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The petrography of glacial sediments in Uckermark, NE Brandenburg – a preliminary study

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Abstract: The Brandenburg section of the hinterland and of the maximum extent of the Pommeranian phase of the last glaciation, formed in two lobes (Schulz, 1967): Joachimsthal-Ringenwalder and Uckermärkischer, have been covered by a study on petrography of a gravelly and a stony fraction. The methods applied followed suggestions of Böse (1989), Trembaczowski (1961, 1967), Meyer (1983), Smed (1993, 1994) and Zandstra (1999). Petrographical analyses undertaken in Uckermark, NE Germany, were focused on: 1) observation of the dynamics of petrographical features along and in the hinterland of the Odra lobus on the German side, 2) indication of the western limit of the Odra lobus upon petrography of glacial sediments, 3) indication of Scandinavian parent areas of sediments of the Pommeranian phase and estimating the routes of ice-sheet onto German Lowland.

The distance between outcrops of Scandinavian rocks causes the number of erratics in sediments of glacial accumulation in the German part of the Odra lobus. There are more Mesosoic rocks in the gravelly fraction as compared with sediments of the same age, but sampled in the Polish part of the Odra lobus. The stony fraction (20–60 mm) is represented mainly by indicator erratics from Smĺland and the Swedish coast in Kalmar Strait. Ĺland erratics, quite frequent in Polish lowlands, are observed rarely in Uckermark. Among statistical erratics there are numerous flints and Mesosoic limestones as well as Lower-Palaeozoic limestones. The theoretical stone centre moves its locality within middle-southern Smĺland.

Key words: indicator erratic, petrography, Pommeranian phase, last glacial, Odra lobus, Uckermark, Brandenburg

Introduction

The relief of maximum extent of the Pommeranian phase is the most diversified and the best formed ice-marginal zone among other recessional phases of the Pleistocene ice sheet in NE Germany. The course of the maximum extent of the Pommeranian ice-sheet from NW towards SE is marked by sedimentary scarps, formed in foreset position of glaciofluvial cones as well as by the thrust moraines in zones of a typical lobe shape (Schulz, Weiße, 1972). This lobe-like character of the Pommeranian end moraine in Mecklenburg-Vorpommern has already been noted by Geinitz (1915, 1917, 1922), who pointed to 12 separate sections of such a typical shape. This character of an icefront is also preserved further to SE, e.g. in Uckermark, in north-eastern Brandenburg, as far as the Odra valley. Within the big form on the Polish side, i.e. in the Odra lobe (Keilhack, 1897, 1898, see Kozarski, 1965), it is difficult to distinguish any traces of smaller, separate ice-surges along the ice front.

Field surveys were carried out in 12 study sites (Fig. 1) located in still active gravel or sand quarries and in natural outcrops. They all were situated along the maximum extent of the Pommeranian phase running across Uckermark from NW to SE, within the following ice-lobes: Uckermärkischer, Joachimsthal-Ringelwalder, Parsteiner.

The research has been conducted in gravel and fluvioglacial facies as well as in till in the ice marginal zone and the hinterland, within recessional phases of Parstein, Angermünde, Zichow-Golmer and Gerswalde.

