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Till stratigraphy and petrography of the northern part of Silesia (southwestern Poland)

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Almost 40 borings have been investigated in northern Silesia (Głogów–Międzybórz region). Eight till horizons, which differ in petrographic composition, have been recognized here. Five of them have been easily correlated by means of petrographic features with tills described previously from the Silesian Lowland and central Great Poland Lowland. These are: Grońsko, Krzesinki, Wierzbno, Smolna/Dopiewiec and Górzno Tills. Other three occur locally. Four tills have been deposited during the Elsterian Stage, where the Grońsko Till represents the early and the Krzesinki Till the Middle Elsterian ice-advance. The latter formed its marginal zone in the region investigated, most probably along the present-day Silesian Rampart. The Wierzbno and Borowiec Tills represent the Late Elsterian ice-advance. They differ in petrographic composition and indicate different geographical distribution. The newly defined Borowiec Till is characterized by large content of Baltic limestones and in its upper part also dolomite. Another four tills have been deposited during the Saalian Stage. The Smolna/Dopiewiec Till represent the Early Saalian ice-advance (Odranian). The local Naratów and Taczów Tills were formed during the Middle Saalian (Early Wartanian) ice-advance and they are equivalent to each other, occurring in different regions: the first one at Leszno Upland and the second along the Silesian Rampart and the Barycz River valley. They differ little in petrographic composition, mainly by dolomite content. The Górzno Till represents the Late Saalian (Late Wartanian) ice-sheet advance. Both Wartanian ice-sheets formed ice-marginal zones in the region investigated: the early one at the axis of Silesian Rampart and the late one probably at Krotoszyn–Wąsosz Hills being northwards.

Besides tills, several fluvial series have been documented. The "pyroxene" series indicates ambiguous stratigraphic position, though it is known from surrounding regions as the Elsterian interstadial series. Also, the fluvial series from the Pilica Interstadial (Odranian/Wartanian) has been documented as well as fluvial series from the Early Eemian and Middle Weichselian. The latter is the most widespread and most thick fluvial deposit in the region, reaching thickness up to 50 m. Additionally, several Eemian lacustrine sites are present, in part palynologically investigated.

The northern Silesia has a complex Quaternary geology, where different regions, although indicating similar stratigraphic assemblages, represent various structural characteristics. Three sub-regions are discussed in the paper: the southern part of the Leszno Upland, the depressions along the Barycz River and a part of the Silesian Rampart (Dalków and Trzebnica Hills).

INTRODUCTION

Fine gravel petrographic analysis of tills has been introduced in Poland in late fifties (B. Krygowski, 1956), although the methodology of till petrographic studies, which has been used until recent, comes only from sixties (J. Trembaczowski, 1961, 1967; R. Racinowski, 1969; R. Racinowski, J. Rzechowski, 1969). The 5–10 mm gravel fraction has been introduced as a standard. Gravel counting includes two main groups of rocks: northern and local ones, where the latter come from the South Baltic Basin and Polish Lowlands. The northern rocks have been grouped into Scandinavian crystalline rocks [K], sedimentary rocks [O], carbonate rocks [W] including the Palaeozoic limestones (Wp) and dolomites (Dp), and in other classification into resistant [B] and non-resistant [A] rocks. Several coefficients as K/W, O/K, A/B and Dp/Wp have been introduced for further interpretation. The methodological approach has remained finished when the coefficients became graphically presented in late seventies (J. A. Czerwonka, B. Witek, 1977; J. Rzechowski, 1977).

A major part of the early till petrographic studies comes from Eastern Poland (J. Trembaczowski, 1961; J. E. Mojski, J. Rzechowski, 1967, 1969; R. Racinowski, 1969; R. Racinowski, J. Rzechowski, 1969; J. Rzechowski, 1974, 1980),

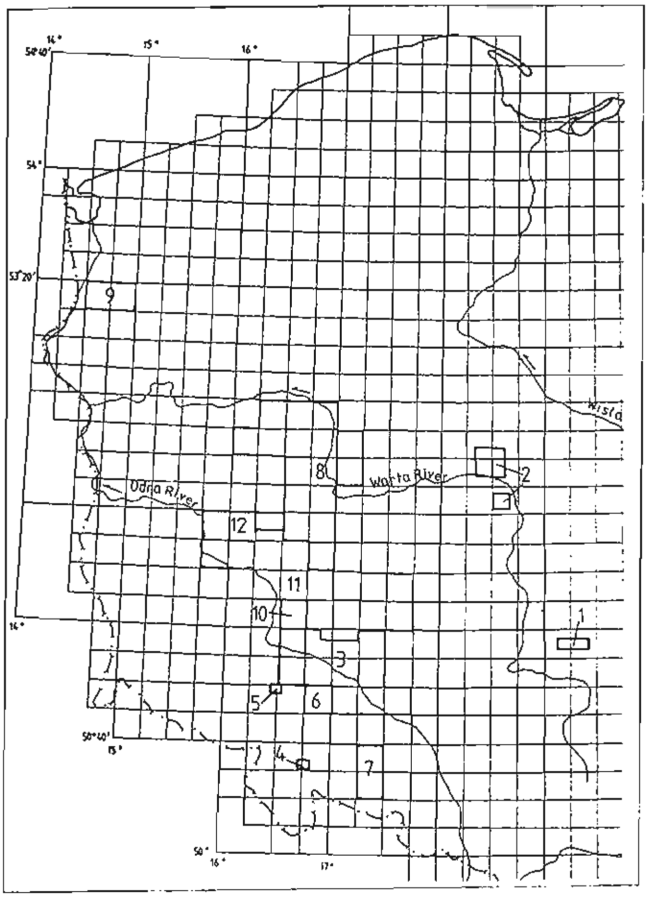


Fig. 1. Till investigations in Western Poland: distribution of regions and sites published since 1990

1 — Bełchatów outcrop (J. A. Czerwonka, D. Krzyszkowski, 1990, 1992*a*); 2 — Konin outcrops (W. Stankowski, D. Krzyszkowski, 1991); 3 — Silesian Lowland (J. A. Czerwonka, D. Krzyszkowski, 1992*b*); 4 — Ząbkowice outcrop (J. Badura *et al.*, 1992); 5 — Jaroszów outcrops (D. Krzyszkowski, A. Czech, 1995); 6 — Jordanów region (D. Krzyszkowski, M. Karanter, in press); 7 — Skoroszyce–Nysa region (J. Badura, B. Przybylski, 1996); 8 — central Great Poland (J. A. Czerwonka, D. Krzyszkowski, 1994); 9 — Szczecin region (D. Krzyszkowski, J. A. Czerwonka, 1994); 10 — Wołów region (J. A. Czerwonka *et al.*, 1991; D. Krzyszkowski *et al.*, 1994); 11 — northern Silesia (J. A. Czerwonka *et al.*, present paper); 12 — Sława Śląska–Włoszakowice region (D. Krzyszkowski *et al.*, in preparation)

Badania glin lodowcowych w zachodniej Polsce: rozmieszezenie regionów i stanowisk opublikowanych od 1990 r.

with some works from central Poland (J. Trembaczowski, 1967; J. Rzechowski, 1971, 1976, 1977, 1982; W. Stankowski, 1976) and only few works from Western Poland (B. Witek, J. A. Czerwonka, 1976; J. A. Czerwonka, B. Witek, 1977; J. Rzechowski, 1980). Results of till petrographic studies from Western Poland have been published systematically since 1991, at first from large brown coal mines at Bełchatów (J. A. Czerwonka, D. Krzyszkowski, 1990, 1992*a*; D. Krzyszkowski, J. A. Czerwonka, 1992) and Konin (W. Stankowski, D. Krzyszkowski, 1991) and then from Silesia (southwestern Poland) (J. A. Czerwonka, D. Krzyszkowski, 1992*b*; D. Krzyszkowski, 1992*a*; J. Badura *et al.*, 1992; D. Krzyszkowski, A. Czech, 1995; J. Badura, B. Przybylski, 1996; D. Krzyszkowski, M. Karanter, in press), central Great Poland Lowland (central-western Poland) (K. Choma-Moryl *et al.*, 1991; W. Gogołek, 1991*a*, *b*; J. A. Czerwonka, D. Krzyszkowski, 1994) and northwestern Poland (D. Krzyszkowski, J. A. Czerwonka, 1994). Almost all these published materials come from borings which have been drilled during the mapping project of the *Detailed Geological Map of Poland* 1:50 000, except D. Krzyszkowski (1992*b*), J. Badura *et al.* (1992) and D. Krzyszkowski, A. Czech (1995), which were based on till outcrops. Figure 1 presents the geographical distribution of investigated sites and regions.

This paper presents till petrographic studies from borings located basicaly in the northern part of Silesia and, in part, in the southernmost Great Poland (Figs. 2, 3). They have been investigated since late seventies, within the following sheets of the *Detailed Geological Map of Poland* 1:50 000 (Figs. 2, 3): Rudna (J. A. Czerwonka, 1978), Głogów (J. A. Czerwonka, 1981), Oborniki Śląskie (J. A. Czerwonka, T. Dobosz, 1981), Trzebnica (J. A. Czerwonka, 1982), Czeszów, Twardogóra (T. Dobosz, B. Skawińska-Dobosz, 1990), Rawicz (T. Dobosz, 1991), Żmigród (J. A. Czerwonka, 1991), Międzybórz (T. Dobosz, 1993), Milicz, Odolanów (T. Dobosz, 1994*a*), Święciechowa (T. Dobosz, 1994*b*), Bytom Odrzański (J. A. Czerwonka *et al.*, 1994*a*), Wschowa, Szlichtyngowa (J. A. Czerwonka, 1995), Wąsosz, Góra (T. Dobosz, 1996). The presented analysis includes also some previously published data from the Wołów (J. A. Czerwonka *et al.*, 1991; D. Krzyszkowski *et al.*, 1994) and Trzebnica vicinity (D. Krzyszkowski, 1992*a*, 1993). Additionally, some data from the marginal zone of the last glaciation between Sława Śląska and Włoszakowice are discussed here (D. Krzyszkowski, 1992*b*; T. Dobosz, 1994*b*), which will be published separately (D. Krzyszkowski *et al.*, in preparation). The materials discussed in the paper are intended to fill the gap of the knowledge of till properties in the area between formerly investigated regions: central part of the Silesian Lowland (J. A. Czerwonka, D. Krzyszkowski, 1992*b*) and central Great Poland (J. A. Czerwonka, D. Krzyszkowski, 1994). Altogether, all these areas give the almost 200 km long and 50–100 km wide zone with continuous till petrographic investigations, that have been made in one laboratory (Proxima S.A., Wrocław) (Fig. 1). Undoubtedly, this may be of a great value in further works on Pleistocene stratigraphy and correlations. Besides the tills, only deposits important for stratigraphic interpretation are described and discussed in the paper, such as fluvial (interstadial or interglacial one) and organic/lacustrine interglacial deposits. Also, the stratigraphic discussion on Tertiary deposits is excluded from discussion and only their position in relation to Quaternary sequences is presented.

The region recently investigated lies entirely south of the marginal zone of the last glaciation (Figs. 2, 3). It is composed of three distinctly different geomorphological zones, which also differ much in Quaternary geology. These are: moraine plateau formed during the Saalian in the north (western and southern part of the Leszno Upland, southwestern part of the Kalisz Upland); central sub-region, dominated by fluviatile morphology and sediments, and including the Głogów Pradolina, the Żmigród Basin and the Milicz Basin, all occupied recently by the Barycz River valley; and the glaciotectonic hills of the Silesian Rampart in the south (eastern part of the Dalków Hills, Trzebnica Hills and Twardogóra Hills) (Fig. 2).

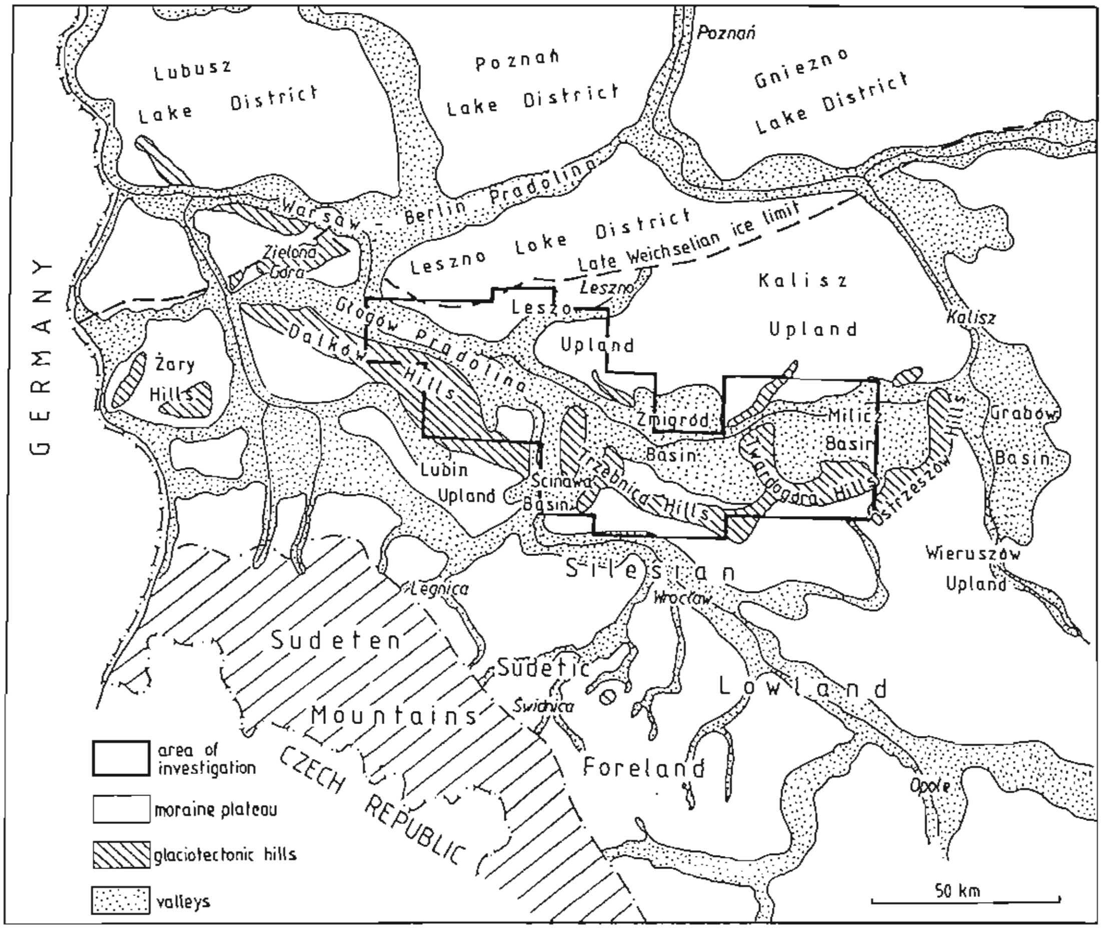


Fig. 2. Location of the area of investigation against the background of main geographic regions of southwestern Poland

Lokalizacja obszaru badań na tle głównych jednostek geograficznych Polski południowo-zachodniej

Borings are located more or less systematically in all these sub-regions, 8 in the northern uplands, including only one boring in the Kalisz Upland, 17 in the central basins and 11 in the southern hills (Fig. 3).

TILL CHARACTERISTICS

Eight till horizons have been recognized, which differ in petrographic composition. However, they probably represent only 5 to 6 ice-sheet advanees belonging to the Elsterian and Saalian Stages.

T1 HORIZON (GROŃSKO TILL)

The T1 till has been found only in four profiles, all located in the central basins. The till oceurs in the lowest position of the Quaternary sequences, always directly on the Tertiary deposits and usually with several other tills above (Figs. 4, 5). This is muddy to sandy till with thickness varying from 3 to 15 m. Calcium carbonate content varies from 5 to 18%, but usually it is above 10%. The entire till horizon may be interfingered with Tertiary clay or glaciolacustrine clay and/or sand (Fig. 4). However, the separate till layers of the T1 complex indicate the same petrographic composition. Hence, this sedimentary complex may represent rather the slighty glaciotectonically disturbed sequence than stratigraphically different tills.

The T1 till is characterized by extremely high predominance of crystalline rocks (40–60%), very low content of Baltic limestones (20–30%) and insignificant dolomite (Table 1). Petrographic coefficients are: O/K 0.56–0.70; K/W 1.90–1.99; A/B 0.50 and Dp/Wp 0.05–0.08, where the K/W ratio seems to be very characteristic and unique among the investigated tills. The content of local rocks is relatively large and varies from 15 to 30%. The main local rock is either Mesozoic sandstone or milk quartz and brown coal particles, or flint and brown coal particles. Thus practically, the T1 till of each

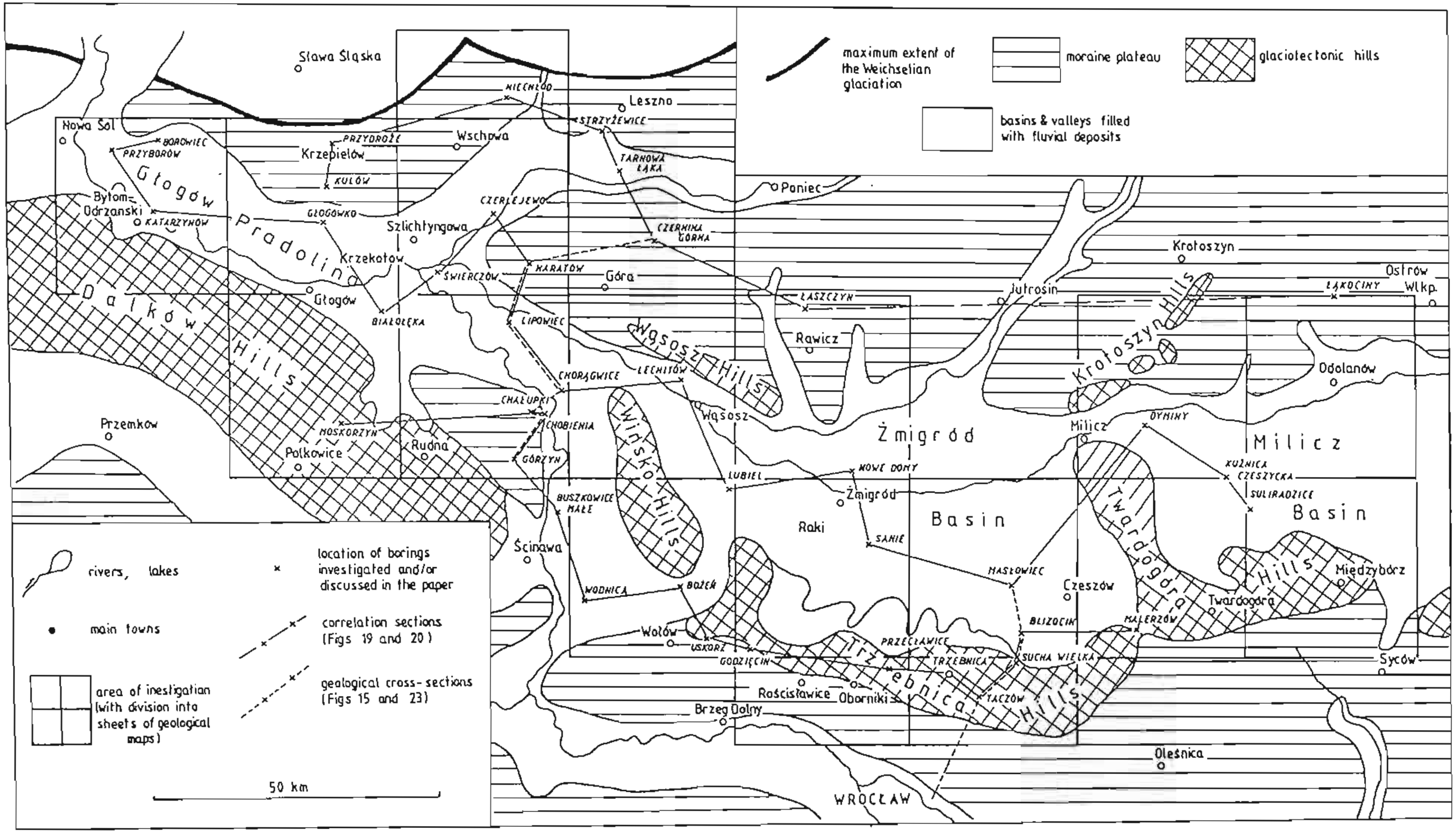


Fig. 3. Surficial geology and location of investigated borings in the northern Silesia and southernmost Great Poland

Geologia powierzchniowa i lokalizacja otworów badawczych na północnym Śląsku i w południowej Wielkopolsce

Table 1

Petrographic composition of the Early Elsterian tills in northern Silesia

Borehole	Petrographic coefficients				Percentage content of local rocks											CaCO3 [vol.%]
	O/K	K/W	A/B	Dp/Wp	total	limestones	sandstones	Palaeogene mudstones	Neogene mudstones	milk quartz	flint	phosph. concret.	pyritic concret.	lignite	other	
	Grońsko Till (T1)															
1/BO	0.60	1.99	0.50	0.05	30.0	2.0	2.8	0.6	0.3	14.9	2.6	3.7	0.1	2.8	–	5
2/Gł	0.70	1.90	0.50	0.08	18.0	2.7	11.0	0.7	–	1.8	1.8	–	–	–	–	10
5/R*	0.56	1.94	0.50	0.15	21.0	–	1.1	3.3	1.5	0.5	9.3	–	–	12.0	–	18
4/R*	0.67	1.90	0.50	0.29	15.0	1.1	0.5	1.4	–	4.6	1.7	–	–	5.3	–	15
4/Ob	0.95	1.30	0.90	0.06	32.0	1.6	3.2	–	1.0	17.6	4.8	–	–	3.2	–	12
	Grońsko Till in the type region															
	0.5–0.8	1.4–1.7	0.5–0.7	0.0–0.02												
	Pietrzykowice Till in the type region															
	0.5–0.6	2.0–2.2	0.5–0.6	0.03–0.05												

*dolomite content may contain analytical error (J. A. Czerwonka, 1978)

