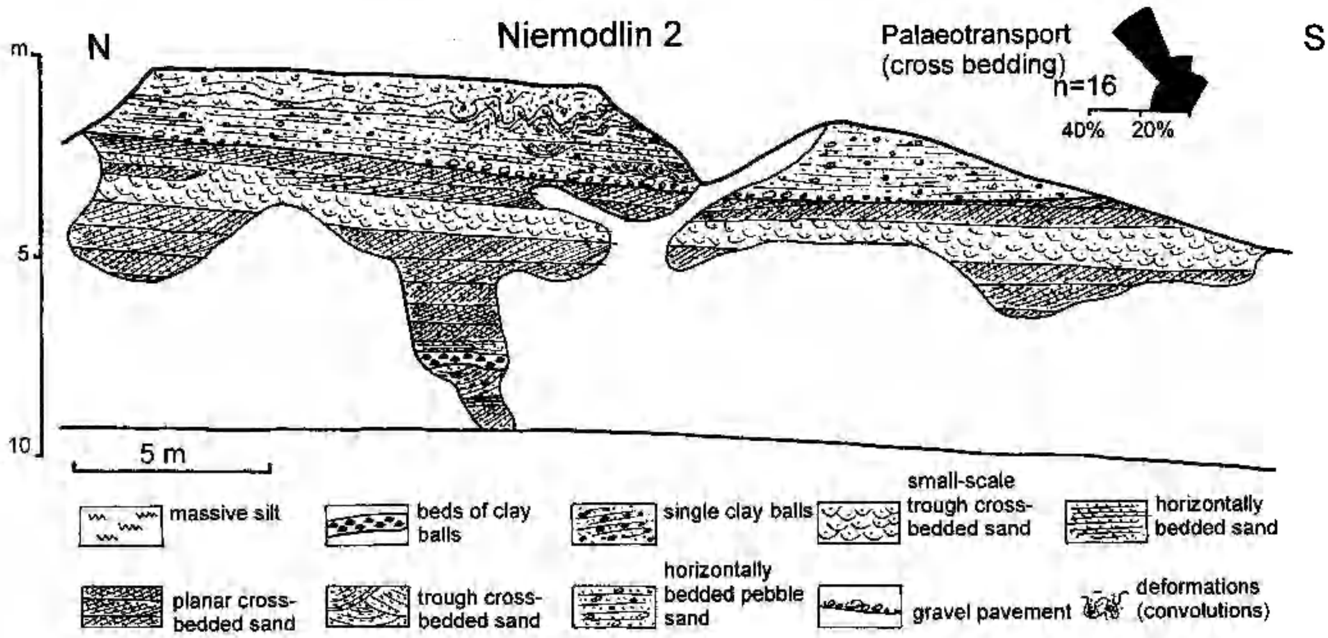

Fig. 10. Sedimentary sequence of preglacial deposits at Niemodlin 2.

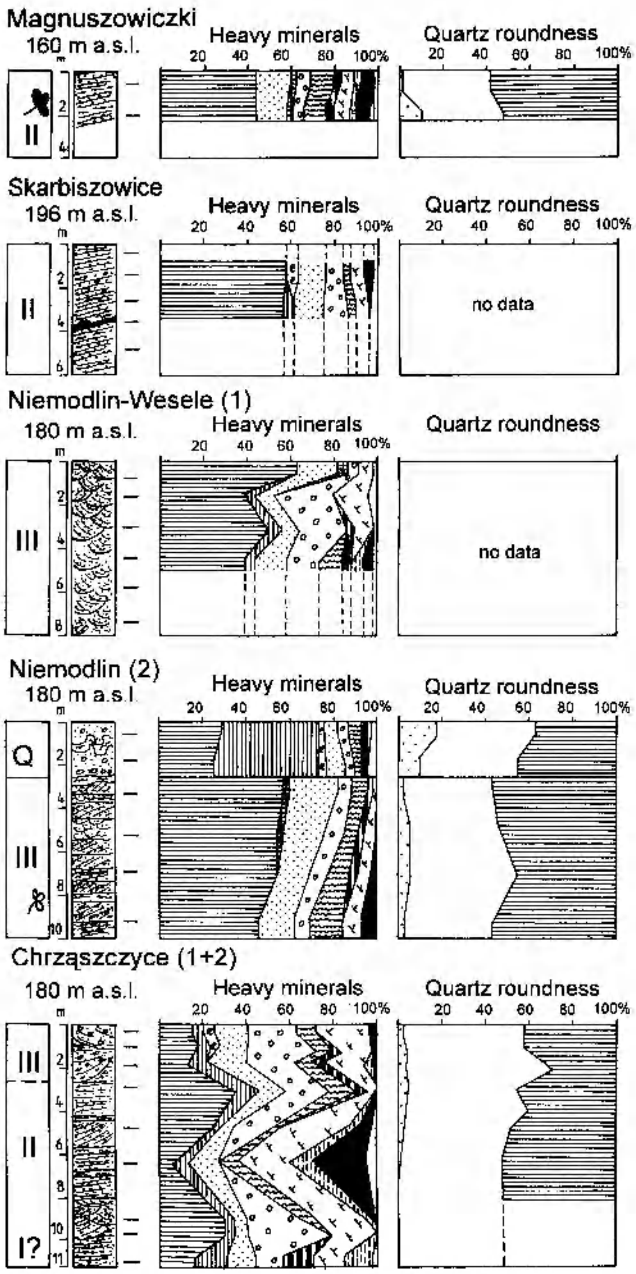

Fig. 11. Lithology, heavy minerals and quartz roundness characteristics of the preglacial series of the central and northeastern parts of the Niemodlin Upland. Location of sites in Fig. 1, explanations in Fig. 4.

processes. The series is garnet-dominated, with a heavy mineral content very similar to the sequences at Niemodlin 2, Jagielno (upper unit), Nowy Dwór and Ziębice.

Tułowice

This is a large outcrop located 8 km southeast of Niemodlin (Fig. 1). The section is 8 m high and several metres long. Data from this section was suplemented with data from a 10 m deep borehole (Fig. 12). The exposed sequence is slighty deformed, but the continouity of strata was not broken (Fig. 12). The sequence mainly consists of horizontally bedded sand, in which medium- to large-scale troughs and thin beds of fine-grained sands with ripple-marks or massive sandy silts occur locally. Several 0.1–0.6 m thick and laterally extensive clayey beds were also observed. These beds are usually formed of partly homogenized clay balls that vary in size from a few millimetres to a few centimetres in diameter. Clay balls are also dispersed in some sandy beds. In one place, a 0.15 m thick, massive, dark brown to black, organic mud layer was documented (Fig. 12). This bed contains very rich leaf impressions. The sequence in the borehole mainly consists of the medium-grained sand, with one layer of the clayey silt, and the clay of the Poznań Series at the base.

The major part of the sequence at Tulowice probably represents the channel deposit of a sinuous river. The occurrence of a floodplain with fine-grained deposits may be assumed from the large redeposition of clays and the occurrence of beds of massive silts. Some of the beds formed of clay balls may represent the floodplain sediment *in situ*, especially those associated with the organic mud layer. Trough axes show palaeotransport from south to north. The deformations structures were probably formed due to glaciotectonic processes, but surprisingly, the deforming force is indicated from strata inclination to have been from southeast.

The preglacial series at Tulowice can be subdivided into two units, according to its heavy mineral content (Fig. 12, 13). The lower unit, entirely documented from the borehole, is garnet-dominated. Its mineral composition is very similar to other garnet-dominated sections, as Niemodlin 2, Skarbiszowice, Jagielno (upper unit), Nowy Dwór and Ziębice. The upper unit, which includes the uppermost samples in the sequence from the borehole and the complete sequence from the exposure, is characterized by a quite different mineral spectrum. Five minerals: garnet, staurolite, zircon, tourmaline and rutile are present in similar, large quantities, each about 10–20%. Other minerals are rare, except biotite (5–10%).

Magnuszowiczki

This is a small section in the northermost part of the Niemodlin Upland (Fig. 1). It is about 4 m high, with only 2 m of exposed sediments. These are laminated fine-grained sand beds and silty beds, with the thickness of each lamina varying from 1–4 centimetres (silt) to about 5–10 cm (sand). This sequence may represent a sediment deposited on the alluvial floodplain and/or on the levee of a sinuous to meandering river. The silty beds contain some leaf impressions. The preglacial series of Magnuszowiczki is garnet-dominated (Fig. 11).