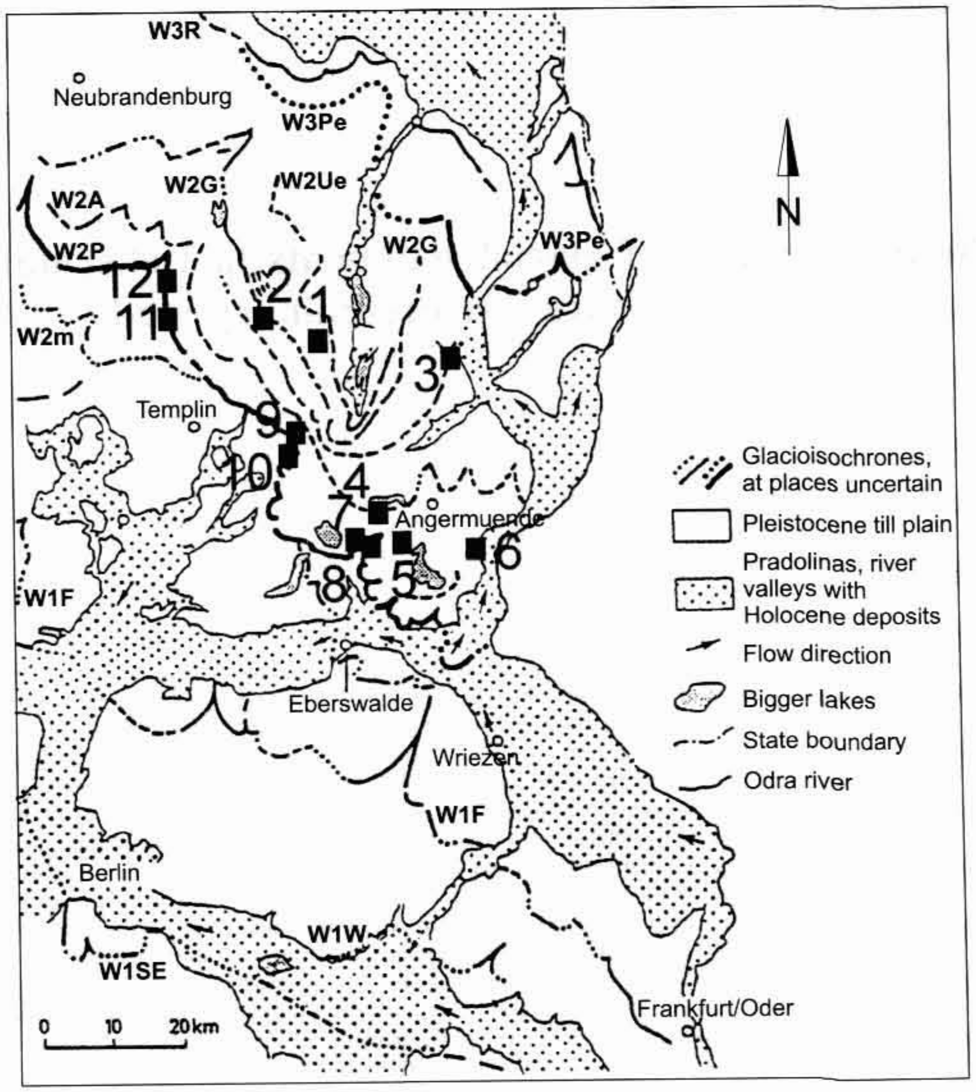

Fig. 1. Location of study sites in Uckermark
Glacioisochrones: W1SE – Spandau-Erkner subphase, W1W – Woltersdorf subphase, W1F – Frankfurt (Poznań) phase, W1E – Eberswalde subphase, W2m – maximum of the Pommeranian phase, WP2 – Pommeranian phase, W2Pa – Parstein subphase, W2A – Angermünde subphase, W2ZG – Zichow-Golmer subphase, W2G – Gerswalde subphase, W2Ü – Üker subphase, W3Pe – Penkun (Mielęcin) subphase, W3R – Rosenthaler (Szczecin) subphase

Former research, which had been undertaken in this area, concerned: 1) the genesis of a young glacial landscape (Gripp, 1925; Hannemann, 1966, 1970; Jäger, 1972; Marcinek, Nitz, 1973; Kozarski, 1978), 2) determination of the course of maximum extent of the Pommeranian phase and its recessional stages (Berendt, 1888; Brose, 1972, 1978), 3) selected petrographical problems (Hesemann, 1932, por. Woldstedt, Duphorn, 1974; Hesemann, 1960; Kliewe, 1960; Cepek, 1969; Cepek, Lippstreu, 1975; Rühberg, 1987, 1999).

Problem, purpose and methods

The investigation in Germany has not really been focused on observations of dynamics of petrographical features of glacial sediments as well as along and in the hinterland of the maximum extent of the Pommeranian ice-sheet (together with the Odra lobe). Principally, there are only these analyses of Hesemann (1933, 1960) and to a certain degree, the investigation of Bussemer *et al.* (1994). There are no responses to doubts of how much petrographically diversified are sediments of the ice-marginal zones, of the hinterland and foreland of the Pommeranian phase within the Odra lobus. Also the following question demands reply: are there any petrographical features, which distinguish significantly the Odra lobus sediments from other sediments, stratigraphically equal, but located to the east and west from this big form.

The petrographical investigation, undertaken so far, has been carried out mainly, apart from those of Hesemann (1932), on the material from drills. The analysed fraction has been 4-40 mm (TGL 25 232). Consequently, there is no information in the literature about the analyses of indicator and so-called statistical (Smed, 1989) erratics. The urgent need of such a research has been raised by Rühberg (1999) lately. These analyses lead indication of alimentation areas in Scandinavia and direction of far transport. They also estimate a route of an ice sheet and its separate ice streams onto German lowland during respective glacial phases, and the Pommeranian one as well.

The Hesemann analysis (1931, 1935), based on four-cipher-formula, has some methodical defects (Górska, 1992, 1998, 2000; Kenig, 1998). Therefore, the results obtained with the help of Hesemann's formula, can not be uncritically taken into account in modern interpretations.

While an eastern limit of the Odra lobus is easily readible in the morphology (by Storkowo Ińskie), the location of the western limit is unclear and indicated in different places. Another question arises, i.e. is it possible to indicate this western border upon petrographical, structural and textural analyses of glacial sediments? Further: is there any need to distinguish the ice stream which had formed the Odra lobe? Has the individualised ice-stream with surge-glaciers on either side of the Odra river been different from other ice-streams of the same age?

The petrographical studies have comprised as well gravelly as stony fractions. The analysis on gravel 4–6.3–10–12 mm has been carried out according to suggestions of Böse (1989), Trembaczowski (1961, 1967); the Scandinavian erratics of 20–60 mm have been separated according to Meyer (1983), Smed (1993, 1994) and Zandstra (1999).

Table 1. Study cases in Uckermark, their abbreviations, full names, geomorphology and location on German topographic maps

Abbr. and number of a study case	Full name and number of a German topogr. map	Geomorphology
Buchh4 1	Buchholz 4 2748	Ücker subphase
Buchh2 1	Buchholz 2 2748	Ücker subphase
Berkh 2	Berkholz 2748	Gerswalde subphase
Lutzl 2	Lützlow 2750	Zichow-Golmer subphase
Altkuenk 4	Altkünkendorf 2949	Angermünde subphase
GrZieth 5	Gross Ziethen 2948	Direct hinterland of the Pomm. Phase
Stolz 6	Stolzenhagen 2950	Parstein subphase
Althlsk 7	Althüttendorf-escarpment 2949	Maximum of the Pomm. phase
Alth5 8	Althüttendorf 2949	Maximum of the Pomm. phase
Goet4 9	Götschendorf 4 2848	Maximum of the Pomm. phase
Goet2 9	Götschendorf 2 2848	Maximum of the Pomm. phase
Milm2 10	Milmersdorf 2948	Maximum of the Pomm. phase
Conow 11	Conow 2746	Maximum of the Pomm. phase
Thom 12	Thomsdorf 2646	Maximum of the Pomm. phase

Results

The present research has confirmed a rule, well known from literature, that the amount of respective petrographical group depends on its fraction (Rutkowski, 1995; Schulz, 1996; Górska, 2000).

