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Conditions of sedimentation in the Weichselian glaciomarginal zone of northeastern Germany

Maria GÓRSKA-ZABIELSKA

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The conditions of glacigenic sedimentation during the Pomeranian Phase of the Weichselian Glaciation in northeastern Germany are reconstructed on the basis of the typical lithofacies successions and the depositional architecture of the distal and proximal parts of a sandur, as well as of those in the hinterland area of the glaciomarginal zone. The proximal parts of the sandur are characterized by the occurrence of boulders, pebbles and gravels, and horizontally stratified sands cut by large channel troughs in the upper parts. The occurrence of the channel structures indicates frequent torrential ablation floods. Horizontally and cross-stratified rhythms of sandy and gravelly lithofacies, indicating pulsatory ablation flows, are also frequent. The distal part of the sandur is dominated by horizontally stratified sands and sands with low-angle tabular cross-stratification. In the hinterland of the Pomeranian Glaciation, a thick layer of till is present, which locally is glaciotectonically deformed. Moraines left during glacial retreat, with gravity-redeposited till, are also present.

Maria Górska-Zabielska, Institute of Palaeogeography and Geoecology, Adam Mickiewicz University, Dzięgielowa 27, 61-680 Poznań, Poland; e-mail: gorska@man.poznan.pl *(received: August 16, 2005; accepted: October 22, 2007).*

Key words: northeastern Germany, Pomeranian Phase, lithofacial analysis, environmental architecture components.

INTRODUCTION

Glaciomarginal forms of the Pomeranian Phase of the Weichselian Glaciation in northeastern Germany have been studied for over a century (Keilhack, 1899; Gripp, 1925; Liedtke, 1956/57; Cepek, 1962, 1967, 1994; Bremer, 1966; Hannemann, 1966, 1970; Schulz, 1966, 1967, 1972, 1975; Jäger, 1972; Brose, 1972, 1978; Schulz and Weiße, 1972; Marcinek and Nitz, 1973; Cepek and Lippstreu, 1975; Rühberg, 1987, 1998; Ehlers, 1990; Bussemer *et al*., 1993/4, 1995*a*, *b*, *c*; Marcinek, 1994, 1995*a*, *b*; Walther, 1995; Müller *et al*., 1995; Rühberg *et al*., 1995; Bremer, 2004). These glaciomarginal forms characterise, according to Liedtke (1981), by for the most diversified relief relating to the earlier phases of the last Scandinavian ice sheet in this area (Schulz, 1967; Liedtke, 1981; Bussemer *et al*., 1995*b*). Due to hilly morphology the area was termed by Keilhack (1904) "the great Baltic end moraine" (in German: *"die grosse baltische Endmoräne"*).

Despite these many investigations, lithofacies and lithogenetic analyses of glaciomarginal deposits in northeastern Germany have not been undertaken. The papers of Hornung *et al*. (2007) and Winsemann *et al*. (2007) review the findings from other regions in Germany (e.g. Seraphim, 1973; Harms, 1983; Groetzner, 1995; Winsemann and Asprion, 2001; Winsemann *et al*., 2003, 2004). This study fills the gap within these investigations from Mecklenburg–Western Pomerania and Uckermark. Comparable research of earlier data includes (e.g.: Miall, 1977, 1978, 1985; Eyles *et al*., 1983; Brodzikowski and Van Loon, 1991; Zieliński, 1992, 1993, 1995, 1998, 2003; Hambrey, 1994; Benn and Evans, 1998; Zieliński and Van Loon, 1998, 1999, 2000, 2003; Marren, 2001; Maizels, 1983, 1991, 1993, 1997; Terpiłowski, 2003; Kjær *et al*., 2004; Pisarska-Jamroży, 2006, 2007).

The ice-marginal environment is dominated by two main types of glacial forms: fan-like end moraines (Zieliński and Van Loon, 2000; Zieliński, 2003) that originated in direct contact with a stagnant or retreating ice sheet, and push moraines that occur mainly in the axial zones of former glacier active lobes (Schulz, 1967; Schulz and Weiße, 1972; Marcinek and Nitz, 1973; Bussemer *et al*., 1993/4, 1995*a*, *b*, *c*).

South of the ice contact area, glaciofluvial gravely-sandy material was distributed by proglacial braided river systems. A distinct increase in the thickness of sandy deposits is noted in the interlobe zones. The interlobe areas were topographically lower than the lobe axis, and therefore they were frequently

