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Institute of Earth Science, M. Curie-Skłodowska University in Lublin

LEOPOLD DOLECKI

Stratigraphy and main lithological features of loess formations in the south-eastern part of the Lublin Upland (SE Poland)

Stratygrafia i główne cechy litologiczne utworów lessowych w południowo-wschodniej części Wyżyny Lubelskiej (SE Polska)

Keywords: mid-eastern Poland, oldest, lower and younger loesses, stratigraphy, lithology
Słowa kluczowe: Polska środkowo-wschodnia, less dolny i młodszy, stratygrafia, litologia

INTRODUCTION

The Horodło Plateau-Ridge is the most eastwards extending loess patch within the Lublin Upland, and is characterized by the occurrence of the thickest and stratigraphically most differentiated loess cover in Poland. First detailed stratigraphical schemes of the Neopleistocene loesses were published as a result of the studies made in few exposures or excavations in brickfields and higher river terraces of the Horodło Plateau-Ridge (A. Jahn 1956, J. E. Mojski 1956, 1965, H. Maruszczak 1972, 1976, 1991). Some information was also obtained from a few borings located in the flat interfluve areas (J. Jersak 1969, 1973, 1988). There, the deposits of different ages are better preserved *in situ* as they are less denuded than those occurring on the slopes.

In the years 1972–1973 the author made first detailed investigations and descriptions of the deposits taken from borings located on the Horodło Plateau-Ridge (L. Dolecki 1975, 1981). New materials from borings were obtained in a later period, when geological mapping of the whole Quaternary cover was made in this area. It was possible to compare the loesses and paleosols of the same age occurring in the flat intefluve areas, slopes and higher terraces (L. Dolecki 1987, 1995a), (Fig.1).

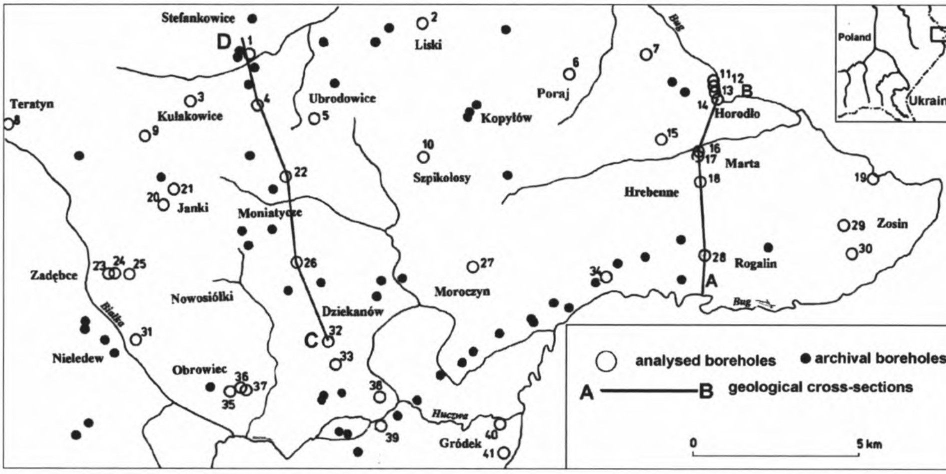

Fig. 1. Location of study area, localisation of main documentation points, and lines of cross-sections. A–B Cross-section Strzyżów–Horodło; C–D Cross-section Hrubieszów CPN–Stefankowice K-3; Numbers of main documentation points on the figure: 1 – Stefankowice K-3, 2 – Liski, 3 – Kułakowice school, 4 – Stefankowice K-4, 5 – Turkołówka, 6 – Poraj, 7 – Kol. Horodło, 8 – Teratyn, 9 – Kułakowice, 10 – Szpikołosy, 11 – Horodło 5, 12 – Horodło 3, 13 – Horodło 2, 14 – Horodło 1, 15 – Hrebenne, 16 – Marta M-21, 17 – Marta, 18 – Kol. Hrebenne K-2, 19 – Łuszków, 20 – Janki 2, 21 – Janki 1, 22 – Moniatycze K-5, 23 – Kol. Zadębce 1, 24 – Kol. Zadębce 2, 25 – Kol. Zadębce 3, 26 – Czartowiec K-6, 27 – Moroczyn, 28 – Rogalin K-1, 29 – Zosin 1, 30 – Zosin 2, 31 – Nieledew, 32 – Hrubieszów CPN, 33 – Hrubieszów-Feliks, 34 – Łukaszówka, 35 – Obrowiec 1, 36 – Obrowiec 2, 37 – Lipice – brickyard, 38 – Świerszczów, 39 – Hrubieszów 2 (slaughterhouse), 40 – Gródek – castle, 41 – Gródek – early medieval castle