While analysing the erratics of glacial material in Wielkopolska (Górska, 2000) of 2–64 (–128) mm it was stated that Palaeozoic limestones reach their maximum percent amount in the fraction of 8–16 mm; afterwards, their amount decreases. Crystallines behave on the contrary: the outermost fractions: 2–4 mm and 32–64 mm are rich in this petrographical group; their minimum percent amount is typical of 8–16 mm fraction. Lower Palaeozoic sandstones, mainly the Jotnian ones, are less numerously, but their presence is constant. The amount of quartz decreases along with the increase of the fraction. The coarsest fraction, which still has any quartz grains, was mainly 16–32 mm. The increase in dolomites as well as, deriving from west-Baltic area, flints and Mesozoic limestones, follows the increase in the fraction (Górska, 2000).

The dependence of the amount of a petrographical group on its fraction is best showed by flints. They reach no more than 1% in gravelly fraction 4–10 mm, while in stony fraction 20–60 mm, they are present at 7% (Table 2, 3).

A short distance between Cretaceous outcrops in Denmark and study sites in Uckermark is marked by a greater amount of flints in the stony fraction. In comparison, the glacial sediments of the Pommeranian age from the Myśliborskie Lakeland (to the east of Uckermark) are characterised by 2–6% (20–60 mm) and as little as only 1% (4–10 mm) of flints.

Table 2. The content (in %) of petrographical groups of glacial sediments in Uckermark, 4–10 mm

	Thom	Conow	Milm2	Goet 2	Goet 4	Alth5	Althlsk.	Stolz	Gr Zieth	Altkuenk	Lutzl	Berkh	Buchh 2	Buchh 4
K	39,8	27,8	50	42	48,5	40,2	55	30,3	29,6	43,6	31,2	64,9	39,2	36,1
S	14,4	12,4	18	11,8	11,8	18,6	13,2	13,9	18,8	16,7	12,1	12,2	15,5	14,1
TU	0,9	11,1	6	3,4	3,8	6	7,3	13,6	12,5	6,8	11,1	5,4	10,4	4,1
F	9	1	1	1,4	4,4	1	0	0,5	0,3	0,4	2	0,1	0,4	0,4
KK	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PKgr	27	40,5	15	37	26	30,6	20,7	33,3	33,1	29,6	39,2	13,8	28,3	39,1
PKr	2,7	3	3	1,4	0,5	1,3	2,2	5,5	2,8	1,1	2	1,8	2,6	2,2
Q	1,8	0,7	4	2,4	4,5	2,2	1,1	0,7	2,4	1,3	2,5	1,2	1,9	3
WQ	0,4	0	0	0,2	0,4	0	0	0	0	0,2	0	0,4	0,9	0
X	4	3,5	1	0,5	0,2	0,2	0,5	2,2	0,3	0,4	0	0,1	0,9	0,9

K – crystallines, S – sandstones, TU – Palaeozoic shales, F – flints, KK – Cretaceous limestones, PKgr – grey Palaeozoic limestones, PKr – red Palaeozoic limestones, Q – quartz, WQ – milk quartz, X – other; explanation of the abbreviation see Table 1.

Flints are followed by a greater amount of Cretaceous limestones. Both groups of erratics derive from the same alimentation area, which is located in western Baltic Sea. Cretaceous limestones have been observed only in stony fractions (0,8–3%, Fig. 9, Table 3). Further to the west, the west-Baltic erratics are more frequently present in glacial sediments. In Cammin (Strelitzer lobus), for instance, the amount of Cretaceous limestones has risen distinctly, up to 19% of the entire pebble spectrum (Table 3).

Palaeozoic shales, soft and non-resistant against abrasion, deriving from southern Bornholm, are present in sediments of Uckermark, as well in the stony fraction (0,4–1,7%) as in the gravelly one (Fig. 2). Palaeozoic shales are more frequent in the latter fraction. Also Rühberg and Krienke (1977) have noted the distinctly high amount of Palaeozoic shales in the gravelly fraction of the Pommeranian till.

Table 3. The content (in %) of petrographical groups within Scandinavian erratics of glacial sediments in Uckermark, 20–60 mm

	Cammin	Milmers-dorf	Götschen-dorf	Althütten-dorf	Buchholz
K	50	45,1	41,4	44,8	33,6
S	29,2	14,7	16,6	19	10,6
PK	1	31,2	30,9	29,3	43,9
KK	18,8	1,1	2,1	0,9	2,9
F	–	5,6	7,8	2,8	5,6
Q	–	0,5	0,3	–	0,4
TU	–	1,8	0,6	1,9	1,6