Skorogoszcz

This site is located at the northern margin of the Niemodlin Upland, beside the Odra river valley (Fig. 1). The main section is 5 m high and several metres long and the two smaller sections are only 1–2 m high. The sequence consists of laminated pebbly sand, massive pebbly sand, massive to crudely laminated gravel and massive to laminated silts. These sediments are strongly deformed, in places with vertical strata (Fig. 14). These deformations can be interpreted as thrusts, especially since two thin clay beds of the Poznań Series have been observed at the base of

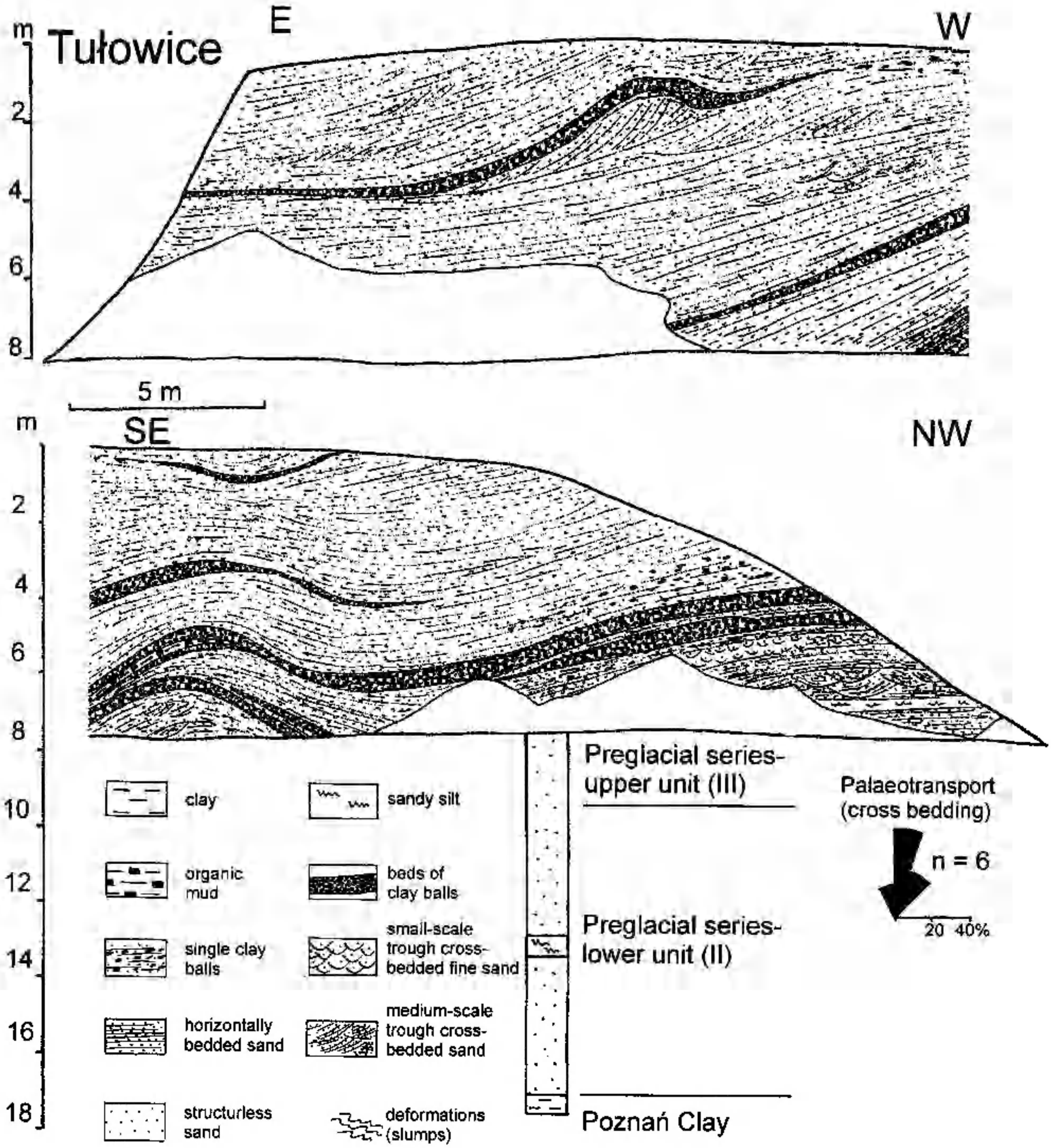

Fig. 12. A sequence of preglacial deposits at Tułowice.

two of the supposed thrust planes. They could have originated due to glaciotectonic processes, although the dips of the thrust planes suggest that the deforming force was from SSW (Fig. 14).

The sequence consists of two different stratigraphic units, that differ distinctly in their gravel petrography and only slightly in their heavy mineral content. One unit is porphyry-bearing, and besides the porphyry (13–17%) it contains quartz (58–76%), siliceous rocks (6–9%) and crystalline rocks (6–11%). The second unit has neither porphyry nor crystalline rocks, and contains practically only quartz (60–86%) and siliceous rocks (15–33%) (Table 1). Both series are garnet-dominated, but the porphyry-free series contains less staurolite and more zircon, tourmaline and rutile than the porphyry-bearing series (Fig. 8). The grain size and sedimentary structures of the sandy/gravelly deposits of both series do not differ much, although the porphyry-bearing bed of massive pebbly sand in the main section has more kaolin matrix than the other deposits. The porphyry-bearing series probably represents the older unit, although this is not certain. The porphyry-bearing deposits are gravel-dominated while the porphyry-free series, besides gravels, also contains silty beds. One of them is at least a few metres thick (Fig. 14). Thus, it seems that the latter series represents certainly the sequence of a sinuous river, with well-preserved floodplain lithofacies. The porphyry-bearing series may also represent a sinuous river environment, as documented in other porphyry-bearing preglacial series in the region, although this is not proved by data from the studied section.

Chrząszczyce

This site is located at the northeastern margin of the Niemodlin Upland, close to the Odra river valley. A detailed sedimentological description of this site was previously presented by August *et al.* (1995). The sequence is about 9 m high and in its eastern corner consists of two distinct stratigraphic units that are separated by an erosional surface (Fig. 15). The lower unit is mainly formed of horizontally to low-angle bedded sands and trough cross bedded sands. The latter occur in co-sets concentrated in the lowest and middle parts of the section. There are also several layers of sandy to clayey silts and clayey beds formed of clay/silt balls. The described sequence is slightly deformed, forming wide-radius folds. The lower unit is truncated here and the upper unit lies above the angular unconformity. The upper unit is formed of large-scale troughs filled with sand and gravel. The average size of the gravel is 1–3 cm across, with a few larger clasts up to 10 cm in diameter. In the western corner of the exposure, the difference between the two units is only in their grain size, as all the beds are conformably deformed with large troughs filling the axes of synclines (Fig. 15). August *et al.* (1995) described three sedimentary units at Chrząszczyce.

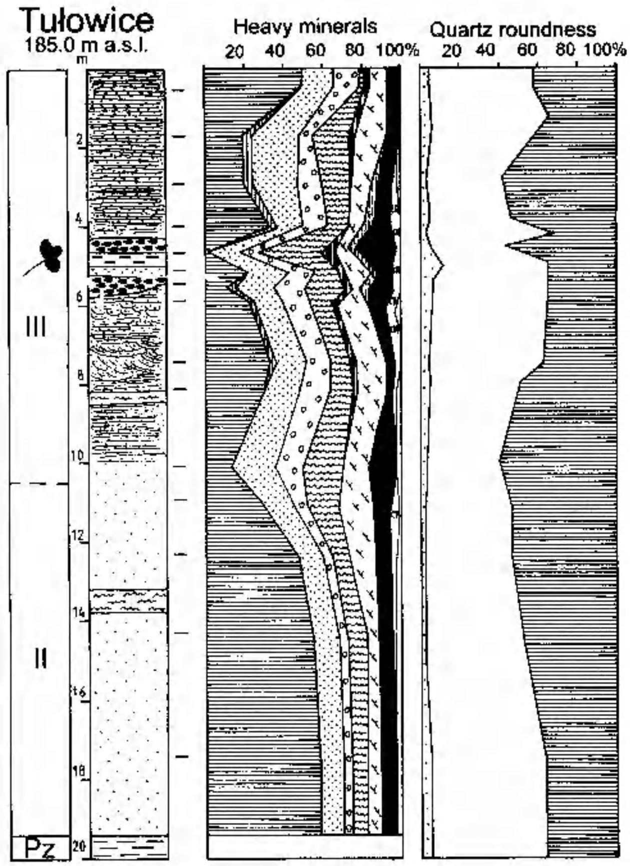

Fig. 13. Lithology, heavy minerals and quartz roundness characteristics of the preglacial series of Tułowice. Location of the site in Fig. 1, explanations in Fig. 4.

