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Derived marine microfossils in loesses of the last glaciation and their significance in the reconstruction of loess-forming processes in central-eastern Europe

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Documented examples of type sections with Pleistocene deposits in southern Poland (Tłumaczów, Branice, Wożuczyn, Tyszowce, Hrubieszów) and southwestern Ukraine (Bojanice, Horokhov, Zhorniv) indicate that loesses of the last glaciation (Vistulian, Valdayan) contain derived marine microfossils of Cretaceous age. The microfossil assemblages studied are richly represented by foraminifers, which are mostly well-preserved, and derived mainly Cretaceous, forms. Suitable Late Cretaceous exposures are nearby, around data shows that these rocks and their debris, and the overlying Pleistocene tills and sands, which are older than the loesses, represent one of the main sources of the loess silt. This fact and the heavy mineral content are evidence of the participation of local material in loess-forming processes in central-eastern Europe. The spatial distribution of the sections studied in relation to the determined sources of loess material indicate that the accumulation of the loesses took place mainly in the presence of western and/or northwestern winds in the lower parts of the atmosphere.

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Key words: S Poland, NW Ukraine, Maastrichtian, foraminifers, coccoliths, calcareous dinocysts, loess, last glaciation.

INTRODUCTION

This paper focuses on the analysis of fragments and whole microfossils (mainly foraminifers) preserved in the upper younger loess (LMg) and middle younger loess ? (LMs) of the Vistulian (Valdayan, Weichselian) Glaciation in central-eastern Europe. Initially, the microfossils were identified during microscopic analyses of powdered samples of the heavy mineral and light fraction of loesses from SE Poland and NW Ukraine (Chlebowski *et al*., 1999; Chlebowski *et al*., 2001, 2002) as well as during similar investigations carried out in SW Poland (Fig. 1). Later the microfossils were subject to detailed micropalaeontological analysis (Paruch-Kulczycka, this paper).

In this project, investigations were carried out in 8 type sections located in the Kłodzko Upland (Tłumaczów), Głubczyce Plateau (Branice), Lublin Upland (Wożuczyn, Tyszowce, Hrubieszów) and the Volhynian Upland (Bojanice, Horokhov, Zhorniv). Each of the sections analysed was sampled (for the detailed location of samples in the lithological column see Figure 2). Furthermore, investigations were conducted in sites with deposits near (Buśno near Białopole) or directly adjacent to the basement rocks (Korshov) of the analysed loesses. Preliminary results of the investigations were presented at the XVIII Palaeontological Conference in Poznań (Paruch-Kulczycka *et al*., 2002).

The investigations follow earlier observations of the authors, focused on the presence of foraminifers in the upper younger loess of the Małopolska Upland (Chlebowski and Lindner, 1975). The methodology of those investigations was based on the separation of the loess fraction (0.06–0.02 mm), and then of the heavy mineral fraction from the light fraction, as well as the determination of the mineral content of the heavy mineral fraction. However, because some of the heavy minerals can occasionally occur in the light fraction (Chlebowski *et al*., 2002), and in order to determine all the heavy minerals, the authors suggested the analysis also of the light fraction. During these analyses, the authors noted the presence of microfossils,

Fig. 1. Areas of occurrence of the upper younger loess from the last glaciation in central-eastern Europe

GP — Głubczyce Plateau, LU — Lublin Upland, VU — Volhynian Upland

mainly foraminifers, the calcareous tests of which occur in this fraction together with quartz, feldspars, calcite and muscovite. In some cases, when the calcite building the tests has been replaced by pyrite or iron hydroxides, the microfossils can occur in the heavy fraction together with heavy minerals.

DEPOSITS OF THE SECTIONS ANALYSED

The samples subject to investigations were taken from 8 loess sections. In most cases they were from the upper younger loess (LMg), in Ukraine referred to as the Bug loess, and representing the last stadial (V3) of the Vistulian = Valdayan Glaciation. In the case of the Tłumaczów and Branice sections, the lower samples come probably from the middle younger loess accumulated during the second last stadial (V2) of this glaciation. The basement to the Pleistocene deposits, comprising Cretaceous marls, was observed in two of the sections analysed (Wożuczyn and Bojanice).

Analysis of all the sections indicates that the oldest Pleistocene deposit is represented by the Sula loess (sl), preserved only in the Bojanice section and correlated with the Sanian 1 Glaciation (S1) (Lindner *et al*., 1998). Sands with gravel and fluvial sands (?) of the Lubna horizon (lu), correlated with the Ferdynandovian Interglacial occur above, succeeded by the Tiligul loess (tl) and till of the Sanian 2 Glaciation (S2) (Elsterian 2). The upper part of the Bojanice section comprises two palaeosols, of which the lower one represents a soil complex from the Sokal horizon (so), correlated with the Mazovian Interglacial (M) (Holsteinian), and the upper is a soil from the Luck horizon (l), correlated with the Zbójnian Interglacial (Z) (Dömnitzian). These soils are separated by a thin loess horizon representing the Orel horizon (or), linked with the Liviecian (Fuhneian) Glaciation.