Lokalizacja terenu badań, rozmieszczenie głównych punktów dokumentacyjnych i linie przekrojów geologicznych. A–B linia przekroju geologicznego Strzyżów–Horodło; C–D linia przekroju geologicznego Hrubieszów CPN–Stefankowice K-3; Numeracja głównych punktów dokumentacyjnych na szkicu: 1 – Stefankowice K-3, 2 – Liski, 3 – Kułakowice szkoła, 4 – Stefankowice K-4, 5 – Turkołówka, 6 – Poraj, 7 – Kol. Horodło, 8 – Teratyn, 9 – Kułakowice, 10 – Szpikołosy, 11 – Horodło 5, 12 – Horodło 3, 13 – Horodło 2, 14 – Horodło 1, 15 – Hrebenne, 16 – Marta M-21, 17 – Marta, 18 – Kol. Hrebenne K-2, 19 – Łuszków, 20 – Janki 2, 21 – Janki 1, 22 – Moniatycze K-5, 23 – Kol. Zadębce 1, 24 – Kol. Zadębce 2, 25 – Kol. Zadębce 3, 26 – Czartowiec K-6, 27 – Moroczyn, 28 – Rogalin K-1, 29 – Zosin 1, 30 – Zosin 2, 31 – Nieledew, 32 – Hrubieszów CPN, 33 – Hrubieszów – cegielnia Feliks, 34 – H – Łuszków, 35 – Obrowiec 1, 36 – Obrowiec 2, 37 – Lipice – cegielnia, 38 – Świerszczów, 39 – Hrubieszów 2 (rzeźnia), 40 – Gródek – zamek, 41 – Gródek – grodzisko

In this paper, I report the results of a research on the loesses from the Horodło Plateau-Ridge (Fig. 2).

Their stratigraphy and spatial differentiation of their thickness, selected chemical features, composition of transparent heavy minerals, and granulometric characteristics are discussed.

The particle size distribution of the examined deposits was determined with the areometric method of Casagrande in Prószyński's modification; sand frac-