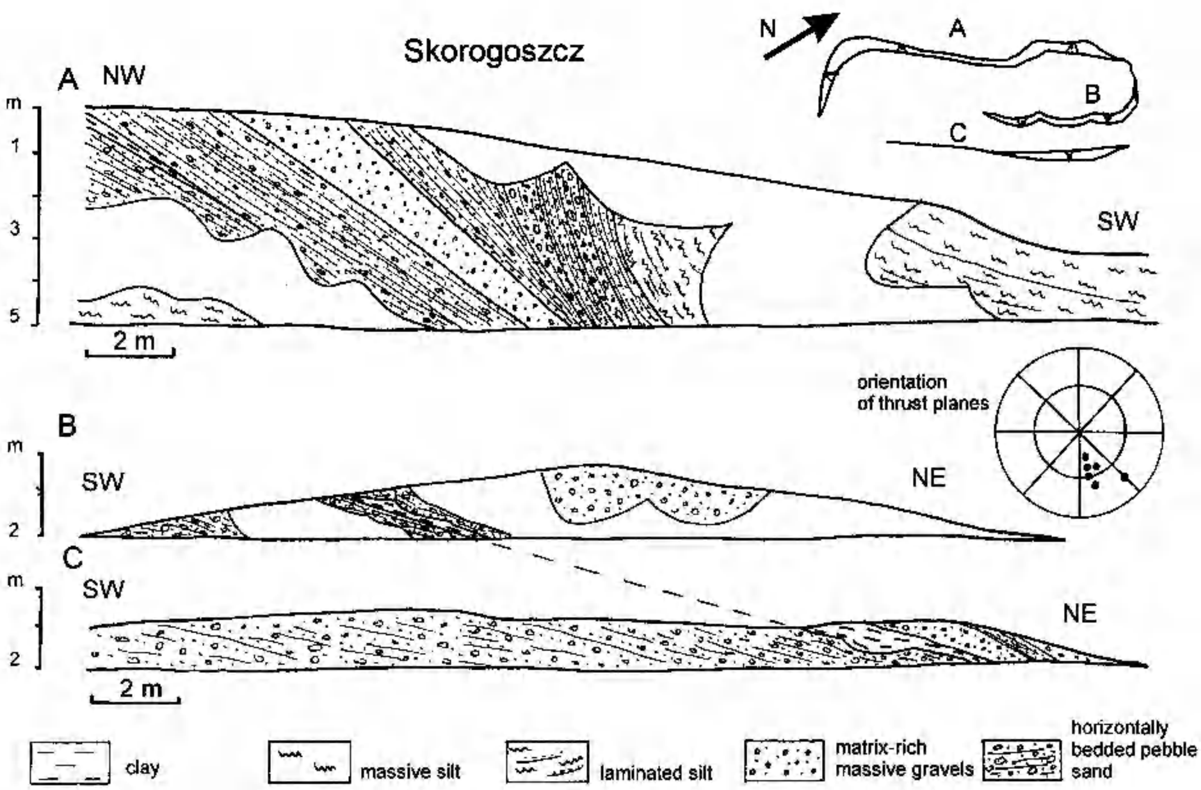

Fig. 14. A sequence of deposits and deformations of the preglacial series at Skorogoszcz.

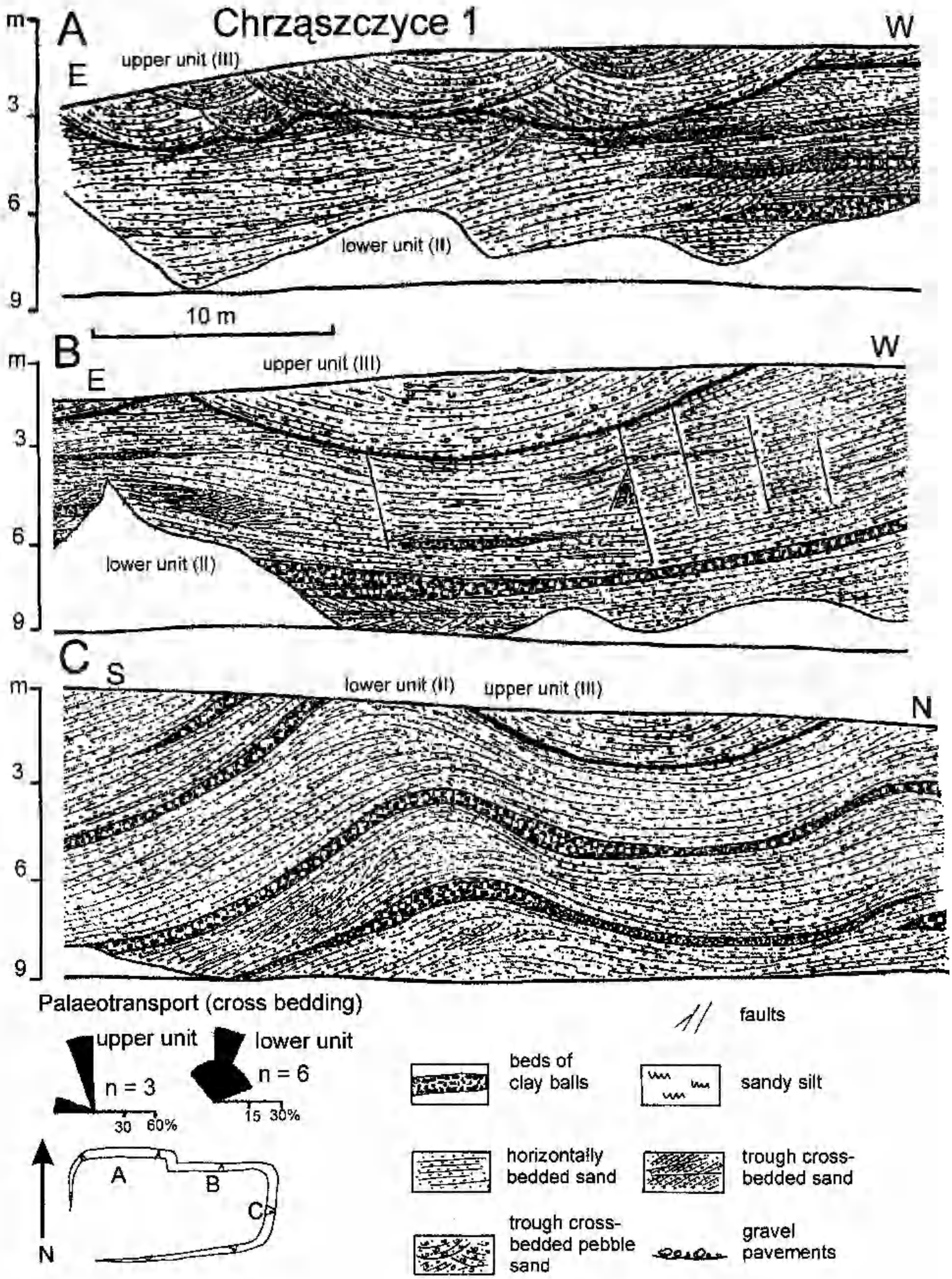

Fig. 15. A sequence of preglacial deposits at Chrząszczyce.

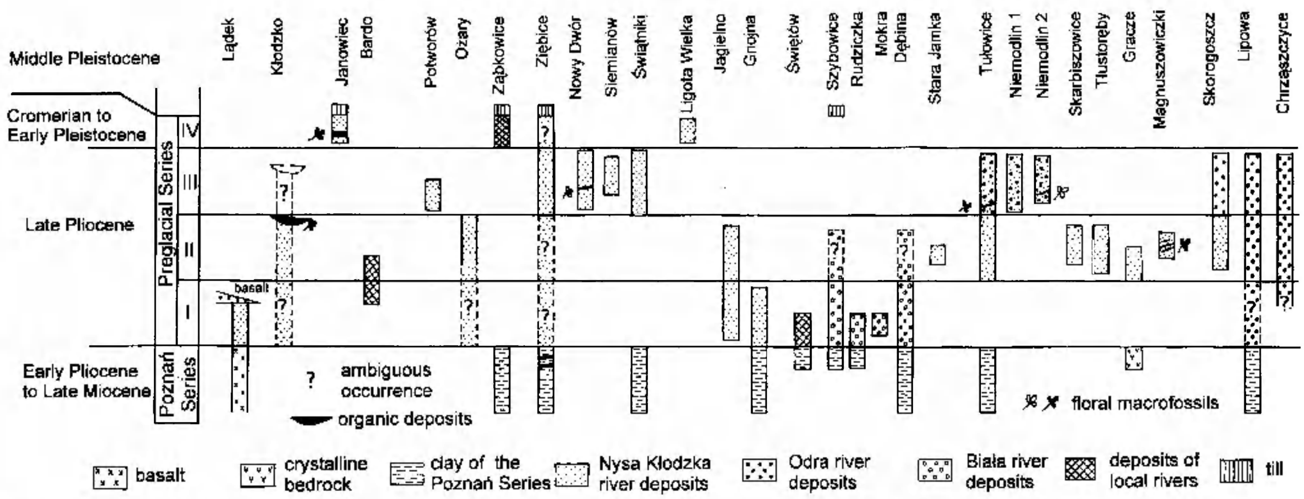

Fig. 16. Stratigraphic correlation of the preglacial deposits in the southern part of the Sudetic Foreland and adjacent regions.