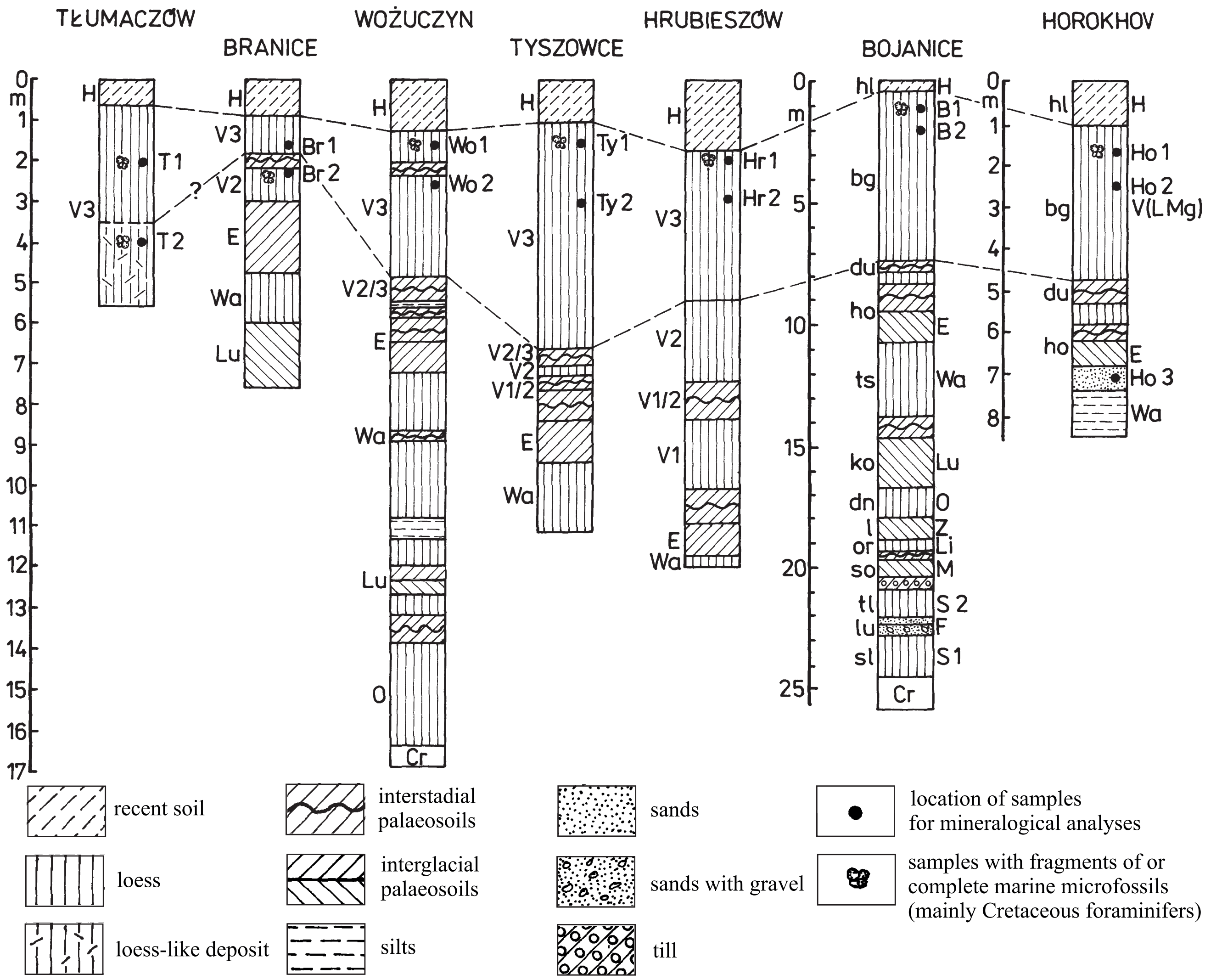

Fig. 2. Generalised lithological columns of the loess sections: Tłumaczów after Chlebowski *et al.* (2001), Branice after Jary and Kida (2001), Wożuczyn and Tyszowce after Buraczyński and Wojtanowicz (1973), Hrubieszów after Dolecki and Maruszczak (1991), Bojanice and Horokhov after Bogutsky *et al.* (1980) and Lindner *et al.* (1998)

The following younger deposit is loess from the Dnieper horizon (dn), preserved at Bojanice and Wożuczyn (Fig. 2). It is considered isochronous with the Odranian Glaciation (O) (Krznanian in the interpretation of Lindner and Marks, 1999). In Wożuczyn this loess is bipartite, which is expressed by the presence of an interstadial soil. There, the younger loess horizon is overlain by a palaeosol complex reflecting the climatic conditions of the Lublinian Interglacial (Lu) (Lubavian = Schöningenian). An analogous soil complex is preserved in the lower part of the Branice section (Fig. 2). At Bojanice it corresponds to palaeosols of the Korshov horizon (ko). In the latter section the soils are overlain by an initial palaeosol of one of the earlier interstadials from the beginning of the climatic cooling influencing the accumulation of loess from the Tyasmyn horizon (ts), correlated with the Wartanian Glaciation (Odranian + Wartanian in the interpretation of Lindner and Marks, 1999). Loess from this horizon is also preserved in the lowermost parts of the Hrubieszów and Tyszowce sections, and in the Branice and Wożuczyn sections, where they attain their largest thickness and are tripartite, as reflected by the presence of silts and an initial interstadial soil (Fig. 2). In Horokhov it corresponds to loess-like silts (?) and sands accumulated in extraglacial conditions of the Wartanian Glaciation, sampled additionally (Ho on Fig. 2) for mineral content analyses.