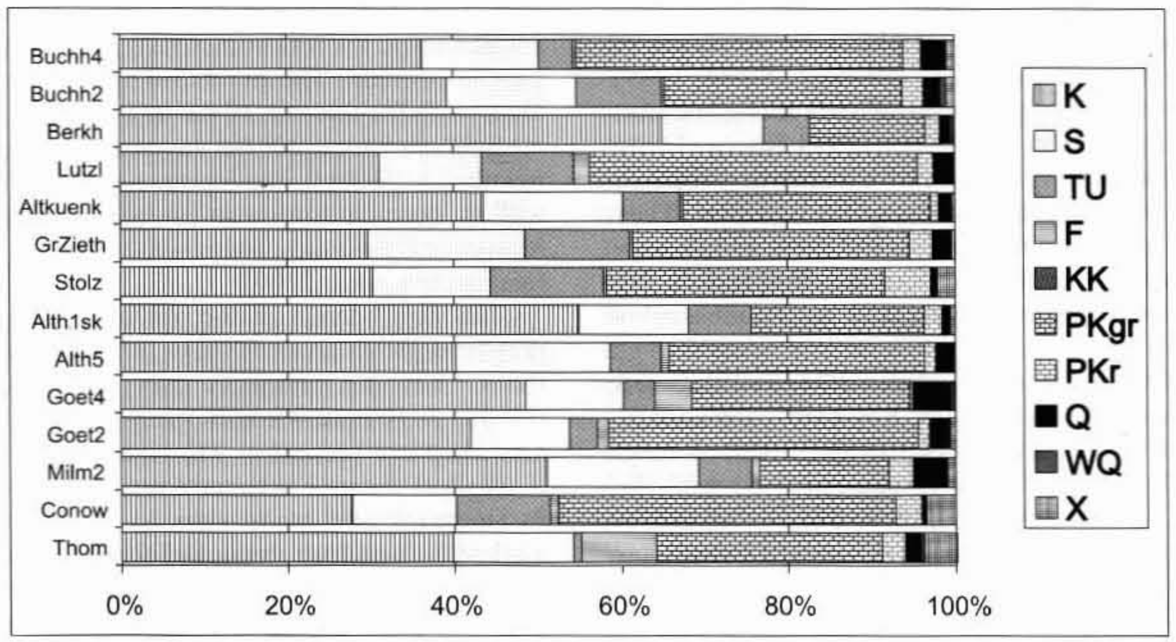

Fig. 2. Petrographical composition of glacial sediments in Uckermark, 4–10 mm
K – crystallines, S – sandstones, TU – Palaeozoic shales, F – flints, KK – Cretaceous limestones, PKgr – grey Palaeozoic limestones, PKr – red Palaeozoic limestones, Q – quartz, WQ – milk quartz, X – other; explanation of the abbreviation see Table 1

The present investigations show that the population of this petrographical group ranges between 3.4% in Götschendorf (fore-set sediments of an outwash plain) and 13.6% in Stolzenhagen (till).

A little different picture can be seen to the west and east from the Odra lobus, where the preliminary analyses show higher and lower amount of these rocks, respectively. The amount of Palaeozoic shales of 4–10 mm ranges between 3-9% in Pommerania (Poland).

The two most numerous petrographical groups, which are separated within pebble spectrum in Uckermark, are Palaeozoic limestones and crystallines. There was a bigger population of crystallines than Palaeozoic limestones in the fraction of 4–10 mm, on the average. This case was observed as well in the end-moraine zone, as in the hinterland (Figs. 2–6, Table 2). It is an important petrographical feature, which distinguishes sediments of the Pommeranian phase from the Leszno–Poznań (Brandenburg–Frankfurt) phase