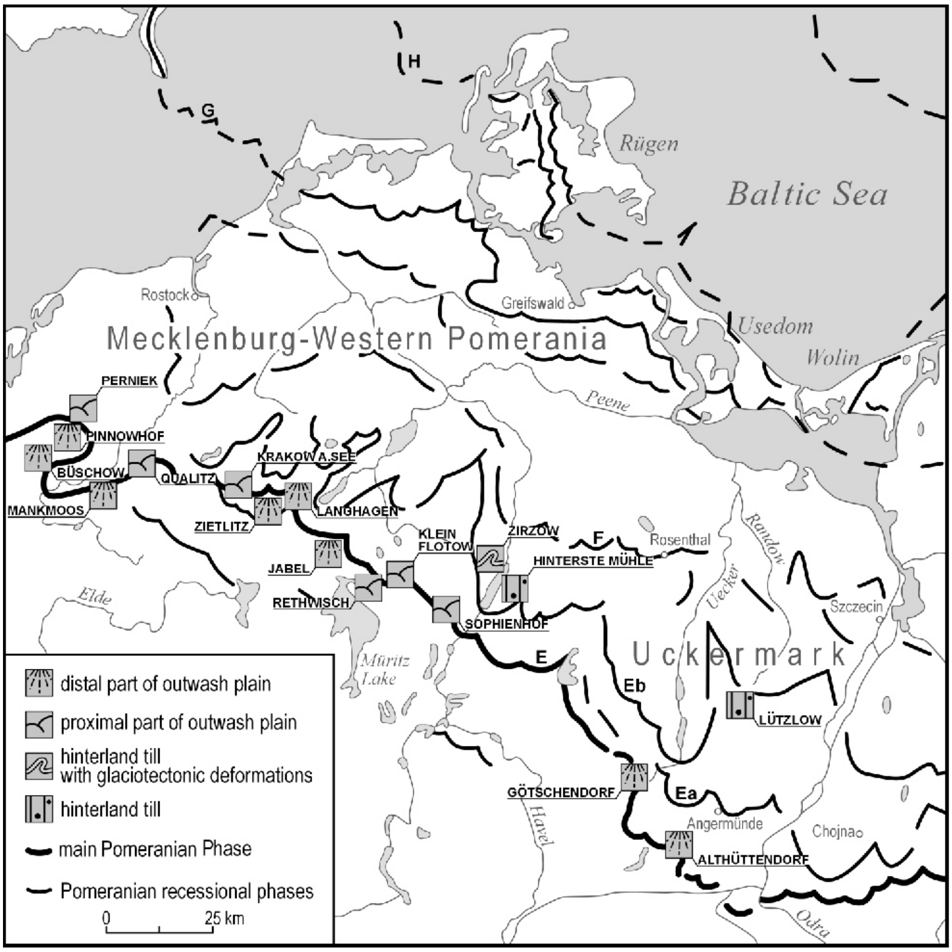

Fig. 1. Location of research sites along the main limits of the Pomeranian Phase and the Weichselian Glaciation recessional phases in northeastern Germany

E — main Pomeranian Phase; Ea — Angermünde–Chojna Phase; Eb — Penkun–Mielęcin Phase; F — Rosenthal–Szczecin Phase; G — Velgaster Phase; H — northern Rügen–Wolin Phase; based on Kozarski (1965), Karczewski (1968), Kliewe and Kozarski (1979) and Liedtke (1981)

flooded with huge amounts of water (Kurimo, 1982; Punkari, 1997). In the interlobe zones the ice movement was significantly reduced as a result of friction between the two neighbouring glacial lobes (*cf*. Kasprzak, 2003), an important factor affecting the "depositional efficiency" of this areas.

The area situated to the north of the Pomeranian Phase main stage (Fig. 1), between the moraines of the succeeding ice sheet retreat phases, comprises a hilly, undulating or flat basal moraine. In some places it accumulated in dynamic conditions marked by well-developed glaciotectonic structures. In other places till was deposited from melt-out processes without disturbances of the underlying deposits. End moraines of the glacial retreat phases form hills with lobe-like outlines, which are easy to trace by their morphology (Fig. 1).

Some selected sites located in the proximal and distal glaciomarginal zone as well as in the hinterland area are described in order to compare the conditions of the glaciofluvial sedimentation during the maximum extent and the decline of the Pomeranian Phase of the Weichselian in northeastern Germany.

RESEARCH AREA AND METHODS

17 sites have been studied. All of them are located in the northeastern Germany, i.e. in Mecklenburg–Western Pomerania (*Mecklenburg–Vorpommern*) and in the northeastern part of *Brandenburg* — in *Uckermark* (Fig. 1). The sites are situated on the proximal and distal parts of the outwash plain as well as on the till plain in the hinterland of the Weichselian Pomeranian Phase (Table 1).

The research was carried out on glaciogenic deposits excavated in gravel-pits (Büschow, Götschendorf, Hinterste Mühle, Qualitz, Krakow am See, Langhagen, Rethwisch, Jabel, Althüttendorf, Mankmoos, Sophienhof, Zietlitz), and exposed in road sections (Pernick, Pinnowhof). Sites in abandonet quarries (Klein Flotow, Zirzow) as well as in valley escarpments (Lützlow on the Randow River) were also chosen for the research.

The landforms were distinguished during geomorphological mapping. In exposures, sedimentological methods were

Table 1

Position of the sites studied along the outwash plain and the hinterland areas in Mecklenburg–Western Pomerania and Uckermark

Site		Depositional environment
Klein Flotow Krakow a. See Perniek	Qualitz Rethwisch Sophienhof	proximal part of outwash plain
Althüttendorf Büschow Götschendorf Jabel	Langhagen Mankmoos Pinnowhof Zietlitz	distal part of outwash plain
Hinterste Mühle	Lützlow	till plain of hinterland
Zirzow		hinterland till with glaciotectonic deformations

Table 2

Lithofacies codes used (based on Zieliński, 1992, 1993, 1998, 2003)

Texture	
G	gravel
GS	sandy gravel
SG	gravelly sand
S	sand
F	fines
D (c, m)	diamicton (clast supported, matrix supported)
Structure	
m	massive
h	horizontal stratification
l	low-angle cross-stratification
p	planar (tabular) cross-stratification
t	trough cross-stratification
e	erosional scours of large scale
s	stratified (only for diamicton)

Table 3

Lithogenetic codes used (based on Miall, 1985; Zieliński, 1995)

Code	Origins
SB	sandy bedforms
LS	laminated sand sheets
OF	overbank fines
CF	channel fill
GS	gravel sheet
GM	glacial melting

applied: textural and structural features of the deposits were characterized. Lithofacies and their associations were classified. The sedimentological analysis allowed identification of the main and accessory lithofacies. The lithofacies associations are interpreted as sedimentary environments of the glaciomarginal zone under study. Symbols of lithofacies (Table 2) and lithogenetic codes (given in brackets in profiles; Table 3) specified according to Miall (1985), with modifications by Zieliński (1992, 1993, 1995, 1998, 2003) were attributed to the lithofacies associations. Wentworth's scale (1922) was used to the grain-size descriptions. Samples were analysed in a laboratory, followed by the graphic calculations (by means of the computer programme *Siewca* 2.0); grain-size coefficients were calculated according to Folk and Ward (1957). Clay index *I* (Karczewski, 1963) was calculating as following: I = (sum <0.002 mm)/(sum >0.002 mm).

PROXIMAL PART OF THE OUTWASH PLAIN

Six sites were investigated in the proximal part of the outwash plain. The main lithofacies presented in the majority of the exposures are described and interpreted below.

DESCRIPTION OF LITHOFACIES

Massive coarse-grained matrix-supported gravels and sandy gravels **Gm**, **GSm** are the most common lithofacies at the Klein Flotow and Sophienhof sites. Their thickness reaches up to 8 m and their lateral extent up to 100 m. The matrix is predominantly of coarse- and medium-grained sand (Table 4). The beds are commonly overlain by horizontally laminated fine-grained sands **Sh** (Fig. 2). The bulk thickness of this facies varies between 0.5 m in Qualitz and 4 m in Sophienhof. The horizontal extent of the bed reaches some 20–50 m.

Farther from the former ice sheet margin, horizontally stratified sand **Sh** is found in beds alternating with massive gravel **Gm**. The gravel beds are up to 1 m thick. These are clast- and matrix-supported beds of massive structure. The lithofacies of medium- and coarse-grained sands with horizontal stratification **Sh** occurs in cosets up to 20–30 cm thick. In places these are intercalated with small-scale lithofacies of silty-clayey deposits of massive structure **Fm**.