In most of the sections studied (excluding Tłumaczów) a palaeosol of the Horokhov horizon (ho) (Bojanice, Horokhov) occurs above. It corresponds to the Eemian Interglacial (E) and also to the earlier (stadial and interstadial) part of the Vistulian Glaciation (V) (Valdayan = Weichselian). This palaeosol is overlain by a lower (Hrubieszów) or middle (Branice, Tyszowce, Bojanice, Horohkov) younger loess linked with the middle part of the Vistulian Glacian (V1 and V2). Most probably, the equivalent of the higher loess is a loess-like deposit preserved in the lowermost part of the Tłumaczów section (Fig. 2). This loess (excluding Tłumaczów) is covered by an interstadial palaeosol at Bojanice and Horokhov referred to as the Dubno

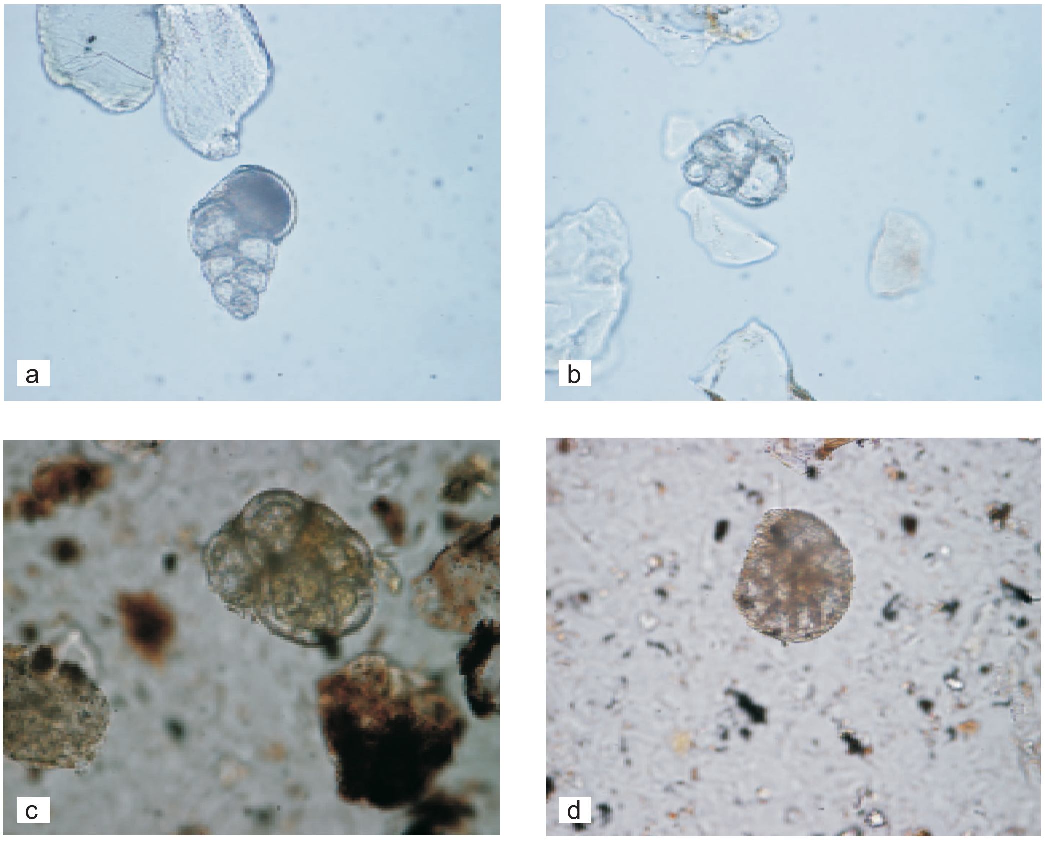

Fig. 3. Microphotographs of the Cretaceous foraminifers determined in microscopic slides for mineralogical analyses of loesses from the following sections: **a** — Bojanice; **b** — Branice; **c**, **d** — Tłumaczów

horizon (du), and in Branice, Wożuczyn and Tyszowce as the interstadial soil (V2/3) of the Vistulian Glaciation (Chlebowski *et al*., 2002).

The uppermost part of these sections and of the Zhorniv section (Fig. 1) is developed as the upper younger loess (LMg), corresponding to the Bug horizon (bg) in Ukraine (Gozhik *et al*., 2000). In Wożuczyn its bipartite character is reflected by the presence of an interphase (?) initial soil. This loess and the middle younger loess from Tłumaczów and Branice, as the main focus of our studies (Chlebowski *et al*., 2001, 2002) was sampled for mineral nalyses. During these analyses the presence of microfossil remains, the subject of this paper, was noted.

RESULTS OF MICROPALAEONTOLOGICAL ANALYSIS

The microfossils separated and systematically analysed, following their initial recognition in the sections. Additionally, for comparison and for determination of possible source areas for the microfossils in the loesses, microfaunas from rocks (chalk) exposed in the direct vicinity of the loess (Buśno near Białopole in Poland) and sub-loess sands (Korshov in Ukraine) were also analysed.

In the case of the Buśno section (Fig. 1), Cretaceous chalk is overlain by Middle Pleistocene deposits with an admixture of erratic material of Scandinavian origin, and by silty-sandy deposits from the latest glaciation (Vistulian), up to 11 m in total thickness (Malicki and Pękala, 1972). Within the chalk, samples Bi 1 and Bi 3 (Table 1) reveal a foraminiferal assemblage from the Late Maastrichtian *Guembelitria cretacea* Zone. This assemblage is characterised by the prevalence of the genera *Heterohelix*, *Guembelitria*, *Globigerinelloides* and *Rugoglobigerina*, with a simultaneous lack of the genus *Globotruncana*. The samples are rich in the following taxa: *Globigerinelloides volutus* (White), *G. asperus* (Ehrenberg), *G. prairiehillensis* Pessagno, *Rugoglobigerina hexacamerata* Brönnimann, *R. macrocephala* Brönnimann, *Heterohelix striata* (Ehrenberg), *H. glabrans* (Cushman), *Guembelitria cenomana* (Keller), *G. cretacea* Cushman, *Cibicidoides bembix* (Marsson) and *Stensioeina pommerana* Brotzen.