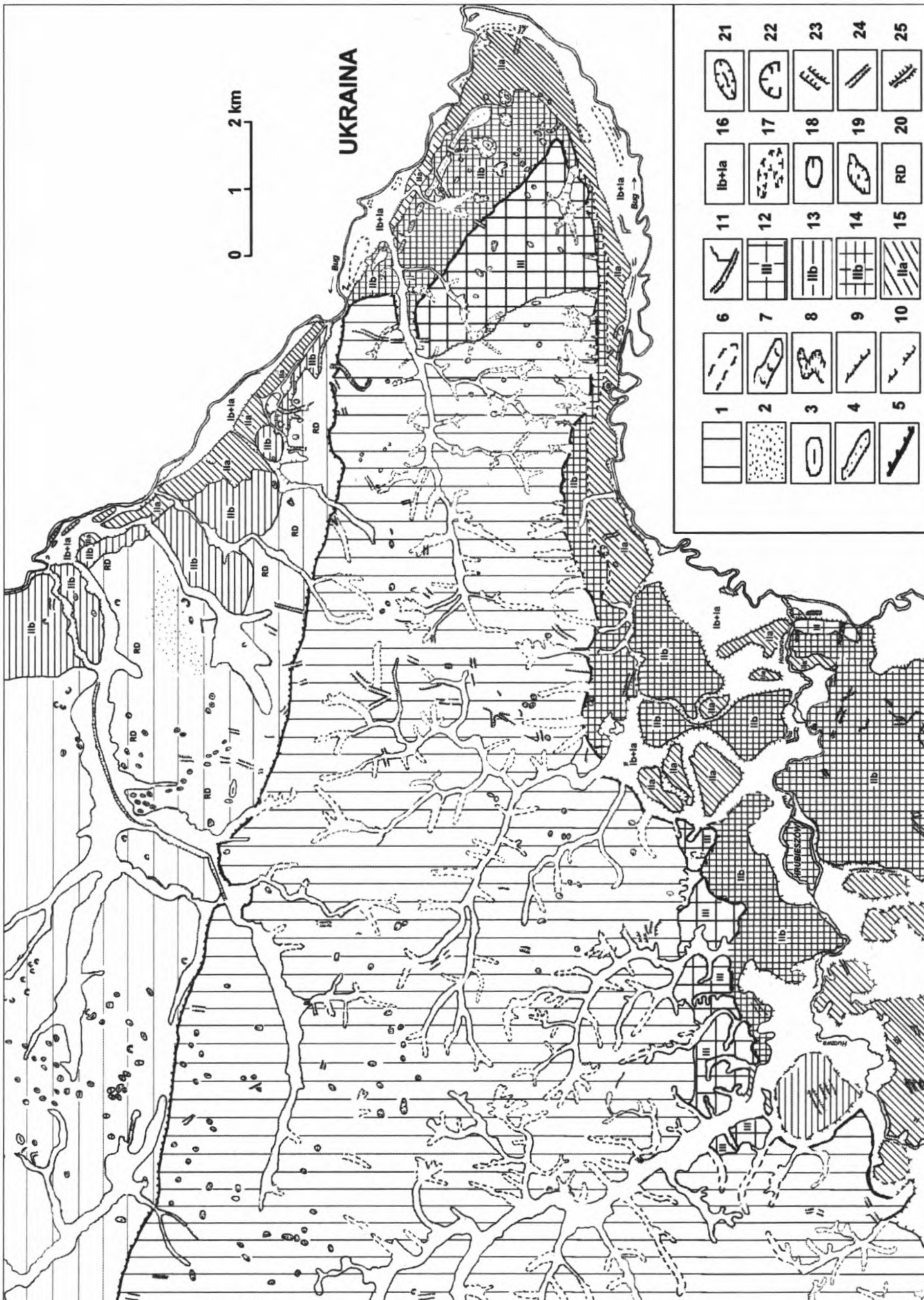
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Fig. 2. Geomorphological sketch of the Horodło Plateau-ridge and adjacent areas. 1 – loessy plains; 2 – areas of deflated sands; 3 – small deflation depressions; 4 – loessy ridges accompanying edges; 5 – scarps of loess patch; 6 – trough-like valleys; 7 – small valleys with flat bottom; 8 – gullies; 9 – distinct edges of river terraces; 10 – indistinct edges of river terraces; 11 – channels of rivers and streams; 12 – supposed extent of the highest buried terrace (III); 13 – higher terrace (IIb); 14 – higher terrace (IIb) with loess cover; 15 – lower terrace (IIa); 16 – flood terrace (Ia+Ib); 17 – abandoned channels; 18 – closed depressions; 19 – suffosion depressions and channels; 20 – denudation plains; 21 – karst sinkholes; 22 – excavations; 23 – cultivated terraces; 24 – road ravines and ditches; 25 – earth banks and dykes