The Qualitz site is dominated by normally graded gravelly-sandy beds where medium-grained gravels in the lower parts of the beds gradationally change into coarse-grained, medium and fine-grained sand. The thickness of these beds does not exceed 50–60 cm, and the thickness of the entire succession reaches 7–8 m. Apart from these graded beds, coarse-grained

Table 4

Average grain-size coefficients according to Folk and Ward (1957) of deposits of the proximal part of the outwash plain of the Pomeranian Phase in NE Germany

Site	Fraction [%]					Mean grain diameter Ø [mm]	Stand. dev. δ [mm]	Skewness S_k
	p	gr	s	silt	clay			
Klein Flotow	0	36	63	1	0	0.87	0.22	–0.31
Krakow a. See	0	16	84	0	0	0.56	0.34	0.012
Perniek	0	26	74	0	0	0.79	0.23	–0.23
Qualitz	0	15	85	0	0	0.68	0.40	–0.1
Rethwisch	0	17	60	13	10	0.70	0.19	0.15
Sophienhof	0	29	71	0	0	1.12	0.35	–0.17

p — pebble, gr — granule, s — sand

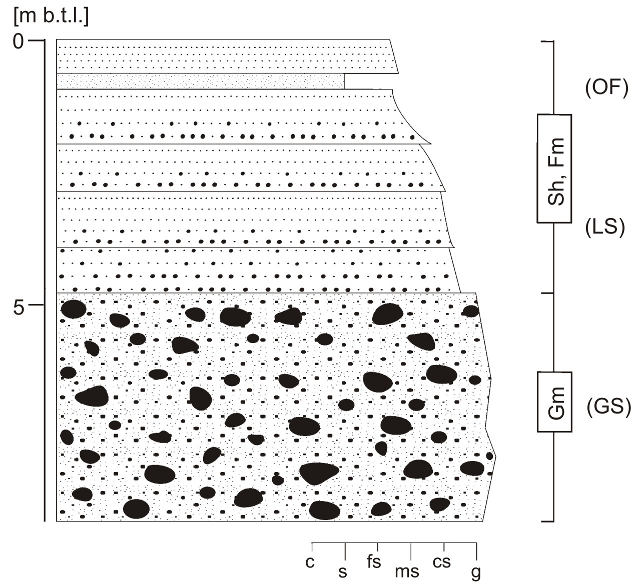

Fig. 2. Fluvioglacial deposits of the proximal part of the outwash plain of the Pomeranian Phase in NE Germany

c — clay, s — silt, fs — fine sand, ms — medium sand, cs — coarse sand, g — gravel; other explanations as in Tables 2 and 3

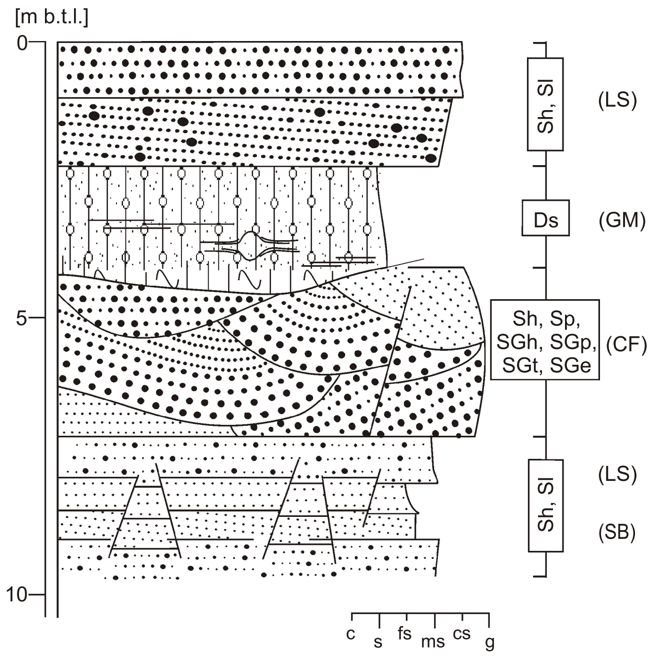

Fig. 3. Krakow am See — fluvioglacial deposits of the proximal part of the outwash plain of the Pomeranian Phase in NE Germany

Explanations as in Figure 2

gravel is noted most often as tabular beds with low-angle cross-stratification **Gl**, locally infilling shallow erosional scours.

The upper parts of the sites located in western Meklemburg (Perniek, Krakow am See) are dominated by sand lithofacies with horizontal and low-angle cross-stratification **Sh, Sl** (Fig. 3). Gravelly sand lithofacies **SGe** infills erosional troughs 50–70 cm deep. The sand infilling the troughs is commonly normally graded. Such successions are underlain by a 0.5 m thick layer of a clayey-sandy diamicton of massive structure, **Dm**, or locally stratified **Ds**. The contact between the trough cross-stratified gravelly sand and the underlying clayey-sandy diamicton **Ds** is gradational. The transitional zone *sensu* Kozarski and Kasprzak (1992) is deformed; load, fold and drag structures are the most common deformations. The two-metre thick clayey-sandy diamicton **Dm(c)s**, banded in places, is characterized by the presence of convolute laminae. The coarse-grained gravels and the boulders are unequally distributed within the silty matrix. Overlapping structures can be found around some boulders. Below the diamicton there are layers of sand and gravel cut by numerous normal faults. The fault displacements are from 20 to 50 cm.

INTERPRETATION

The coarse-grained gravel and sand lithofacies **Gm** and **GSm** are the record of hyperconcentrated flow of coarse clasts and fine-grained suspended material. The massive structure of the gravel lithofacies as well as the very weak sorting (Table 4) may indicate sudden deposition as a result of water loss or decrease in slope inclination (Zieliński, 2003). Over a short time all grain movement ceased simultaneously, which is marked in the massive sediment structure. After deposition of the coarsest grains, the low-energy shallow sheet flows carrying grains of sand were still functioning, as is shown by the fine-grained, horizontally stratified sands **Sh**. Locally fine-grained silts **Fh** were deposited in standing water.

The lithofacies **Gl** in tabular beds testifies to pulsatory, shallow sheet flows. Where the lithofacies infill erosional scours, they may have originated in two phases: firstly, when the scours were formed and secondly, when they were infilled.