In Korshov (Fig. 1) near Łuck the sub-loess sands analysed (sample Ko 2) reach *ca*. 60 cm in thickness and lie on loess from the Wartanian Glaciation (Bogutsky *et al*., 1980; Lindner *et al*., 1998). They are overlain by a soil deposit of the Horohkov type, which is in turn overlain by a loess cover from the last glaciation (Vistulian). The sands probably represent a fluvioperiglacial flow deposit of the Wartanian Glaciation. Within them, derived Late Cretaceous foraminifers, characteristic of Maastrichtian assemblages, were observed. The foraminifers are dominated by the taxa *Heterohelix striata* (Ehrenberg), *H. glabrans* (Cushman), *Heterohelix* sp., *Guembelitria cretacea* Cushman, *Globigerinelloides volutus*

Table 1

Occurrence of microfauna in the sections analysed

Localities	Lublin Upland				Volhynian Upland		
	Buśno k.Białopola Bi 1, Bi 3	Tyszowce Ty 1	Wożuczyn Wo 1	Hrubieszów Hr 1	Korshov Ko 2	Zhorniv Zh 1	Horokhov Ho 1
Stratigraphy / Foraminifer taxa	Maastrichtian *in situ*	Maastrichtian derived to Pleistocene			Basement	Maastrichtian derived to Pleistocene	
planktic forms							
Guembelitria cenomana (Keller)	○	○	○	○	○	○	○
Guembelitria cretacea Cushman	○	○	○	○	○	○	○
Heterohelix carinata (Cushman)	○	○			○	○	
Heterohelix glabrans (Cushman)	○	○	○	○	○	○	○
Heterohelix globulosa (Ehrenberg)	○	○					
Heterohelix planata (Cushman)	○	○			○	○	
Heterohelix robusta Stenetad	○	○			○	○	
Heterohelix striata (Ehrenberg)	○	○	○	○	○	○	○
Heterohelix vistulaensis Peryt	○	○					
Globigerinelloides asperus (Ehrenberg)	○	○	○	○	○	○	○
Globigerinelloides messine Brönnimann					○	○	
Globigerinelloides multispinus (Lalicker)					○	○	
Globigerinelloides volutus (White)	○	○	○		○	○	
Hedbergella planispira (Tappan)	○	○					
Hedbergella telatynensis Gawor-Biedowa	○	○			○	○	
Rugoglobigerina hexacamerata Brönnimann	○	○	○		○	○	
Rugoglobigerina macrocephala Brönnimann	○	○			○	○	
Rugoglobigerina reicheli Brönnimann					○	○	
Rugoglobigerina rugosa (Plummer)	○	○	○	○	○	○	○
benthic forms							
Bolivina crassa Vassilenko et Mjatliuk	○	○	○		○	○	
Tappanina selmensis (Cushman)					○	○	
Pyramidina cimbrica (Brotzen)	○	○	○	○	○	○	○
Eponides concinna Brotzen	○	○					
Eponides karsteni (Reuss)	○	○			○	○	
Cibicidoides bembix (Marsson)	○	○	○	○	○	○	○
Cibicidoides voltzianus (d'Orbigny)	○	○	○		○	○	
Stensioeina pommerana Brotzen	○	○					
Gavelinella complanata (Reuss)	○	○	○	○	○	○	○
Gavelinella sahlstroemi (Brotzen)	○	○			○	○	

Fig. 4. The SEM of the Maastrichtian foraminifers derived to the younger loesses

a, **b** — *Globigerinelloides asperus* (Ehrenberg), Zhorniv; **c**, **d** — *Rugoglobigerina rugosa* (Plummer), Zhorniv; **e** — *Rugoglobigerina hexacamerata* Brönnimann, Tyszowce; **f** — *Hedbergella telatynensis* Gawor-Biedowa, Tyszowce; **g**, **h** — *Rugoglobigerina reicheli* Brönnimann, Zhorniv; **i** — *Guembelitria cenomana* (Keller), Tyszowce; **j** — *Guembelitria cretacea* Cushman, Tyszowce; **k** — *Heterohelix planata* (Cushman), Zhorniv; **l** — *Heterohelix striata* (Ehrenberg), Wożuczyn; **m** — *Heterohelix vistulaensis* Peryt, Tyszowce; **n** — *Heterohelix carinata* (Cushman), Tyszowce; **o** — *Heterohelix robusta* Stenetad, Tyszowce; **p** — *Heterohelix glabrans* (Cushman), Tyszowce; **r** — *Heterohelix* cf. *glabrans* (Cushman), Zhorniv; MUZ PIG, coll. J.Paruch-Kulczycka