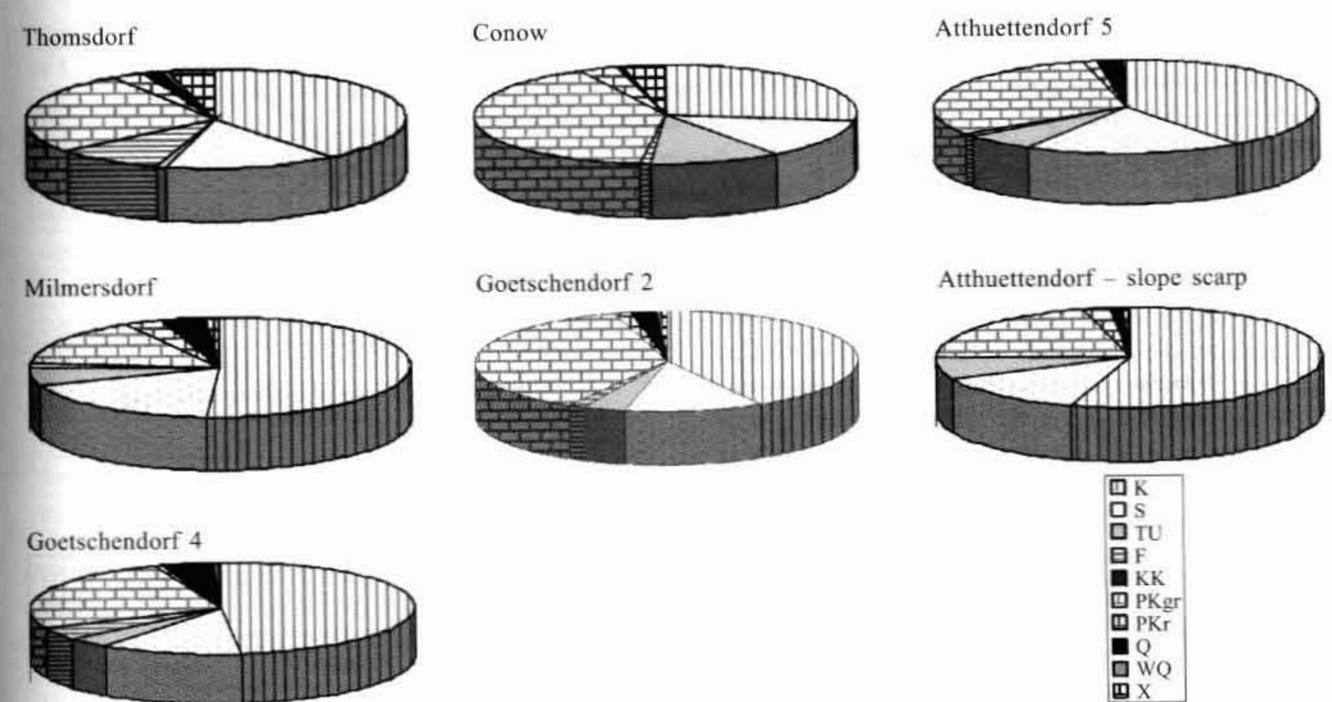

Fig. 3. Petrographical composition of 4–10 mm glacial sediments of the maximum extent of the Pommeranian phase in Uckermark
K – crystallines, S – sandstones, TU – Palaeozoic shales, F – flints, KK – Cretaceous limestones, PKgr – grey Palaeozoic limestones, PKr – red Palaeozoic limestones, Q – quartz, WQ – milk quartz, X – other; for percentage values see Table 2

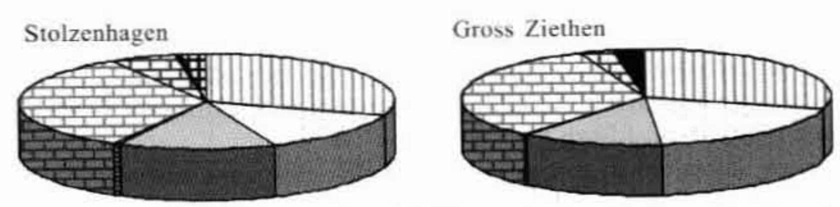

Fig. 4. Petrographical composition of 4–10 mm glacial sediments of the Parstein recessional phase in Uckermark
Legend in Fig. 3, for percentage values see Table 2

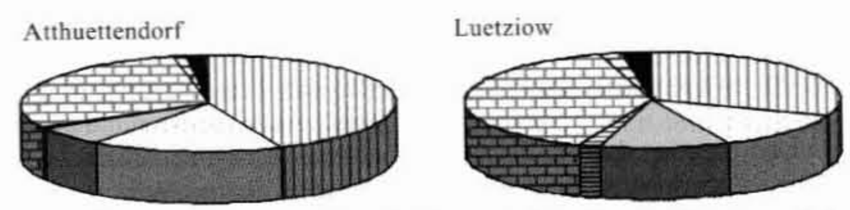

Fig. 5. Petrographical composition of 4–10 mm glacial sediments of the Angemünde and Zichow-Golmer recessional phases in Uckermark
Legend in Fig. 3, for percent values see Table 2

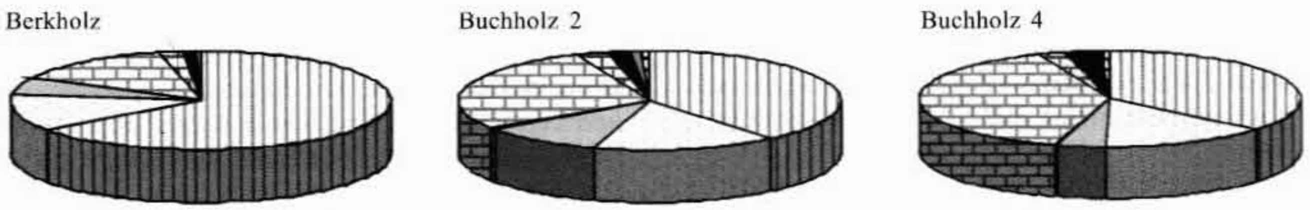

Fig. 6. Petrographical composition of 4–10 mm glacial sediments of the Gerswalde recessional phase in Uckermark
Legend in Fig. 3, for percent values see Table 2