Synsedimentary faults may have been the result of buried dead ice melting. Such deformation structures are typical of ice-marginal environments. Flow folds indicate rapid redeposition, connected with fluidisation of the deposits or changes in the slope inclination, which could have been also an indirect result of the undermelting processes.

Taking into account the geological context, all the lithofacies types described suggest deposition in an ice-marginal environment (Zieliński, 2003). The sediments were transported in braided river channels and deposited as torrential floods. Dead ice blocks were buried quickly due to the high accumulation rate. Undermelting of the ice caused instability of the sediment surface, causing deformation.

Diamictons are interpreted as deposited by cohesive flows which incorporated the sandy gravel. Diamicton of flow till type is common in fan-like end moraines (Zieliński and Van Loon, 2000; Zieliński, 2003), known in Polish literature also as "sedimentary scarps" (Kasprzak and Kozarski, 1989; Kasprzak, 2003). In the most proximal (*sensu* Karczewski, 1989) parts of an outwash plain allochthonous flow tills were deposited (Kasprzak and Kozarski, 1984).

It can be summarised that the ice-marginal area of the Pomeranian Phase in northeastern Germany is characterised by a rhythmic, pulsatory type of deposition resulting from ablation processes, although the marginal depressions were filled with diamictons deposited from dense mass flows.

DISTAL PART OF THE OUTWASH PLAIN

DESCRIPTION OF LITHOFACIES

Eight sites (Fig. 1) have been studied in the distal outwash plain. These are sandy and sandy-gravely lithofacies, most commonly gravelly sand **SGh** and sandy gravel **GSh**, both horizontally stratified. Low-angle planar cross-stratified sand **Sl** noted in tabular beds is the subordinate lithofacies (Fig. 4).

Lithofacies associations with normally graded rhythmic sandy and gravelly beds (e.g. in Langhagen, Althüttendorf) are characterized by considerable lateral extents (up to 200 m in Langhagen). The associations of the gravelly-sandy lithofacies **SGh**, **SGl** are cut in places by very shallow channel troughs (Althüttendorf — Figs. 5 and 6; Götschendorf, Mankmoos, Pinnowhof, Zietlitz). The thickness of these erosional structures varies between 10 and 50 cm while their width reaches 2–3 m. The channel troughs are filled with sand and gravel with low-angle cross-stratification **Sl**, **Gl**. Some channel infills (e.g. in Langhagen, Mankmoos) display normal grading. Other

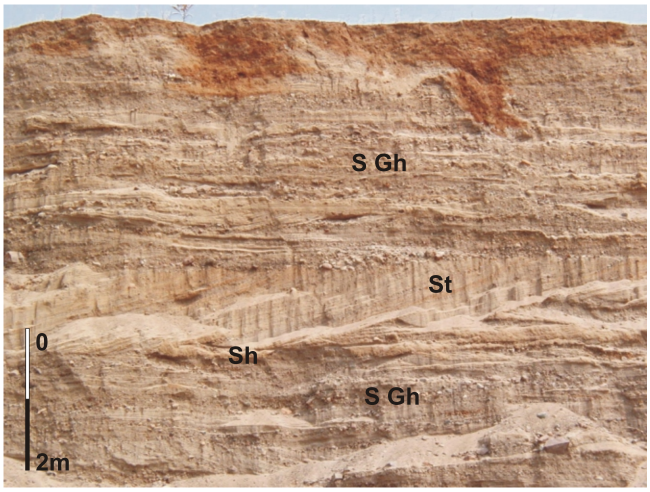

Fig. 5. Althüttendorf — sandy-gravelly lithofacies with horizontal and trough stratification SGh, St, filling shallow channels on the distal outwash plain

Explanations as in Table 2

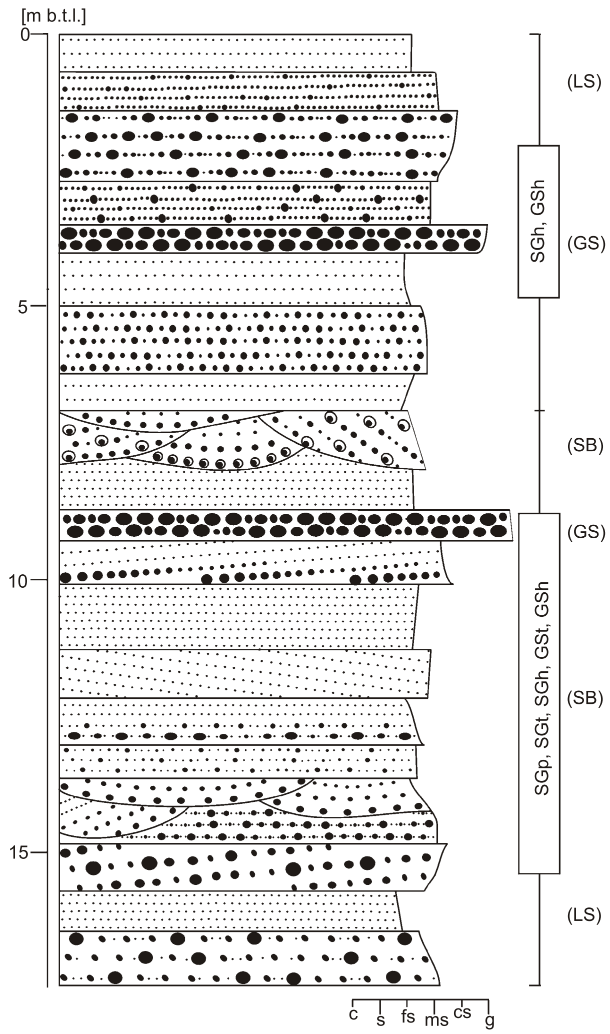

Fig. 4. Glaciofluvial deposits of the distal part of the outwash plain of the Pomeranian Phase in NE Germany