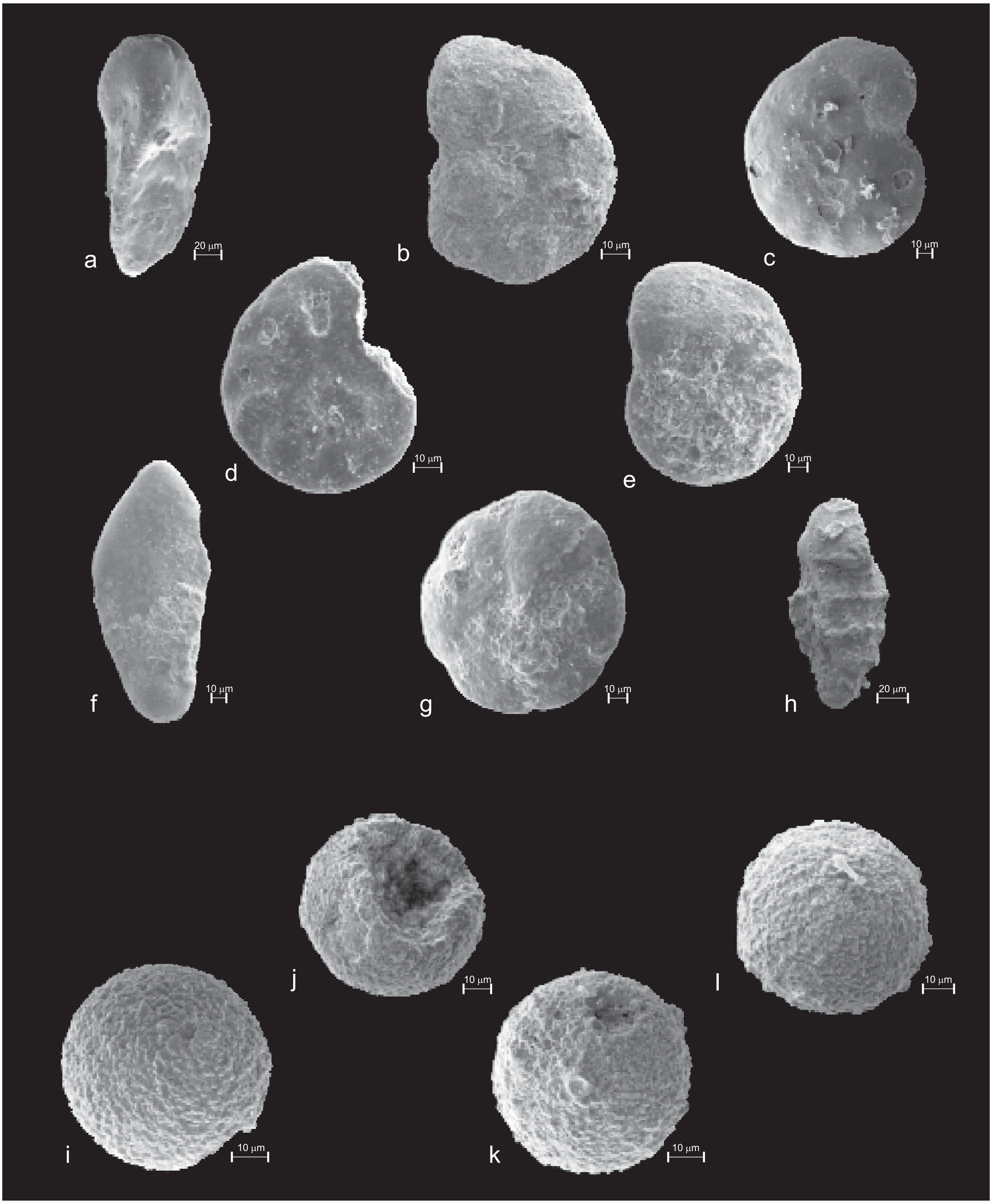

Fig. 5. The SEM of the Maastrichtian foraminifers (a–h) and calcareous dinocysts (i–l) derived to the younger loesses

a — *Pyramidina cimbrica* (Brotzen), Tyszowce; **b** — *Cibicidoides bembix* (Marsson), Tyszowce; **c** — *Cibicidoides voltzianus* (d'Orbigny), Tyszowce; **d** — *Gavelinella sahlstroemi* (Brotzen), Zhorniv; **e** — *Gavelinella complanata* (Reuss), Tyszowce; **f** — *Bolivina crassa* Vassilenko et Mjatliuk, Tyszowce; **g** — *Eponides karsteni* (Reuss), Hrubieszów; **h** — *Tappanina* cf. *selmensis* (Cushman), Horokhov; **i** — *Orthopithonella* sp., Zhorniv; **j–l** — *Obliquipithonella* sp., Zhorniv; MUZ PIG, coll. J. Paruch-Kulczycka