Szkic geomorfologiczny Grzędy Horodelskiej i przyległego obszaru. 1 – równiny lessowe; 2 – pola piasków przewianych; 3 – drobne zagłębienia deflacyjne; 4 – przykrawędziowe wały lessowe; 5 – krawędzie płata lessowego; 6 – doliny denudacyjne; 7 – doliny nieckowate; 8 – wąwozy; 9 – krawędzie teras rzecznych wyraźne; 10 – krawędzie teras rzecznych niewyraźne; 11 – koryta rzek i potoków; 12 – terasa nadzalewowa najwyższa; 13 – terasa nadzalewowa wyższa; 14 – terasa nadzalewowa wyższa z pokrywą lessu; 15 – terasa nadzalewowa niższa; 16 – terasy zalewowe; 17 – starorzecza; 18 – zagłębienia bezodpływowe; 19 – zagłębienia termokrasowe; 20 – równiny denudacyjne; 21 – leje krasowe; 22 – wyrobiska; 23 – teraski uprawowe; 24 – głębocznice i rowy; 25 – wały, nasypy, groble tions were separated by sieving. Granulometric indices were estimated with the graphic method. Heavy minerals were analysed in 0.1–0.05 mm fraction, and in exceptional cases in 0.25–0.1 mm fraction. Two weathering indices were calculated: O/(S+N) – the ratio of minerals most resistant to weathering to medium resistant and non-resistant ones, and C/(G+A) – the ratio of zircon grains to the sum of garnet and amphibole grains. Carbonate content was determined with the volumetric method, humus – with the Tiurin method, Fe_2O_3 – with the colorimetric method. Granulometric analyses were made by the author, chemical analyses – by D. Portka and the author, and heavy minerals analyses – by M. Wilgat. H. Maruszczak's stratigraphic scheme (1972, 1976, 1980, 1991) was used for the Neopleistocene loesses (Fig. 3), while for the Mesopleistocene ones – the one published by L. Dolecki (1995a).

The oldest loesses distinguished in Polish stratigraphical schemes correspond to marine stages older than stage 9 in global oxygen isotope timescale (Imbrie et al. 1984). Therefore, they were deposited during periods older than the Zbójnian interglacial *sensu lato*. Loess covers of different ages accumulated during the Elsterian Glacial. They are facially differentiated, and their top parts are usually destroyed in great part by successive denudation, erosion, and exaration processes associated with following, younger advances of the Pleistocene ice sheets. In Central Europe, where the highest number of glacial events was found, the oldest loesses are preserved only as isolated and incomplete patches covered by younger deposits.

The oldest loesses have been studied in the South Polish Uplands for many years (A. Jahn 1956, A. Jahn, M. Turnau-Morawska 1952). In the Polish Lowland they were described on the basis of borings (A. Makowska et al. 1976, J. Rzechowski 1986). The oldest loesses found at Załubińcze near Nowy Sącz (the Carpathian Foreland) were dated by means of the palaeomagnetic method (J. Nawrocki, A. Wójcik 1995). Some units of these loesses were also found at Zakłodzie in the Zamość Basin (L. Dolecki 1998a), at Siedliska near Przemyśl in the Carpathian Foothills (M. Łanczont 1995), in the Sokal Plateau-ridge at Wożuczyn (J. Buraczyński et al. 1988) and at Zwiartów (J. Rzechowski 2001), at Błażek in Western Roztocze (J. Wojtanowicz, M. Łanczont 1998), at Nieledew near Hrubieszów in the Horodło Plateau-ridge (J. E. Mojski 1965). The oldest loesses were also discovered in borings in the Holy Cross Mountains, the Miechów Upland and the Nida Basin (L. Lindner 1991). Rather long sequence of the oldest loesses and intraloess paleosols of various stratigraphic rank was found in the exposures at Kolonia Zadębce in the Horodło Plateau-ridge and in borings made for the Detailed Geological Map of Poland 1: 50 000, Kopyłów and Horodło sheets. Tills which separate these loesses are important strati-