Explanations as in Figure 2

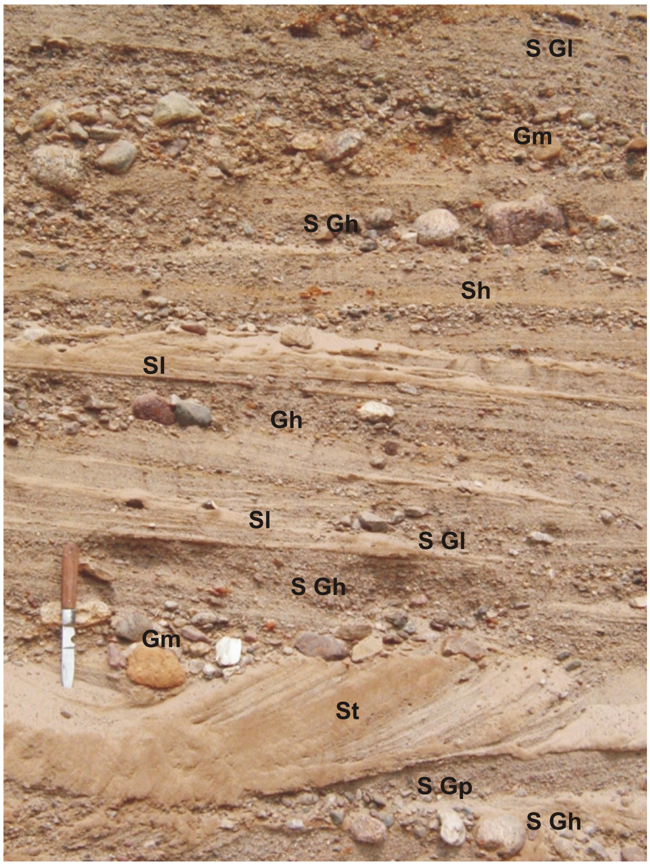

Fig. 6. Althüttendorf — lithofacies SGh, SGl with a shallow channel structure St; the knife serves as scale

Explanations as in Table 2

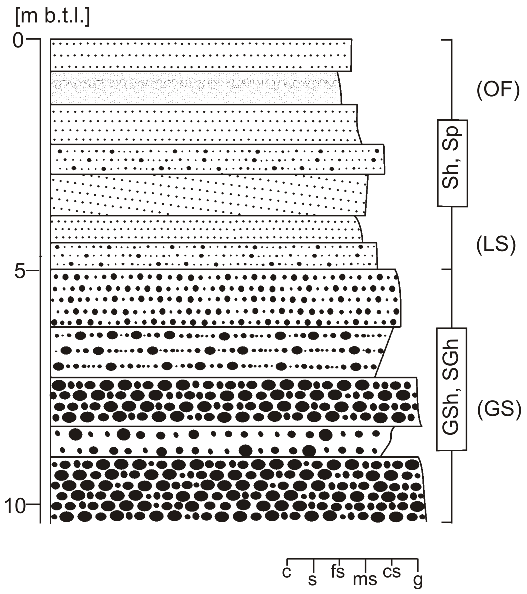

Fig. 7. Jabel — fluvioglacial deposits of the distal part of the outwash plain of the Pomeranian Phase in NE Germany

Explanations as in Figure 2

Table 5

Average grain-size coefficients of distal part of the outwash plain sediments of the Pomeranian Phase in NE Germany (obtained by a graphic method) according to Folk and Ward (1957)

Site	Fraction [%]					Mean grain diameter ∅ [mm]	Stand. dev. δ [mm]	Skewness S_k
	p	gr	s	silt	clay			
Büschow	0	22	78	0	0	0.69	0.29	–0.38
Götschendorf	0	10	90	0	0	0.48	0.43	–0.28
Jabel	0	7	93	0	0	0.31	0.40	–0.36
Althüttendorf	0	18	82	0	0	0.66	0.34	–0.37
Langhagen	0	31	69	0	0	1.30	0.36	–0.15
Mankmoos	0	22	78	0	0	0.54	0.27	–0.43
Pinnowhof	0	37	63	0	0	1.32	0.27	–0.12
Zietlitz	0	30	70	0	0	1.2	0.31	–0.11

Explanations as in Table 4

channels are filled with the trough cross-stratified gravelly-sandy lithofacies **GSt** (e.g. Götschendorf, Althüttendorf, Zietlitz). Clast-supported gravelly beds of massive structure **Gm** are very rare.

In Jabel pit (Fig. 1), situated to the north of Müritz Lake, the succession is a little different. A lithofacies of coarse-grained and massive gravel **Gm** occurs in the bottom of the pit, overlain by horizontal beds of fine-grained sand **Sh** or in places with low-angle cross stratification **Sl** (Fig. 7). A characteristic trend was observed in the vertical succession: a gradual upwards decrease in average grain-size, progressively less frequent cross-stratification, and in the mostupper part, a predominance of fine-grained deposits from suspension.

Beds approx. 0.5 m thick of fine- and very fine-grained sand with well-developed deformations of diapir and loadcast type occur in the top of the profile. Isoloted faults were observed in the walls of the Langhagen and Althüttendorf gravel pits.

The distal outwash plain deposits (Table 5) consist predominantly of sand (63–93%) and to much smaller extent of gravel (7–37%). Taking into consideration the standard deviation values, these sediments are well sorted.

INTERPRETATION

Deposition took place during sheet floods in the floodplain area as a result of supercritical flows. In places the deposition took place in shallow sandy-bed channels with transverse bars.

Sedimentation took place in braided channels of a large width and small depth. Periodic changes of flow dynamics were associated with the rhythm of ablation. In conditions of shallow and fast flows, upper-stage plane bed (lithofacies **SGh**) and low-relief dunes (lithofacies **SGl**) were formed. Locally, in deeper parts of channels the flow was channelized and the shallow troughs originated there. The successions with normal grading can be regarded as indicating gradually decreasing currents during the flood waning stages. Lithofacies **Gm** presumably originated during unusual flood peaks when vigorous currents in the central parts of channels deposited the gravel sheets.

Deformation structures disturbing the original arrangement of the sandy-gravelly layers were rarely found at the research sites on the Pomeranian Phase distal outwash plain. The diapir and load-cast structures are caused by reversed density gradients. This suggests that sedimentation rate was high. The faults can be explained by the melting of buried ice blocks or by deposition upon naleds.

The gradual upwards decrease in the average grain-size in Jabel shows that the energy of the glaciofluvial water generally decreased with time and that the area became more and more distal to the ice sheet, due to the latter's retreat. However, the possible reduction of ice ablation rate as a reason for such a structural picture cannot be rejected. The succession resembles the outwash retreat succession model of Zieliński and Van Loon (2003).

The discussed lithofacies of the Pomeranian Phase distal outwash plain demonstrate that deposition took place in a proglacial environment in a braided river system with occasional sheet floods. This environment is typical of a distal braided river with sandy bottom. The increased energy of the proglacial water flow during peaks of ablation, is locally recorded by structures typical of a deeper river channel system, that is by the lithofacies of the medium scale sandy gravel with trough cross-stratification **GSt**.