Table 2

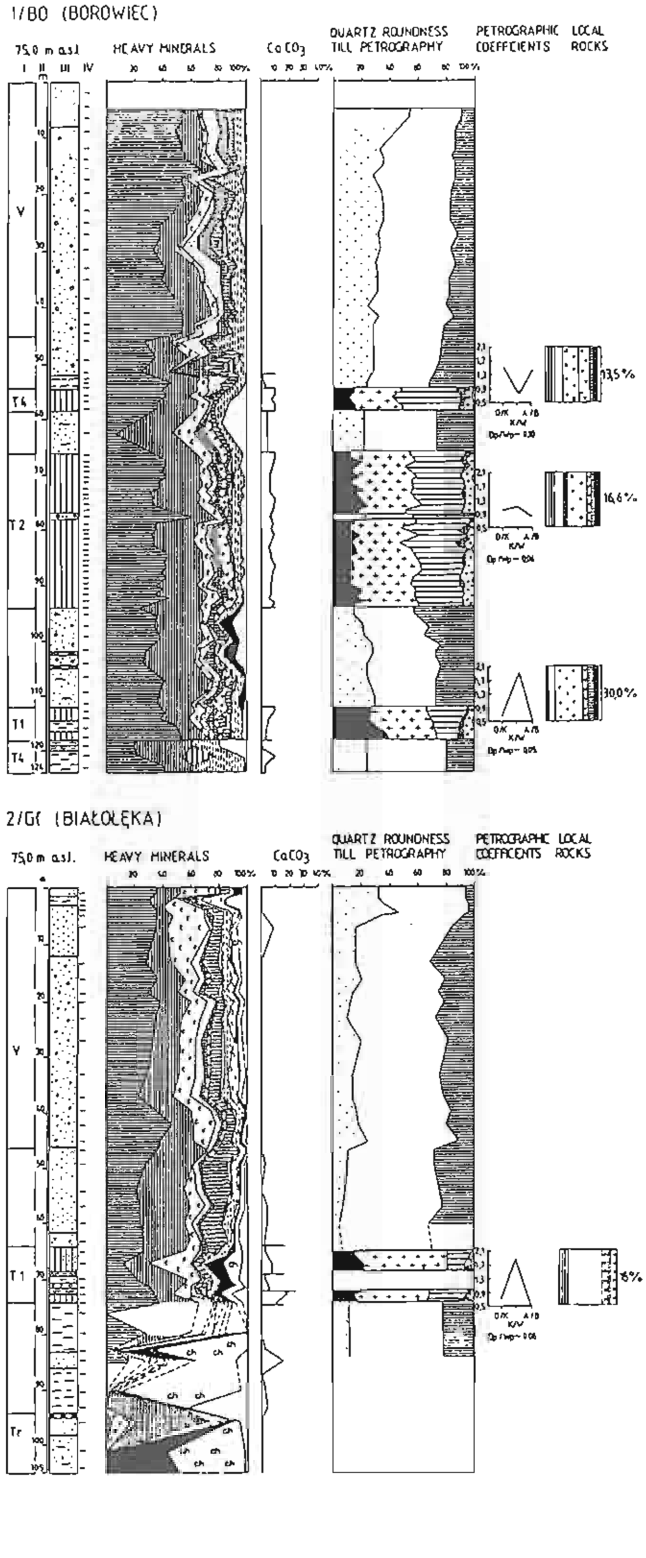
Petrographic composition of the Middle Elsterian tills in northern Silesia

Borehole	Petrograhic coefficients				Percentage content of local rocks											CaCO3 [vol.%]
	O/K	K/W	A/B	Dp/Wp	total	limestones	sandstones	Palaeogene mudstones	Neogene mudstones	milk quartz	flint	phosph. concret.	pyritic concret.	lignite	other	
	Krzesinki Till (T2)															
1/BO	0.95	1.15	0.85	0.06	16.6	2.5	2.7	0.5	0.5	6.1	1.4	0.6	0.1	2.4	–	8
3/Ws	1.11	1.04	0.90	0.03	20.0	1.1	3.1	–	0.2	12.4	2.1	0.2	0.8	–	–	6
1/Ws	1.01	1.05	0.89	0.00	22.0	1.0	0.7	0.7	0.9	15.7	2.0	1.1	0.3	–	0.6	2
4/R*	1.13	1.10	0.84	0.40	19.2	0.2	1.5	0.1	0.2	4.4	2.4	–	–	10.0	–	11
1/SW	1.27	0.91	0.94	0.10	13.2	3.6	0.9	0.6	–	5.9	1.5	–	0.4	0.4	–	6
1/G	0.99	1.09	0.88	0.08	15.0	3.0	3.9	–	–	4.1	2.2	0.4	0.4	0.2	0.8	16
1/W	1.04	1.09	0.94	0.11	22.0	4.8	3.3	–	0.2	6.1	2.7	–	0.6	–	4.1	12
4/Ob	1.10	1.05	1.05	0.05	20.7	2.1	4.1	–	–	11.4	2.1	–	–	–	–	11
	Krzesinki Till in the type region															
	0.9–1.1	0.9–1.3	0.8–1.2	0.02–0.03												

*dolomite content may contain analytical error (J. A. Czerwonka, 1978) profile is characterized by another spectrum of local rocks (Table 1, Figs. 4, 5).

The heavy mineral content is uniform in all outcrops of the T1 till. Garnet represents a dominant mineral, which is associated by amphibole and epidote. Altogether, these three minerals are about 60–75%. Other minerals, such as zircon, tourmaline and cyanite may increase locally (Fig. 5), most probably around the outcrops of the preglacial deposits.

The petrographic composition of the T1 till is very similar to features of the Pietrzykowice Till of the central Silesia (J. A. Czerwonka, D. Krzyszkowski, 1992*b*) and the Grońsko Till in the central Great Poland (J. A. Czerwonka, D. Krzyszkowski, 1994). This similarity is exhibited both in specific K/W ratio as well as in very changeable spectrum of local rocks. As the Pietrzykowice Till indicates K/W ratios usually



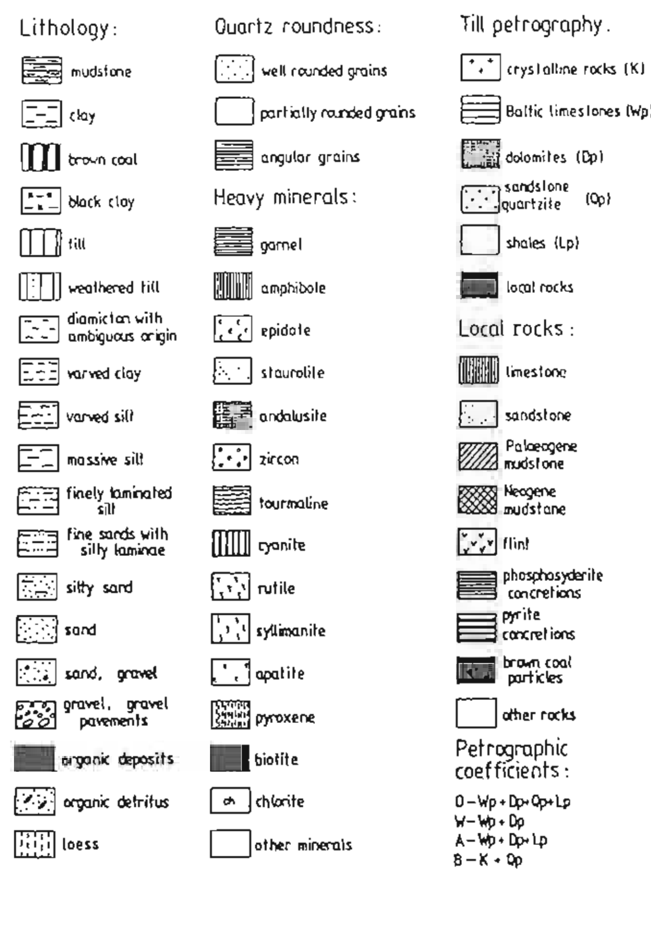


Fig. 4. Charts of borings Borowiec (1/BO) and Białołęka (2/GŁ) with a sequence of results of the standard petrological studies

I — stratigraphy: T — Triassic rocks, Tr — Miocene deposits, P — preglacial (Pliocene) deposits, T1 — Grońsko Till, T2 — Krzesinki Till, T3 — Wierzbno Till, T4A — Borowiec Till, T4B — dolomite-rich Borowiec Till, T5A — Smolna Till, T5B — Dopiewiec Till, T6A — Naratów Till, T6B — Taczów Till, T7 — Górzno Till, E — Eemian deposits, V — Weichselian deposits, Ol — Oleśnica "pyroxene" Formation, Pw — Pawłowice "pyroxene" Formation, F — fluvial deposits from the Pilica Interstadial; II — depth; III — lithology; IV — sampling

Karty otworów Borowiec (1/BO) i Białołęka (2/GŁ) z wynikami standardowych badań petrologicznych

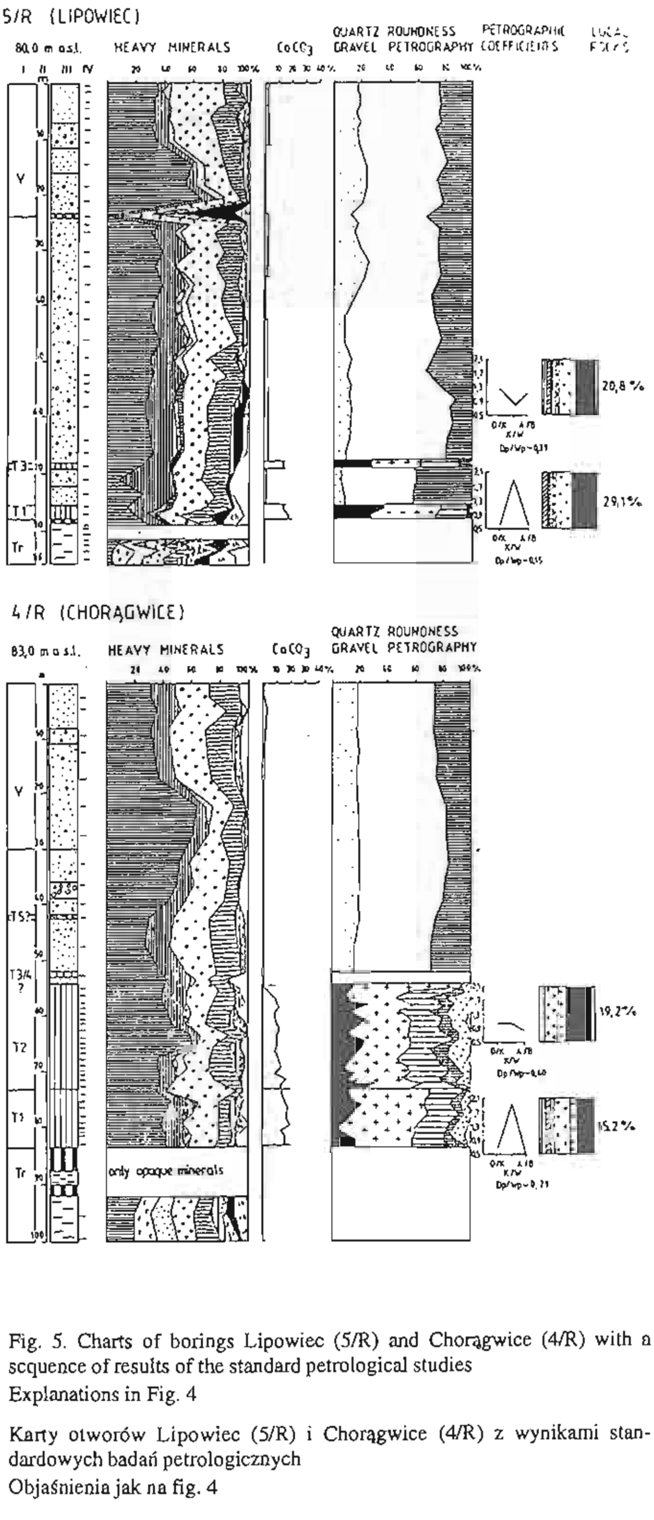


Fig. 5. Charts of borings Lipowiec (5/R) and Chorągwice (4/R) with a sequence of results of the standard petrological studies
Explanations in Fig. 4

Karty otworów Lipowiec (5/R) i Chorągwice (4/R) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

above 2.0, but the Grońsko Till usually around or below 2.0, the T1 till of the investigated region has been correlated with the latter and defined as the Grońsko Till.

T2 HORIZON (KRZESINKI TILL)

This till has been found in 8 profiles located in all sub-regions. The till lies either above the T1 till (Figs. 4, 5) or directly on the Tertiary deposits (Fig. 6). The till is usually thick, ranging from 10 to 25 m, except the Trzebniea Hills where it is thinner (ca. 5 m). The till is usually massive and muddy, although it may comprise some thin sandy or clayey intercalations, especially in the lower part of the till bed. The $CaCO_3$ content varies from 2 to 16%, in average 6–12% .

The T2 till is characterized by an almost equal content of crystalline and carbonate rocks or the first one slighty predominates. Dolomite is rare (below 3.1%) or even does not occur. Petrographic coefficients are: O/K 0.91–1.15; K/W

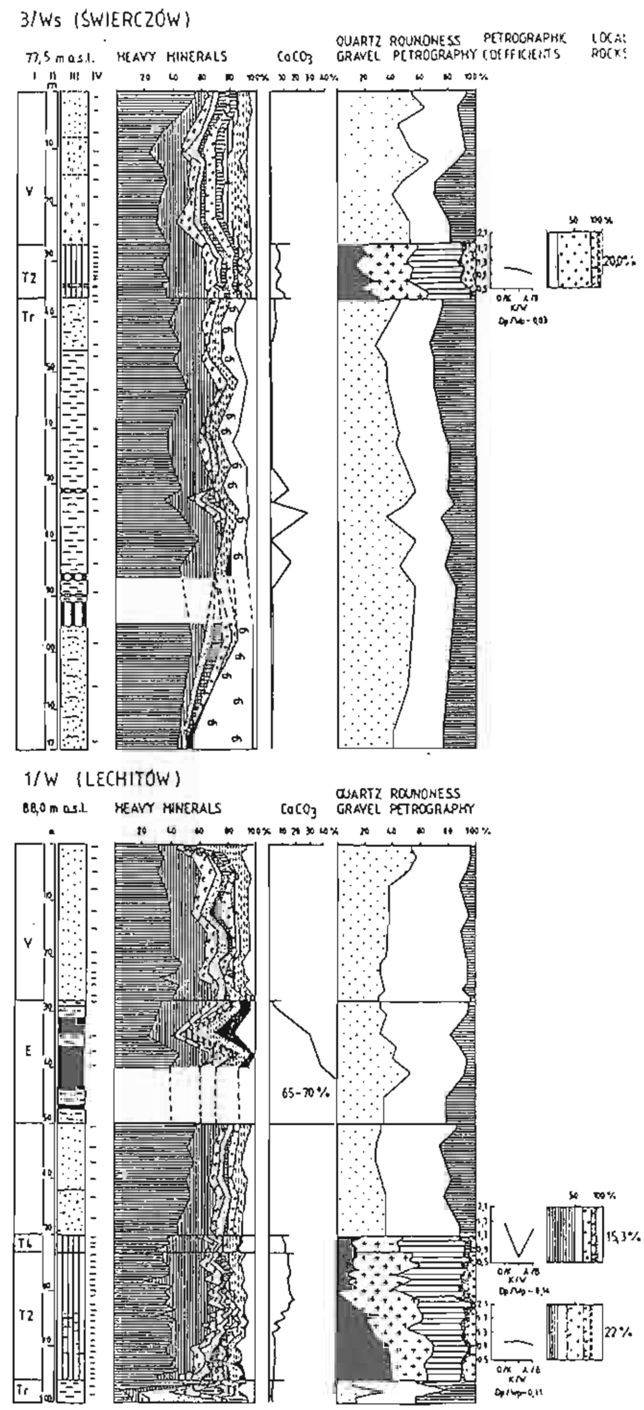


Fig. 6. Charts of borings Świerczów (3/Ws) and Lechitów (1/W) with a sequence of results of the standard petrological studies
Explanations in Fig. 4

Karty otworów Świerczów (3/Ws) i Lechitów (1/W) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

Table 3

Petrographic composition of the Late Elsterian tills in northern Silesia

Borehole	Petrographic coefficients				Percentage content of local rocks											CaCO3 [vol.%]
	O/K	K/W	A/B	Dp/Wp	total	limestones	sandstones	Palaeogene mudstones	Neogene mudstones	milk quartz	flint	phosph. concret.	pyritic concret.	lignite	other	
	Wierzbno Till (T3)															
2/Bo	1.29	0.80	1.23	0.09	13.7	1.9	2.8	–	–	1.4	0.5	0.5	–	6.6	–	10
5/R*	1.26	0.86	1.10	0.29	20.8	2.0	0.7	1.6	2.3	0.7	5.3	–	–	6.7	1.3	14
1/R*	1.31	0.87	1.00	0.42	34.0	1.0	3.5	5.4	1.8	0.9	8.0	–	–	13.4	–	10
4/Ob	1.35	0.90	1.10	0.06	27.6	1.6	4.1	–	1.2	9.7	69	0.8	0.8	2.8	–	16
1/T	1.27	0.89	1.15	0.02	12.5	0.8	1.2	–	2.5	0.6	4.5	0.5	0.5	2.5	–	3
2/Cz	1.38	0.83	1.11	0.11	12.9	3.7	1.6	–	–	3.1	1.4	–	0.5	1.6	0.8	11
3/Tw	1.25	0.88	1.08	0.15	22.4	4.8	0.5	0.7	0.6	12.2	1.2	0.9	0.8	0.9	–	2
	Borowiec Till (T4)															
1/BO	1.49	0.74	1.34	0.10	13.5	1.8	1.9	0.1	0.4	4.1	2.4	0.8	–	2.0	–	9
3/Bo	1.94	0.62	1.66	0.11	23.0	2.2	2.2	0.8	0.2	4.4	2.3	0.8	0.2	9.9	–	6
1/Sz	1.53	0.69	1.39	0.04	15.7	3.6	2.9	1.4	0.5	4.0	0.8	0.8	0.4	1.4	–	10
1/W	1.69	0.62	1.51	0.14	15.3	7.2	2.3	0.3	–	2.1	1.1	0.7	–	0.2	1.5	12
1/Żm	1.72	0.60	1.68	0.11	28.5	13.0	0.5	0.5	3.0	3.0	0.5	0.1	0.1	6.8	–	9
2/M	1.40	0.80	1.22	0.12	39.0	31.7	1.8	–	–	3.8	0.2	0.8	0.8	–	–	6
1/Tw	1.50	0.66	1.48	0.14	32.8	17.8	1.6	0.2	0.5	3.3	0.5	4.3	0.5	3.7	–	11
1/Mb	1.44	0.77	1.24	0.11	20.7	11.7	1.2	0.4	–	3.5	0.4	1.3	0.6	0.1	1.5	6
1/Od	1.60	0.75	1.30	0.13	13.0	5.1	1.4	–	–	2.5	1.1	0.6	0.3	2.0	–	7
2/Ws**	1.67	0.61	1.57	0.27	14.4	2.9	2.4	0.2	0.9	4.4	0.5	–	0.8	1.3	–	10
2/Ws	1.80	0.61	1.42	0.08	10.2	1.1	1.5	0.5	0.3	4.0	1.0	0.4	0.3	1.6	–	10
2/Ra**	1.65	0.67	1.37	0.21	15.1	4.5	1.5	0.7	0.4	3.5	0.9	0.1	0.7	2.3	0.5	12
2/Ra	1.40	0.77	1.21	0.12	14.4	5.0	0.8	–	–	4.3	0.8	0.2	0.6	2.2	0.3	14
	Wierzbno Till in the type region															
	1.1–1.3	0.8–1.1	0.8–1.2	0.0–0.09												
	Witosław Till in the type region															
	1.2–1.4	0.8–0.95	1.0–1.3	0.05–0.11												

* dolomite content may contain analytical error (J. A. Czerwonka, 1978); ** dolomite-rich till bed at the top of Borowiec Till (see discussion in the text)

0.95–1.13 (exceptionally in one profile 1.27); A/B 0.84–0.90 and Dp/Wp 0.00–0.11 (in average 0.03–0.08). The content of local rocks is large, ranging from 13 to 22%. Main local rocks are milk quartz and Mesozoic sandstone. Mesozoic limestone and flint are also relatively frequent, although with more changeable quantities (Table 2, Figs. 4–6).

Main heavy minerals of the T2 till are garnet and amphibole, which indicate usually almost equal contents (altogether 60–70%), although in several samples garnet predominates. Epidote and pyroxene contents varies between 5 and 10%; other minerals are less frequent.

The T2 till features well correspond with the petrographic composition of the Krzesinki Till, either in the type profile near Poznań or its equivalents near Leszno (J. A. Czerwonka, D. Krzyszkowski, 1994). Not only petrographic coefficients, but also total dolomite content and a number and types of main local rocks are similar. Hence, the T2 till of the region investigated is defined as the Krzesinki Till, which thus has extended to the south.

T3 HORIZON (WIERZBNO TILL)

This till has been found in 7 profiles, where 5 are located along the glaciotectonic hills and only two in the central basins. The T3 till does not occur in the northern uplands of the region investigated. The till is usually thin (1–3, at maximum 5 m), although it preserves nicely all features typical for glacial tills. $CaCO_3$ content varies from 2 to 14%. The till lies above older Quaternary deposits, including tills T1 and T2 (Fig. 5), or directly above the Tertiary strata (Fig. 7). Very often, the T3 till represents the only till bed in the profile, although usually superposed by glaciofluvial and/or glaciolacustrine deposit. Occasionally, thin beds of the T5 and T6 tills may occur above it. Position of this till in the southern hills will be discussed in detail later, as it is quite complex due to glaciotectonic deformation.

The T3 till is characterized by predominance of carbonate rocks (35–45%) over the crystalline one (30–35%). Dolomite content is low to medium (1–5%) (Table 3). Petrographic coefficients are: O/K 1.25–1.35; K/W 0.80–0.90; A/B 1.08–1.23 and Dp/Wp 0.02–0.15. Local rocks are frequent (12–34%), where flint is the main component in almost all profiles. It is associated with milk quartz, Mesozoic sandstone and limestone, which in other profiles may dominate. Some profiles contain also abundant brown coal particles and Neogene mudstone.

Among heavy minerals, amphibole usually predominates over garnet and they together represent 60–70%. Epidote and pyroxene varies between 3 and 10%. Other minerals are less frequent.

Petrographic features of the T3 till and especially K/W ratio well correspond with features of the Wierzbno Till of the central Silesia (J. A. Czerwonka, D. Krzyszkowski, 1992*b*) and the Witosław Till of the Poznań and Leszno regions (J. A. Czerwonka, D. Krzyszkowski, 1994). As all profiles with T3 till lie geographically more closely to central Silesia, thus the till is defined as the Wierzbno Till. It must be stressed out, however, that there is no significant difference in petrographic

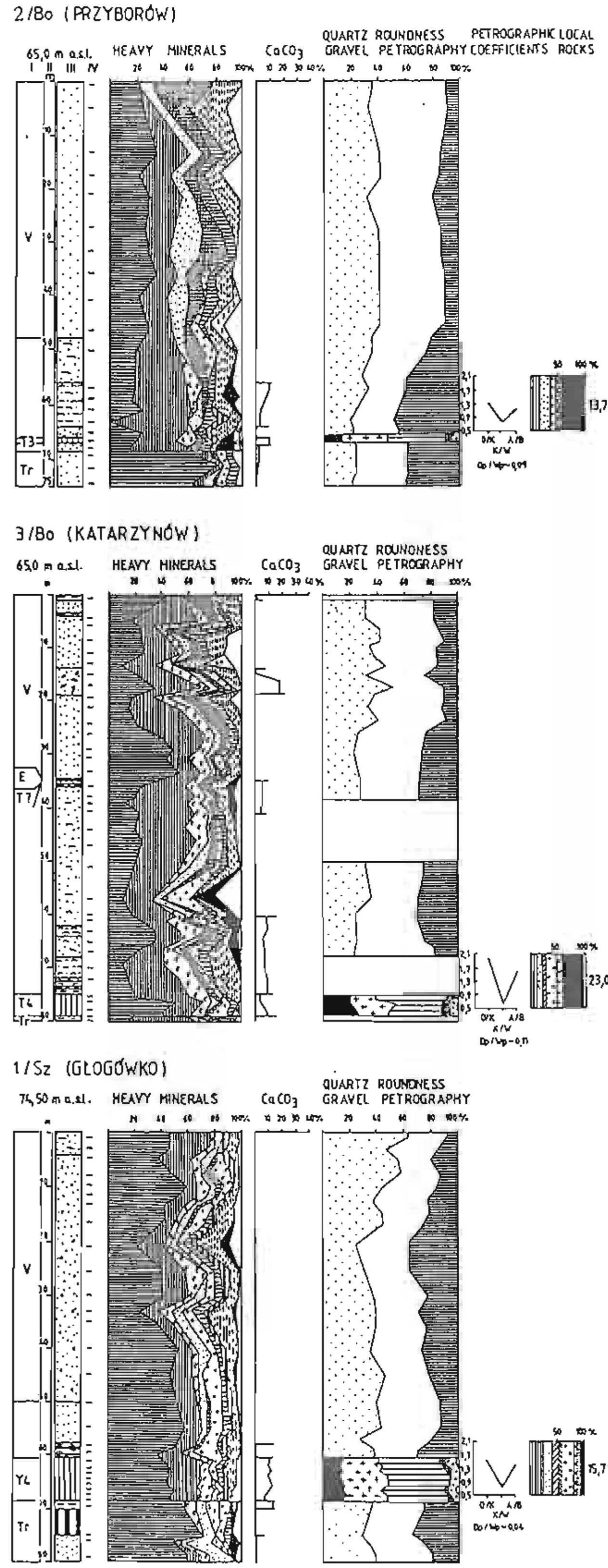


Fig. 7. Charts of borings Przyborów (2/Bo), Katarzynów (3/Bo) and Głogówko (1/Sz) with a sequence of results of the standard petrological studies
Explanations in Fig. 4

Karty otworów Przyborów (2/Bo), Katarzynów (3/Bo) i Głogówko (1/Sz) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

composition between the Wierzbno and Witosław Tills (J. A. Czerwonka, D. Krzyszkowski, 1994). These two tills, together with T3 till of the region investigated, form one, very homogeneous and continuous till bed outcroping from the Silesian Lowland in the south to at least Poznań region in the north.