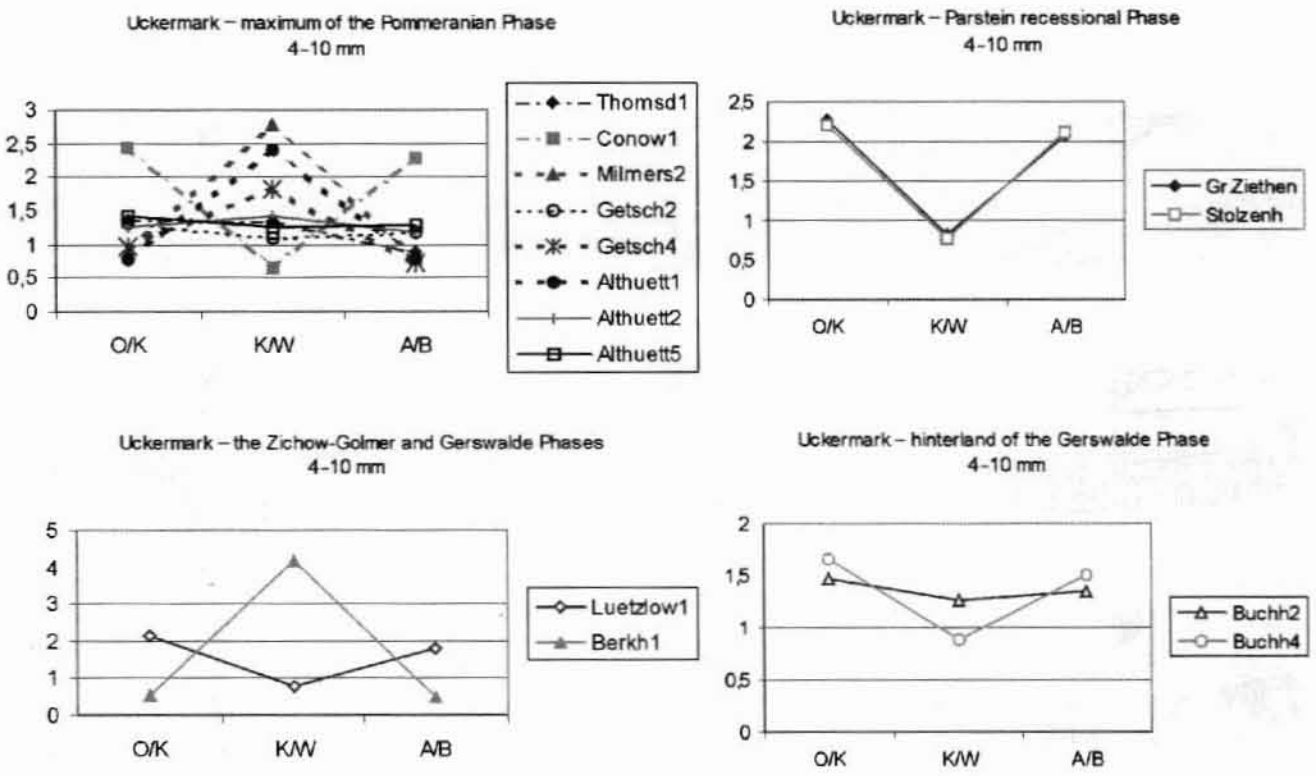

Fig. 7. Stone coefficients O/K, K/W, A/B of 4–10 mm glacial sediments, Uckermark
O/K (relation of sedimentary rocks to crystallines), K/W (relation of crystallines to carbonate rocks), A/B (relation of low-resistant rocks to resistant against abrasion types)

in Wielkopolska, where the relation was opposite (Górska, 1998a, 2000).

The dependence of the amount of petrographical components on lithology has drawn our attention. The typical gravelly material, filling fore-set zones of outwash plains, have, on the average, more crystallines (e.g. Milmersdorf, Götschendorf, Althüttendorf). Their population decreases for Palaeozoic limestones in ablation and basal tills (Conow, Lützlow, Stolzenhagen, Gross, Ziethen). A certain tendency can be clearly visible from Figure 3, presenting the petrographical composition of gravel of the maximum extent of the Pommeranian phase.

Four of seven pies have similar shapes. These are graphic presentations of study sites located in stoss sides of outwash plains. A similar picture is drawn in the diagram (Fig. 7), which is based on stony coefficients (O/K, K/W, A/B).

Apart from the Parstein recessional phase, it is difficult to find any distinct petrographical similarities in sediments of the same glacial events in Uckermark (Figs. 3–7).

Indicator and so-called statistical erratics

The analysis of Scandinavian erratics of 20–60 mm fraction consists in distinguishing of indicator erratics, i.e. such rocks, that are relatively easy to recognise macroscopically. These rocks have only one outcrop, known today, sharply localised with the help of geographical coordinates. As a consequence, the correspondence between an erratic and its parent area must be indicated undoubtedly.

Within indicator erratics the following rocks, deriving from south-eastern Sweden have been distinguished: Småland granite, Småland quartz porphyry, Påscallavik porphyry and grey Växjö granite. Also rocks from the Swedish coast in the Kalmar Strait have been indicated (Tessini sandstones, Kalmar sanstones). Erratics from Skåne are present in each analysed sample (Hardeberga sandstones, Höör sandstones). Few examples of Åland granites, Stockholm granites, brown Baltic porphyries were observed. Quartz Åland porphyries are present in every study case in Uckermark, but their amount is far smaller than in study cases in the Polish Pommerania. Bredvad porphyry and Grönklitt porphyry, quite frequent

Table 4. Indicator erratics (20–60 mm) of glacial sediments in Uckermark

Indicator erratic	Study site			
	Milmersdorf	Götschendorf	Althüttendorf	Buchholz
Bredvad porphyry	–	1	–	–
Grönklitt porphyrite	3	–	–	–
Dalarna porphyry	5	4	2	–
Uppsala granite	–	1	–	–
Stockholm granite	2	–	2	1
Åland granite	1	5	2	2
Haga granite	–	1	–	–
Brown Baltic porphyry	1	1	–	–
Red Växjö granite	–	7	–	–
Grey Växjö granite	–	–	–	1
Halen granite	–	–	1	–
Trikolore granite	–	–	1	–
Småland granite	6	11	11	2
Quartz Småland porphyry	1	1	4	1
Almesåkra sandstone	–	1	–	–
Västervik porphyrite	1	4	1	4
Kalmar sandstone	–	1	3	–
Tessini sandstone	–	–	10	8
Hardeberga sandstone	5	11	8	4
Höör sandstone	1	4	5	1
Nexø sandstone	–	–	2	–
SUM (pcs.)	26	53	52	24

on the European Lowland, have been found only in three samples in Uckermark. Table 4 shows an exact content of the indicator erratics of glacial sediments in Uckermark.