THE HINTERLAND TILL

DESCRIPTION OF LITHOFACIES

The lower parts of the succession in the Hinterste Mühle and the Lützlow pits (Fig. 1) consist of gravelly sand with trough cross-stratification **SGt**, filling the shallow channel troughs. The gravelly sand in tabular cross-stratified beds **SGp** as well as the horizontally stratified gravelly sand **SGh** are strongly faulted (Fig. 8). These sandy lithofacies are covered by a 3–5 m thick clayey-sandy diamicton of massive structure **Dm**. In places the diamicton beds are characterized by poorly developed horizontal stratification **Ds** (Lützlow), which may represent pseudolamination from shearing. The till in the hinterland area does not build up a continuous layer (Bremer, 1994, 2004); it outcrops rather locally over the till plain.

In Zirzow, the site situated in the northern extension of the interlobal system between the lobes of Tollensee and Peckatel–Möllenhagen (Schulz, 1967), approx. 2 m of thick massive, clayey-sandy, matrix-supported diamicton **Dm** occurs. The following structures formed in the dynamic subglacial environment: upright, inclined and overturned folds, diapir structures, shear planes and numerous faults (Fig. 9). All the structures are inclined towards NNE, i.e. upwards the direction of the incursion. The deformation zone thickness is 4–6 m, the top of the underlying deposits are either deformed or erosionally cut (Fig. 9).

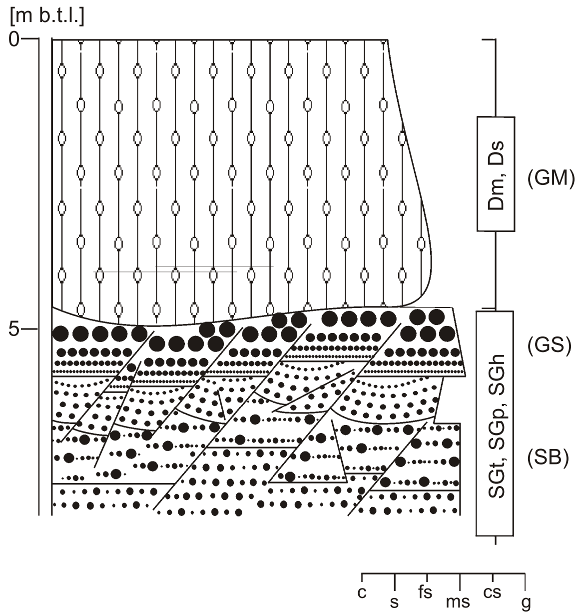

Fig. 8. Till and fluvioglacial deposits of the hinterland of the Pomeranian Phase ice margin in NE Germany

Explanations as in Figure 2

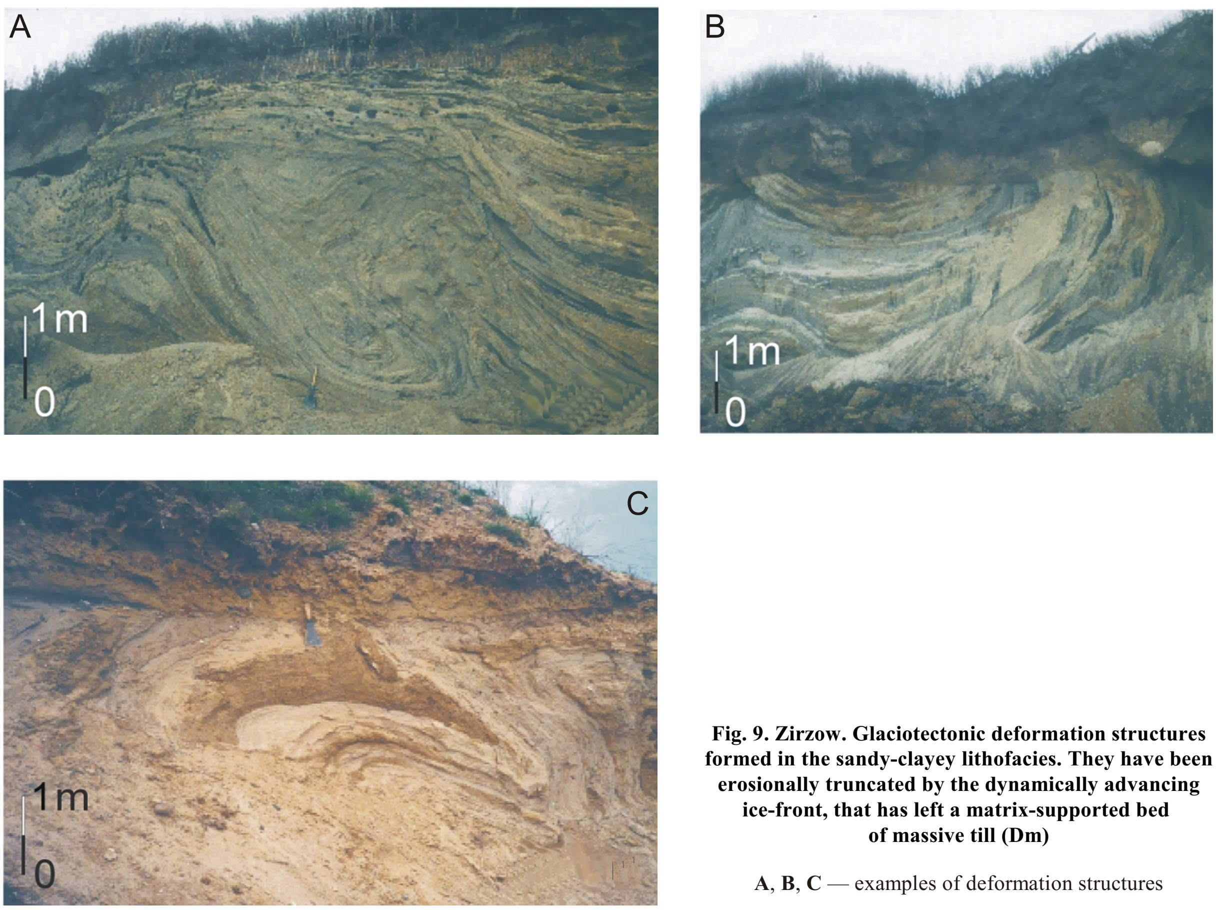

Fig. 9. Zirzow. Glaciotectonic deformation structures formed in the sandy-clayey lithofacies. They have been erosionally truncated by the dynamically advancing ice-front, that has left a matrix-supported bed of massive till (Dm)