T4 HORIZON (BOROWIEC TILL)

This till has been found in 11 profiles, all located in the central basins. The till is massive, muddy and it is usually 4–11 m thick and contains 6–14% of $CaCO_3$. It occurs above the older tills only in two profiles: Borowiec (T1 and T2, Fig. 4) and Lechitów (T2, Fig. 6). In other profiles it lies either directly on the Tertiary strata or more rarely on glaciolacustrine or glaciofluvial deposits (Figs. 7–9). The T4 and T3 tills are never in superposition, even if profiles containing them are very close to each other (e.g. Borowiec, Katarzynów and Przyborów, Fig. 3). They both have similar stratigraphic position above the T2 till or directly above the Tertiary basement (Figs. 4, 7). Very often, the T4 till represent the only till bed in the profile, although usually overlain by glaciofluvial and/or glaciolacustrine deposits. Occasionally, thin beds of the T5 and T6 tills may occur above it (Figs. 7–9).

The T4 till is characterized by extremely high predominance of limestones (45–50%) over the crystalline rocks (25–35%) and relatively high dolomite content (4–15%). It is clear from the profile Czerlejewo (Fig. 9), that the T4 horizon may be subdivided into two sub-horizons, named the T4A and the T4B, which differ in dolomite content. The lower till (T4A) comprises 4–8% of the dolomite, whereas the upper till (T4B) twice or three times more (8–15%). Other petrographic features are the same in both units, as well as there is no sedimentary break between them. Hence, it seems the T4A and T4B units form one till bed, and high dolomite content at the top is probably due to a change of regional ice movement (e.g. J. Ehlers *et al.*, 1984; J. Ehlers, 1992). The dolomite-rich T4B till occurs only in two profiles: Czerlejewo and Nowe Domy (Fig. 9). The latter profile contains practically only the T4B unit. However, thin diamicton beds interbedded with glaciolacustrine deposits, which lie below T4B unit, are characterized by dolomite content close to the T4A till characteristics (Fig. 9, Table 3). Petrographic coefficients are in both T4A and T4B units as follows: O/K 1.40–1.94; K/W 0.60–0.80; A/B 1.30–1.68 and Dp/Wp 0.08–0.14 (T4A) and 0.21–0.27 (T4B). The content of local rocks is very large and varies from 13 to 39%. Profiles from Milicz and Żmigród Basins are dominated by Mesozoic limestone (40–80% of all local rocks, which gives from 5 to 32% in total), which are usually associated by milk quartz and occasionally by Mesozoic sandstone, flint, phosphosyderite and pyrite concretions. In turn, the T4 tills from the Głogów Pradolina comprise more

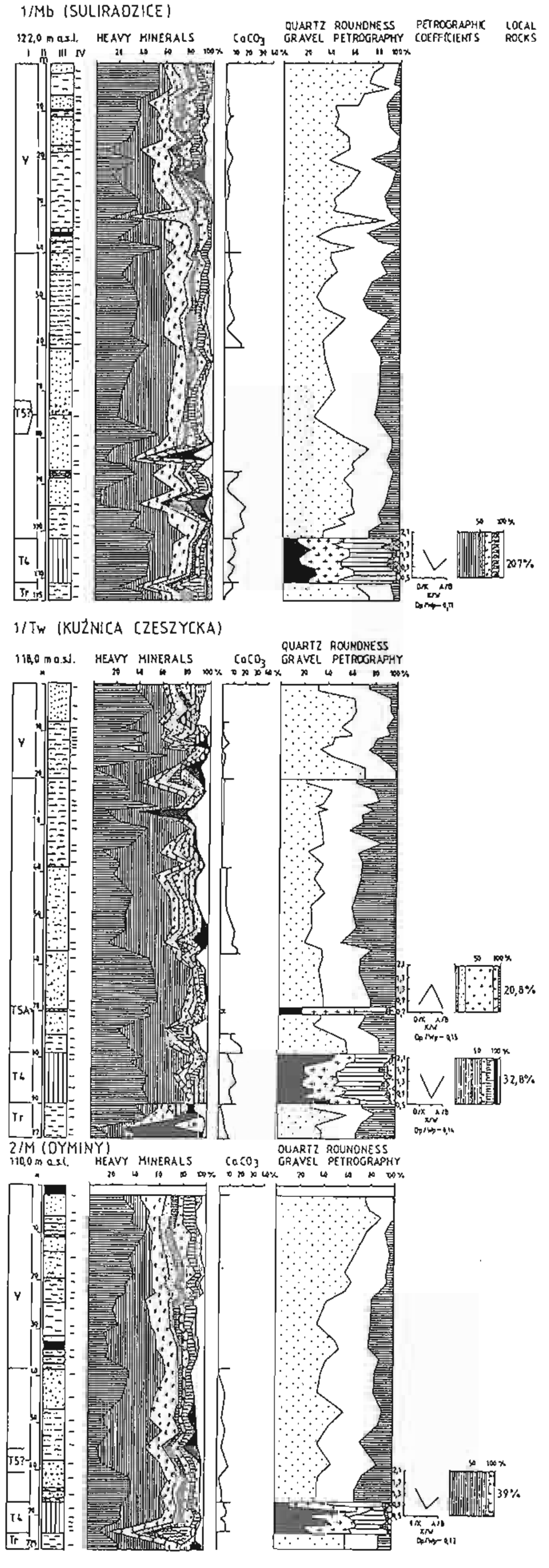


Fig. 8. Charts of borings Suliradzice (1/Mb), Kuźnica Czeszycka (1/Tw) and Dyminy (2/M) with a sequence of results of the standard petrological studies Explanations in fig. 4

Karty otworów Suliradzice (1/Mb), Kuźnica Czeszycka (1/Tw) i Dyminy (2/M) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

dispersed spectrum of local rocks, with milk quartz, Mesozoic sandstone, Mesozoic limestone and brown coal particles as main rocks, which are associated by less frequent flint, Palaeogene and Neogene mudstones, and phosphosyderite and pyrite concretions.

Garnet and amphibole represent together about 70–80% of total heavy minerals in the T4 horizon and the first one dominates. Epidote content ranges between 5 and 10%. Other minerals are infrequent.

The till T4 indicates very specific petrographic features, especially K/W ratio and limestone and dolomite contents. These features are comparable either with features of the Górzno Till in the Leszno region (T4A) or Kopaszewko Till in the Poznań region (T4B) (J. A. Czerwonka, D. Krzyszkowski, 1994). However, another till has been found in the region investigated as a better candidate for Górzno Till (T7) and correlation with both the Górzno and the Kopaszewko Tills is unsound as the T4 till is present always in the lower part of the Quaternary sequence, often directly on Tertiary strata, whereas the Górzno and the Kopaszewko Tills are very young and often occur near the ground surface.

From the above, it follows that the T4 till must represent a separate till horizon. We have decided to define it as a new till type (T4), which has been named the Borowiec Till. The Borowiec profile (Fig. 4) is designated as a stratotype, because this boring has the most complete stratigraphy, where the T4 till lies both above T1 and T2 tills. Parastratotype profile is represented in boring Kuźnica Czeszycka (Fig. 8), where the T4 till is superposed by the T5 till. The latter profile represents also the Mesozoic limestone-dominated till, by means of local rocks characteristics. Another parastratotype is represented by profile Czerlejewo (Fig. 9), where normal T4 till (T4A) is superposed by the dolomite-rich till facies (T4B).

T5 HORIZON (SMOLNA TILL AND/OR DOPIEWIEC TILL)

This till has been described surely in 11 profiles, and it possibly occurs also in two other one. The till is present in all sub-regions, although it is relatively rare in the central basins. The stratigraphic position of the T5 till is the best recognized within the Leszno Upland, where it lies in some profiles above the T2 till or glaciofluvial deposits, or Tertiary deposits, and simultaneously below the T6 till (Figs. 10, 11). Within the central depressions the T5 till occurs above the T4 till or only above glaciofluvial deposits and usually with no other till above (Figs. 8, 9). In turn, the T5 till occurring in the southern hills represents either the single bed with no stratigraphic contex (e.g. Fig. 12) or is a part of very complex sequences formed due to glaciotectonic deformation. The till is massive, muddy or occasionally sandy, and it is from 3 to 28 m thick.

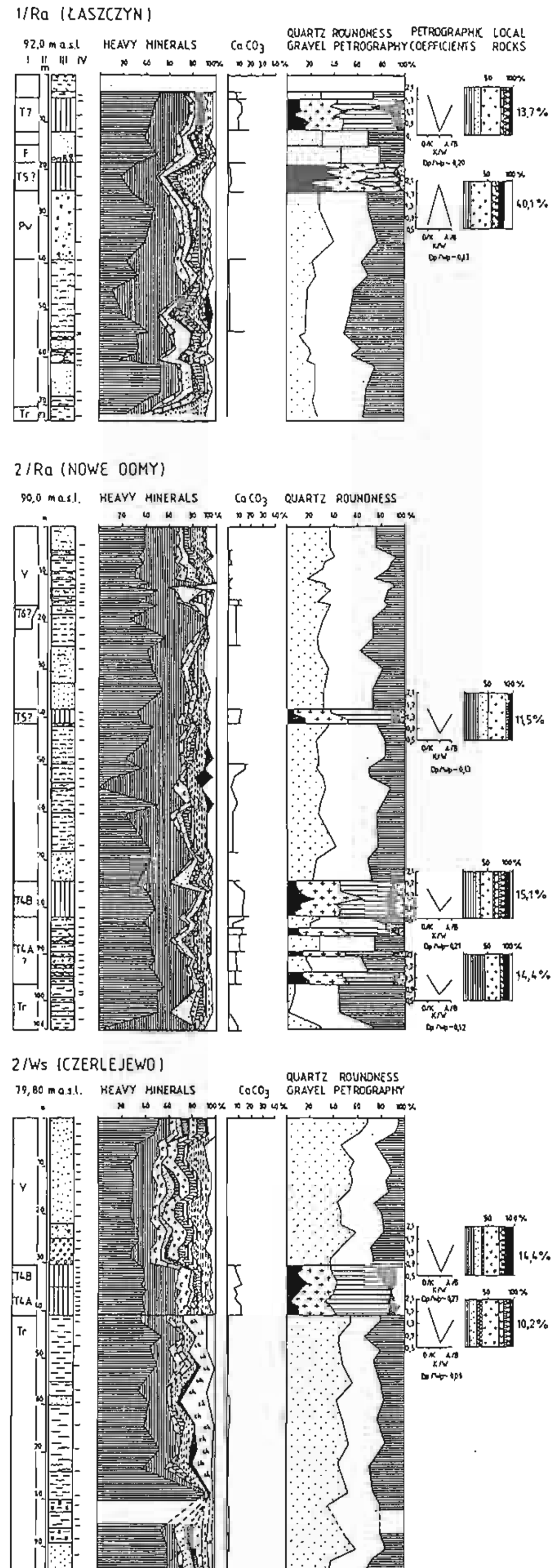


Fig. 9. Charts of borings Łaszczyn (1/Ra), Nowe Domy (2/Ra) and Czerlejewo (2/Ws) with a sequence of results of the standard petrological studies
Explanations in Fig. 4

Karty otworów Łaszczyn (1/Ra), Nowe Domy (2/Ra) i Czerlejewo (2/Ws) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

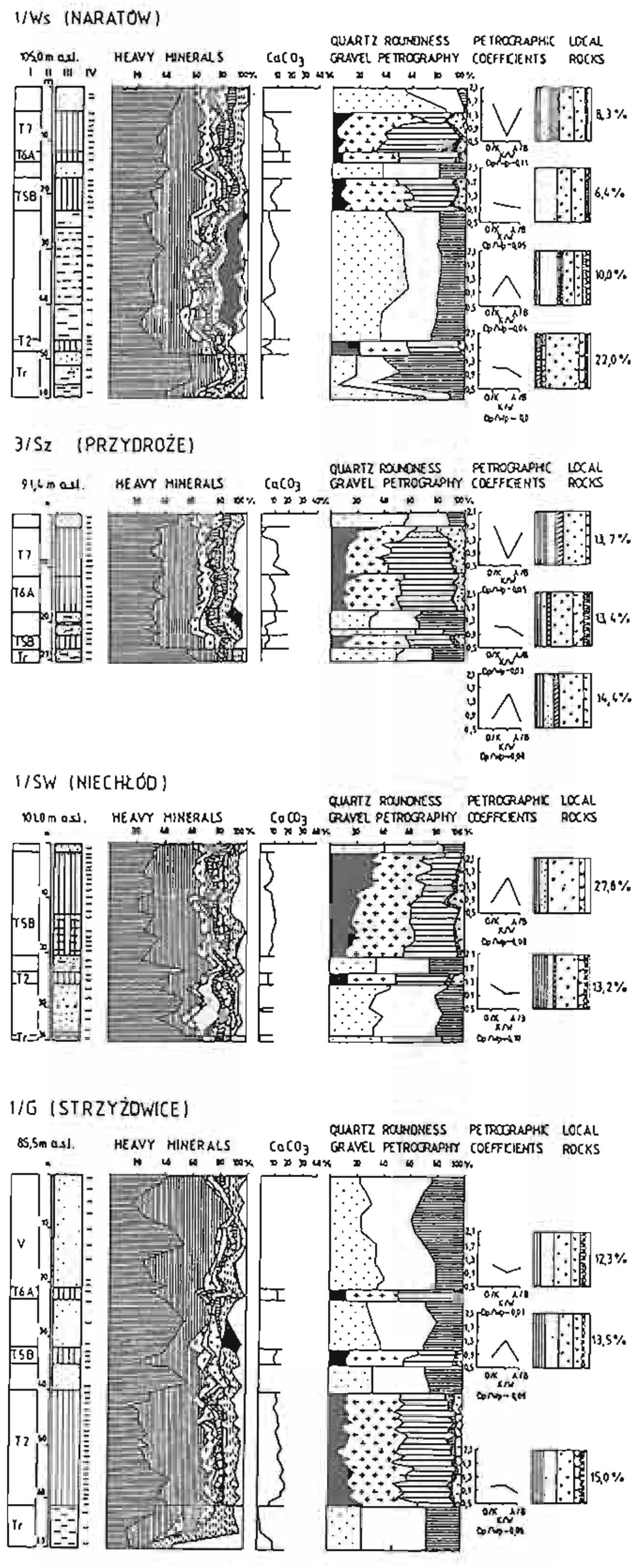


Fig. 10. Charts of borings Naratów (1/Ws), Przydroże (3/Sz), Niechłód (1/SW) and Strzyżewice (1/G) with a sequence of results of the standard petrological studies

Explanations in Fig. 4

Karty otworów Naratów (1/Ws), Przydroże (3/Sz), Niechłód (1/SW) i Strzyżewice (1/G) z wynikami standardowych badań petrologicznych

Objaśnienia jak na fig. 4

Calcium carbonate content varies from 2 to 13%, usually it is about 8–10%.

The T5 till is characterized by a predominance of crystalline rocks (40–50%) over the carbonate one (30–40%) and very low dolomite content (below 3%). Petrographic coefficients are: O/K 0.78–0.95; K/W 1.25–1.35; A/B 0.65–0.90 and Dp/Wp 0.02–0.09 (exceptionally 0.15 and 0.22) (Table 4). The content of local rocks is rather large, ranging from 10 to more than 30%. The main local rock is usually milk quartz (1–18%), which is associated by abundant Mesozoic sandstone (1–14%) and in some profiles also by Mesozoic limestone (1–6%), and particles of brown coal (0–7%). Flint is present in all profiles, ranging between 1 and 6%. Other rock types occur sporadically.

The special cases are possible T5 tills in profiles Łaszczyn and Nowe Domy (Fig. 9). These till beds lie in the stratigraphic position presumed for the T5 till, i.e. above the T4 till and below T6 or T7 tills (Fig. 9). However, their petrographic composition is quite different. The till at Łaszczyn is similar to the T1 till, whereas the till at Nowe Domy is like the T4 till. Both till beds are not weathered and enough thick (3–6 m) to preserve original petrographic composition of the glacial horizon. Hence, their petrographic composition, if their correlation with T5 horizon is correct, is somewhat striking. Further works on till petrography should be done eastwards (Jutrosin region) to solve this problem definitively.

Heavy minerals of the T5 till are very like to those of other tills, with garnet and amphibole as main components. Here, they indicate usually equal contents, each about 30–35%. Epidote and pyroxene may reach up to 6–8%; other minerals are less frequent, usually below 5%.

The T5 till indicates absolutely the same petrographic composition as the Smolna Till in central Silesian Lowland (J. A. Czerwonka, D. Krzyszkowski, 1992*b*) and the Dopiewiec Till in central Great Poland (J. A. Czerwonka, D. Krzyszkowski, 1994). As the investigated T5 till outcrops lie in between formerly investigated regions, and simultaneously throughout the entire northern Silesia, it is difficult to mark any boundary between the formerly defined tills. Hence, we decided to use conventionally the name Dopiewiec Till (T5B) for T5 tills northwards the Barycz River and the name Smolna Till (T5A) for T5 tills soutwards this river. This boundary is absolutely arbitrary and regional, as all T5A and T5B as well as the Smolna and Dopiewiec Tills represent one, very uniform till bed extending from Silesian Lowland to at least Poznań region (J. A. Czerwonka, D. Krzyszkowski, 1994).

T6A HORIZON (NARATÓW TILL)

This till has been found in four profiles of the Leszno Upland. It lies in between T5 and T7 tills in two profiles (Fig. 10), between T5 till and Weichselian fluvial deposits in one profile and in the isolated position in another one (Fig. 13). The till is 2–10 m thick, massive and muddy. In two profiles, Naratów and Przydroże (Fig. 10), the T6A till forms lithologically uniform till bed with the T7 horizon, where they differ from each other only in petrographic composition and $CaCO_3$

content. The average calcium carbonate content of the T6A till is 8–15%.

The T6A till is characterized by an almost equal content of crystalline and carbonate rocks, each about 40%, and a relatively small dolomite content (2–4%). Petrographic coefficients are: O/K 1.08–1.15; K/W 0.90–1.08; A/B 0.88–1.07 and Dp/Wp 0.03–0.08. The content of local rocks varies from 6 to 13% and is much lower than in older tills. Main local rocks are milk quartz, Mesozoic sandstone and flint, with small admixtures of Mesozoic limestons, Palaeogene mudstones and phosphosyderite concretions (Table 5).

Garnet and amphibole represent main heavy minerals (together about 70%) and the first one slighty predominates. Other minerals are infrequent, each usually 1–4%. Among them only pyroxene may reach up to 6–8%.

The T6A till indicates petrographic features which are very similar to those of the Karolewo Till near Poznań (J. A. Czerwonka, D. Krzyszkowski, 1994). Not only petrographic coefficients but also dolomite and local rocks content are almost the same. Also, a large number of flint is another common feature. However, we have decided to define T6A till as a separate till horizon. This is because that the gap of about 100 km is present in between outcrops of the T6A till and the outcrops of the Karolewo Till (J. A. Czerwonka, D. Krzyszkowski, 1994). The T6A till has been named the Naratów Till and the Naratów profile (Fig. 10) has been designated as a stratotype.

T6B HORIZON (TACZÓW TILL)

This till has been found in 5 profiles; four of them are located along the southern hills and/or on its northern foreland and one profile is located in the Żmigród Basin (Figs. 11, 13). This till occurs in the isolated position or above the T5 till and/or T3 till. This till is sandy to muddy, usually massive, and it contains 2–13% $CaCO_3$.

The petrographic composition of the T6B till is identical as this of the T6A till, except dolomite content, which is here up to 12% (usually 5–8%) (Table 5). Petrographic coefficients are: O/K 1.09–1.16; K/W 0.90–1.13; A/B 0.80–1.10 and Dp/Wp 0.14–0.28. The content of local rocks is 11–16%, which is slighty larger than in the T6A till, but still much less than in older tills. Main local rocks are also the same as in the T6A till: milk quartz, Mesozoic sandstone and flint, with some small admixtures of Mesozoic limestons, Palaeogene mudstones and phosphosyderite concretions, although it contains also a significant brown coal particles.

Heavy mineral content is also similar as in the T6A till, although in some profiles at the southern hills, there is more tourmaline, zircon and cyanite.