Apart from indicator erratics (Figs. 8 (1–4)), sediments of glacial accumulation have been analysed for so-called statistical erratics (Smed, 1989). These rocks are easy to recognise and they differ from their indicator counterparts by deriving from more than one alimentation areas. Such an outcrop may cover a relatively huge area (Górska, 2000). In the described study area in NE Germany, the following rocks were separated: flints and Mesosoic limestones, deriving from Denmark and surrounding sea bottom, as well as red-violet Jotnian sandstones, which have their outcrops among others in the middle Baltic Sea (Fig. 8(6)).

Besides grey Lower-Palaeozoic limestones, that show no indicator features, some statistical erratics should be listed. These are: 1) red Ordovician limestones, which have their alimentation outcrop on the Öland Isl., 2) Palaeoporella limestones, deriving from the bottom of the Baltic Sea, between Gotland and Öland Islands and 3) so-called east-Baltic limestones, of "fat" fracture, coming from the western neighbourhood of Hiumaa and Saarema Islands (Fig. 8(6)).

Theoretical stone centre (TCG), which is mathematically calculated averages of a geographic latitude and longitude of the alimentary area of the entire erratic spectrum, moves slightly within middle-southern Småland. Comparison of investigations, which have been carried out by the present author in the region to the west and east of the Odra lobus and concerned sediments of the same stratigraphic position, have proved that the TCG values change there distinctly (in preparation).

The study on petrography of glacial sediments in Uckermark is systematically carried out. Since the petrographical analyses in the Polish Pommerania had started earlier, the results of both projects will serve to undertake a comparative research. Also the study on petrography of sediments to the west of the Odra lobus, will be used for comparison.

Acknowledgements

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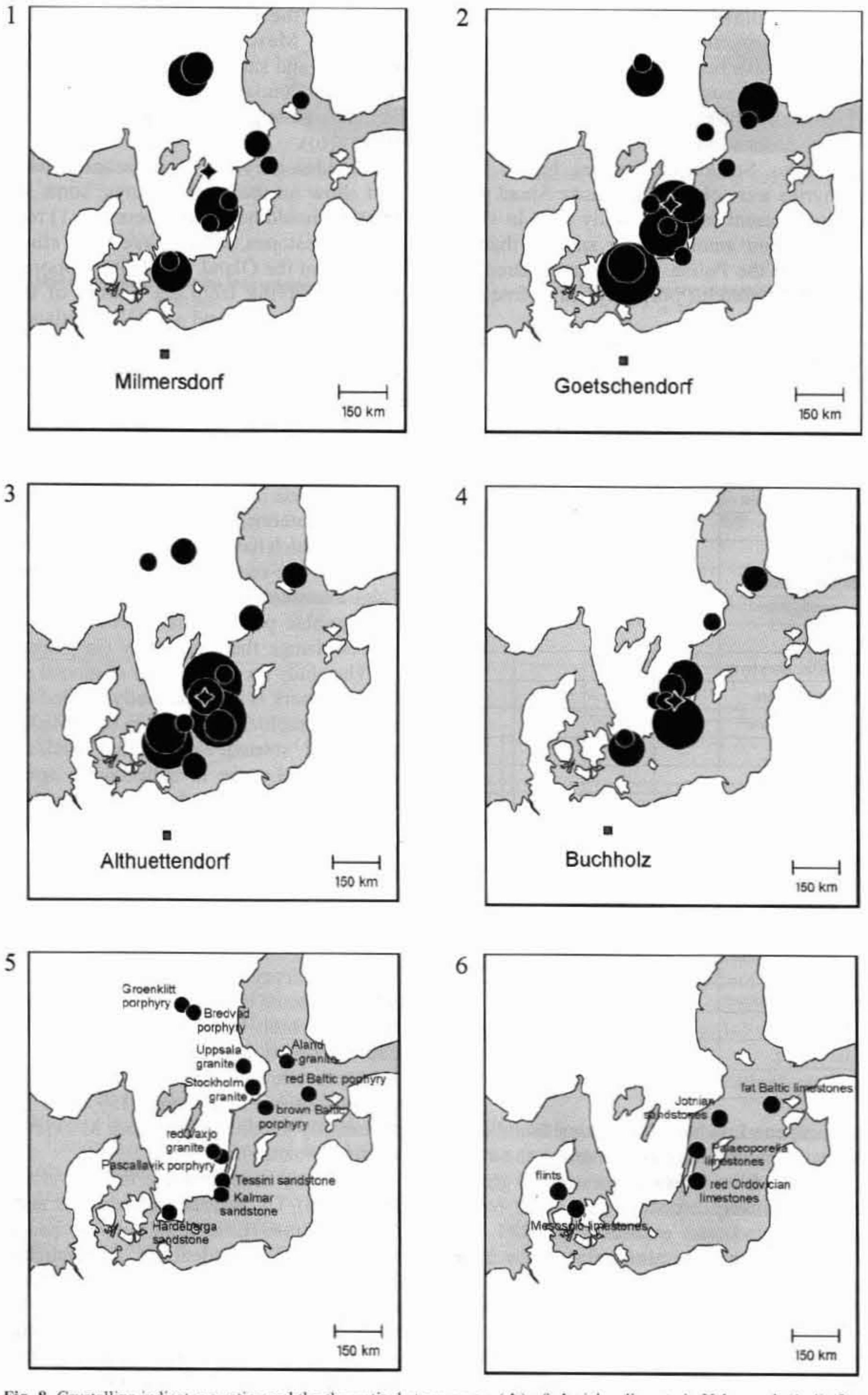