A, **B**, **C** — examples of deformation structures

Table 6

Average grain-size coefficients of the hinterland till of the Pomeranian Phase in NE Germany, following to Folk and Ward (1957)

Site	Fraction [%]					Mean grain diameter ∅ [mm]	Stand. dev. δ [mm]	Skewness S_k
	p	gr	s	silt	clay			
Hinterste Mühle	0	7	80	9	4	0.25	0.25	0.08
Lützlow	1	0	52	30	17	0.03	0.03	0.54
Zirzow	0	2	53	27	18	0.03	0.06	0.53

Explanations as in Table 4

The examples show that the tills of the Pomeranian Phase end moraine in northeastern Germany are of different lithologies. The till from Hinterste Mühle shows a high content of sand whereas the till from the Lützlow and Zirzow sites shows a high content of silt and clay. Clay index *I* reaches, at the two latter sites, up to 0.17–0.18, which there represents a subglacial type of till. Grain-size analysis showed that the deposits consist predominantly of sand (52–80%), with an admixture of silt (9–30%) and clay (4–17%) (Table 6). The deposits are well sorted (δ <0.5).

INTERPRETATION

The examples mentioned above indicate the existence of different till types in the area of north-east Germany examined. There is lodgement till (e.g. Zirzow) as well as flow till (e.g. Hinterste Mühle). The lodgement till deposition took place in a dynamic environment. The advancing ice sheet locally plastically deformed the substrate, creating associations of glaciotectonic deformation structures (Zirzow). In places, however, the presence of an ice sheet led to the development of a dense fault network in the horizontally stratified underlying deposits (e.g. Hinterste Mühle).

DEPOSIONAL ARCHITECTURE

Deposits of the glaciomarginal zone of the Pomeranian Phase in northeastern Germany, as a general rule represent the proximal part of an outwash plain, with sudden, violent ablation outflows. This environment is indicated by the coarse-grained sand, the gravelly sand and the sandy gravel with large-scale trough cross-stratification (Tables 4 and 7; Figs. 10 and 11). They were deposited in deep erosional channel troughs or erosional scours carved by proglacial water. Tabular beds of horizontally laminated sands **LS** intercalated with gravel channel sheets **GS** as well as with channel fill structures **CF** can be therefore distinguished in the analysis of the proximal outwash plain environment architecture. Sandy bedforms **SB** are also frequent (Fig. 12A, Table 7).

Pulsatory outflows, characteristic of the central and distal outwash areas were responsible for the origin of the sandy, lithofacies horizontally stratified **Sh** (Tables 5 and 7; Figs. 10 and 11). Faster flowing water created the medium-scale channel trough structures of gravelly sand **SGt**. Sandy bedforms **SB** and channel gravel sheets **GS** dominated in the distal outwash plain (Fig. 12B, Table 7). Tabular beds of horizontally laminated sands **LS** are very common. In places fine-grained floodplain deposits **OF** are also present.

In the hinterland area of the Pomeranian Phase, where the ice sheet margin was enriched with fine-grained material, glacial till deposition took place. The tills were deposited in the glaciomarginal zones of the main and of the retreat stage, succeeding the Pomeranian Phase. Folded laminae or crude stratification in diamicton lithofacies **Ds** show redeposition and therefore the gravity-flow nature of the deposit (Tables 6 and 7; Figs. 8, 10, 11). The presence of redeposited diamictons in the proglacial zone may suggest that these are end moraines of fan-like type (Zieliński and Van Loon, 2000; Zieliński, 2003). The limited regional extent of the diamicton lithofacies compared to more widespread sandy and gravely ones suggest that

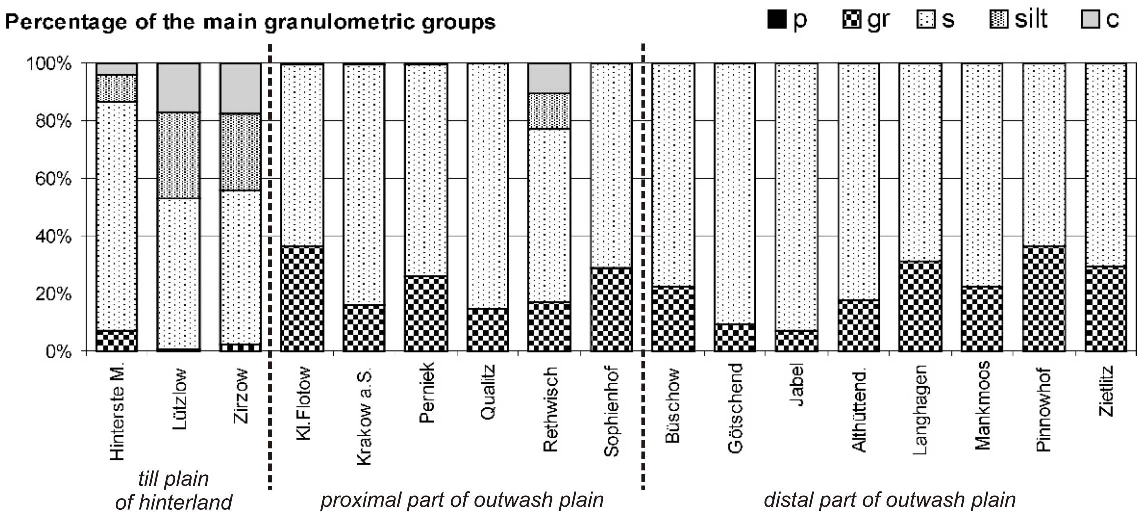

Fig. 10. Comparison of the percentages of the main grain-size groups in the hinterland till and the proximal and distal parts of the outwash plain of the Pomeranian Phase ice margin in NE Germany