The T6B till seems to be an equivalent of the Naratów Till (T6A), although with different geographical distribution, limited to the Dalków and Trzebnica Hills and their northern forelands. The geological cross-section (Fig. 15) shows that the T6A and T6B tills occur in similar geological position and above the T5 till on both sides of the Odra/Barycz River valleys. They both form the uppermost till bed of the moraine plateau, although the T6B till is always the youngest one in

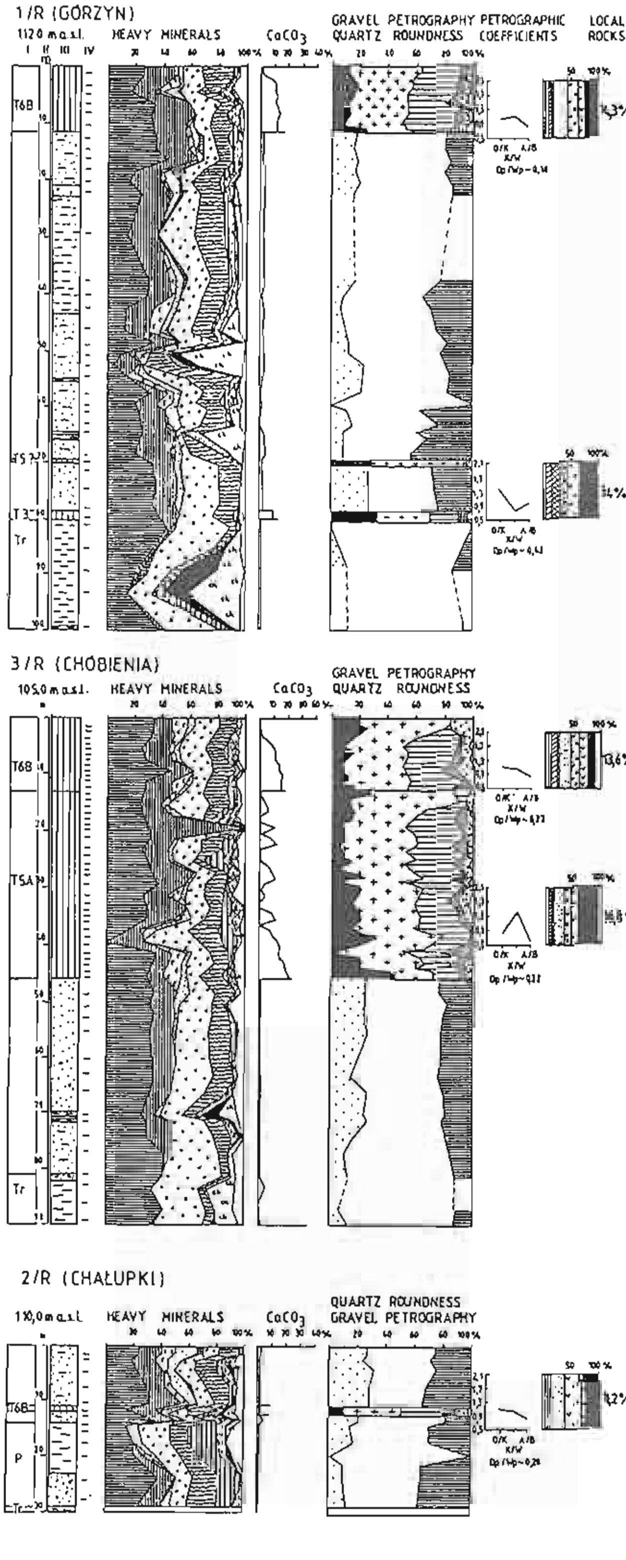


Fig. 11. Charts of borings Górzyn (1/R), Chobienia (3/R) and Chalupki (2/R) with a sequence of results of the standard petrological studies
Explanations in Fig. 4

Karty otworów Górzyn (1/R), Chobienia (3/R) i Chalupki (2/R) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

Table 4

Petrographic composition of the Early Saalian tills in northern Silesia

Borehole	Petrographic coefficients				Percentage content of local rocks											CaCO$_3$ [vol.%]
	O/K	K/W	A/B	Dp/Wp	total	limestones	sandstones	Palaeogene mudstones	Neogene mudstones	milk quartz	flint	phosph. concret.	pyritic concret.	lignite	other	
	Dopiewiec Till (T5B)															
3/Sz	0.80	1.35	0.70	0.08	14.4	1.3	3.3	1.3	–	6.9	1.4	–	–	0.4	–	5
1/SW	0.80	1.45	0.68	0.08	27.8	3.1	4.4	0.3	–	14.5	2.1	0.2	0.3	0.5	0.1	8
1/Ws	0.81	1.34	0.73	0.04	10.0	1.0	3.2	0.7	0.7	1.9	1.5	0.7	0.6	–	–	10
1/G	0.84	1.30	0.78	0.09	13.5	2.8	3.6	0.3	0.1	3.6	2.3	–	0.4	–	0.5	10
1/Ra	0.55	2.05	0.55	0.13	40.1	8.2	1.0	–	1.5	16.4	2.0	0.5	2.0	8.0	2.5	2
2/Ra	0.60	0.70	1.40	0.13	11.5	3.5	2.3	–	–	3.8	0.1	0.5	–	1.2	–	10
	Smolna Till (T5A)															
1/Gł	0.90	1.35	0.70	0.01	16.0	4.8	4.0	0.8	–	0.8	2.4	–	–	3.2	–	13
3/R*	0.88	1.36	0.65	0.22	16.8	0.5	2.9	0.8	1.4	1.5	2.4	–	–	7.1	–	8
2/Żm	0.85	1.25	0.70	0.02	28.2	5.5	1.5	0.6	–	18.1	1.5	–	1.0	–	–	10
1/Tw	0.78	1.39	0.68	0.15	20.8	1.4	2.8	–	–	12.5	2.8	1.4	0.2	–	–	3
2/T	0.92	1.32	0.70	0.03	30.0	–	14.0	–	4.5	1.5	6.0	–	–	3.0	–	10
1/T	0.90	1.29	0.70	0.04	17.0	1.9	5.5	–	1.7	0.8	4.5	–	–	2.6	–	12
4/Ob	0.95	1.30	0.90	0.06	32.0	1.6	3.2	–	1.0	17.6	4.8	–	–	3.2	–	12
	Dopiewiec Till in the type region															
	0.6–1.0	1.3–1.5	0.6–0.9	0.0–0.05												
	Smolna Till in the type region															
	0.8–0.9	1.3–1.5	0.6–0.7	0.03–0.09												

* dolomite content may contain analytical error (J. A. Czerwonka, 1978)

the sequence and the T6A till is overlain additionally by the T7 horizon. The surficially lying till of the Trzebnica Hills, that is different from the Smolna Till (T5), has been defined as the Taczów Till (D. Krzyszkowski, 1993), following older descriptions (*vide* M. Schwarzbach, 1942; D. Krzyszkowski, 1993). The type sections of the Taczów Till near Trzebnica, Taczów and Głuchów Dolny are not available recently. Hence, we have designated parastratotypes of this till at Chobienia (Fig. 11) in the Dalków Hills and at Blizocin (Fig. 14) in the Trzebnica Hills.

T7 HORIZON (GÓRZNO TILL)

This till has been found in 5 profiles and only in the Leszno and Kalisz Uplands. The till represents the youngest glacial deposit, lying at the ground surface or below thin cover of sands (Figs. 9, 10, 16). This till lies above the Naratów Till (T6A) in two profiles (Fig. 10), where they form one, lithologically uniform till bed. In other profiles, the T7 till forms a separate unit lying above the T5 till or in one case on the Tertiary clay (Figs. 9, 16). The till is 8–30 m thick, massive and muddy. $CaCO_3$ content is 8–12%.

The T7 till is characterized by a high predominance of limestones (40–50%) over crystalline rocks (35–40%) and relatively high dolomite content (3–7%). The latter is larger than in the Naratów Till (T6A), although smaller than in the Taczów Till (T6B). It is, however, very similar to this of the Borowiec Till (T4A). Petrographic coefficients of the T7 till are: O/K 1.34–1.76; K/W 0.55–0.80; A/B 1.18–1.56 and Dp/Wp 0.11–0.20 (exceptionally 0.05). Local rocks are from 8 to 19% and milk quartz and Mesozoic limestone are dominant rocks. They are associated mainly by Mesozoic sandstone and flint (Table 5).

Main heavy minerals are represented by garnet and amphibole, which have varying contents, but together reaching up to 65–75%. Epidote is quite frequent reaching up to 8–12%, whereas pyroxene is up to 10%. Other minerals are less frequent, each usually less than 3%.

The petrographic composition of the till T7 and its position near the ground surface corresponds well with features of the

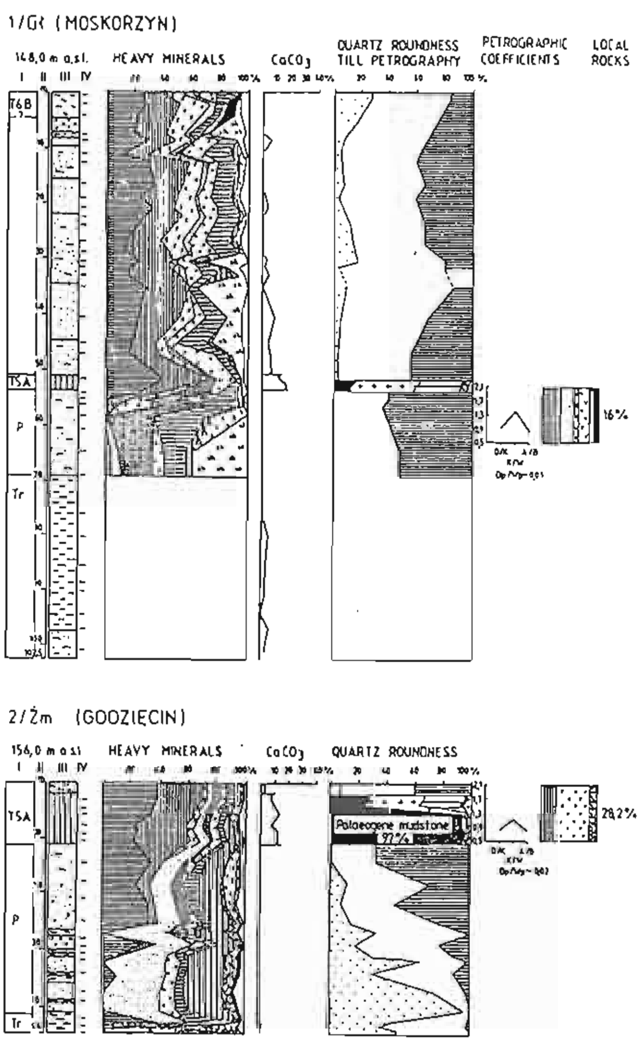


Fig. 12. Charts of borings Moskorzyn (1/Gł) and Godzięcin (2/Żm) with a sequence of results of the standard petrological studies
Explanations in Fig. 4

Karty otworów Moskorzyn (1/Gł) i Godzięcin (2/Żm) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

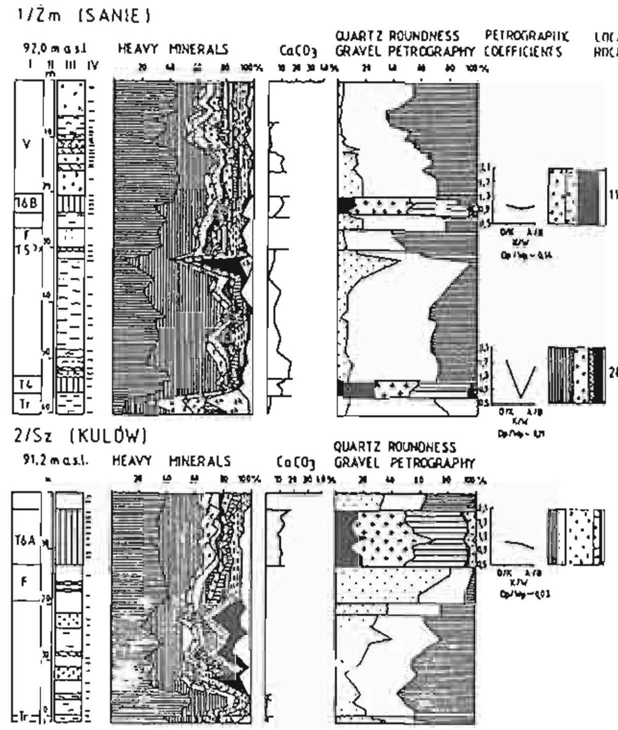


Fig. 13. Charts of borings Sanie (1/Żm) and Kulów (2/Sz) with a sequence of results of the standard petrological studies
Explanations in Fig. 4

Karty otworów Sanie (1/Żm) i Kulów (2/Sz) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

Table 5

Petrographic composition of the Late Saalian tills in northern Silesia

Borehole	Petrographic coefficients				Percentage content of local rocks											CaCO$_3$ [vol.%]
	O/K	K/W	A/B	Dp/Wp	total	limestones	sandstones	Palaeogene mudstones	Neogene mudstones	milk quartz	flint	phosph. concret.	pyritic concret.	lignite	other	
	Naratów Till (T6A)															
1/Ws	1.11	0.99	0.92	0.05	6.4	–	2.5	–	–	1.6	1.6	0.7	0.2	–	–	15
3/Sz	1.12	1.08	0.95	0.03	15.6	2.5	2.1	0.3	0.1	7.3	1.7	0.1	0.2	1.0	–	10
2/Sz	1.08	1.04	0.88	0.03	13.4	1.0	1.5	0.5	–	6.0	2.5	1.0	0.4	0.6	–	8
1/G	1.15	0.90	1.07	0.08	12.3	1.6	3.2	–	–	3.5	1.9	0.3	0.9	–	0.9	12
	Taczów Till (T6B)															
1/Żm	1.12	0.90	1.10	0.14	11.4	0.3	0.6	–	–	3.5	2.3	–	–	4.8	–	6
3/R*	1.16	1.13	0.78	0.22	13.6	1.5	2.6	1.5	1.0	2.2	1.9	–	–	1.4	1.1	13
1/R*	1.09	1.12	0.80	0.18	14.3	1.3	3.3	0.9	1.2	2.6	1.5	–	–	4.6	0.2	12
2/R*	1.11	1.09	0.83	0.28	11.2	1.9	2.8	–	–	–	2.8	–	–	3.7	–	2
2/Cz	1.19	0.90	1.03	0.28	15.6	6.3	1.0	–	–	3.1	1.0	–	–	2.1	2.1	10
	Górzno Till (T7)															
1/Ws	1.69	0.62	1.56	0.11	8.3	0.8	1.1	0.4	1.4	2.2	1.6	0.6	0.1	0.1	–	10
3/Sz	1.70	0.65	1.50	0.05	13.7	2.5	2.2	1.4	–	5.7	0.9	–	–	0.8	–	12
3/G	1.55	0.70	1.35	0.05	28.5	13.7	2.8	–	–	6.9	1.4	0.2	–	–	3.4	12
3/G	1.34	0.80	1.18	0.18	13.7	4.6	2.4	–	0.1	3.6	1.6	0.5	0.3	0.1	0.6	12
1/Ra	1.76	0.55	1.50	0.20	13.7	2.6	2.4	–	–	4.9	0.6	0.4	0.8	1.5	0.5	10
1/Od	1.60	0.70	1.30	0.14	T9.0	6.9	1.8	–	–	5.5	1.2	0.7	0.4	0.6	1.5	8
	Górzno Till in the type region															
	1.3–1.7	0.7–1.0	1.1–1.6	0.0–0.15												
	Kopaszewko Till in the type region															
	1.7–2.1	0.5–0.7	1.5–1.8	0.1–0.22												
	Karolewo Till in the type region															
	1.0–1.3	0.9–1.1	0.9–1.2	0.01–0.4												

* dolomite content may contain analytical error (J. A. Czerwonka, 1978)

Górzno Till near Leszno (J. A. Czerwonka, D. Krzyszkowski, 1994). Hence, it seems, that the T7 till directly corresponds with the latter. The Górzno Till near Leszno has occurred as the single till bed, what it is the case also for some investigated profiles (Figs. 9, 16). Two profiles investigated recently contain a flint-rich and dolomite-poor till (Naratów Till, T6A) and the relatively dolomite-rich till (Górzno Till, T7) in superposition and forming one, uniform till bed (Fig. 10). This resemble the stratigraphic relation between the Karolewo Till (here interpreted as direct equivalent of the Naratów Till) and the Kopaszewko Till near Poznań (J. A. Czerwonka, D. Krzyszkowski, 1994). In both regions there is, however, not sure whether these tills represent separate ice-sheet advances or only a change of regional ice-flow with no ice-melting. Przydroże profile (Fig. 10) may suggest the first possibility, as there is a slight difference in $CaCO_3$ content between both tills, which may even suggest weathering in the lower one.

FLUVIAL AND LACUSTRINE DEPOSITS

PREGLACIAL FLUVIAL SERIES

Preglacial fluvial deposits, i.e. Pliocene fluvial deposits lying above the Miocene Poznań clay and below the glacial suites, have been documented undoubtedly only in three investigated borings (Figs. 11, 12). However, these deposits are surely more widespread, especially along the Silesian Rampart (J. A. Czerwonka, D. Krzyszkowski, 1992*b*, in preparation). Provisionally, three zones with different heavy minerals can be distinguished in the preglacial deposits of the Silesian Rampart: western zone with mainly the andalusite and tourmaline, central zone with mainly the zircon, tourmaline and cyanite and the eastern zone with mainly the staurolite and garnet (Fig. 17A). The heavy mineral characteristics of preglacial deposits of the Moskorzyn profile well fit with the western zone, this one of the Chałupki profile with the central zone and heavy mineral assemblages of the Godzięcin profile belong to the eastern zone of the preglacial series (Fig. 12). Profiles with preglacial deposits of the central zone have been described also by J. A. Czerwonka and D. Krzyszkowski (1992*b*) at Radecz and Rościsławice (Fig. 17A). Futhermore, many Quaternary deposits contain here large zircon and tourmaline admixture (e.g. Figs. 5, 11), that may come from redeposition of preglacial sediments of the central zone.

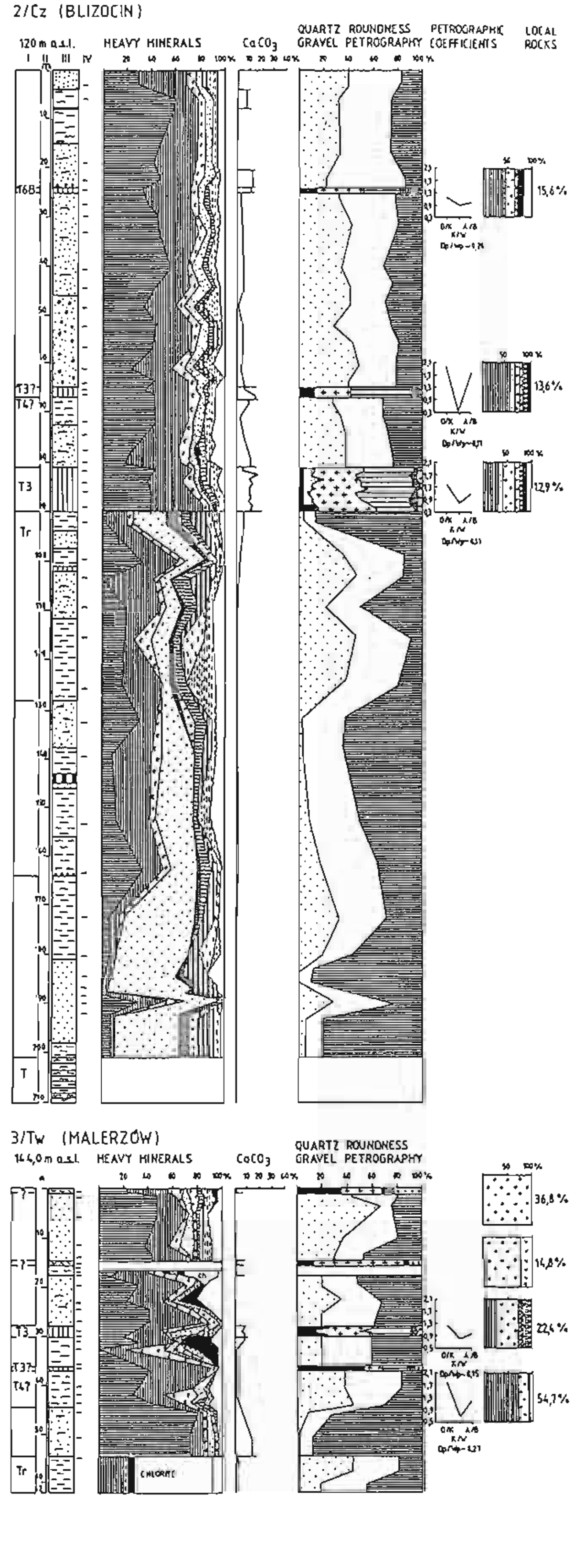


Fig. 14. Charts of borings Blizocin (2/Cz) and Malerzów (3/Tw) with a sequence of results of the standard petrological studies
Explanations in Fig. 4

Karty otworów Blizocin (2/Cz) i Malerzów (3/Tw) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

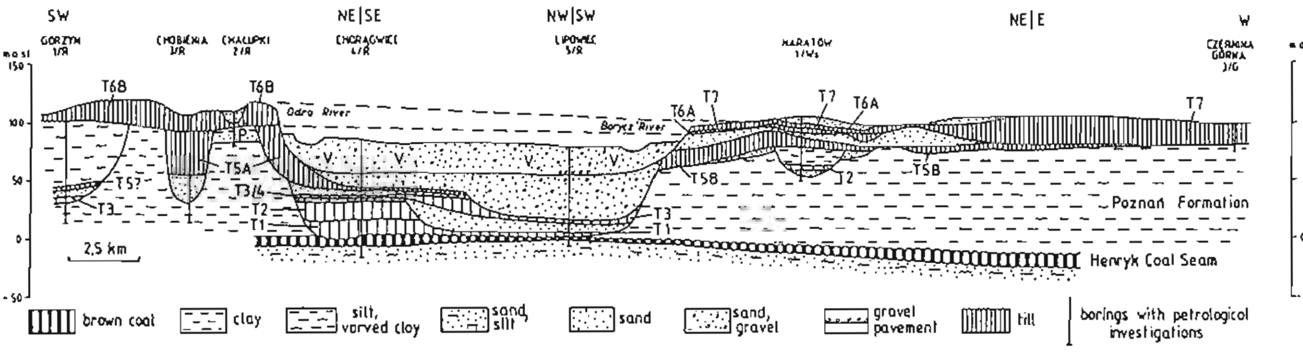


Fig. 15. Geological cross-section Górzno–Chorągwice–Naratów throughout the Odra and Barycz River valleys and adjacent moraine uplands

P — preglacial deposits, T1 — Grońsko Till, T2 — Krzesinki Till, T3 — Wierzbno Till, T3/4 — possible Borowiec Till, T5A — Smolna Till, T5B — Dopiewiec Till, T6A — Naratów Till, T6B — Taczów Till, T7 — Górzno Till, V — Weichselian fluvial deposits; location of the section in Fig. 3

Przekrój geologiczny Górzno–Chorągwice–Naratów przez doliny Odry i Baryczy oraz sąsiednie wysoczyzny morenowe

P — utwory preglacjalne, T1 — glina typu Grońsko, T2 — glina typu Krzesinki, T3 — glina typu Wierzbno, T3/4 — prawdopodobna glina typu Borowiec, T5A — glina typu Smolna, T5B — glina typu Dopiewiec, T6A — glina typu Naratów, T6B — glina typu Taczów, T7 — glina typu Górzno, V — osady rzeczne vistulianu; lokalizacja przekroju — na fig. 3

"PYROXENE" FLUVIAL SERIES

J. A. Czerwonka and D. Krzyszkowski (1992*b*, 1994) have described the possible fluvial deposit in central Silesia and Leszno region, which is characterized by an increased pyroxene content and the relatively low content of angular quartz grains (Oleśnica and Pawłowice Formations, respectively). These series occur below the Wierzbno Till in central Silesia and between the Krzesinki and Witosław Tills in the Leszno region, and hence the series has been interpreted as the interstadial fluvial deposit formed between the Middle and Late Elsterian ice-advances. J. A. Czerwonka *et al.* (1991) have described the "pyroxene" series from Bożeń (Fig. 17A), although this profile does not contain tills.