The third one was said to be below the 'lower unit' of the sequence described here, and it contained similar lithofacies, but did not contained clayey silt beds. Indeed, the lowest part of the presented section has no clayey silt beds, but neither an erosional nor any other stratigraphically important boundary can be traced in the sediment sequence. August *et al.* (1995) interpreted all their three units as representing sinuous rivers, with the river of the two lower units having contained more material in suspension and probably having formed an extensive floodplain.

Petrographic data are only available from the coarse-grained upper unit. This unit has a very specific gravel assemblage, with practically only quartz (77–92%) and siliceous rocks (4–22%). This is not a sediment from the Nysa Kłodzka river system. The large siliceous rock content suggests an eastern source in the Carpathian Mts, and so the upper unit may have been deposited by the Odra river system. The heavy mineral contents of both units are similar (Fig. 11). Zircon and rutile are the main minerals (each about 20–30%), and they are associated with staurolite (5–15%) and garnet (10–30%). Other minerals are less common, except for biotite in one sample. This indicates that both the lower and upper units at Chrząszczyce were deposited by the same river system.

A similar sequence with a sandy lower unit and a gravelly upper unit has been documented from the Lipowa borehole, about 20 km to the northwest of Chrząszczyce (Fig. 1). This sequence may correlate with the Chrząszczyce profile, but the heavy mineral content is slightly different. The high amphibole and pyroxene content may have resulted from a drilling mud-fluid incorporation (Fig. 8), the rest of mineral assemblage is similar to that of the Chrząszczyce section.

Siemianów and Świątniki

These two sites are located near Jordanów Śląski, in the northwestern part of of the studied area, near the Mt. Ślęża massif (Fig. 1). They are described in detail by Krzyszkowski & Karanter (in press). Both sequences are garnet-dominated, with abundant staurolite and some zircon, tourmaline and rutile. The topmost part of the sequence, which contains practically only zircon and rutile, represents a weathering horizon. At Siemianów, two samples from gravelly beds mainly contained quartz (71–55%), siliceous rocks (4–20%), crystalline rocks (up to 1.5%) and porphyry (up to 3%). Siemianów and Świątniki represent the most northwestern sequences of the porphyry-bearing preglacial series of the Sudetic Foreland deposited by the Nysa Kłodzka river.

LITHOSTRATIGRAPHY, PALAEOTRANSPORT AND DEFORMATION OF FLUVIAL SEQUENCES

Recently, four stratigraphic units are postulated in the preglacial series of the Sudetic Foreland (Czerwonka, 1994, 1996; August *et al.*, 1995; Wojewoda *et al.*, 1995). In the studied area, only a few investigated sites contain sedimentary sequences which may, without any doubt, be separated into units of different age. These are sequences at Chrząszczyce, Skorogoszcz, Tułowice and Jagielno. Their subdivision reflects rapid changes in gravel and heavy mineral assemblages between the units supplemented by the occurrence of distinct erosional surfaces when they are present in the sequence.

At Chrząszczyce there are two units. Both are porphyry-free and were deposited by the same fluvial system. They are characterized by a gravel assemblage that only contains quartz and siliceous rocks, and has heavy mineral assemblage with garnet, zircon, tourmaline and rutile as the major minerals with staurolite as an important admixture. At Skorogoszcz, the porphyry-free unit is probably younger than the porphyry-bearing unit. A similar sequence is assumed to occur at Tułowice, although here

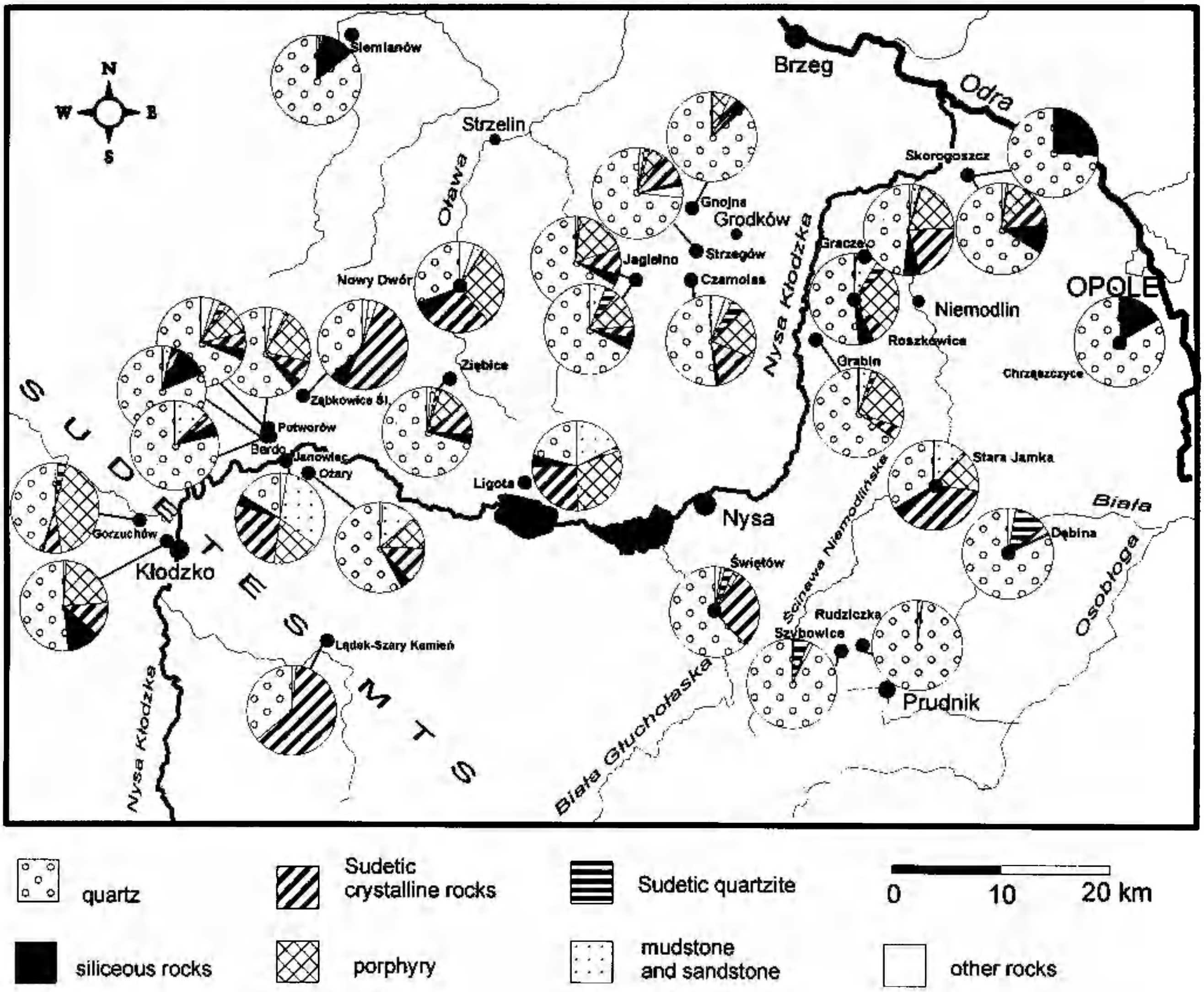

Fig. 17. Variations of the petrographic composition of the preglacial series in the southern part of the Sudetic Foreland and the adjacent regions.

subdivision is based only on heavy mineral changes. The upper unit contains significantly more zircon, tourmaline and rutile, and may correlate with the upper unit at Skorogoszcz. The lower unit at the Tulowice sequence is garnet dominated, and by analogy to the other garnet-dominated profiles described in this paper, probably represents a porphyry-bearing horizon. The Jagielno section contains two porphyry-bearing units that differ in their heavy mineral contents. The lower one has equal staurolite and garnet, and the upper one has dominant garnet.

When integrated, these data from Jagielno, Tułowice and Skorogoszcz show that in the central part of the studied area (the Grodków and Niemodlin Uplands) the preglacial series may be subdivided into three stratigraphic units: the oldest one porphyry-bearing with staurolite and garnet (series I), the next one porphyry-bearing and garnet-dominated (series II), and the uppermost one porphyry-free with increased zircon, tourmaline and rutile (series III). All these units contain a kaolin matrix, but their content of it is so variable that it cannot be used as a stratigraphic criterion. In other regions, the stratigraphic affiliation of the porphyry-bearing preglacial sequences is more difficult to establish, as they are mineralogically uniform, *i.e* they are only garnet-dominated. The other unit (IV), which does not generally contain a kaolin matrix, is characterized by more various, quartz-poor gravel assemblages and a significant amphibole content among the heavy minerals, and it can be divided out based on the sections at Ząbkowice Śląskie, Janowiec and Ligota Wielka. This unit probably represents the youngest stratigraphic unit of the preglacial series. However, this cannot be proved unambiguously, as all the studied sites, where it is present, lie in positions isolated from other preglacial units. If the 'brown gravels' of Ziębice represent the yougest preglacial unit (Table 2), this may prove the position of unit IV to be above the garnet-dominated sediments. Figure 16 presents the adopted lithostratigraphic correlation of the preglacial sediments in the sudied area. It should be taken as a first proposal, with wide scope for further changes.