c — clay; other explanations as in Table 4

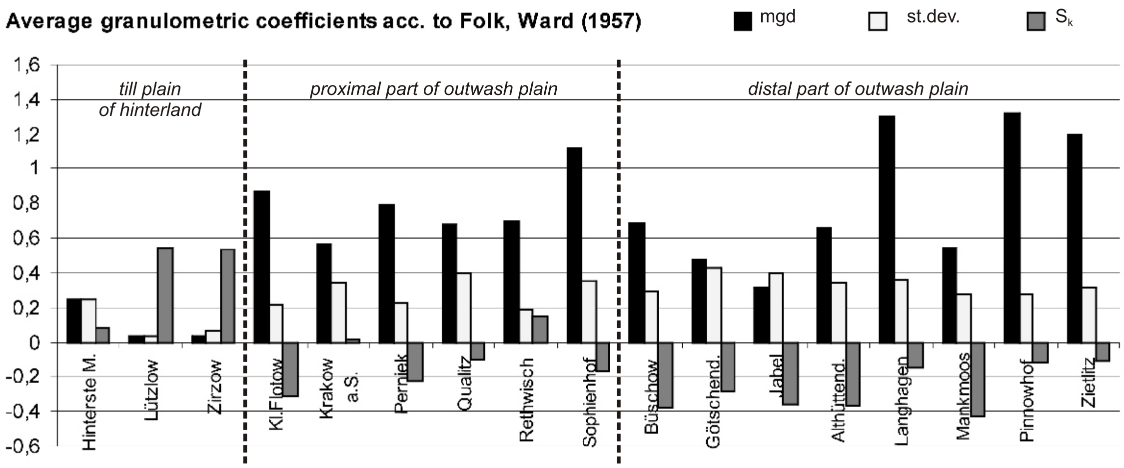

Fig. 11. Comparison of average grain-size coefficients according to Folk and Ward (1957) of the hinterland till and the proximal and distal outwash of the Pomeranian Phase in NE Germany

mgd — mean grain diameter [mm], st.dev. — standard deviation, S_k — skewness

Table 7

Character of the depositional environment in northeastern Germany

Lithology	Proximal part of outwash plain	Distal part of outwash plain	Till plain of hinterland
	Gm, GSm, SGe, SGp, SGt, SGh, Sp, Sl, Sh, (Ds)	SGt, SGp, SGh (GSt, GSh), Sl, Sh	Dm, Ds
Depositional forms	lag deposits in the bottom, horizontal sand stratification in the top; channel troughs; deep erosional channels; fractional grain-size; normal faults; in the outwash proglacial part: sedimentary escarpments	sandy lithofacies associations of the horizontally stratification as well as of the low-angle planar cross-stratification; subordinate gravelly lithofacies horizontally stratified	glacial till bed with matrix-supported bed; upright, inclined and overturned folds, diapir structures, shear planes, faults
Processes	shallow pulsatory sheet floods, in places torrential, violent ablative flows; sudden flow deposition with big concentration of coarse-grained clasts and fine-grained suspension; allochthonous tills flows in the proglacial zone	pulsatory sheet floods in the near-channel floodplain, in places in shallow sandy bed channels with transverse bars and shallownesses of the upper-stage plane bed	subglacial lodgement; thick cohesive flows; glaciotectonic deformation of the substratum deposits (faults cracking and the substratum deposits top cutting off)
Architectural elements	GS, LS, CF, SB, GM, OF	GS, SB, LS, OF	GM, SB, GS
General profile of depositional environment	shallow, broad, plane bed channels; in places bed troughs; locally proximal part of the glaciomarginal alluvial fan with the tills flows	sandy bed braided channel with transverse bars	alluvial fans of the retreat zones with the glacial tills flows and gravelly bed flows; locally glaciotectonic deformations of the sandy lithofacies in substratum

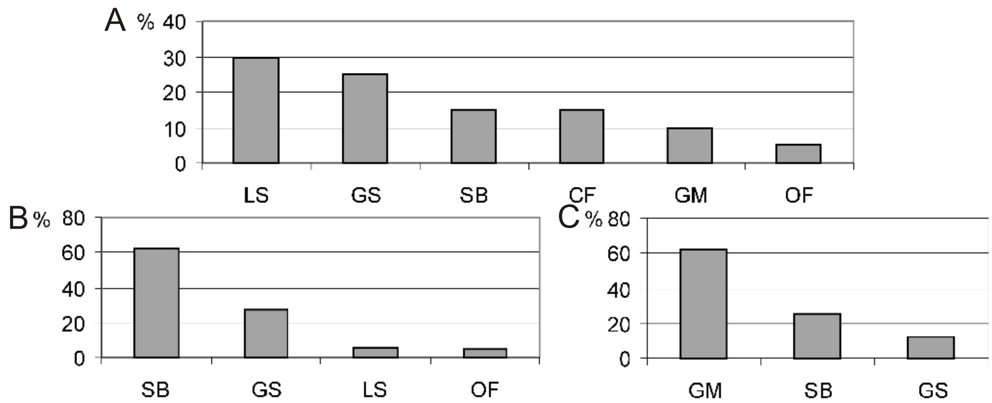

Fig. 12. Architectural elements of the glaciomarginal environment of the Pomeranian Phase in NE Germany

Genetic code signs are explained in Table 3; **A** — proximal part of the outwash plain; **B** — distal part of the outwash plain; **C** — till plain of the hinterland the ice sheet retreated mainly in oversaturated environment. The amount of water flowing out from the ice sheet created conditions where the diamictons could have been washed away. The finest-grained sediments were distributed via the braided channels into the outwash distal zones. The environmental architecture of the glaciomarginal hinterland zone shows glacial deposition **GM**, sandy bedforms **SB** as well as channel gravel sheets **GS** (Fig. 12C).

The lodgement till accumulated beneath the ice sheet in the hinterland of the Pomeranian Phase. The advancing glacier deformed the substratum deposits shaping a wide array of glaciotectonic structures (Fig. 9).

CONCLUSIONS

Sedimentation conditions during the Pomeranian Phase of the Weichselian Glaciation in northeastern Germany have been reconstructed on the basis of lithofacial as well as lithogenetical analysis. The latter consisted of determination of the typical lithofacial suites and the components of the environmental architecture of the proximal and distal parts of the outwash plains as well as of the hinterland of the section of the glaciomarginal zone analysed. The proximal part of the outwash plain is characterized by the occurrence of the lag deposits at the base, while at the top there are horizontally stratified sands and channel troughs showing that torrential ablation flows took place there. Rhythms of sandy and gravelly lithofacies indicating pulsatory ablation flows are also frequent. The successions of horizontally stratified and low-angle planar cross-stratified sandy lithofacies are the main depositional forms of the distal part of the outwash plain. In the hinterland of the northeastern Germany Pomeranian Phase there is a till bed that is glaciotectonically deformed in places. Alluvial fans of the glacial retreat zones were observed with the ablation till flows.

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