Two additional profiles of the region investigated contain sequences with an increased pyroxene content, which may represent the "pyroxene" fluvial series. At Łaszczyn (Fig. 9), this series is 14 m thick and comprises sands and gravels. The pyroxene is about 10%, but the lowest sample of the overlying till contains up to 27% of pyroxene. The latter may come from redeposition of the underlying fluvial sequence. Other features of the series do not differ from the series characteristics in the central Silesia and especially this of the Leszno Upland (Table 6). However, stratigraphic position of the "pyroxene" series at Łaszczyn is ambiguous. Indeed, it lies below the till, but just this one has very ambiguous documentation and it is only temporarily correlated with the T5 till. Even more complex stratigraphy is observed at Sucha Wielka profile (Fig. 18). This profile comprises at least three fragments of the sedimentary sequence, which contain more pyroxene than other (7–20%, Table 6). This may be due to glaciotectonic deformation of the original sequence, the more as the profile contains also doubled T5A till and thick Tertiary clay bed within the Pleistocene deposits. The lowest pyroxene-rich fragment is assumed to be not, or only little bit, thrusted up and it probably represents more or less original position of the series. The sandy fluvial deposit is here 44 m thick and occurs below the T3 till (Fig. 18). The heavy mineral and quartz roundness characteristics well fit with features of the "pyroxene" series of the Silesian Lowland.

From the above, it follows that none of the profile of the region investigated contain "pyroxene" series in unambiguous stratigraphic position. However, if we assume that its position is the same as in regions southwards and northwards, the fluvial tract of the "pyroxene" river may be as presented in Figure 17A.

FLUVIAL SERIES BETWEEN T5 AND T6/T7 TILLS

Three profiles of the region investigated and the additional one at Sława Śląska (D. Krzyszkowski *et al.*, in preparation) contain deposits which may be interpreted as fluvial series. These deposits are characterized, first of all, by absolute predominance of well and partially rounded quartz grains (36–70 and 23–51%, respectively) and very low content of angular grains (5–21%) (Table 6). Additionally, an upward increase of well rounded grains has been observed. Similar features have been described for periglacial and/or interstadial fluvial deposits in central Poland (J. Goździk, 1980; D. Krzyszkowski, 1990*a*, *b*, *c*). Also, the heavy mineral characteristics may suggest fluvial origin of deposits, as garnet is a dominant mineral, with decreased amphibole and increased locally-derived minerals, such as staurolite, tourmaline, andalusite and cyanite (Table 6) (D. Krzyszkowski, 1990*a*, *b*, *c*).

The described fluvial deposits lie at different altitudes in different profiles: 71 and 73 m a.s.l. at Kulów and Łaszczyn and 62 m a.s.l. at Sanie and Sława Śląska (Figs. 9, 13). Precise stratigraphy is known only from profile Sława Śląska (D. Krzyszkowski *et al.*, in preparation), where the series occurs directly between T5 and T6A tills. At Kulów (Fig. 13) it lies below the Naratów Till (T6A) with no other till below. Similar profile is at Sanie, although here the series occurs below the Taczów Till (T6B), and the thin till below have not been investigated. At Łaszczyn (Fig. 9) this series occurs below the Górzno Till (T7) and above the possible Dopiewiec Till (T5). Two fluvial tracts have been interpreted (Fig. 17B), taking into account the altitudes of fluvial deposits and possible source of staurolite and other local minerals from the outcrops of the preglacial series near Leszno (J. A. Czerwonka *et al.*, 1994*b*).

"CHLORITE" FLUVIOLACUSTRINE SERIES

This series have been described by D. Krzyszkowski *et al.* (1994) from two borings: Bożeń (fluvial series) and Lubiel (lacustrine series) (Fig. 17B). D. Krzyszkowski *et al.* (1994) assumed, that the "chlorite" river run from SW to NE, crossing and eroding the Trzebnica Hills during the Wartanian Stage, and then the valley (Bożeń) and the valley-lake (Lubiel) have been filled with sediments during the Early Eemian.

EEMIAN LACUSTRINE DEPOSITS

Eemian deposits have been decribed only in three borings of the region investigated, where Lechitów (Fig. 6) comprises a sequence with complete Eemian pollen succession, Katarzynów (Fig. 7) only a fragment from the optimum phase and Lubiel only a fragment from the begining of the interglacial (D. Krzyszkowski *et al.*, 1994; T. Kuszell, A. Sadowska,

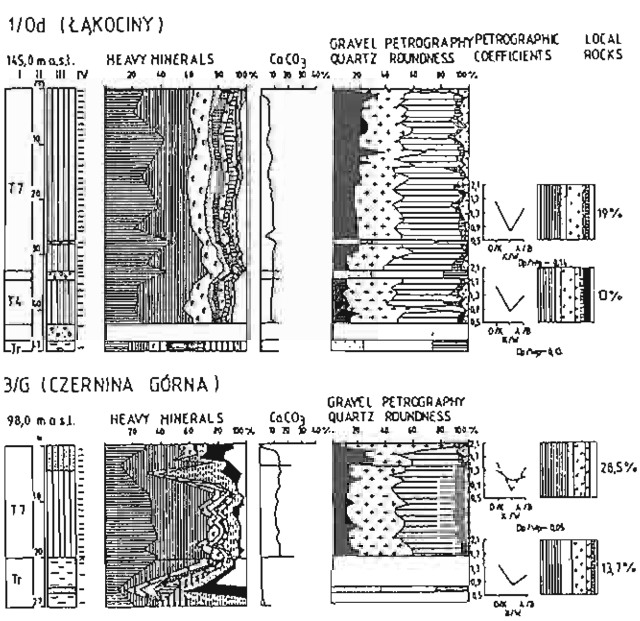


Fig. 16. Charts of borings Łąkociny (1/Od) and Czernina Górna (3/G) with a sequence of results of the standard petrological studies
Explanations in Fig. 4

Karty otworów Łąkociny (1/Od) i Czernina Górna (3/G) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

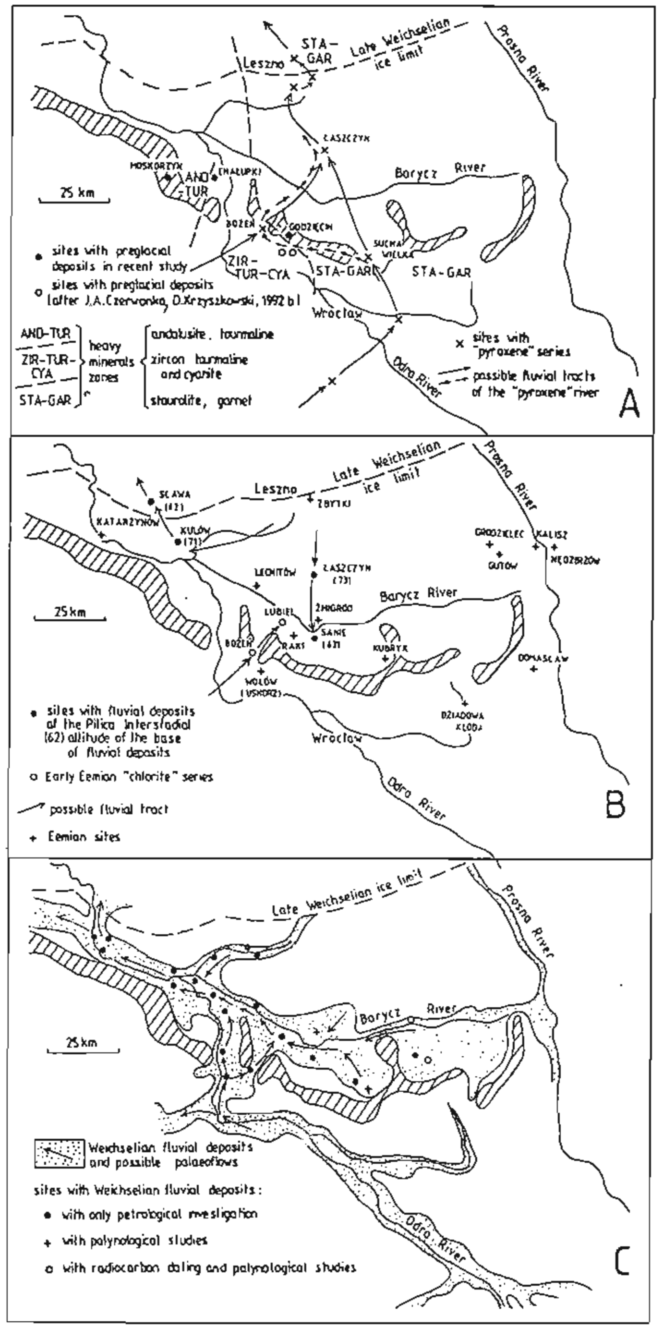


Fig. 17. Distribution of fluvial deposits in the region investigated: **A** — Pliocene preglacial series and Mid-Elsterian interstadial "pyroxene" series; **B** — fluvial deposits of the Pilica Interstadial and the Early Eemian against the background of distribution of the Eemian lacustrine sites; **C** — Middle and Late Weichselian fluvial series

Rozmieszczenie kopalnych osadów rzecznych na badanym obszarze: **A** — plioceńskie serie preglacjalne i piroksenowa seria rzeczna z interstadiału zlodowacenia południowopolskiego; **B** — osady rzeczne interstadiału pilicy na tle występowania eemskich osadów jeziornych; **C** — środkowo- i późnovistuliańskie serie rzeczne

1994; A. Sadowska *et al.*, 1995). Lechitów and Katarzynów contain organic deposits (gyttja, peat) and Lubiel clastic deposits (silts) with only few and thin organic layers. All these profiles lie in the central basins and lithostratigraphic position

Table 6

Selected mineralogical properties of the fluvial series in northern Silesia

Borehole	Base of series	Heavy minerals [%]											Quartz roundness [%]		
		garnet	amphibole	epidote	pyroxene	staurolite	andalusite	tourmaline	zircon	cyanite	biotite	chlorite	well	partially	angular
		pyroxene fluvial series													
Oleśnica Fm.	85–90 m a.s.l.	26–38	14–28	10	14–20	1–7	–	3–8	–	–	–	–	40	40	20
Sucha Wlk.	glacitec. def.	16	28	16	12	7	–	7	2	–	1	10	15	65	20
Sucha Wlk.	glacitec. def.	18	18	16	7	11	–	10	3	4	–	3	2	70	28
Sucha Wlk.	40 m a.s.l.	23	43	13	20	3	–	2	–	–	–	5	10	70	20
Borzeń	30 m a.s.l.	26	7	3	14	8	7	16	2	2	2	3	35	45	20
Łaszczyn	52 m a.s.l.	39	29	4	10	2	2	2	2	2	1	–	30	40	30
Pawłowice Fm.	40–55 m a.s.l.	19–33	23–39	6–8	8–13	1–7	–	3–8	–	–	3–17	–	45	40	15
		fluvial series of the Pilica Interstadial													
Sława	62 m a.s.l.	33	16	4	9	9	8	6	4	4	–	–	36	51	13
Kulów	71 m a.s.l.	41	15	4	8	5	5	6	4	4	–	–	70	23	7
Sanie	62 m a.s.l.	34	25	4	10	6	5	1	3	9	2	–	55	40	5
Łaszczyn	73 m a.s.l.	50	18	5	3	10	1	2	4	2	–	–	48	31	21

of interglacial deposits in relation to tills is ambiguous (Figs. 6, 7). Also, other Eemian sites described in the region (Fig. 17B), e.g. Uskorz (Wołów), Raki and Żmigród (S. Dyjor, T. Kuszell, 1975; T. Kuszell, 1980; S. Skompski, 1983; D. Krzyszkowski *et al.*, 1994), indicate ambiguous lithostratigraphic position. However, in all these sites Eemian deposits lie directly below the Weichselian fluvial deposits and above either Tertiary deposits (Uskorz) or glaciofluvial deposits (Leehitów), or glaeiolacustrine deposits (Lubiel), or poorly documented till and/or glaciolacustrine deposits (Katarzynów).

WEICHSELIAN FLUVIOLACUSTRINE SERIES

These deposits have been found in more than 20 borings (Fig. 17C). The complete Weichselian sequence comprises two units. The lower one eonsists of lacustrine silts with thin peaty layers, which are often interbedded with diamicton layers. This unit is 5–15 m thick. The upper unit consists sands with silty and organic layers, sands or sands and gravels. They are from few metres up to 50 m thick. The lower unit oceurs only in the Rawicz and Żmigród Basins. The most thick, up to 50 m, sequences occur in the Głogów Pradolina (Fig. 7). Radiocarbon dates from the lower unit are 46 100±1800 yrs BP (Gd 7252) and 25 900±700 yrs BP (Gd 6787) and from the upper unit 20 800±600 yrs BP (Gd 6790), thus the sediments represent most probably the Middle Pleniglacial (lower unit) and the Upper Pleniglacial (upper unit) of the Weichselian. At the top of upper fluvial unit, there are some other sandy fluvial deposits with varying thickness, that may represent the postglacial times.

The Weichselian fluvial deposits are characterized by a predominance of well and partially rounded quartz grains, where the first one often increases upwards, and a small number of angular grains (Figs. 4–9, 13, 14). Among heavy minerals, garnet predominates and often also increascs upwards. These two features have been commonly found also in Weichselian fluvial deposits of central Poland (J. Goździk, 1980; D. Krzyszkowski, 1990*c*). Postglacial dcposits at the top of the sequence differ little bit in heavy mineral content, with an increased number of local minerals.

TILL STRATIGRAPHY

The stratigraphic position of tills and correlation with neighbouring regions are presented in Table 7. Undoubtedly, several till beds defined in the region investigated can be easily correlated. The T1, T2 and T3 tills well correlate with the Grońsko/Pietrzykowice, Krzesinki and Witosław/Wierzbno Tills. Thus, they represent the Elsterian Stage, and its early, middle and late ice-sheet advances (stadials), respectively. The T5 till well correspond with the Dopiewiec and Smolna Tills and it may be easily interpreted as the Early Saalian (Odranian) glacial deposit. In turn, the T7 till well corresponds with the Górzno Till, pressumed to represent the

Late Saalian (Wartanian) ice-sheet advance (J. A. Czerwonka, D. Krzyszkowski, 1992*b*, 1994). The Taczów Till (T6B) was deposited by definition (M. Schwarzbach, 1942; D. Krzyszkowski, 1993) by the Wartanian ice-sheet near its maximum extent. Hence, if correlation of the Taczów Till with the Naratów Till is correct, what seems to be the case (e.g. Fig. 15), and the latter corresponds with the Karolewo Till near Poznań, that means that all of them represent an early ice-sheet advance from the Wartanian Stage. The Górzno Till (T7) represents later ice-advance from this stage and may correspond with the Kopaszewko Till outcroping northwards (Table 7).

From the above, it also follows that the fluvial deposits lying in between the T5 and T6/T7 tills may have been deposited during the Pilica Interstadial (Odranian/Wartanian Stage). The Borowiec Till (T4) seems to be only one till bed of the region investigated with ambiguous correlation and age. These must be inferred from geological context (Figs. 19, 20).

The Leszno Upland indicates quite simple Quaternary geology which is formed of tabular layers of tills, glaciofluvial and glaciolacustrine deposits, with only few palaeovalleys filled with fluvial sequences. The Tertiary deposits lie here quite high (50–70 m a.s.l.), being only occasionally incised down to 20–30 m a.s.l. (Fig. 19A). The Pleistocene deposits are usually 20–40 m thick and up to 70 m within the incisions. The Elsterian Krzesinki Till (T2) occurs only occasionally and usually directly on the Tertiary deposits. Other Elsterian tills are not present in the investigated profiles. The Odranian Dopiewiec Till (T5B) is more continuous, lying either above the T2 till and/or glaciofluvial and glaciolacustrine deposits or directly above the Tertiary strata. The Wartanian glacial sequence forms very continuous, 5–20 m thick, bed at the ground surface. It comprises either T6A and T7 tills in superposition or each of them separately (Fig. 19A).

The central basins preserve well usually only the lower part of the Pleistocene glacial sequence (T1–T4 tills), as the upper tills (T5–T7) are most often eroded and in part replaced by the young fluvial deposits. However, some Saalian glaciofluvial and glaciolacustrine deposits are still preserved (Fig. 19B). Total thickness of Quaternary deposits in this sub-region is from 50 to 120 m. The top surface of Tertiary deposits lies at 20–40 m a.s.l. in the Milicz Basin, 0–20 m a.s.l. in the Żmigród Basin and 0–40 m a.s.l. in the Głogów Pradolina (Fig. 19B).

The basic stratigraphic problem of the central sub-region is position of the T4 till and its relation to older tills (T1, T2) and the T3 till. From the correlation diagram (Fig. 19B) it seems, that both T3 and T4 tills occur in similar geological position, i.e. above both T1 and T2 tills. If no different petrographic composition, they should be classified as one till bed. This is especially well visible in Borowiec, Przyborów and Katarzynów profiles and also in Lipowiec, Chorągwice and Lechitów profiles of the Głogów Pradolina (Fig. 19B). At the moment, the Borowiec (T4) and Wierzbno/Witosław (T3) Tills are interpreted as one, stratigraphically uniform till horizon, although with geographically variable petrographic composition. Thus, the Borowiec Till may also represent the Late Elsterian ice-sheet advance.

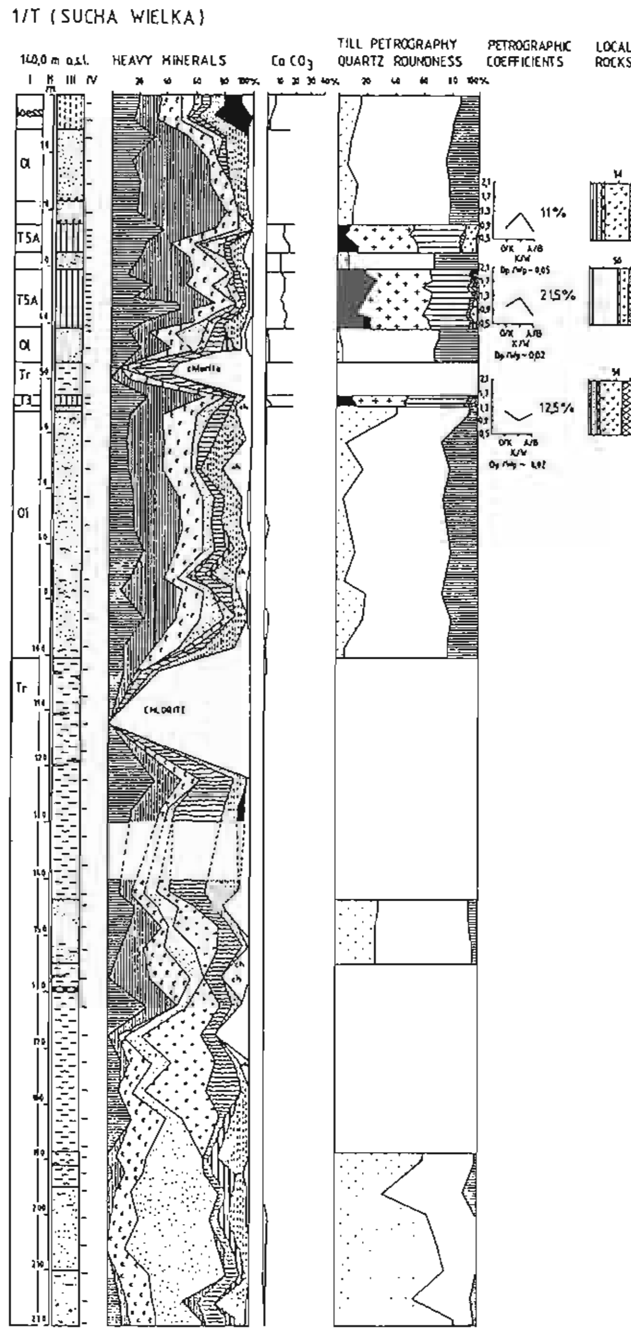


Fig. 18. Chart of boring Sucha Wielka (1/T) with a sequence of results of the standard petrological studies
Explanations in Fig. 4

Karta otworu Sucha Wielka (1/T) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

Except six profiles mentioned above, which comprise at least two Elsterian tills in the sequence, other profiles contain usually only one Elsterian till. The complete Elsterian sequences occur only in the Głogów Pradolina, although even here many profiles contain only one Elsterian till. The Milicz and Żmigród Basins comprises practically only the Borowiec Till. The Early Saalian (Odranian) till has been documented here

Table 7

Correlation of tills and other deposits in southern Poland

Stratigraphy		Poznań region (J. A. Czerwonka, D. Krzyszkowski, 1994)	Leszno region (J. A. Czerwonka, D. Krzyszkowski, 1994)	Investigated region			Silesian Lowland (J. A. Czerwonka, D. Krzyszkowski, 1992*b*)
				northern upland	central basins	southern hills	
Weichselian		T9B Bytyń Till T9A Maliniec Till	T9A Maliniec Till		V fluvial deposits		fluvial deposits (middle and lower terraces)
Eemian		Złotkowo and Szeląg Formations	Szeląg and Zbytki Formations		E Eemian deposits at Żmigród, Raki, Lechitów and Katarzynów	Eemian deposits at Uskorz	fluvial deposits (upper terrace)
Saalian	Wartanian	T7 Mutowo Till T6 Kopaszewko Till T5 Karolewo Till	T8 Górzno Till	T7 Górzno Till T6A Naratów Till	E? chlorite fluvial series T6B Taczów Till	T6B Taczów Till	
	Pil. Inter.			F fluvial deposits	F fluvial deposits		
	Odranian	T4 Dopiewiec Till	T4 Dopiewiec Till	T5B Dopiewiec Till	T5A Smolna Till	T5A Smolna Till	T3 Smolna Till
hiatus							
Elsterian		T3 Witosław Till T2 Krzesinki Till T1 Grońsko Till	T3 Witosław Till Pw pyroxene series (Pawłowice Formation) T2 Krzesinki Till T1 Grońsko Till	Pw pyroxene series (Łaszczyn) T2 Krzesinki Till	T4 Borowiec Till T3 Wierzbno Till T2 Krzesinki Till T1 Grońsko Till	T3 Wierzbno Till Ol pyroxene series T2 Krzesinki Till	T2 Wierzbno Till Ol pyroxene series (Oleśnica Formation) T1 Pietrzykowice Till
			pregiacial deposits	preglacial deposits		preglacial deposits	preglacial deposits