The gravel assemblages in the studied sediments show that, in addition to those deposited by the Nysa Kłodzka river system, there are preglacial sequences deposited by some other rivers (Fig. 17, 18). They occur at the margins of the porphyry-bearing series and, in the eastern sector represented by the Odra river system (quartz, siliceous rocks; rich in zircon, tourmaline, rutile), the Biała Głuchołaska river system (quartz, quartzite; rich in staurolite and amphibole) and the unknown river system between Biała Głuchołaska and Nysa Kłodzka (quartz, crystalline rocks). In the western sector, there are two local rivers, one which deposits are characterized by quartz, crystalline and siliceous rocks (the Bardo boreholes, a small, local river) and the other one by quartz and Sowie Mts gneiss and heavy mineral assemblage with garnet and amphibole (possibly the Budzówka river system). However, the sediments of these river systems cover relatively small areas in contrast to the preglacial sediments of the Nysa Kłodzka river system, which are distributed over the a large zone in the Sudetic Foreland. This zone is about 5–10 km wide near the Sudetes Mts margin and widens to more than 60 km across on the northern margin of the Sudetic Foreland and adjacent Silesian Lowland (Fig. 17, 18). The lowest unit (I) of the porphyry-bearing series has a limited extent, which occupies the central part of the studied area (Fig. 19A), similarly to the extent of the preglacial series suggested by Wroński (1974). The next two units (II, III) of the porphyry-bearing series have very large N-S extent, from the Sudetes Mts margin to the northernmost regions of the studied area. However, these two units cannot be easily separated from each other using petrological criteria and this creates problem with the interpretation of their W–E distribution. Unit III appears to have a more limited extent in the eastern sector as the garnet-dominated series is replaced here by the series rich in zircon, tourmaline and rutile. Consequently the younger unit has been placed in the western sector, along the Oława river valley (Fig. 19B and C). The youngest unit (IV) has a limited extent, that is restricted to the zone adjacent to the Sudetes Mts margin (Fig. 19D).

The sedimentary sequences of the preglacial series of the Sudetic Foreland were deformed. Two probable deforming agents can be distinguished: neotectonic large-scale uplift and local glaciotectonic thrusting and folding. The neotectonic movements that uplifted or lowered different fragments of the preglacial series were formerly described by Wroński (1974, 1975). He found that the amplitude of these neotectonic movements reached up to 90 m. Recent study allows more precise discussion, as more sites are available. The analysis takes into account the positions of the base and top of the series deposited by the Nysa Kłodzka and Biała Głuchołaska river systems (Fig. 20). It is clear that both analysed surfaces show similar trends, being inclined to the N and NE and forming three distinct segments. Two segments are characterised by generally moderately inclined surfaces (0.1–0.4%), that suggest either an original fluvial surface of a mountainous river or only slight steepening of the longitudinal profiles. In contrast, the zone between them is characterised by very steeply inclined surfaces which have a gradient of 0.5–1.0%. Such inclined surfaces (Fig. 20, 21) cannot be formed due to fluvial processes, and so this zone may represent the zone of tectonic uplift, the more so as it correlates in part with the Niemcza–Strzelin horst. The uplift, probably, took place along the fault zone separating the Sudetic Foreland from the Silesian Lowland and its total value varies from 40 to 80 m (Fig. 19, 20, 21). Minor deflections in the moderately inclined segments may reflect local movements within tectonic blocks, especially those adjacent to the Sudetes Mts as the Paczków Graben, the Kamieniec Ząbkowicki horst and the Ząbkowice Sląskie Trough (Fig.19, 20, 21). The resultant vertical amplitude of movements in these blocks is only 10–15 m.

Glaciotectonic deformation structures occur locally. The sequences at three sections: Siemianów, Skorogoszcz and Ligota Wielka, are strongly deformed, with distinct thrusts and overturned or inclined folds. Several other sites, such as Chrząszczyce, Tułowice, Skarbiszowice, Magnuszowiczki and Ząbkowice Śląskie are only slightly folded. These glaciotectonic structures have different orientations that do not form any consistent pattern of deforming forces and directions of ice-movements.

AGE OF DEPOSITS

PALYNOLOGICAL RESEARCH

Palynological dating of the preglacial deposits is available from a few sections. Its lower age boundary is documented from Gnojna, where palynological studies have been done in the the uppermost member of the Poznań Series which underlies the unit I (Sadowska, 1985; Badura *et al.*, 1998a). Early Pliocene flora, which is very similar to flora at Sośnica was found (Sadowska, 1985, 1992; Stachurska *et al.*, 1973). Another profile on which palynological research was done was described from Kłodzko in the Sudetes Mts (Fig. 1) (Jahn *et al.*, 1984). The organic bed was found at the top of the preglacial series that may represent unit II and/or III (Krzyszkowski *et al.*, 1998). Its age has been estimated as Late Pliocene (Reuverian) (Jahn *et al.*, 1984; Sadowska, 1995).

Several profiles of the preglacial series in the studied area contained silt/clay beds, but most of them do not contain pollen. The best profile from this point of view is at Tułowice. The upper unit (III) of this sequence contains numerous clay beds, and one of them includes 15 cm of black, organic mud. Ten samples have been investigated, five from this organic mud (no. 3–7), and the other five from the adjacent grey clay (no. 1–2, 8–10) (Table 3). All ten samples are characterised by a low frequency of sporomorphs, with extremely low frequency in samples 1, 9 and 10. The latter contained only 4–9 pollen grains of *Pinus sylvestris*, *Betula* and Polypodiaceae. The other samples (2–8) are characterised by a more complex pollen spectrum, with mainly coniferous trees, where *Pinus t. sylvestris* is