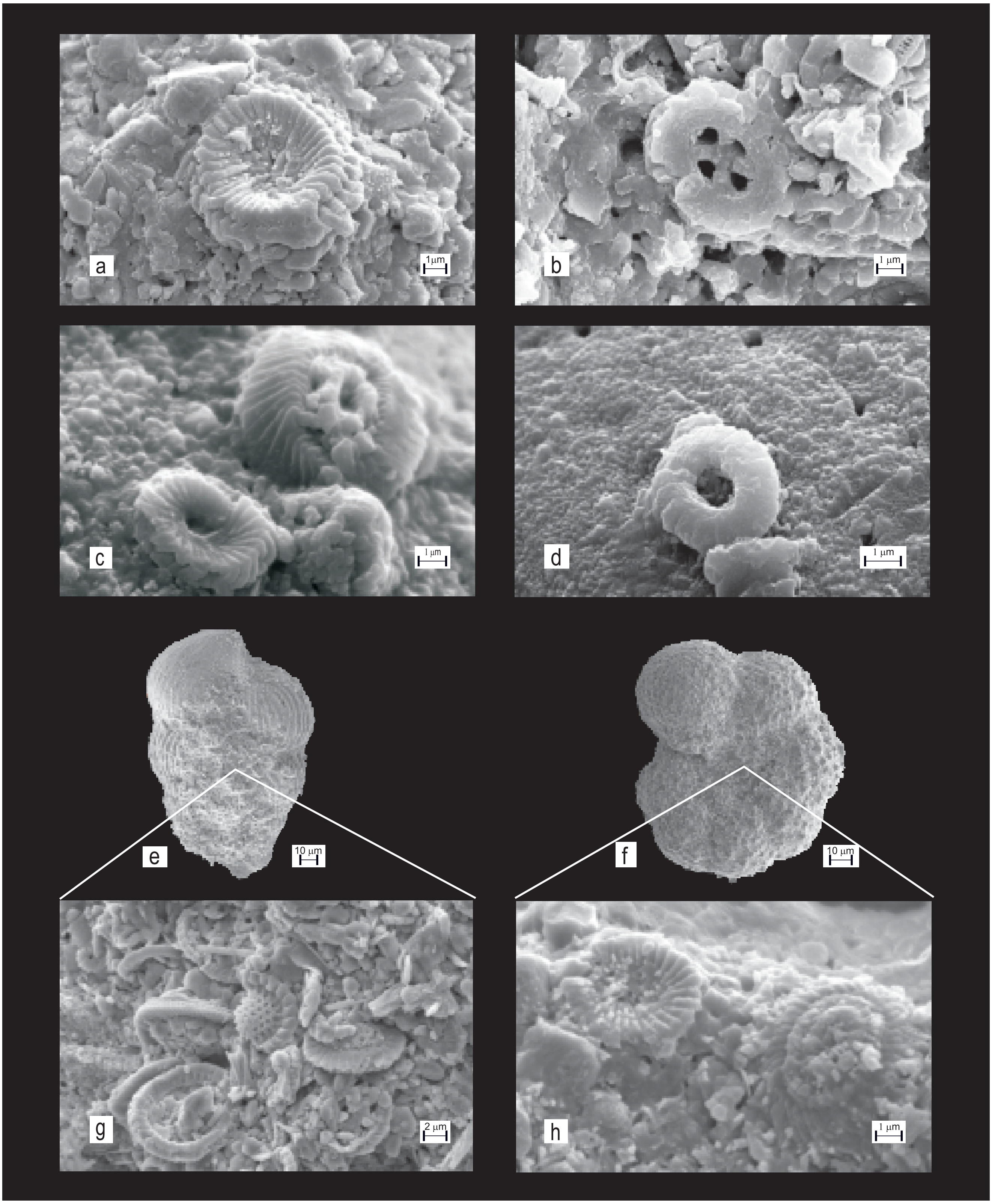

Fig. 6. The SEM of the Maastrichtian calcareous nannoplankton (a–d) derived to the younger loesses

a — *Watznaueria barnesae* (Black), Zhorniv; **b** — *Prediscosphaera cretacea* (Arkhangelsky), Tyszowce; **c**, **d** — *Biscutum* sp., Tyszowce; **e**, **g** — thick film of calcareous nannoplankton covering Maastrichtian *Heterohelix striata* (Ehrenberg) test, Wożuczyn; **f**, **h** — calcareous nannoplankton remains adhering to *Hedbergella telatynensis* Gawor-Biedowa foraminifer test, derived to the younger loesses, Tyszowce; MUZ PIG, coll. J. Paruch-Kulczycka

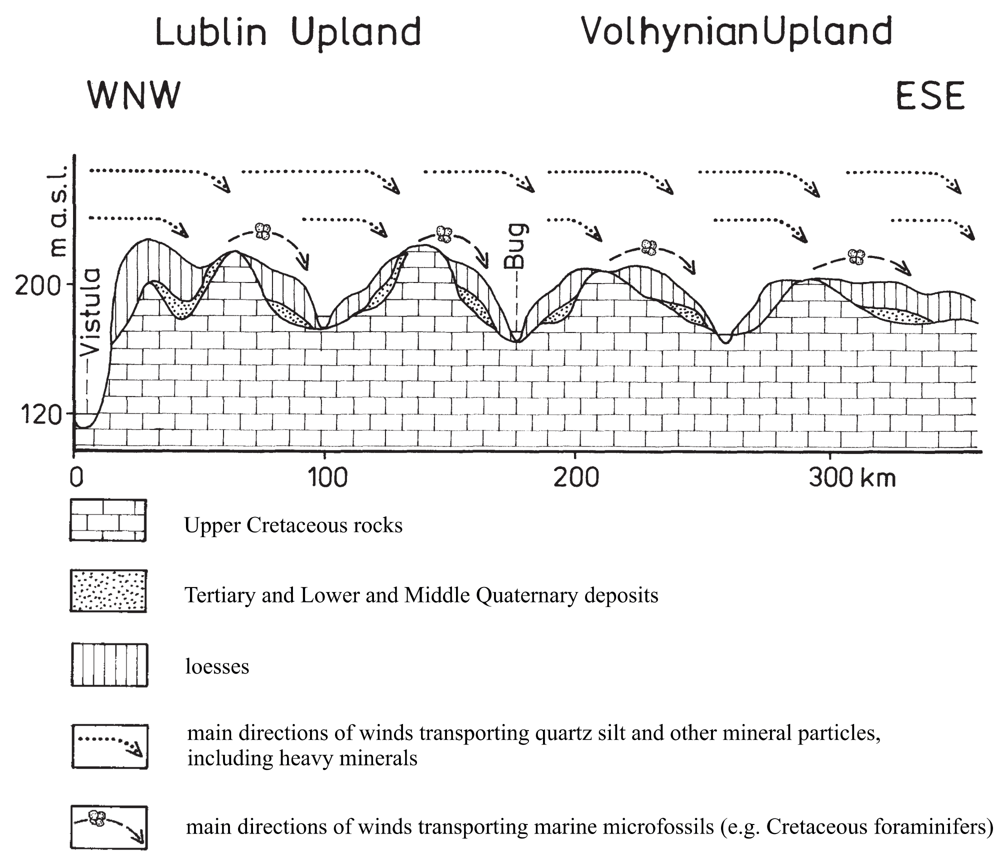

Fig. 7. Scheme of conditions of loess sedimentation in the Lublin and Volhynian Upland

(White), *G. asperus* (Ehrenberg), *G. messinae* Brönnimann, *Rugoglobigerina rugosa* (Plummer), *Tappanina selmanis* (Cushman) and *Cibicidoides bembix* (Marsson). In this section some of the foraminifer tests are strongly silicified. The distribution of particular foraminiferid taxa is shown in Table 1.