Fig. 8. Crystalline indicator erratics and the theoretical stone centre (✦) of glacial sediments in Uckermark (1–4). Outcrops of selected Scandinavian indicator erratics (5) and probable outcrops of statistical erratics (6)

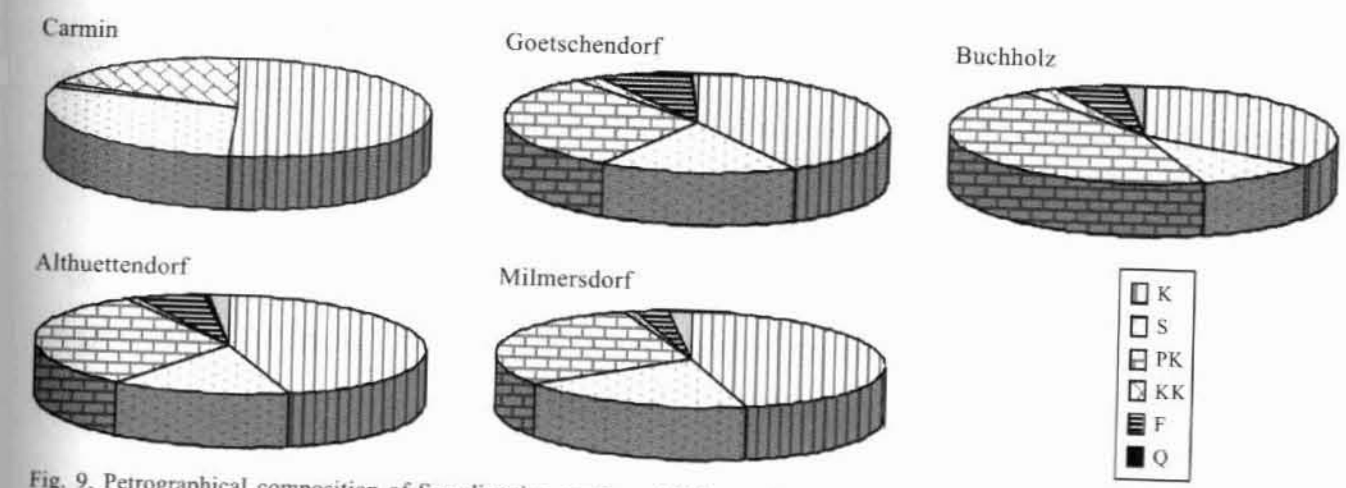

Fig. 9. Petrographical composition of Scandinavian erratics of Uckermark, 20–60 mm fraction
K – crystallines, S – sandstones, PK – Palaeozoic limestones, KK – Cretaceous limestones, F – flints, Q – quartz

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Water erosion and supply of material for fluvial transport under episodic surface flow conditions in the semi-arid zone on Boa Vista (Cabo Verde)

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Abstract: This paper presents the effects of the natural conditions of the semi-arid zone on the temporal and spatial variability of production and supply of material for fluvial transport under conditions of episodic surface flow. Based on measurements of water runoff, concentration of suspension and dissolved material in the course of a one-hour rainfall, it has been determined that the catchments under study have a considerable resistance to the effects of water erosion. Some protection is supplied by the ablation pavement, which reduces rainsplash and slopewash and prevents flow concentration. Considerably more erosion has been noted on unpaved roads concentrating water flow even on plateaux and gently inclined slopes. Obviously the potential for leaching rock material in short-duration flow is limited. Large proportions of the dissolved material carried away from the catchments are salts of marine and aeolian provenance. The high intensity of erosional processes in the early phase of runoff is evidence of the role of physical weathering between rainfalls, which supplies the material for fluvial transport.

Key words: surface flow, water erosion, suspended sediment, dissolved material, semi-arid, Cabo Verde

Introduction

The Cabo Verde Archipelago is a group of 18 volcanic islands, 4033 km^2 in area. They are situated in the Atlantic Ocean, 460 km west of the African coast, at the latitude of the southern extremity of the Sahara (Fig. 1). The eastern, older group of islands, including Boa Vista, probably emerged from the ocean in the Miocene (Mitchell-Thome, 1972). The western islands of the archipelago are younger, a notion supported by the contemporary vulcanicity on the islands of Fogo. The differences in the volcanic relief provide further evidence of the different ages of the islands, and consequently of different lengths of time of action of exogenous factors weathering volcanic rocks. The eastern islands (Sal, Boa Vista, Maio) are nowhere higher than 436 m a.s.l. and have gentle relief whereas the others are higher (from 774 to 2829 m a.s.l.) and much more diversified morphologically.

Boa Vista, like the remaining islands of the archipelago, consists of volcanic rocks, mainly basalts, phonolites and tuffs. Sedimentary rocks, up to several meters thick, represented by limestone, sandstones and conglomerates, occur only on marginal benches, which represent former sea levels (Mitchell-Thome, 1972). The island's relief is dominated by vast flat pediments, glacis and marine terraces with gentle slopes. They are dissected by valleys of temporary rivers. Volcanic necks dominate the island's scenery.

The climate of the Cabo Verde islands is determined by their situation in the Atlantic tropic zone, which is dominated by northeastern trade winds. By contrast, the close vicinity of the African continent causes an influx of dry and warm land air-masses. The average annual rainfall on the eastern flat islands of the archipelago does not usually exceed 150 mm (Klug, 1973). More than 90% of the annual rainfall is concentrated in the period from July to October.