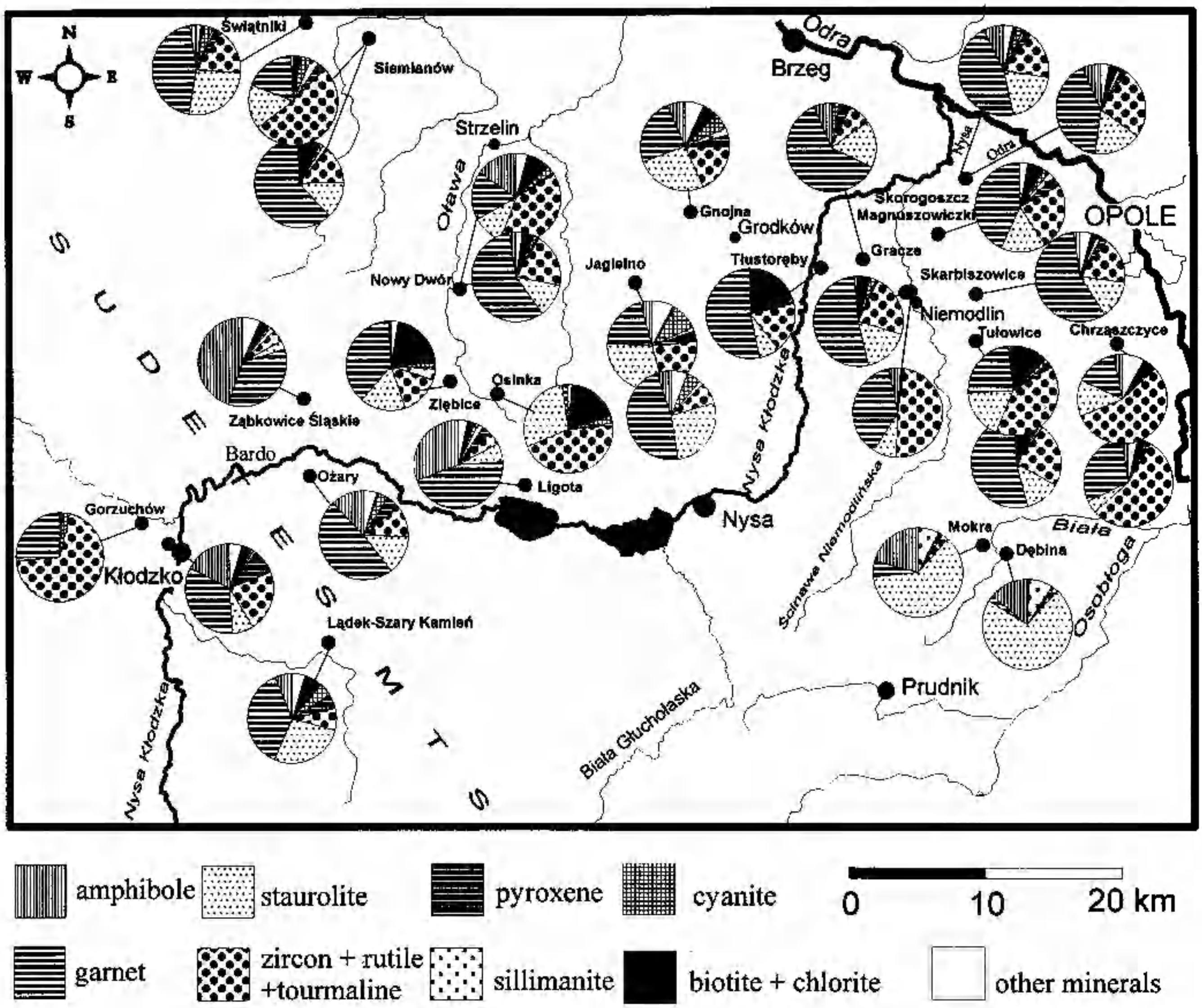

Fig. 18. Heavy mineral content of the preglacial series in the southern part of the Sudetic Foreland and the adjacent regions. Note variable heavy mineral assemblages at Jagielno, Skorogoszcz, Tułowice and Chrząszczyce, which follow changes in fluvial pattern and stratigraphy, and similar variations at Nowy Dwór and Siemianów, which are caused due to wheathering of the topmost part of the sequences.

more abundant than *Pinus t. haploxylon*. Other conifers, such as *Picea*, *Abies*, Taxodiaceae–Cupressaeae and *Tsuga* are less common. Among deciduous trees *Betula*, *Alnus*, *Ulmus*, *Pterocarya*, *Ilex*, *Liquidambar* and *Fagus* are relatively more common, whereas *Myrica*, *Tilia*, *Celtis*, *Carya* and *Tricolporopollenites edmundi* occur sporadically (Table 3). Herbaceous plants are only represented by Polypodiaceae and Dinophlagellatae, which occur in almost all the samples, along with single grains of Ericaceae, Compositae and Monocotyledons.

The age of the flora at Tułowice cannot be precisely established. The low frequency of sporomorphs and low number of species do not allow any floristic reconstruction. Most of the pollen is of Tertiary age, and some are characteristic also for Pliocene flora (*Pinus t. haploxylon*, *Tsuga*, *Liquidambar*, *Carya*, *Ilex*, *Pterocarya*), but there are also some older, Palaeogene or Cretaceous pollen (*Nudopolis*) and marine Dinophlagellatae. Thus it seems that the pollen flora at Tułowice represents a redeposited material that contains both Neogene and older pollen.

FLORAL MACROFOSSILS

Floral macrofossils have been documented in the Poznań Series at Ziębice (Jentzsch & Berg, 1913; Friedensburg, 1914; Frech, 1915; Kräusel, 1919) and Gnojna (Krajewska, 1996), in both cases Late Miocene and/or Miocene/Pliocene in age. Late Pliocene fruits and seeds have also been documented in the preglacial series at Klodzko (Jahn *et al.*, 1984). More recently, numerous leaf impressions have been found in the preglacial series in the studied region. There are badly preserved impressions at Nowy Dwór and Niemodlin 2, and better preserved material has been collected from Magnuszowiczki and Tułowice. The latter profile is very rich in leaf impressions, which occur in the

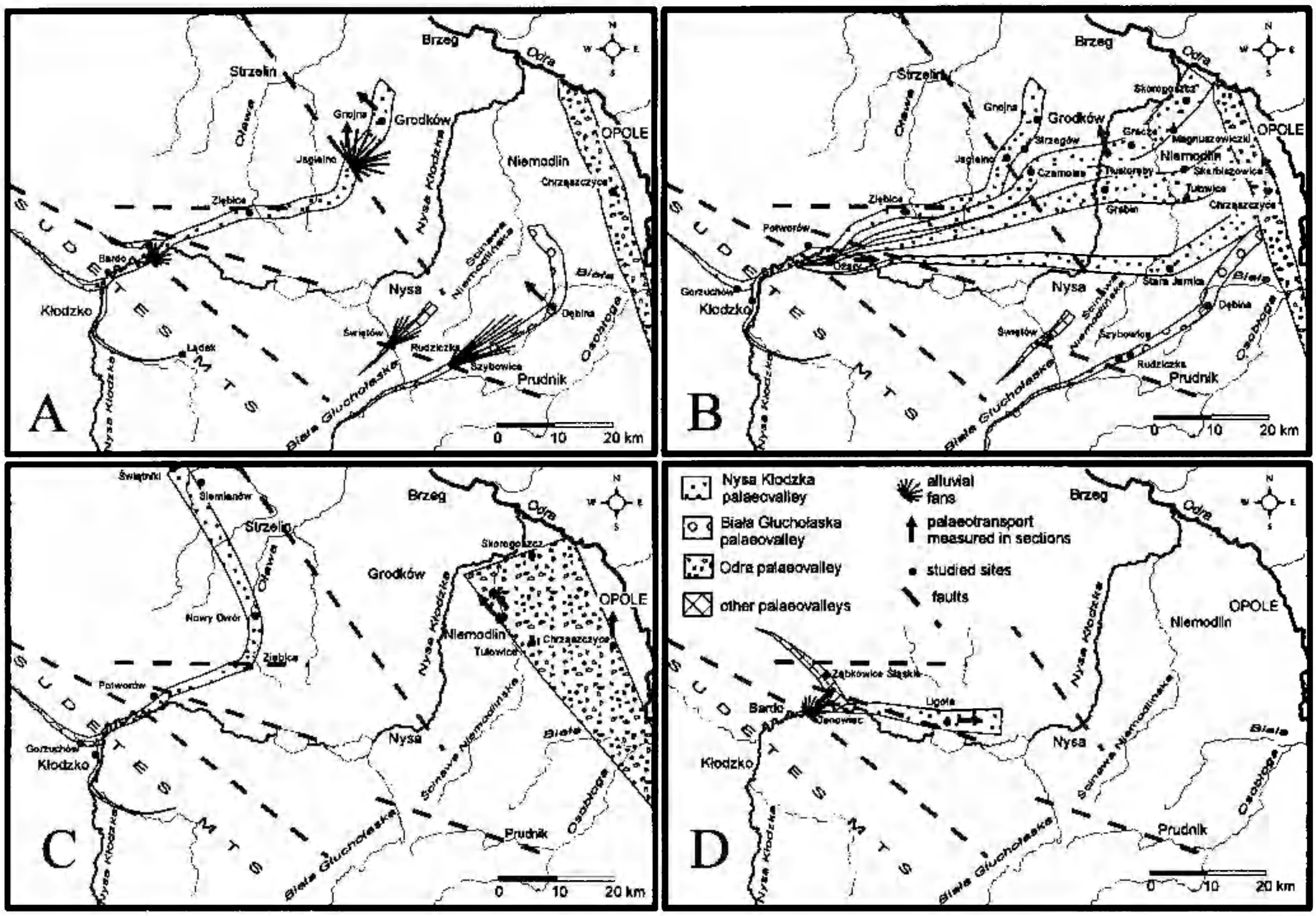

Fig. 19. The preglacial fluvial pattern of the southern part of the Sudetic Foreland and adjacent regions and its evolution during the Pliocene (A–C) and Early Pleistocene (D):

clayey bed which was investigated palynologically.

The investigated material contains 70 specimens from Tulowice, which contained about 80 fragments of floral remains, and 19 specimens from Magnuszowiczki which contained about 25 fragments of floral remains The material was prepared with scalpel, preparation needle and brush. The floral remains are mainly badly preserved impressions of leaves of trees and shrubs. There are no fruits or seeds at all. The specimens do not contain organic matter, and they are the same colour as the sediment. The state of venation preservation is variable, depending on the type of deposit. Most often, 1st and 2nd order venation has been preserved, while 3rd and greater order venation preservation is rarer. The leaf margins are usually badly damaged. This analysis was only based on morphological features, as cuticular analysis was impossible.

The leaf flora at Tulowice is taxonomically homogenous; it practically only includes leaves of bicotyledons, along with also one shoot of a monocotyledon (*Monocotyledones gen. et sp. indet.*), three needles and one shoot of Taxodiaceae (*Taxodium vel Sequoia*). Betulaceae are the most common (25 specimens), with leaves of *Betula* (*B. cf subpubescens Goepp.*), *Carpinus grandis Ung. Emend. Heer.* and *Alnus sp.*, and Ulmaceae: *U. pyramidalis Goepp.* (12 specimens) and *U. minuta Goepp. sensu Knobloch* (1 specimen). Leaves of Fagaceae (*Fagus silesiaca Walther & Zastawniak*, 6 specimens), Aceraceae (*A. quercifolium (Goepp.) Kovar-Eder*, 2 specimens; *A. obtusilobum Unger f. Obtusilobum Prochazka & Buzek*, 3 specimens), Salicaceae (*Populus sp. cf. P. balsamoides Goepp.*, 7 specimens, *cf. Salix sp.*, 1 specimen), Hamamelidaceae (*Parrotia pristina (Ett.) Stur*, 4 specimens) and Altingiaceae (*Liquidambar europaea A.Br.*, 2 specimens) are much less common. One leaf fragment of Juglandaceae and another one of Myricaceae (*cf. Myrica sp.*) have also been found.