In the case of microfossils preserved in the loess sections at Tłumaczów (central Sudetes) and Branice (Głubczyce Plateau), loess samples T1 and T2 from Tłumaczów indicated the presence of probable Cretaceous foraminifers. They were noted, however, only in powdered microscopic slides prepared for mineralogical analyses (Chlebowski *et al*., 2001), whereas a later micropalaeontological analysis did not indicate their presence. Therefore their documentation is based only on microscopic photographs (Fig. 3c, d) of the powdered mineralogical samples. Similarly, in the case of samples Br 1 and Br 2 from Branice the presence of single foraminifers was noted only in powdered samples of the light fractions (Fig. 3b). Crushed tests were accompanied by well-preserved ornamented tests, comparable to the Cretaceous foraminifers of the taxa described above.

Well-preserved foraminifers (Fig. 3a) were noted for the first time in the Bojanice section near Sokal during mineralogical analyses of loesses with a high carbonate content. They are derived from the Cretaceous rocks locally occurring in the basement (Chlebowski *et al*., 1999).

Results of detailed analysis of the remaining sections (Wożuczyn, Tyszowce, Hrubieszów, Korshov, Horokhov, Zhorniv) are shown in Table 1. The microfossil assemblage studied showed abundantly representatives of the following taxa: *Heterohelix glabrans* (Cushman) (Fig. 4p); *H. striata* (Ehrenberg) (Fig. 4l); *H. carinata* (Cushman) (Fig. 4n); *Heterohelix* sp., *Guembelitria cretacea* Cushman (Fig. 4j); *G. cenomana* (Keller) (Fig. 4i); *Globigerinelloides asperus* (Ehrenberg) (Fig. 4a, b); *Globigerinelloides* sp., *Rugoglobigerina rugosa* (Plummer), (Fig. 4c, d); *R. hexacamerata* Brönnimann, (Fig. 4e); *Gavelinella sahlstroemi* (Brotzen) (Fig. 5d); *Gavelinella* sp., *Cibicidoides bembix* (Marsson) (Fig. 5b); and *Pyramidina cimbrica* (Brotzen) (Fig. 5a).

SEM images indicate coccoliths attached to the surfaces of some of the foraminifer tests. These are by *Watznaueria barnesae* (Black) (Fig. 6a); *Prediscosphaera cretacea* (Arkhangelsky) (Fig. 6b); and *Biscutum* sp. (Fig. 6c, d). In the Zhorniv section the microfossil assemblage contains also numerous calcareous dinocysts: *Orthopithonella* sp. (Fig. 5i); *Obliquipithonella* sp. (Fig. 5j); *Pithonella* sp.

During later investigations, derived foraminifers in loess were compared with microfauna from the earlier documented *in situ* Cretaceous deposits (Peryt, 1980; Gaździcka, 1981; Gawor-Biedowa, 1992; Smit and Zachariasse, 1996; Willems, 1996; Witte and Schuurman, 1996). This comparison indicates that all described taxa determined in the upper younger loess were earlier described in Late Maastrichtian strata from boreholes located in the Lublin Upland: Lubartów IG 2, Dorohucza IG 5, Gorzów IG 1, Tyszowce IG 1, Talatyn IG 1

Table 2

Stratigraphic ranges of derived foraminifers in loesses from the last glaciation in SE Poland and NW Ukraine

Stratigraphy / Foraminifer taxa	Late Cretaceous	
	Campanian	Maastrichtian
planktic forms		
Globigerinelloides asperus (Ehrenberg)	←————————	————————
Hedbergella planispira (Tappan)	←————————	————————
Heterohelix carinata (Cushman)	←————————	————————
Heterohelix globulosa (Ehrenberg)	←————————	————————
Heterohelix robusta Stenetad	←————————	————————
Globigerinelloides volutus (White)	←——————	——————
Hedbergella telatynensis Gawor-Biedowa	←——————	————————
Rugoglobigerina rugosa (Plummer)	←————	————————
Heterohelix glabrans (Cushman)	←——	————————
Heterohelix planata (Cushman)	←——	————————
Heterohelix striata (Ehrenberg)	←——	————————
Globigerinelloides multispinus (Lalicker)	←——	————————
Heterohelix vistulaensis Peryt		←——————
Rugoglobigerina hexacamerata Brönnimann		←——————
Rugoglobigerina reicheli Brönnimann		←——
Guembelitria cenomana (Keller)		←————
Guembelitria cretacea Cushman		←————
Rugoglobigerina macrocephala Brönnimann		←————
Globigerinelloides messine Brönnimann		←————
benthic forms		
Eponides concinna Brotzen	←————————	————————
Stensioeina pommerana Brotzen	←————————	————————
Eponides karsteni (Reuss)	←————————	————————
Cibicidoides voltzianus (d'Orbigny)	←——————	————
Bolivina crassa Vassilenko et Mjatliuk		←———————
Cibicidoides bembix (Marsson)		←———————
Gavelinella complanata (Reuss)		←——————
Tappanina selmensis (Cushman)		←————
Pyramidina cimbrica (Brotzen)		←————
Gavelinella sahlstroemi (Brotzen)		————→

(Gawor-Biedowa, 1992) and from exposures at Kazimierz, Bochotnica, Nasiłów, Męćmierz and Lucinia (Peryt, 1980). Most of the material analysed represented taxa indicative for the Maastrichtian (Table 2).

The abundance of foraminifers varies within the sites described in this paper. In S Poland the foraminifers are most abundant in loesses from the Tyszowce section; they are much less abundant in the Hrubieszów and Wożuczyn sections (Table 1). In Tłumaczów and Branice the presence of foraminifers was determined solely during microscopic analysis of the mineralogical content Fig. 3a–d. In Ukraine foraminifers are most abundant in the Zhorniv section (Table 1).

The majority of the microfossils studied are well-preserved, despite their being derived. Generally, the ornamentation of the foraminifer tests is clear, and some specimens even show the final chamber. Only some are badly damaged. The tests were probably covered by a protective layer of coccoliths material, typical for chalk (Fig. 6e, g). Similarly, the silification of foraminifer tests increased their resistance to abrasion.