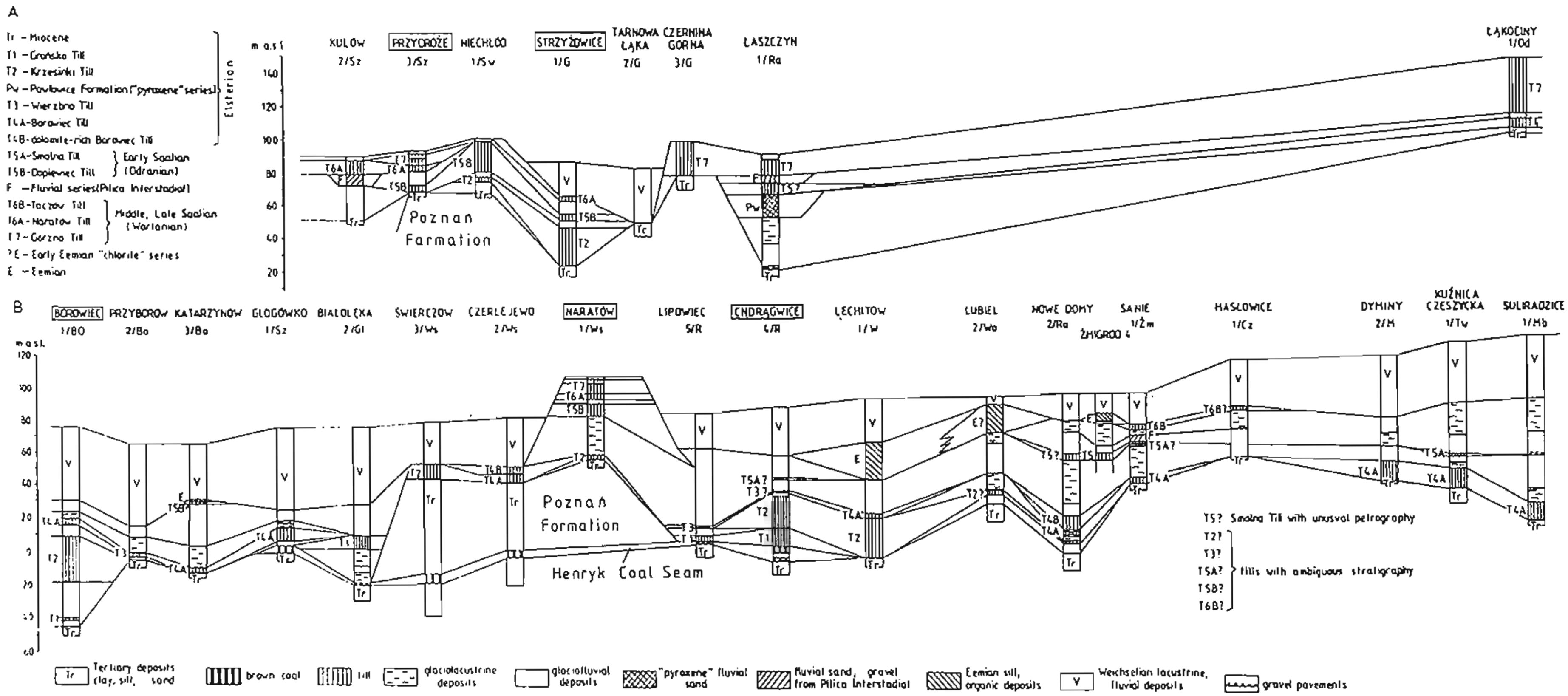


Fig. 19. Correlation of the Pleistocene deposits of the Leszno and Kalisz Uplands (A) and along the central depressions (Milicz and Żmigród Basin and Głogów Pradolina) (B)

Korelacja osadów plejstoceńskich z Wysoczyzny Leszczyńskiej i Kaliskiej (A) oraz wzdłuż centralnej depresji (Kotlina Milicka i Żmigrodzka oraz Pradolina Głogowska) (B)

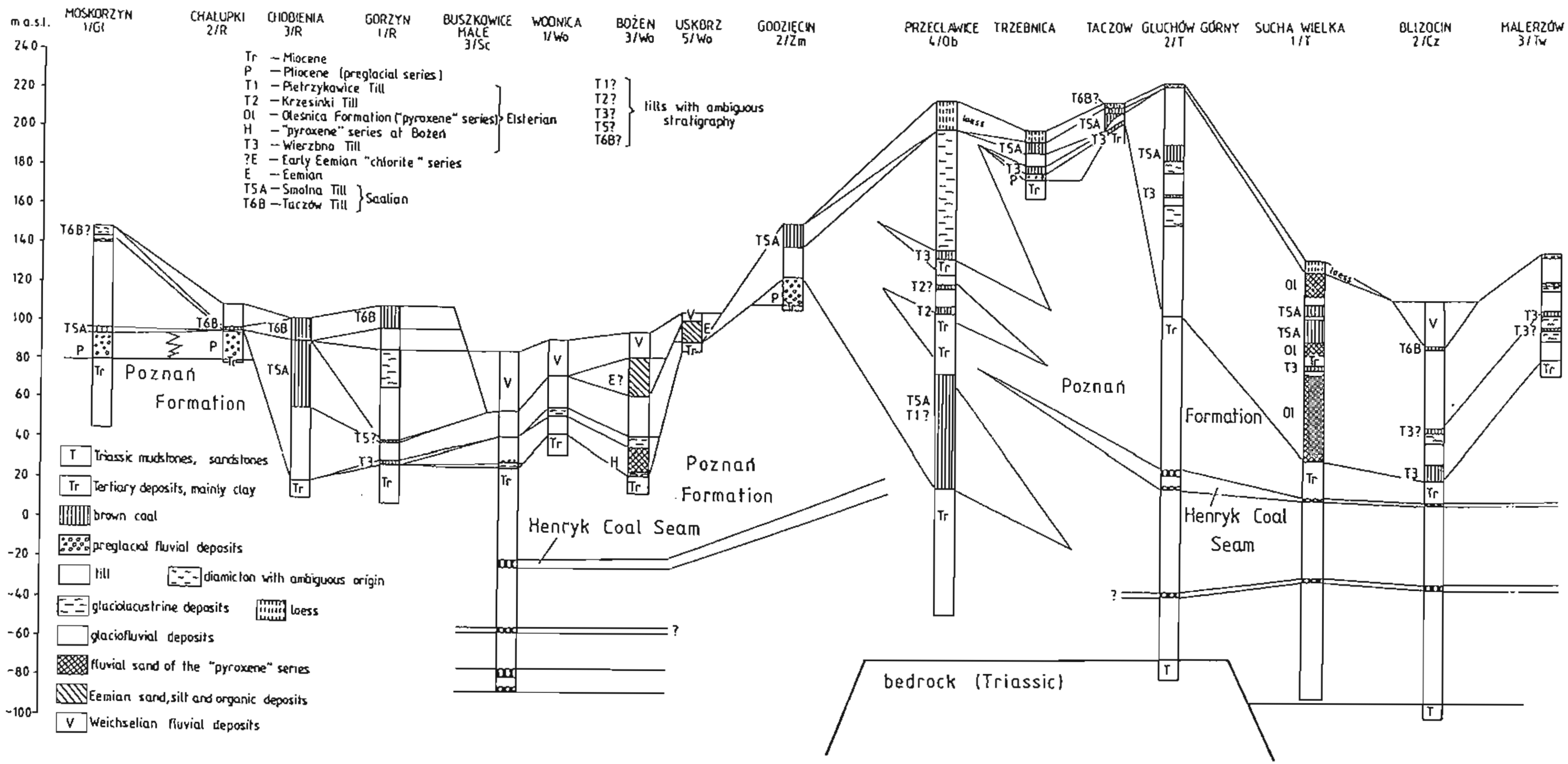


Fig. 20. A tentative correlation of the Pleistocene and Neogene deposits along the Silesian Rampart

Tymczasowa korelacja osadów plejstoceńskich i neogeńskich wzdłuż wału śląskiego only in one boring, with possible occurrence in other four, whereas the Late Saalian (Wartanian) till has been documented in central basins only in one profile (Sanie) (Fig. 19B). Saalian tills have been found only in the Milicz and Żmigród Basins and none in the Głogów Pradolina. Limited occurrence of tills in central basins may suggest strong erosional processes throughout the Pleistocene. Indeed, many fluvial deposits are present here: the Middle Elsterian "pyroxene" series, fluvial series of the Pilica Interstadial (Odranian/Wartanian), Late Wartanian/Early Eemian "chlorite" series, and, of course, the very extensive Middle and Late Weichselian fluvial series. However, neither lacustrine/organic nor fluvial deposits of the Holsteinian or other old interglacials have been recognized in northern Silesia.

The most complex stratigraphy is in the southern hills sub-region. Some fragments of the "Saalian uplands" are preserved in the northern foreland of the hills and these indicate simple and not disturbed stratigraphy. The Pleistocene sequence is 10–80 m thick, with Tertiary deposits ranging between 20 and 90 m a.s.l. Usually two or three tills occur here and these are the Wierzbno (T3), Smolna (T5A) and Taczów Tills (T6B) (Figs. 15, 20). In the axial part of the Silesian Rampart the Quaternary sequences are variable and often interbedded with Tertiary deposits (Fig. 20). In total, the deformed Quaternary sequences are here from 0 to 200 m thick and Tertiary deposits occur often at the ground surface. Type sections of this region, near Trzebnica, comprise the Wierzbno and Smolna Tills (D. Krzyszkowski, 1992*a*). The same tills have been found in superposition in Sucha Wielka profile (Fig. 18), whereas at Moskorzyn, Godzięcin (Fig. 12) and Głuchów Górny (Fig. 21) only Smolna Till has been documented and at Blizocin and Malerzów only the Wierzbno Till (Fig. 14). The most complex till sequence has been found at Przecławice (Fig. 23). Here, four till beds are present, with the Wierzbno type till (T3), and two tills with petrographic composition resembling the Krzesinki Till (T2). Another till is present below them and it would be nicely to interprete it as the T1 till and get the complete Elsterian sequence. This till, however, indicates petrographic characteristics as in the Smolna Till (compare Tables 1 and 4). Indeed, the profile must be disturbed, the more as many Tertiary rafts are present in the sequence (Figs. 20, 23). Strong deformation of deposits may be also assumed at Sucha Wielka (Fig. 18), where the T5 till and the pyroxene series are multiplied as well as at Blizocin and Malerzów where T3 till is multiplied (Fig. 14). A model of the geological structure is interpreted in the geological cross-section along the central part of Trzebnica Hills (Fig. 22). In this model, the Elsterian and Odranian tills and deposits interbedded with them are strongly deformed, folded and thrusted, whereas the Taczów Till lies discordantly above the deformed suite. The Taczów Till contacts laterally with glaciofluvial deposits of the Siedlec Sandur (Siedlec Formation), extending beyond the southern margin of the hills (Fig. 22).

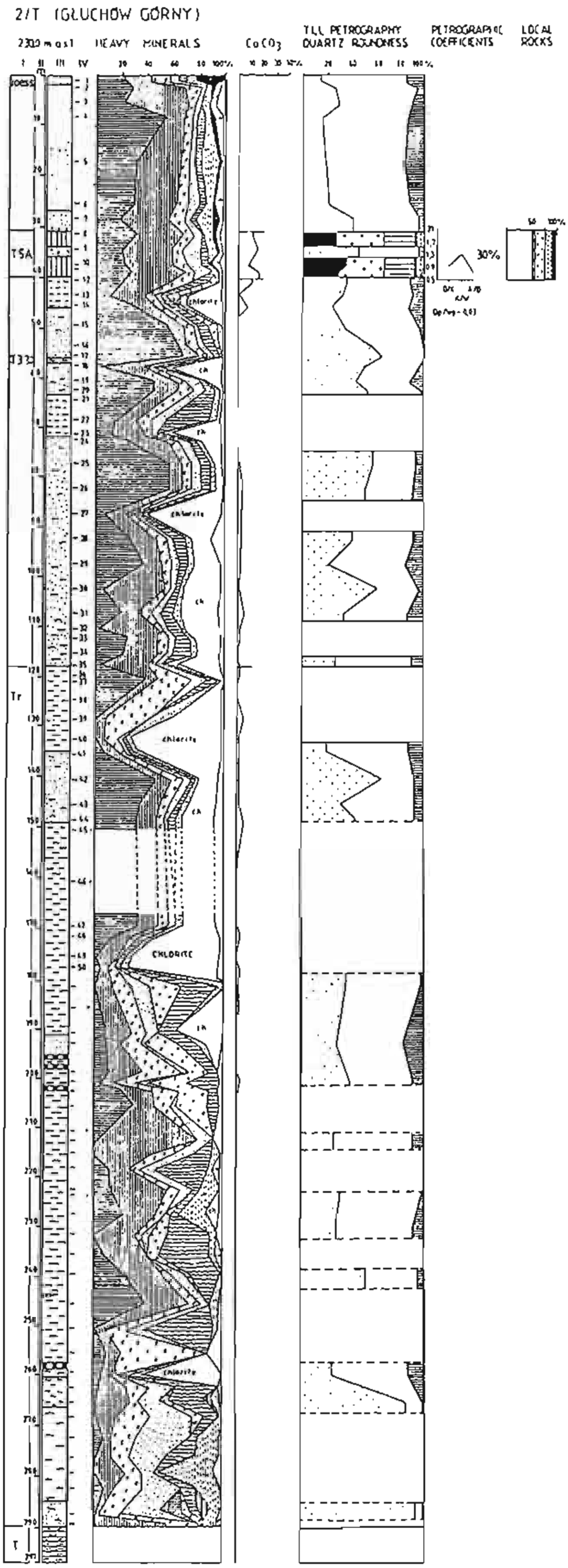


Fig. 21. Chart of boring Głuchów Górny (2/T) with a sequence of results of the standard petrological studies
Explanations in Fig. 4

Karta otworu Głuchów Górny (2/T) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

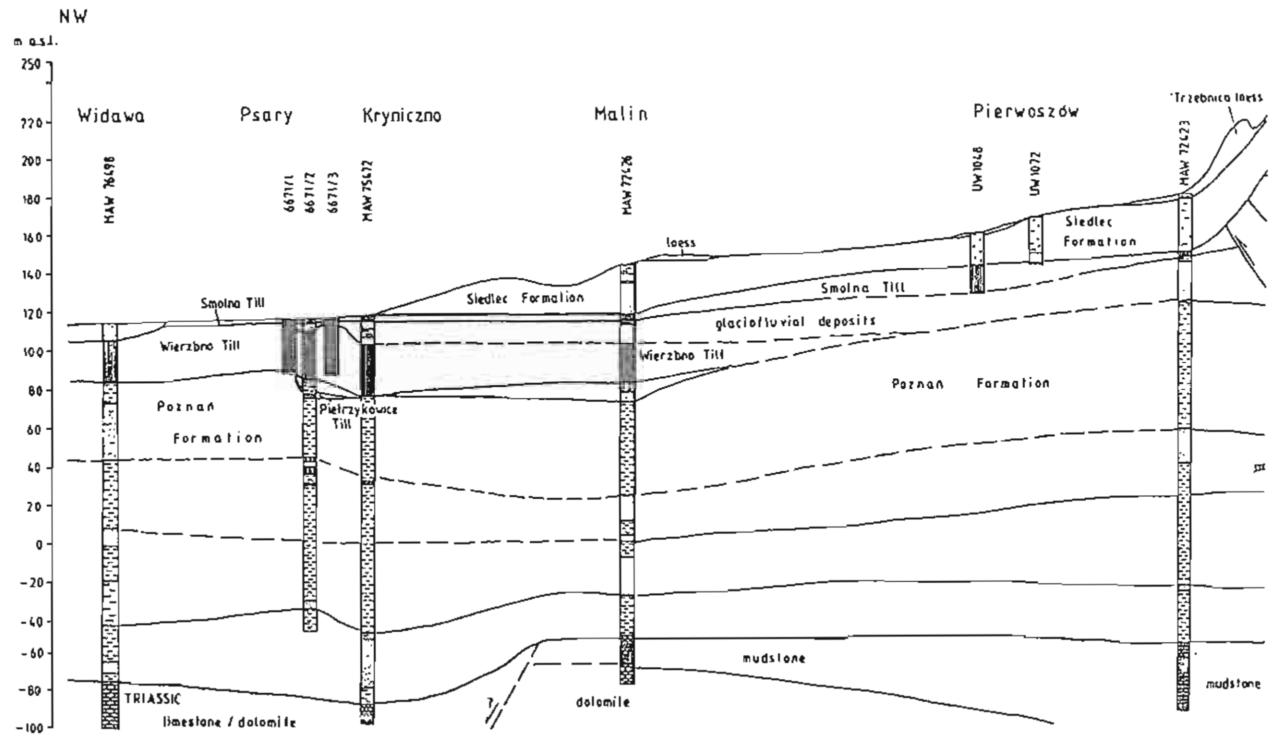


Fig. 22. Geological cross-section throughout the Trzebnica Hills: Widawa–Pierwoszów–Głuchów Górny–Sucha Wielka–Blizocin

Location of the section in Fig. 3; explanations of lithology as in Fig. 15; other explanations as in Fig. 4

DISCUSSION

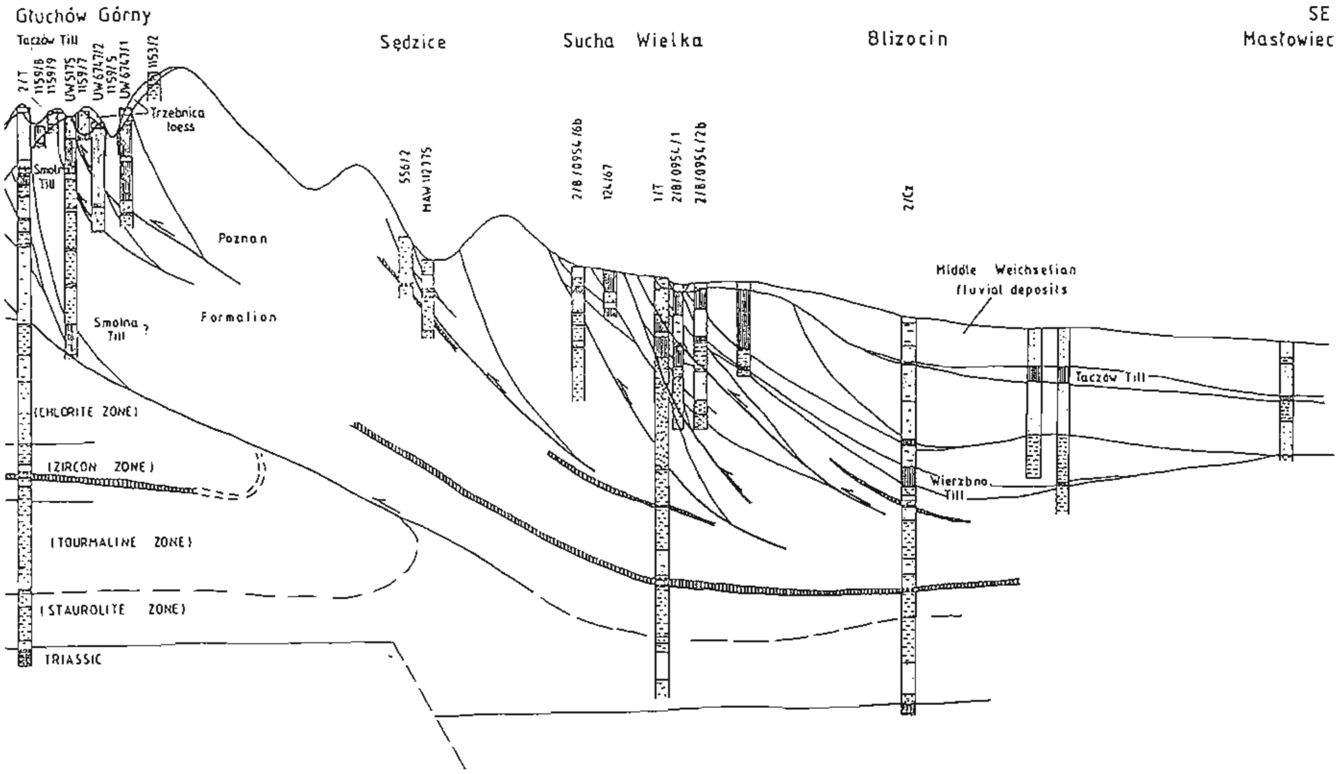
TILL DISTRIBUTION AND ICE-SHEET EXTENTS

The materials and interpretation presented above clearly show that tills may be correlated by means of their petrographic composition over very long distances (Table 7). It was hitherto suggested theoretically (J. A. Czerwonka, D. Krzyszkowski, 1994), as regions with the till investigations were geographically isolated. The presented materials, filling the gap in between two formerly investigated regions (J. A. Czerwonka, D. Krzyszkowski, 1992*b*, 1994), have only confirmed this conclusion. Also, two profiles published by J. A. Czerwonka and B. Witek (1977) are located among these recently discussed. Krzekotów profile has been located in the Głogów Pradolina and between Białołęka and Głogówek. The one till of this profile, lying directly on Tertiary strata, indicated features typical for the Wierzbno Till (K/W 0.8). The Krzepielów profile of the upland zone indicated the Smolna (K/W 1.3) and Górzno Tills (K/W 0.85) in superposition. The latter profile is located between Kulów and Przydroże. As the previously published results (J. A. Czerwonka, B. Witek, 1977) well fit with presented materials, this well confirms that petrographic analysis is a very good tool for lithostratigraphic correlation.

It seems, that some till horizons, as these from Early and Late Elsterian or from Early Saalian, not only occur in similar lithostratigraphic position, but also preserve almost the same petrographic features throughout the Western Poland. Other tills, although more restricted, are petrographically uniform over large distances, too. Futhermore, the region investigated include marginal zones of some ice-sheet advances, as indicated from limited southwards extent of some tills.

The Elsterian Glaciation indicated three separate ice-sheet advances (stadials) in the investigated region. The Early Elsterian ice-sheet advanced extremely southwards and at least to the foothills of the Sudetes (J. Badura *et al.*, 1992). The till deposited during this substage is very widespread in the Silesian Lowland (J. A. Czerwonka, D. Krzyszkowski, 1992*b*) (Fig. 24A). It is much less preserved norhwards: with one site near Leszno (Górzno profile, J. A. Czerwonka, D. Krzyszkowski, 1994), four sites in the investigated region, and two additional between Sława Śląska and Włoszakowice (D. Krzyszkowski *et al.*, in preparation) (Fig. 24A). The Early Elsterian till has not been recognized, yet, in the glaciotectonically deformed sequences of the Silesian Rampart. However, it theoretically should exist there as this glacial horizon occurs on both southern and northern sides of the hills.

The Middle Elsterian ice-sheet advance indicated, most probably, a limited southward extent. The Krzesinki Till is quite frequent in the Leszno Upland and Głogów Pradolina. More southwards it was recognized only in one site of the Trzebnica Hills (Fig. 24B). It seems, that the lower till of the



Przekrój geologiczny przez Wzgórza Trzebnickie: Widawa–Pierwoszów–Głuchów Górny–Sucha Wielka–Blizocin

Lokalizacja przekroju znajduje się na fig. 3; objaśnienia litologii jak na fig. 15; pozostałe objaśnienia jak na fig. 4

Rościsławice profile southwards of Trzebnica Hills (J. A. Czerwonka, D. Krzyszkowski, 1992*b*, fig. 9) may be reinterpreted. Formerly, this till was classified as the Pietrzykowice Till, even if petrographic composition was different from that of the type profiles. The till is very thin and former interpretation overestimated this fact. Recently we may conclude that the features of the lower till at Rościsławice well fit with the Krzesinki Till and that the former interpretation is unsound. If so, the newly defined Krzesinki Till at Rościsławice represents the southernmost site with the Middle Elsterian stadial deposits in Western Poland (Fig. 24B). This may lead into conclusion, that the ice-marginal zone of this stadial occurred somewhere along recent Silesian Rampart or slighty southwards.

The Late Elsterian ice-advance was as extensive as this one from the Early Elsterian and the till from this stadial occurs both in the foothills of the Sudetes and in the Silesian Lowland (Fig. 24C) (J. Badura *et al.*, 1992; J. A. Czerwonka, D. Krzyszkowski, 1992*b*). It is also very widespread in the Leszno Upland and northwards (J. A. Czerwonka, D. Krzyszkowski, 1994). However, the Borowiec Till of the region investigated forms a belt in between two another, well petrographically correlative till beds: the Wierzbno and Witosław Tills (Fig. 24C). If all of them represent one, Late Elsterian ice-sheet advance, the reason for different petrographic composition of the till in sites occurring very close to each other remains very mysterious. Although they all are characterized by the predominance of Baltic limestones, the Borowiec Till indicates much increased limestone and much more dolomite. These features do not occur in Late Elsterian tills either to south or to north of the limestone-rich belt located along central depressions (Fig. 24C).