At Magnuszowiczki only bicotyledons have been found, with examples of Aceraceae, Betulaceae, Fagaceae, Juglandaceae, ? Platanaceae and Salicaceae present. This flora is badly preserved, with only single specimens of *Parrotia pristina (Ett.) Stur*, *Fagus silesiaca Walther & Zastawniak*, *cf. Juglans acuminata A.Br ex Unger*, *Alnus alnoidea (Mentzel) Knobloch*, *Platanus sp.* and *Acer sp.*, along with five specimens of *Populus sp. cf. balsamoides Goepp.*, 4 specimens of *Betulaceae gen. et sp. indet.* and 2 specimens of *Juglandaceae gen. et.sp. indet.*

All the taxons documented at Tulowice and Magnuszowiczki belong to arcto-tertiary plant communities, and there is a complete lack of paleotropical elements, which suggests rather temperate climatic conditions. It seems that two plant communities developed during sedi-

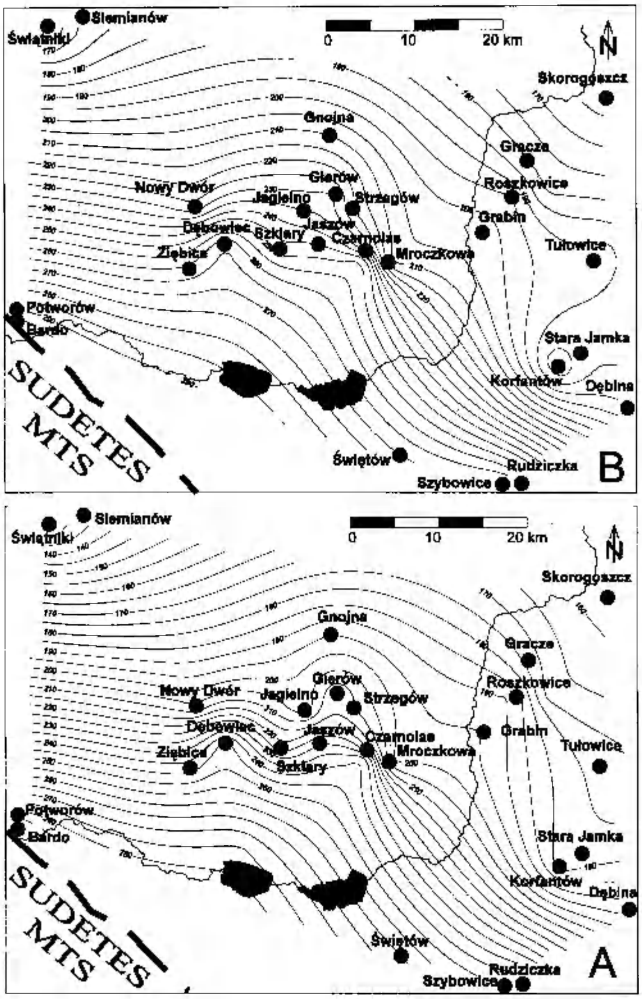

Fig. 20. Position of the base (A) and top (B) surfaces of the units I–III of the preglacial series in the southern part of the Sudetic Foreland and the adjacent regions. The isohypses are in metres a.s.l. and were interpolated using only outcrops and boreholes with the documented base of the preglacial series by kriging method.

ment deposition, one of mesophilous, deciduous forests and another one of swamp forests. The age of the described floras is ambiguous. Most of the taxons have a very wide stratigraphic occurrence, from the Palaeogene to the Pliocene. However, the complete lack of palaeotropical elements suggests an age of at least Late Miocene. On the other hand, the lack of recently growing species, which are characteristic for the Pliocene, suggests that flora at Tułowice and Magnuszowiczki is not older than the Late Pliocene. It is possible that the flora under discussion represents the Late Miocene to Miocene/Pliocene, especially as it resembles the leaf flora at Gnojna and Sośnica (Goeppert, 1855; Kräusel, 1919, 1920; Lańcucka-Środoniowa, *et al.*, 1981; Krajewska, 1996).

PALAEOMAGNETIC RESEARCH

The preglacial series is underlain by basaltic lavas (basalt, basanite, nephelinite) at Gracze and it is overlain by basanite lava at Lądek (Krzyszkowski *et al.*, 1998). Both lavas showed normal magnetization (Birkenmajer *at al.*, 1970, 1977). The Lądek lava may be interpreted as representing the Late Pliocene (Gauss epoch) (Birkenmajer *et al.*, 1970). The basaltic lavas from Gracze are, most probably, of Miocene age; more precise dating is impossible (Birkenmajer, 1974).

DISCUSSION AND PALAEOGEOGRAPHIC RECONSTRUCTION

From the above it follows that the preglacial series in the southern part of the Sudetic Foreland is not older than the Early Pliocene. The upper age boundary is less precisely established. The kaolin-rich units in the Sudetes Mts are not younger than the Late Pliocene, as indicated by the Reuverian flora at Klodzko and basanite lava at Lądek. This may also be true for the sequences in the Sudetic Foreland, although here the assumed position of the Reuverian horizon is either at the top of unit II or at the top of unit III. The pollen and leaf flora found in the deposits of unit III at Tułowice at least in part represent redeposited material and cannot be used for precise dating. The preglacial sediments of units I–III consists of strongly reworked, quartz-rich material and a kaolin matrix, that probably came from Tertiary weathering mantles of the Sudetes Mts. The kaolin-free deposits of unit IV are undoubtedly older than the oldest glaciation in the region, *i.e.* older than the Elsterian, as documented at Janowiec and Ząbkowice Śląskie. Unit IV was probably deposited during the Early Pleistocene and/or Cromerian stage (Krzyszkowski *et al.*, 1998).

The subdivision of the preglacial deposits into four units has some restrictions, particularly due to the small difference between units II and III in the porphyry-bearing series (Fig. 16). These two units are often arbitrally defined, based on the fact that the porphyry-bearing series at Tulowice (II) is overlain by the series with a large amount of zircon, tourmaline and rutile (III). Consequently, a similar dual subdivision of the porphyry-bearing series is anticipated in the western zone, even if unit III does not differ petrologically from unit II. The large amount of zircon, tourmaline and rutile in the eastern sector of the studied area has been interpreted as an admixture of material from the Odra river system on the basis of data from the Chrząszczyce profile, where these minerals dominate throughout the sequence, including both the II and III unit. However, many profiles in the western sector, such as Osinka, Nowy Dwór and Siemianów, also show a strong increase of these minerals in their uppermost parts. Here, they are interpreted as a result of the weathering of exposed fluvial deposits causing relative increase of resistant minerals.

In spite of the restrictions listed above, the reconstruction of the fluvial history of the studied area can be presented in four age horizons, that follow the four lithostratigraphic units of the preglacial series (Fig. 19). The porphyry-bearing sediments of unit I are exposed only in the Sudetes Mts (Lądek) and in the Silesian Lowland (Grod-