The presence of extremely small foraminifers in loesses in comparison to the *in situ* assemblages may be caused by sorting during eolian transport and deposition: larger specimens were rapidly broken, and their fragments co-occur with small individuals in the silty fraction of the analysed loesses.

The observed state of preservation of the loess-hosted microfossils may indicate a relatively short transport from their place of origin, and additionally suggests a direct source of material carried by winds transporting the loess material. The taxonomic content as well as the preservation of the Late Maastrichtian microfauna in the loess suggests derivation from the Late Maastrichtian chalk, which locally represents the basement to the Quaternary deposits. The assemblages are essentially of uniform stratigraphically, without admixtures of Jurassic or Early Cretaceous microfauna.

DISCUSSION

The observed presence of Cretaceous marine microfossils in loess sections in southern Poland and northwestern Ukraine is an important addition to investigations of the Late Pleistocene loess-forming processes in central-eastern Europe. It provides direct evidence as to the origin of the loess silt. Discussions of this topic were initiated by Łoziński (1909) — the creator of the term "periglacial" — who linked the development of the silt fraction of loesses with frost weathering. W. Łoziński suggested that, in southern Poland silt of such origin was transported for small distances. This interpretation was later disputed by researchers who favoured more distant sources for the loess silt (Kuźniar, 1912). Similarly, Jahn (1950) suggested that the main source of loess were "fluvioglacial and fluvial deposits of the Polish Lowlands".

Later, Malicki (1950) and Jahn (1956) suggested short range transport of loess silt, a notion supported by detailed analyses of the heavy mineral fraction of the upper younger loess of the Małopolska Upland (Chlebowski and Lindner, 1975), which indicated the considerable role of local material in the loess-forming process. At present this idea is generally accepted, although not all authors agree on the degree of the local character of the loesses (i.e. Różycki, 1967; Maruszczak, 1967, 1991; Jersak, 1976; Chlebowski and Lindner, 1976; Lindner, 1976; Kenig, 1997; Łanczont, 1997). However, it has also been suggested recently that the accumulation of loesses in Poland was linked mainly with winds "transporting silts from distant areas on the border with Asia" (Mycielska-Dowgiałło *et al.*, 2001, p.107). There has also been little consensus regarding the directions from which loess silt was transported. One group of works has suggested the prevalence of eastern, northeastern or southeastern winds transporting the loess silt (Jahn, 1956; Maruszczak, 1967; Jersak, 1976; Mycielska-Dowgiałło *et al.*, 2001), whereas another has favoured the prevalence of western or northwestern winds (Różycki, 1968; Łyczewska, 1969; Chlebowski and Lindner, 1992; Chlebowski *et al.*, 2002).

The documented presence of marine microfossils, mainly Cretaceous foraminifers, in loesses of the Vistulian Glaciation preserved in eight sections (Tłumaczów, Branice, Wożuczyn, Tyszowce, Hrubieszów, Bojanice, Horokhov and Zhorniv) in central-eastern Europe in the direct vicinity of Upper Cretaceous exposures indicates the role of these rocks and their debris, and the overlying pre-loess Pleistocene tills and sands, as some of the main sources of the loess silt. This fact is supported by the results of mineral content analyses, particularly of heavy minerals of the same loess samples. In most cases these mineral groups prevail which characterise a "local material vector" (Chlebowski *et al.*, 2002). These comprise minerals, which due to their physical properties (amphiboles and pyroxenes), or chemical composition (glauconite) do not survive long transport, but are derived from short distances, resembling thus the debris of local rocks. In areas close to the loess sections described the rocks include those of Cretaceous age (chalk, gaizes), commonly occurring both on the Lublin and Volhynian Uplands, as well as fluvioglacial deposits rich in debris of igneous and metamorphic rocks and Tertiary sandy deposits rich in glauconite.

In the case of the Branice section (Głubczyce Plateau) and Tłumaczów (Kłodzko Basin) the local origin of the loess material is indicated by a very high content of amphiboles in the Branice loess, reflecting metamorphic rocks (amphibolites) of the nearby Sudetes, whereas the mineral content of the Tłumaczów loess reflects the debris of Palaeozoic rocks from the Kłodzko Basin area as well as sedimentary rocks from the Stołowe Mts. (Chlebowski *et al.*, in press).

The spatial distribution of the loess areas analysed of the Lublin and Volhynian Uplands in relation to potential sources of the loess material in the form of local rock debris allows determination of the main directions of winds transporting the material (Fig. 7). The winds were generally from the west and north-west (Chlebowski *et al.*, 2002). Moreover, the presence of marine microfossils (mainly foraminifers) from rocks directly nearby the loesses analysed supports the interpretation of Chlebowski and Lindner (1989, 1999) regarding the importance of winds in the lower parts of the atmosphere in the development of the loess cover, without excluding, though, an admixture of far-transported silt.

FINAL REMARKS

The presence of marine microfossils (foraminifers) from Cretaceous rocks within the analysed loesses in the type sections of the last glaciation (Vistulian) are direct evidence of the role of local material in the Pleistocene loess-forming processes in central-eastern Europe. In the first place the material included quartz silt with a small admixture of feldspars and heavy minerals. In the main phase its origin was linked with the deflation of products of frost weathering from Cretaceous chalk, marls and sandstones, Tertiary sandy deposits and Pleistocene tills and glacifluvial, fluvioperiglacial and fluvial sands. The variable state of preservation of the marine microfossils in loesses may indicate that the more abraded ones were derived several times, being blown out from older Pleistocene deposits. Only slightly damaged and well-preserved Cretaceous foraminifers could be included within the loess in course of corrosion-deflation activity taking place on surfaces of Cretaceous rock exposures in the direct vicinity of, or within, the loess covers analysed.

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