As the fluvial deposits were deposited only between the Middle and Late Elsterian ice-sheet advances ("pyroxene" series), it seems, that this ice-free substage was longer than the older interstadial.

The Early Saalian (Odranian) ice-sheet advance has reached the Sudetes in the south (J. Badura *et al.*, 1992) and deposited a continuous till over the Silesian Lowland (J. A. Czerwonka, D. Krzyszkowski, 1992*b*). This till is also very widespread in the Leszno and Poznań regions (J. A. Czerwonka, D. Krzyszkowski, 1994) as well as in the region investigated (Fig. 25A). In all regions the Odranian till indicates very uniform petrographic composition. In turn, the Wartanian tills (Middle and Late Saalian ice-sheet advances) have more limited extents. The first Wartanian ice-sheet advance (Middle Saalian), depositing the Naratów and Taczów Tills, extended at the furthest to axial part of the Silesian Rampart (Fig. 25B) (D. Krzyszkowski, 1993). Thus, the southernmost Wartanian ice-marginal zone is just located at the top of the hills. This may be confirmed by widespread occurrence of alluvial fans (sandur) at the southern margin of Trzebnica and Twardogóra Hills, that overlie the Early Saalian (Odranian) till (Fig. 23) (D. Krzyszkowski, 1993). The Górzno Till (T7) may have been deposited by separate and second Wartanian ice-sheet advance (Late Saalian), but it is also possible that this till resulted only due to change of regional ice-flow, with no regional ice-retreat. The change of ice-flow direction to

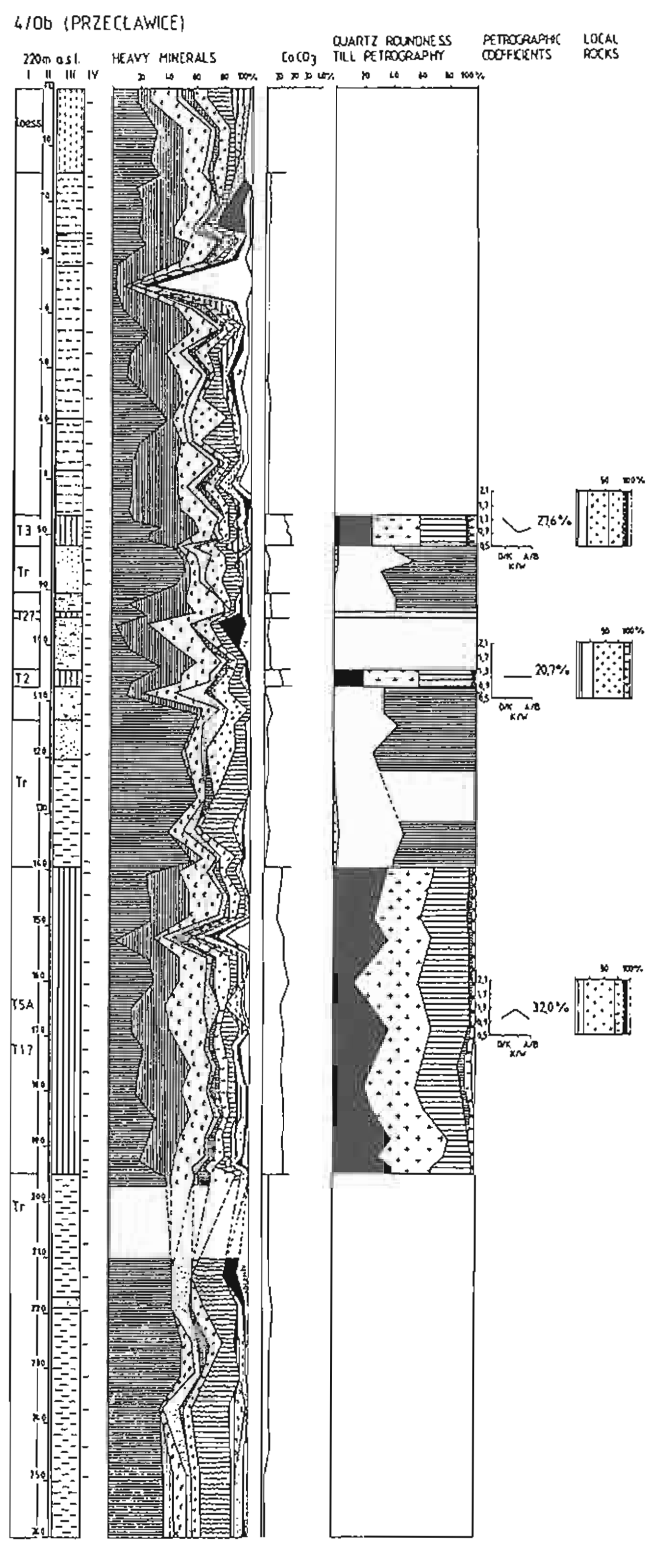


Fig. 23. Chart of boring Przeelawiee (4/Ob) with a sequence of results of the standard petrological studies
Explanations in Fig. 4

Karta otworu Przecławice (4/Ob) z wynikami standardowych badań petrologicznych
Objaśnienia jak na fig. 4

more eastern sector (= more limestones) in the late glacial stages have been described in many European profiles, including Saalian tills (J. Ehlers *et al.*, 1984; M. Böse, 1989; J. Ehlers, 1992). Nevertheless, the Górzno Till extends only to the southern part of the Leszno and Kalisz Uplands (Fig. 25C), that suggests at least partial ice-sheet retreat. The position of new, Late Wartanian ice-marginal zone is not precisely established, but it seems possible that glaciotectonically disturbed sequences of the Krotoszyn and Wąsosz Hills were formed in this zone (Fig. 25C).

The presence of fluvial deposits between the Odranian till and the first Wartanian till suggest that this interstadial period was quite extensive. This seems to be a common feature over the central Europe as fluvial deposits of the Pilica Interstadial are known also in central Poland and Eastern Germany (J. Goździk, 1980; D. Krzyszkowski, 1990*b*; A. G. Cepek, W. Nowel, 1991; D. Krzyszkowski, M. Nita, 1995). The interstadial fluvial deposits in between Middle and Late Saalian ice-advances have not been found, yet, in Western Poland, although they are present in Eastern Germany (A. G. Cepek, W. Nowel, 1991).

In conclusion, it seems that three ice-sheet advances crossed the region investigated indicating very southern extent. These are the Early and Late Elsterian and the Early Saalian advances. In turn, another three, the Middle Elsterian and Middle and Late Saalian (Wartanian), definitevely have finished in the area of investigations. The Middle Elsterian ice-marginal zone was formed roughly along the recent Silesian Rampart, although the present-day hills seems to be formed much later. In turn, the Middle Saalian ice-marginal zone formed just along these hills, which probably come from this time. The Late Saalian ice-marginal zone was probably more northwards at the southern margin of Leszno and Kalisz Uplands.

GENERAL MODEL OF THE PLEISTOCENE GEOLOGY AND POSSIBLE ORIGIN OF DEPRESSIONS ALONG THE BARYCZ RIVER VALLEY

In spite of the occurrence of almost the same till horizons, the three sub-regions of the area of investigation indicate quite different geological structure. The Leszno Upland is characterized by a simple cake stratigraphy, with several tabular till layers interbedded with glaciofluvial and glaciolacustrine deposits. This sequence is only occasionally incised by tunnel valleys and/or fluvial palaeovalleys (Figs. 15, 26). In turn, the southern hills indicate very complex geology (Figs. 22, 26), most probably formed due to glaciotectonic folding and thrusting. The origin of glaciotectonic deformation of the Silesian Rampart was broadly discussed (F. Berger, 1937; C. Pachucki, 1952; B. Krygowski, 1962*a*, *b*, 1975; K. Rotnicki, 1960, 1967, 1976, 1983; K. Brodzikowski, 1982, 1987), although the last model, presented by W. Jaroszewski (1991), seems to be the best one.

The origin of central depressions seems to be problematic. B. Krygowski (1962*a*, *b*, 1975) suggested that these depressions are very young and formed due to glacial erosion and deformation, simultaneously with formation of the Silesian Rampart. Some other authors (K. Rotnicki, 1967; K. Brodzikowski, 1982) suggest, that the depressions were at least in part formed in this way. In turn, S. Dyjor and T. Kuszell (1975) suggest, that depressions were originally formed dur-

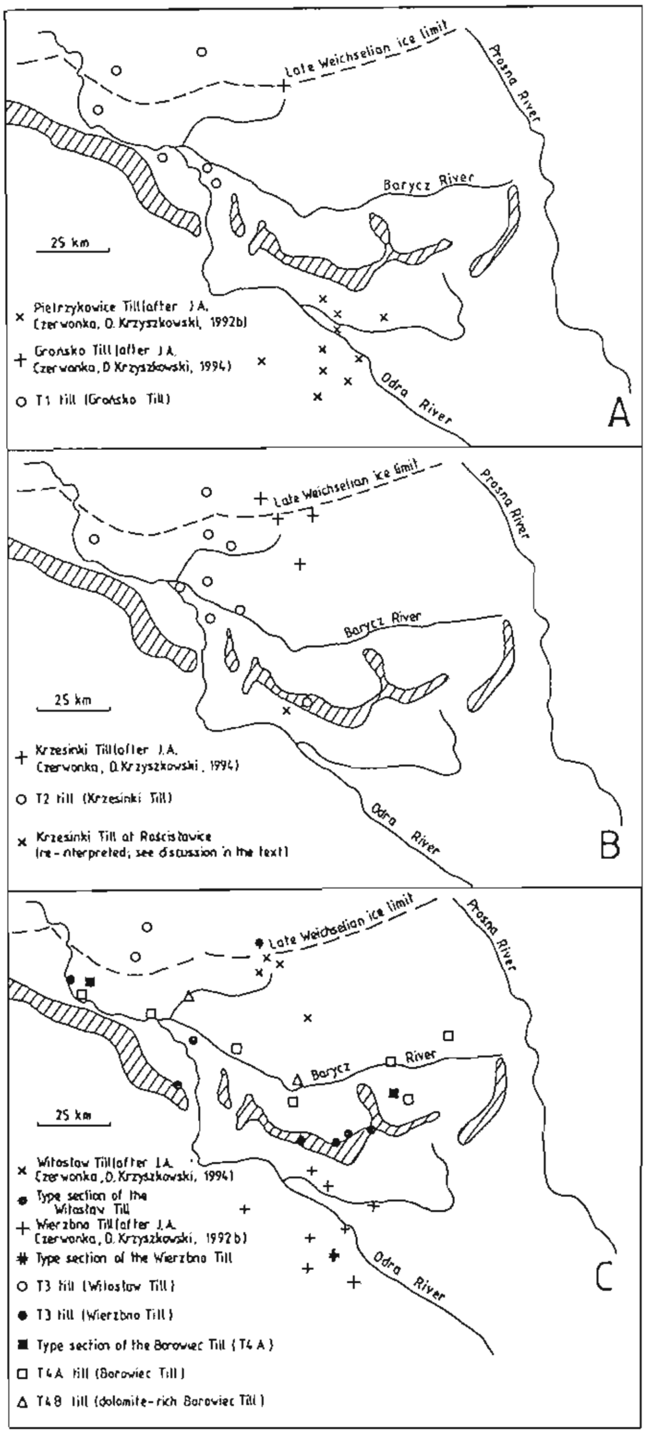


Fig. 24. Distribution of the Elsterian tills: A — Early Elsterian ice-advance, B — Middle Elsterian ice-advance, C — Late Elsterian ice-advance

Detailed discussion in the text

Rozmieszczenie glin zlodowacenia południowopolskiego: A — stadiał starszy, B — stadiał środkowy, C — stadiał młodszy

Szczegółowa dyskusja w tekście

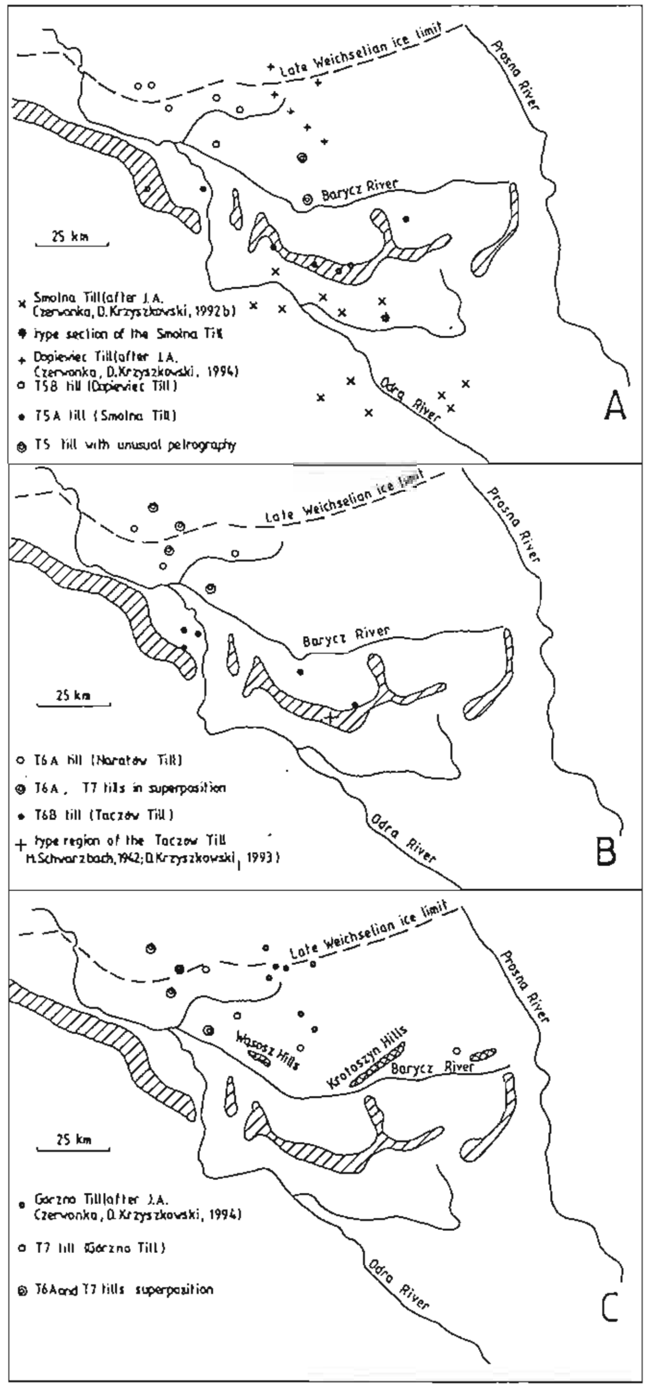


Fig. 25. Distribution of the Saalian tills: A — Early Saalian ice-advance (Odranian), B — Middle Saalian ice-advance (Early Wartanian), C — Late Saalian ice-advance (Late Wartanian)

Detailed discussion in the text

Rozmieszczenie glin zlodowacenia środkowopolskiego: A — starszy (główny) stadiał (odry), B — środkowy stadiał (starszy awans stadiału warty), C — młodszy stadiał (młodszy awans stadiału warty)

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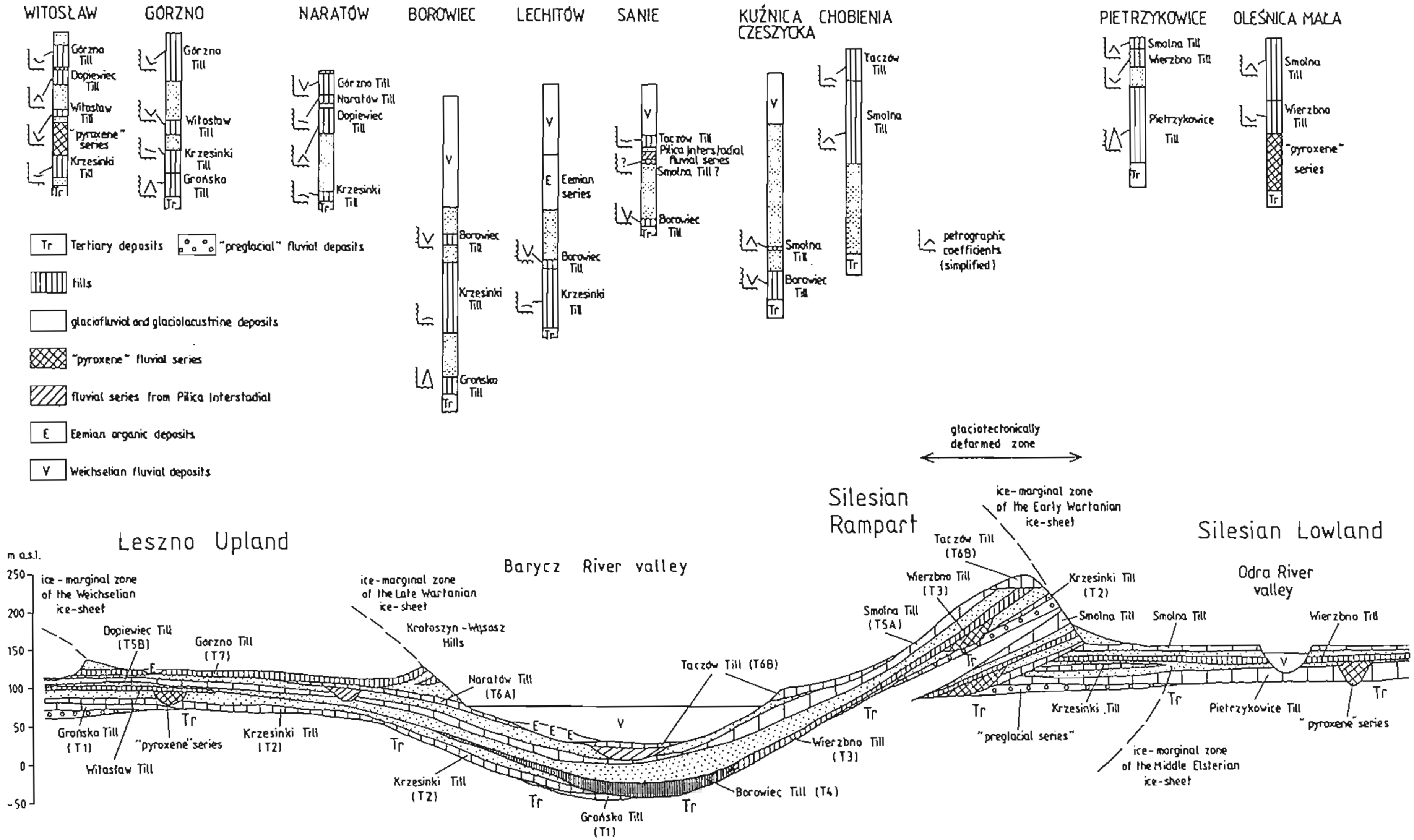

Fig. 26. A model of Quaternary geology of northern Silesia (lower section; geological structure of the Silesian Rampart highly simplified) and main type profiles of the Pleistocene of the lowland regions of southwestern Poland

Detailed discussion in the text

Model budowy geologicznej czwartorzędu na północnym Śląsku (dolny przekrój; budowa geologiczna wału śląskiego mocno uproszczona) oraz główne profile stratotypowe plejstocenu niżowego Polski południowo-zachodniej

Szczegółowa dyskusja w tekście

Table 8

Position of tills in different geomorphic regions of northern Silesia

Deposits	Position of tills [m a.s.l.]				Heigh diffrence between uplands and depression [m]
	northern uplands	central depression	southern hills	Silesian Lowland	
Present-day ground surface	90–100	70–80	150–250	140–160	20
Wartanian till (T6)	85–95	80	150–250	–	10
Odranian till (T5)	70–100	50–60	150–220	130–160	30
Late Elsterian till (T3/4)	50–70	0–30	140–170	110–140	45
Middle Elsterian till (T2)	50–70	–20–+20	120	–	60
Early Elsterian till (T1)	50	–40	–	80–110	90

ing the Pliocene and/or Early Pleistocene and since that time existed as permanently renewed river valleys.

The bottom of Quaternary depressions lie at +40 m to –45 m, whereas the top surface of Tertiary deposits at northern uplands is at 100 to 40 m a.s.l., and in all cases the height difference is between 60 and 90 m. The depressions are undoubtedly of erosional origin, as the Poznań Formation is here almost completely removed down to the Henryk Coal Seam lying at its base (Fig. 19). Beyond the depression, the Poznań Formation is up to 60–90 m thick, what just gives the height difference of the Tertiary top surfaces in different sub-regions. The thickness of glacial suites on uplands and in depressions is almost the same, 20–50 and 30–70 m, respectively, as well as almost the same stratigraphic horizons are present in both positions. Afterwards, all till beds which continue southwards across the depressions (T1, T2, T3/T4, T5 and T6) indicate much lower positions within depressions than in the surrounding uplands (Table 8). Moreover, it seems that the depression was the deepest during the first ice-advance (height difference ca. 90 m) and gradually become less deep during the later advances (Table 8). The conclusion must be, that the depression occurred during all ice-sheet advances and it was systematically filled up. Moreover, erosional processes were present almost after all glacial events. Glacial stratigraphic horizons, though present in this zone in full assembly, occur in thin patches. The older tills occur often as single beds lying directly on the bottom of the depression (T1, T2, T3/T4 horizons) and the younger tills are very rare (T5 and T6 horizons). The younger glacial sequences are mainly represented by glaciofluvial and glaciolacustrine deposits. The nature of this erosion remains unsolved. S. Dyjor and T. Kuszell (1975) suggest a river valley from the Pliocene, filled with the preglacial deposits, and then renewed during the Pleistocene interglacials. This cannot be the case as the Pliocene (Preglacial) deposits do not occur within depressions and their original position is much higher, not only at the Silesian Rampart and the Silesian Lowland, but also at the Leszno Upland (Fig. 26) (J. A. Czerwonka *et al.*, 1994*b*; J. A. Czerwonka, D. Krzyszkowski, in preparation). Thus, it seems that depressions must be younger. Early Pleistocene fluvial activity is another possibility, but deposits of this age have not been recognized neither in the discussed depression nor in the lowlands of Western Poland as a whole. The same is with possible Holsteinian fluvial activity in the region. Deposits which have been interpreted by S. Dyjor and T. Kuszell (1975) as Holsteinian suites in fact represent glaciofluvial sequences, as can be seen from their heavy mineral content and quartz roundness characteristics (Figs. 4–14). Anyway, no organic deposits from this stage have been documented in contrast to the Eemian Stage. On the other hand, all existing fluvial series, including thick Middle Weichselian series, preserve at least a part of glacial deposits from the previous glacial stage (Fig. 19). Thus, it is clear that the global base level which controlled erosion was enough high at least since the Middle Elsterian not to allow incision again down to the bottom of depressions.

Subglacial erosion must be discussed, too, the more that depressions are ovate, not linear as can be expected for fluvial features (Fig. 3). If the case, depressions must have originated during the first glaciation. Similar ovate depressions, filled with complex glacial suites and with the Grońsko Till at the bottom, have been documented also in central-western Poland (B. Krygowski, 1975; J. A. Czerwonka, D. Krzyszkowski, 1994). After all, each younger ice-advance have got less erosional power, as older sequences are usually preserved. This is problematic as at least the Early Saalian ice-sheet was at the same order as the Early Elsterian one.