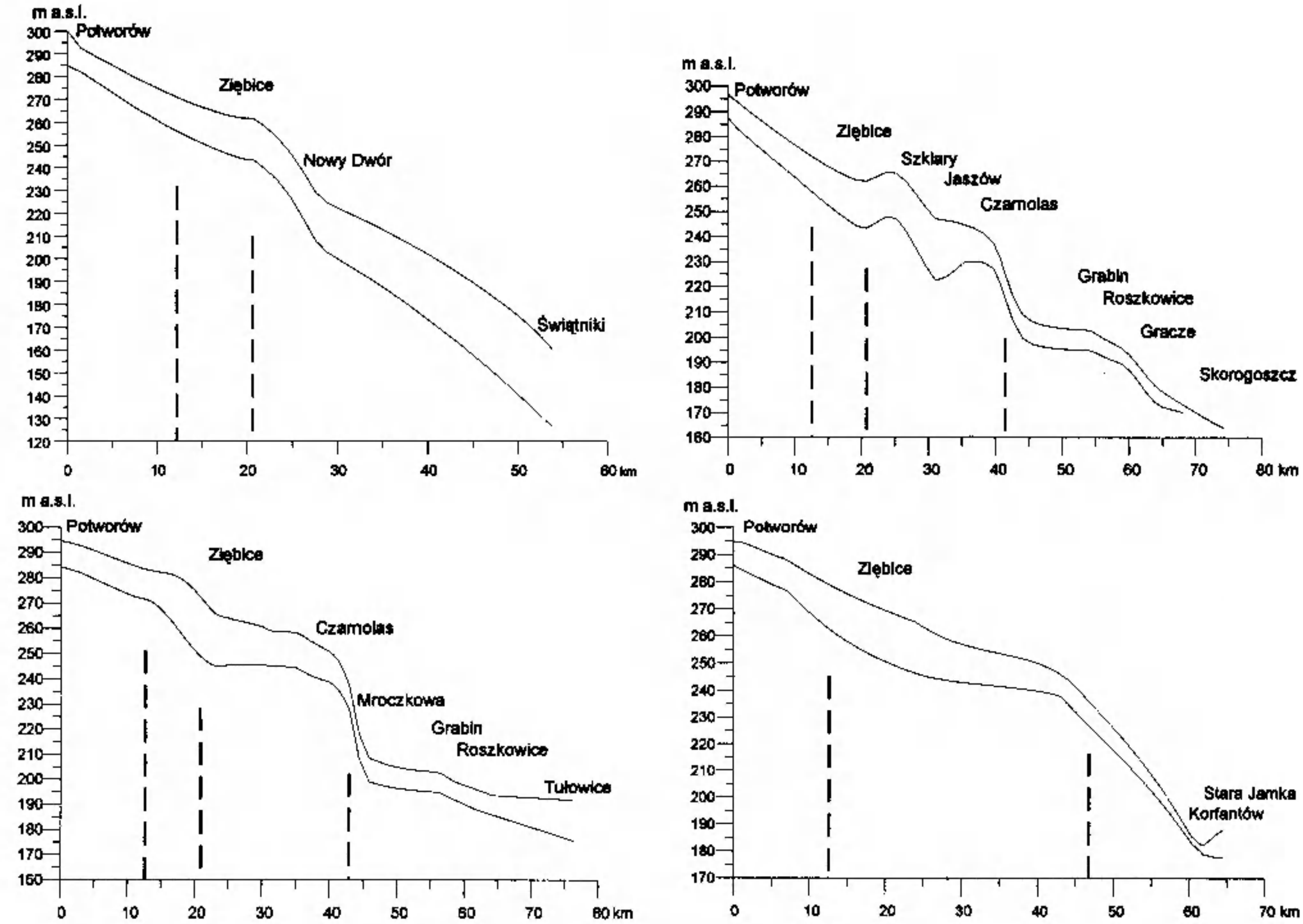

Fig. 21. Deformation of longitudinal profiles of the base and top surfaces of the units I–III of the preglacial series; compare with Fig. 20. Profiles are located along the main river courses, as shown in Fig. 19.

ków Upland) (Fig. 19A). In between these two location, these sediments are probably buried below the younger units, and have been not exposed in shallow outcrops. The Nysa Kłodzka river sediments of unit I are coarse-grained gravels or sand with gravels. The fluvial sequences represent either alluvial fan (Jagielno) or channelized, high energy river sediments (Gnojna, Jagielno). A local alluvial fan may have been created near Jagielno at the scarp formed by the fault separating the Sudetic Foreland from the Silesian Lowland (Fig. 19A). Unit I of the Biala Glucholaska river at Dębina is also coarse-grained and gravel-rich. It seems that the Sudetic Foreland was tectonically active during the deposition of unit I. This conclusion is based on the high energy of rivers down to the Silesian Lowland, 40–60 km away from the Sudetes Mts margin, and on the presence of the fault scarp between the Sudetic Forland and the Silesian Lowland. This fault generated local fan (Jagielno) and distinct deflection of river valley along the fault line (Fig. 19A). Local fans could have existed that time also along the Sudetes Mts margin.

Unit II is the most widespread in the Sudetic Foreland. Its sedimentary sequences are usually fine-grained, with dominant sand in sections other than those near the mountain margin (Ożary, Ziębice). Gravel-load, high energy rivers only occurred within a 30 km belt adjacent to the mountainous region. Further to the north only sinuous to meandering rivers with high suspension load occurred. The fluvial pattern included the Odra river system in the most eastern sector (Chrząszczyce), possibly also the Biala Glucholaska river system in the south, and the Nysa Kłodzka river system. The last was quite complex, as the porphyry-bearing deposits indicate a fan-like distribution (Fig. 19B). This was presumably formed by migration of the river from its primary, W–E stretching valley (Ożary–Stara Jamka) located along the Paczków Graben, to the northeast, north and northwest (Fig. 19B). It is possible that when the Nysa Kłodzka river migrated to a position similar to that of unit I (Jagielno), the Odra river could migrate more to the west, reaching Lipowa and Skorogoszcz for the first time (Fig. 19B). The sinistral migration of the Nysa Kłodzka river valley during deposition of unit II may reflect some tectonic fault activity, although it can be also explained by a shifting of the river course by another large river (Odra river).

Unit III probably records the renewed stronger tectonic activity in the Sudetic Foreland. The Nysa Kłodzka river was diverted into the Olawa river valley, and the position of this new valley was strongly dependent on bedrock outcrops. Simultaneously, the Odra river valley extented more to the west, flowing more or less parallel to the presnt-day Odra river (Fig. 19C). The sediments of unit III of the Odra river system are coarser than those of

Table 3
Absolute content of sporomorphs in samples from Tułowice section

Samples:	1	2	3	4	5	6	7	8	9	10
Pinus sylvestris	2	21	14	18	19	15	4	13	2	1
Pinus haploxylon		13	2	3	3	3	1	4	1	
Picea					5	1				
Albies					3			1		
Taxodiaceae-Cupressaceae		1			1		1		1	
Tsuga		1	1				1	1	1	
Betula		1	1	1	1	1				
Alnus		1	3							
Myrica							1			
Corylus					1		1			
Quercus		1								
Fagus				1	1		1			
Ulmus		1		1	1			1		
Tilia					1		1			
Celtis								1	1	
Ilex		1			2			2		
Carya					1		1			
Pterocarya			1		1		3			
Liquidambar				1			1	1		
Tricolporopollenites edmundi								1		
Ericaceae								1		
Compositae								1		
Monocotyledones	1	4	2							2
Polypodiaceae	2	3		3	1			2		1
Nudopolis	1									
unrecognised Palaeogene forms	3						2			
Dinophlagellate		9	1	3		1	1	1		
Σ	9	57	25	31	41	21	19	30	6	4

unit II at Chrząszczyce and Skorogoszcz, probably reflecting the larger energy of the river, but in the other sequences, both representing the Odra and Nysa Kłodzka river systems, the sedimentary environments are similar to those of unit II.

Unit IV of the preglacial series reflects a major change in the landscape, which was probably caused by the uplift of the Sudetes Mts. Krzyszkowski *et al.* (1998) and Krzyszkowski & Biernat (1998) suggest at least a 60–70 m uplift along the Sudetic Marginal Fault during the Early Pleistocene. In the studied area, these tectonic movements strongly deformed the fluvial beds of units I–III (Fig. 20, 21), with local vertical displacements of sediments of 40–80 m. As a consequence, new valleys were formed, partly incised into older sediments (Janowiec) and partly superposed on them (Ziębice, Ligota Wielka?) (Fig. 21D). The sediments of unit IV were deposited in high energy, gravel-load rivers. They at least in part were cut into fresh bedrock, as local rocks dominate over quartz (Krzyszkowski *et al.*, 1998).

CONCLUSIONS

1. The preglacial series deposited by the Nysa Kłodzka river has a much wider extent in the Sudetic Foreland than hitherto supposed. It can be found from the 5–10 km wide belt near the Sudetes Mts. margin to the over 60 km wide belt in the outer part of the Sudetic Foreland and the adjacent part of the Silesian Lowland.

2. This series was deposited during four episodes as indicated by the four lithostratigraphic units (I–IV). These units usually differ one from another in their heavy mineral content, although all of them are porpyry-bearing. The porphyry-free sediments, deposited by other river systems of the Sudetic Foreland, occur at the margins of the porpyry-bearing series, or in part overlie it.

3. Units I–III were mainly deposited by low energy, sinuous, suspended-load rivers and only locally by gravel-load, high energy rivers. The preglacial sediments of units I–III comprise strongly re-worked, quartz-rich material and some kaolin matrix, that most probably come from the Tertiary weathering mantles of the Sudetes Mts. The fluvial sequences were deposited by rivers with widely migrating valleys, a situation probably caused by the tectonic activity of some faults in the region.

4. Unit IV was deposited by high energy, bed-load rivers that were formed during the general landscape reorganisation caused by strong regional tectonic uplift. The new valleys were incised which provided local, kaolin-free material eroded directly from the fresh bedrock. The amplitude of these vertical tectonic movements in the Sudetic Foreland was at that time about 40–80 m, with simultaneous uplift of the adjacent part of the Sudetes Mts. about 60–70 m.

5. Units I–III are most probably of Late Pliocene age, whereas unit IV could have been deposited during the Early Pleistocene or the Cromerian age.

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