In conclusion, it must be stresses out that:

1. Depressions along Barycz River are very old and formed at least during the first glaciation in the region or earlier, as the Early Elsterian Grońsko Till was recognized at the bottom of structures.

2. Although permanent fluvial activity occurred along the depressions throughout the Pleistocene and until recent, the fluvial origin of the primary erosional forms remains problematic, as there is no fluvial deposits from that time.

3. Glacial erosion could have created depressions along the Barycz River, but special subglacial hydrology must occurred during the first glaciation, which have not repeated during the next ice-advances.

4. The origin of depressions is absolutely not connected with formation of glaciotectonic hills of the Silesian Rampart. The latter are much younger and have been formed, most probably, during the Early Wartanian as the Taczów Till overlies discordantly all older glacial deposits. However, the pre-existing depression could have supplied glacial deformation and/or formation of ice-marginal zones. It seems, that besides the Early Wartanian, also the Middle Elsterian ice-advance formed marginal zone on the southern side of the discussed depressions.

5. Anyway, further investigations are necessary as origin of large depressions filled with thick glacial suites in Western Poland (see also discussion in J. A. Czerwonka and D. Krzyszkowski, 1994) remains unsolved. The depressions of the region investigated differ from those near Poznań only with the more extensive Upper Pleistocene non-glacial sequences.

REFERENCES

BADURA J., PRZYBYLSKI B., KRZYSZKOWSKI D. (1992) — Stratotype of Pleistocene deposits in Przedgórze Sudeckie: preliminary report (in Polish with English summary). Prz. Geol., **40**, p. 545–551, no. 9.

BADURA J., PRZYBYLSKI B. (1996) — Analiza petrograficzna glin zwałowych południowo-wschodniej części Dolnego Śląska. Acta Univ. Wratisl. Pr. Inst. Geogr., Ser. A, Geogr. Fiz., **8**, p. 5–26.

BERGER F. (1937) — Die Anlage der schlesischen Stauchmoränen. Zbl. Miner., Abt. B, p. 417–434 and 481–497.

BÖSE M. (1989) — Metodisch-stratigraphische Studien und paläomorphologische Untersuchungen zum Pleistozän südlich der Ostsee. Berl. Geogr. Abh., **51**, p. 1–114.

BRODZIKOWSKI K. (1982) — Deformacje osadów nieskonsolidowanych w obszarach niżowych zlodowaceń plejstoceńskich na przykładzie Polski SW. Acta Univ. Wratisl., 574, Ser. Geogr., 36.

BRODZIKOWSKI K. (1987) — Środowiskowe podstawy analizy i interpretacji glacitektonizmu Europy Środkowej. Acta Univ. Wratisl., 934, Stud. Geogr., 43.

CEPEK A. G., NOWEL W. (1991) — Zum Pleistozän im Raum Klinge-Dubrau (ostlische Niederlausitz), ein Typusgebiet für den Saale Komplex. Z. Geol. Wiss., **19**, p. 289–316.

CHOMA-MORYL K., CZERWONKA J. A., MORYL J. (1991) — Petrograficzno-mineralogiczna charakterystyka glin zwałowych okolic Szamotuł. In: Geneza, litologia i stratygrafia utworów czwartorzędowych (ed. A. Kostrzewski). Zesz. Nauk. UAM Poznań, Ser. Geogr., **50**, p. 227–236.

CZERWONKA J. A. (1978) — Badania granulometryczno-petrograficzne osadów kenozoicznych, arkusz Rudna (manuscript). Komb. Geol. Zachód. Wrocław.

CZERWONKA J. A. (1981) — Badania litostratygraficzne osadów kenozoicznych, arkusze Głogów i Chocianów (manuscript). Przeds. Geol. Wrocław.

CZERWONKA J. A. (1982) — Badania litostratygraficzne osadów kenozoicznych, arkusze Trzebnica i Wrocław (manuscript). Przeds. Geol. Wrocław.

CZERWONKA J. A. (1991) — Badania litostratygraficzne osadów kenozoicznych, arkusz Żmigród (manuscript). Przeds. Geol. Wrocław.

CZERWONKA J. A. (1995) — Badania litostratygraficzne osadów kenozoicznych, arkusze Wschowa i Szlichtyngowa (manuscript). Przeds. Geol. Proxima S.A. Wrocław.

CZERWONKA J. A., DOBOSZ T. (1981) — Badania litostratygraficzne osadów kenozoicznych, arkusze Oborniki i Leśnica (manuscript). Przeds. Geol. Wrocław.

CZERWONKA J. A., KRZYSZKOWSKI D. (1990) — Saalian tills in the Bełchatów outcrop, central Poland. Bull. Pol. Acad. Sc. Earth Sc., **38**, p. 63–75, no. 1–4.

CZERWONKA J. A., KRZYSZKOWSKI D. (1992*a*) — Till characteristics and stratigraphy in the Kleszczów Graben (central Poland). Quatern. Stud., **11**, p. 43–64.

CZERWONKA J. A., KRZYSZKOWSKI D. (1992*b*) — Pleistocene stratigraphy of the central part of Silesian Lowland, southwestern Poland. Bull. Pol. Acad. Sc. Earth Sc., **40**, p. 203–233, no. 3.

CZERWONKA J. A., KRZYSZKOWSKI D. (1994) — Pleistocene stratigraphy and till petrography of the central Great Poland Lowland, western Poland. Folia Quatern., **65**, p. 7–71.

CZERWONKA J. A., KRZYSZKOWSKI D. (in preparation) — Osady preglacjalne Polski południowo-zachodniej.

CZERWONKA J. A., WITEK B. (1977) — Granulometric and petrographic studies of tills of south-western Poland. Biul. Inst. Geol., **305**, p. 45–58.

CZERWONKA J. A., DOBOSZ T., KRZYSZKOWSKI D. (1994*a*) — Badania litostratygraficzne utworów kenozoicznych, arkusz Bytom Odrzański (manuscript).

CZERWONKA A. J., GRATZKE B., KRZYSZKOWSKI D. (1994*b*) — Pre-glacial deposits near Stankowo, Leszno region, western Poland and their redeposition during the Middle Pleistocene. Folia Quaternaria, **65**, p. 195–220.

CZERWONKA J. A., KRZYSZKOWSKI D., ŁABNO A. (1991) — Korelacja litostratygraficzna osadów czwartorzędowych z otworów wiertniczych na arkuszu Wołów Szczegółowej Mapy Geologicznej Polski 1:50 000. Kwart. AGH, Geologia, **17**, p. 43–67, no. 4.

DOBOSZ T. (1991) — Badania litostratygraficzne osadów kenozoicznych, arkusz Rawicz (manuscript). Przeds. Geol. Wrocław.

DOBOSZ T. (1993) — Badania litostratygraficzne osadów kenozoicznych, arkusz Międzybórz (manuscript). Przeds. Geol. Proxima S.A. Wrocław.

DOBOSZ T. (1994*a*) — Badania litostratygraficzne osadów kenozoicznych, arkusze Milicz, Odolanów, Ostrzeszów (manuscript). Przeds. Geol. Proxima S.A. Wrocław.

DOBOSZ T. (1994*b*) — Badania litostratygraficzne osadów kenozoicznych, arkusze Sława i Święciechowa (manuscript). Przeds. Geol. Proxima S.A. Wrocław.

DOBOSZ T. (1996) — Badania litostratygraficzne osadów kenozoicznych, arkusze Wąsosz i Góra (manuscript). Przeds. Geol. Proxima S.A. Wrocław.

DOBOSZ T., SKAWIŃSKA-DOBOSZ B. (1990) — Badania litostratygraficzne osadów kenozoicznych, arkusze Czeszów i Twardogóra (manuscript). Przeds. Geol. Wrocław.

DYJOR S., KUSZELL T. (1975) — The geologic structure of the Barycz Ice-Marginal Valley (in Polish with English summary). Acta Univ. Wratisl., **247**, Pr. Geol.-Miner., **4**, p. 115–150.

EHLERS J. (1992) — Origin and distribution of red tills in North Germany. Sver. Geol. Unders. Ser. Ca, **81**, p. 97–105.

EHLERS J., MEYER K.-D., STEPHAN H.-J. (1984) — Pre-Weichselian Glaciations of north-west Europe. Quatern. Sc. Rev., **3**, p. 1–40.

GOGOŁEK W. (1991*a*) — The Quaternary of Szamotuły and Buk region (Wielkopolska Lowland). Kwart. Geol., **35**, p. 37–56, no. 1.

GOGOŁEK W. (1991*b*) — Stratygrafia czwartorzędu północno-wschodniej części Pojezierza Poznańskiego, rejon Szamotuł. In: Geneza, litologia i stratygrafia utworów czwartorzędowych (ed. A. Kostrzewski). Zesz. Nauk. UAM Poznań, Ser. Geogr., **50**, p. 435–448.

GOŹDZIK J. (1980) — Zastosowanie morfoskopii i graniformametrii do badań osadów w kopalni węgla brunatnego Bełchatów. Studia Reg., **4**, p. 101–114.

JAROSZEWSKI W. (1991) — Considerations on the opinion of glaciotectonic structures (in Polish with English summary). Ann. Soc. Geol. Pol., **61**, p. 153–206, no. 3–4.

KRYGOWSKI B. (1956) — Granulometric investigations on the Pleistocene of Western Poland (in Polish with English summary). Biul. Inst. Geol., **100**, p. 503–608.

KRYGOWSKI B. (1962*a*) — The part played by glacitectonics in the development of the lowland relief of western Poland (in Polish with English summary). Czas. Geogr., **33**, p. 313–325, no. 3.

KRYGOWSKI B. (1962*b*) — Bemerkungen über einige Typen glazitektonischer Störungen im Flachland Westpolens (in Polish with German summary). Bad. Fizjogr. Pol. Zach., **9**, p. 61–94.

KRYGOWSKI B. (1975) — Einige Probleme aus der Morphodynamic des Grosspolnischen Tieflandes. Bad. Fizjogr. Pol. Zach., **27**, p. 89–156.

KRZYSZKOWSKI D. (1990*a*) — Litostratygrafia osadów czwartorzędowych w rowie Kleszczowa. Kwart. AGH, Geologia, **16**, p. 111–137, no. 1.

KRZYSZKOWSKI D. (1990*b*) — Chojny Formation in the Kleszczów Graben (central Poland) — an example of the fluvial activity during the Pilica Interstadial (Drenthe/Warthe Stage). Bull. Pol. Acad. Sc. Earth Sc., **38**, p. 77–99, no. 1–4.

KRZYSZKOWSKI D. (1990*c*) — Middle and Late Weichselian stratigraphy and palaeoenvironments in central Poland. Boreas, **19**, p. 333–350, no. 4.

KRZYSZKOWSKI D. (1992*a*) — Pleistocene stratigraphy near Trzebnica, Silesian Rampart, southwestern Poland. Bull. Pol. Acad. Sc. Earth Sc. **40**, p. 235–249, no. 3.

KRZYSZKOWSKI D. (1992*b*) — Badania litostratygraficzne utworów kenozoicznych, arkusz Konotop (manuscript).

KRZYSZKOWSKI D. (1993) — The Wartanian Siedlec Sandur (Zedlitzer Sander) southwards the Trzebnica Hills, Silesian Lowland, Southwestern Poland: re-examination after fifty years. Eiszeital. Gegenw., 43, p. 53–66.

KRZYSZKOWSKI D., CZECH A. (1995) — Directions of the Pleistocene ice-sheet advances in the northern margin of the Strzegom Hills, Sudetic Foreland (SW Poland) (in Polish with English summary). Prz. Geol., 43, p. 647–651, no. 8.

KRZYSZKOWSKI D., CZERWONKA J. A. (1992) — Quaternary geology of the Kleszczów Graben (central Poland): a study based on boreholes from the western forefield of the "Bełchatów outcrop". Quatern. Stud. Pol., **11**, p. 91–129.

KRZYSZKOWSKI D., CZERWONKA J. A. (1994) — Korelacja litostratygraficzna osadów czwartorzędowych z obszaru na południe od Szczecina. Acta Univ. Wratisl., 1702, Pr. Inst. Geogr., Ser. A, Geogr. Fiz., 7, p. 37–61.

KRZYSZKOWSKI D., KARANTER M. (in press) — Neogene and Pleistocene geology of the northeastern foreland of the Mt. Ślęża Massif, southwestern Poland. Ann. Soc. Geol. Pol.

KRZYSZKOWSKI D., NITA M. (1995) — The intra-Saalian interstadial floras of the Chojny Formation of Bełchatów, central Poland. J. Quatern. Sc., **10**, p. 225–240.

KRZYSZKOWSKI D., GIZLER H., JODŁOWSKI J., DOBOSZ T. (in preparation) — Strefa marginalna ostatniego zlodowacenia pomiędzy Sławą Śląską a Włoszakowicami.

KRZYSZKOWSKI D., KUSZELL T., ŁABNO A., PYSZYŃSKI W. (1994) — Lacustrine deposits of the Eemian Interglacial in Wołów (Silesia, SW Poland) (in Polish with English summary). Prz. Geol., **42**, p. 539–547, no. 7.

KUSZELL T. (1980) — Three new localities of Eemian flora in Lower Silesia (in Polish with English summary). Geol. Sudetica, **15**, p. 143–167, no. 1.

KUSZELL T., SADOWSKA A. (1994) — Badania palinologiczne do Szczegółowej Mapy Geologicznej Polski dla arkusza Bytom Odrzański (manuscript). Przeds. Geol. Proxima S. A. Wrocław.

MOJSKI J. E., RZECHOWSKI J. (1967) — Some results of petrographic-lithological researchs of Quaternary deposits in eastern and central parts of Poland (in Polish with English summary). Zesz. Nauk. UAM Poznań, Ser. Geogr., **7**, p. 131–147.

MOJSKI J. E., RZECHOWSKI J. (1969) — The Pleistocene from the vicinity of Podgłębokie in the Lublin Polesie (in Polish with English summary). Biul. Inst. Geol., **220**, p. 13–50.

PACHUCKI C. (1952) — Geological research of the Trzebnica and Syców sheet of the 1:100 000 map (in Polish with English summary). Biul. Inst. Geol., **66**, p. 355–394.

RACINOWSKI R. (1969) — Grain-size and mineralogical-petrographic analysis of tills from Eastern Poland (in Polish with English summary). Biul. Inst. Geol., **220**, p. 289–324.

RACINOWSKI R., RZECHOWSKI J. (1969) — Selected problems of lithology and petrography of the boulder clays in central and eastern Poland. Geogr. Pol., **17**., p. 319–340.

ROTNICKI K. (1960) — Considerations of the genesis of the Ostrzeszów Hills (southern Great-Poland Lowland, the Warta stadium) in the light of new geological and geophysical data (in Polish with English summary). Zesz. Nauk. UAM Poznań, Ser. Geogr., 3, p. 105–124.

ROTNICKI K. (1967) — Origin of Ostrzeszów Hills (in Polish with English summary). Bad. Fizjogr. Pol. Zach., 19, p. 93–153.

ROTNICKI K. (1976) — The theoretical basis for and a model of the origin of glaciotectonic deformation. Quaest. Geogr., 3, p. 103–139.

ROTNICKI K. (1983) — Glaciotectonics and the problem of correct stratigraphy and correlation of the Quaternary deposits in the areas of Pleistocene inland glaciations. In: Quaternary glaciations in the Northern Hemisphere (eds. A. Billard *et al.*), report 9, p. 42–64.

RZECHOWSKI J. (1971) — Granulometric-petrographic properties of the till in the drainage basin of the Middle Widawka (in Polish with English summary). Biul. Inst. Geol., **254**, p. 111–156.

RZECHOWSKI J. (1974) — On lithotypes of Lower and Middle Pleistocene tills in Polish Lowland (in Polish with English summary). Zesz. Nauk. UAM Poznań, Ser. Geogr., **8**, p. 87–100.

RZECHOWSKI J. (1976) — Lithological pecularities of Polish lowland tills. In: Till, its genesis and diagenesis (ed. W. Stankowski). Zesz. Nauk. UAM Poznań, Ser. Geogr., **12**, p. 33–48.

RZECHOWSKI J. (1977) — Main lithotypes of tills in the central Polish area. Biul. Inst. Geol., **305**, p. 31–44.

RZECHOWSKI J. (1980) — An attempt of lithostratigraphical subdivision of the Vistulian Glaciation tills in Poland. Quatern. Stud. Pol., **2**, p. 107–120.

RZECHOWSKI J. (1982) — Dependence of till lithology on properties of a local Quaternary bedrock in central Poland. Biul. Inst. Geol., **343**, p. 111–134.

SADOWSKA A., KUSZELL T., MALKIEWICZ M. (1995) — Badania palinologiczne osadów kenozoicznych, arkusz Wąsosz (manuscript). Przeds. Geol. Proxima S.A. Wrocław.

SCHWARZBACH M. (1942) — Das Diluvium Schlesiens. Neues Jb. Miner., Geol. Paläont., 86, p. 189–246.

SKOMPSKI S. (1983) — Eemian Interglacial molluscans from Żmigród upon the Barycz River (in Polish with English summary). Kwart. Geol., **27**, p. 151–188, no. 1.

STANKOWSKI W. (1976) — Homogenity-heterogenity of glacial tills in Kleczew Plain near Konin. In: Till, its genesis and diagenesis (ed. W. Stankowski). Zesz. Nauk. UAM Poznań, Ser. Geogr., **12**, p. 233–238.

STANKOWSKI W., KRZYSZKOWSKI D. (1991) — Stratygrafia czwartorzędu okolic Konina. In: Przemiany środowiska geograficznego obszaru Konin-Turek, wyniki realizacji programu RPII14 w okresie 1986–1990 (ed. W. Stankowski). Inst. Bad. Czwart., UAM Poznań, p. 11–31.

TREMBACZOWSKI J. (1961) — Przyczynki do metodyki badań granulometryczno-petrograficznych utworów morenowych. Ann. Univ. M. Curie-Skłodowska, sect. B, **16**,

TREMBACZOWSKI J. (1967) — Granulometric-petrographic characteristic of till in the North-Konin High-Plain (in Polish with English summary). Pr. Inst. Geol., **48**, p. 147–162.

WITEK B., CZERWONKA J. A. (1976) — Granulometrical and petrographical studies on tills of southwestern Poland. In: Till, its genesis and diagenesis (ed. W. Stankowski). Zesz. Nauk. UAM Poznań, Ser. Geogr., **12**, p. 123–128.

STRATYGRAFIA I PETROGRAFIA GLIN PÓŁNOCNEJ CZĘŚCI ŚLĄSKA

Streszczenie

Ponad 40 otworów badawczych zostało opracowanych na północnym Śląsku (obszar między Głogowem a Międzyborzem). Większość otworów doszła do osadów trzeciorzędowych (iły poznańskie, żwirowo-piaszczyste osady serii preglacjalnej). W otworach opisano czwartorzędowe osady glacjalne, w tym gliny, osady rzeczne oraz serie jeziorne. Przeprowadzono standardowe badania litologiczno-petrologiczne, przy czym do korelacji litostratygraficznych wykorzystano cechy składu petrograficznego glin lodowcowych oraz składu minerałów ciężkich w innych osadach.

W profilach wiertniczych wyróżniono 8 poziomów glin, które różnią się pod względem składu petrograficznego. Pięć z nich można było łatwo skorelować za pomocą cech petrograficznych z glinami opisanymi poprzednio na Nizinie Śląskiej i w środkowej części Niziny Wielkopolskiej. Poziomy te reprezentują gliny typu: Grońsko, Krzesinki, Wierzbno, Smolna/Dopiewiec i Górzno. Pozostałe trzy gliny występują lokalnie. Cztery z opisanych glin były deponowane w czasie zlodowacenia południowopolskiego, gdzie glina typu Grońsko reprezentuje starszy stadiał, a glina typu Krzesinki jego stadiał środkowy. Ta ostatnia glina ma swój maksymalny południowy zasięg na obszarze objętym badaniami, prawdopodobnie mniej więcej wzdłuż współczesnego wału śląskiego. Gliny typu Wierzbno i Borowiec reprezentują młodszy stadiał zlodowacenia południowopolskiego. Różnią się one składem petrograficznym frakcji żwirowej i występują w różnych rejonach badanego obszaru. Nowo zdefiniowana glina typu Borowiec charakteryzuje się bardzo wysoką zawartością wapieni bałtyckich oraz w jej górnej partii także dolomitów.

Pozostałe cztery gliny reprezentują zlodowacenie środkowopolskie. Gliny typu Smolna i Dopiewiec, mające ten sam skład petrograficzny a zdefiniowane tylko dla innych obszarów (odpowiednio Niziny Śląskiej i Wielkopolski), łączą się na badanym obszarze w jeden horyzont. Był on deponowany w starszym (głównym) stadiale zlodowacenia środkowopolskiego (odry). Lokalne gliny typu Naratów i Taczów były prawdopodobnie deponowane w środkowym stadiale tego zlodowacenia (starszy awans stadiału warty). Reprezentują one jeden poziom gliny lodowcowej o lokalnie zmiennym składzie petrograficznym, gdzie składnikiem różnicującym jest dolomit. Gliny te występują także na różnych obszarach: glina typu Naratów na Wysoczyźnie Leszczyńskiej, a glina typu Taczów wzdłuż wału śląskiego i doliny Baryczy. Glina typu Górzno reprezentuje młodszy stadiał zlodowacenia środkowopolskiego (młodszy awans stadiału warty). Obydwa nasunięcia lądolodu warciańskiego utworzyły swoje strefy marginalne na badanym obszarze: wcześniejszy awans mniej więcej na osi wału śląskiego, a późniejszy wzdłuż Wzgórz Krotoszyńsko-Wąsoszskich leżących bardziej na północ.

Oprócz glin na badanym obszarze opisano kilka serii rzecznych. Najstarsze reprezentują tzw. serię preglacjalną (plioceńską). W jej obrębie rozpoznano aż trzy strefy o różnym składzie minerałów ciężkich, prawdopodobnie deponowanych przez różne rzeki sudeckie. Kolejna seria, zawierająca zwiększoną ilość piroksenu (seria piroksenowa), ma wątpliwą pozycję stratygraficzną na badanym obszarze. Z sąsiednich terenów wiadomo, że analogiczne serie piroksenowe były deponowane w młodszym interstadiale zlodowacenia południowopolskiego. Ponadto udokumentowano cienkie serie osadów rzecznych z interstadiału pilicy oraz miąższe serie z początku interglacjału eemskiego oraz środkowego vistulianu. Ta ostatnia seria jest najbardziej rozpowszechniona i osiąga do 50 m miąższości. Występuje tu także kilkanaście stanowisk interglacjału eemskiego (osady jeziorne), z których część została opracowana palinologicznie.

Obszar północnego Śląska ma bardzo złożoną budowę geologiczną serii czwartorzędowej. Różne regiony tego obszaru, chociaż wykazują podobne sekwencje stratygraficzne, to mają całkowicie różne plany strukturalne. Generalnie można wyróżnić trzy rejony: silnie, glacitektonicznie zaburzony i wyniesiony (do 250 m n.p.m.) wał śląski, strefę kotlin wzdłuż doliny Baryczy i Odry koło Głogowa o permanentnej i silnej erozji glacjalnej i fluwialnej oraz wysoczyzny południowej Wielkopolski (leszczyńska i kaliska) o budowie generalnie warstwowej, z podrzędnym występowaniem stref erozyjnych i zaburzonych.