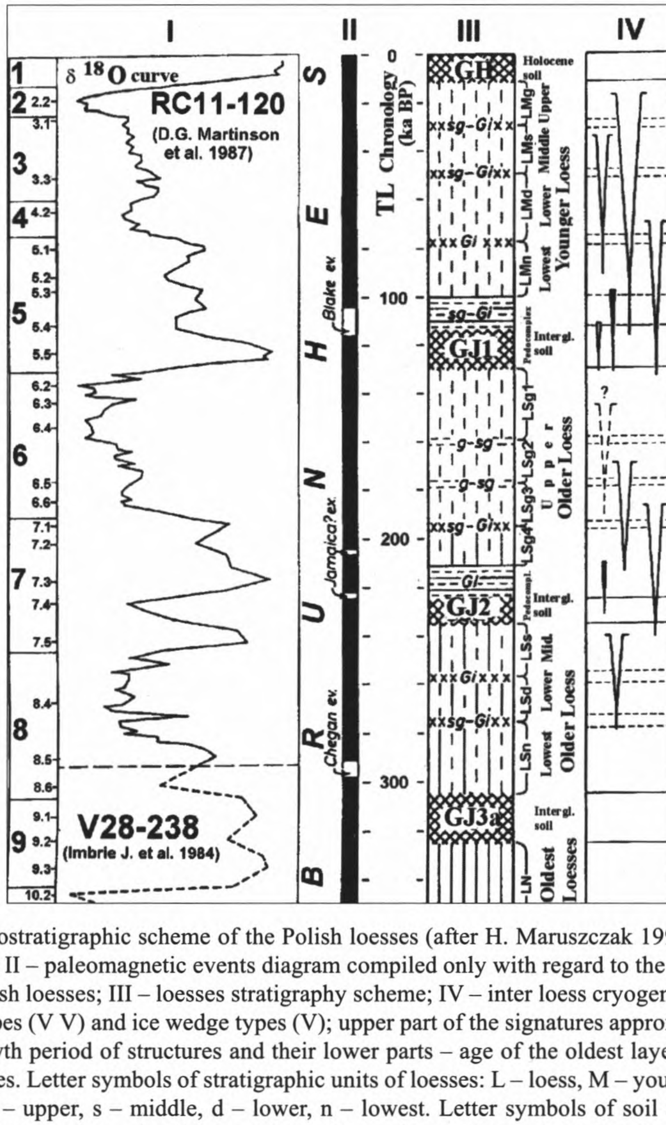

Fig. 3. Chronostratigraphic scheme of the Polish loesses (after H. Maruszczak 1991). I – oxygen isotope stage; II – paleomagnetic events diagram compiled only with regard to the results of studies of the Polish loesses; III – loesses stratigraphy scheme; IV – inter loess cryogenic structures of the fissure types (V V) and ice wedge types (V); upper part of the signatures approximately designate full growth period of structures and their lower parts – age of the oldest layers which reach these structures. Letter symbols of stratigraphic units of loesses: L – loess, M – younger, S – older, N – oldest, g – upper, s – middle, d – lower, n – lowest. Letter symbols of soil units: G – soil, H – recent (Holocene), J – fossil interglacial soil, i – fossil interstadial soil, sg – soil sediments, g – symptoms of the development of pedogenesis

Schemat chronostratygraficzny lessów polskich (według H. Maruszczaka 1991). I – stadia izotopowo-tlenowe; II – diagram zdarzeń paleomagnetycznych zarejestrowanych w lessach polskich; III – schemat stratygrafii lessów; IV – zaburzenia kriogeniczne w lessach typu szczelinowego i typu klinów lodowych V: górna część struktur w przybliżeniu oznacza okres pełnego rozwoju struktur, a dolna – wiek najstarszych warstw do których sięgnęły. Symbole literowe jednostek stratygraficznych lessów: L – less, M – młodszy, S – starszy, N – najstarszy, g – górny, s – środkowy, d – dolny, n – najniższy. Symbole literowe jednostek glebowych: G – gleba, H – dzisiejsza (holoceńska), J – kopalna interglacjalna, i – kopalna interstadialna, sg – sedymenty glebowe, g – oznaki rozwoju pedogenezy graphic units corresponding to oxygen isotope stages 12 and 16. The first stratigraphic scheme of the oldest loesses in South-Eastern Poland has been made on the basis of the results of geological mapping (L. Dolecki 1991a, 1995a, 2001) Fig. 4.

Numerical code used in this scheme arranges the loess beds according to their increasing ages. The youngest bed of the oldest loess is correlated with oxygen isotope stage 10, and is denoted as LN1. The second loess bed is denoted as

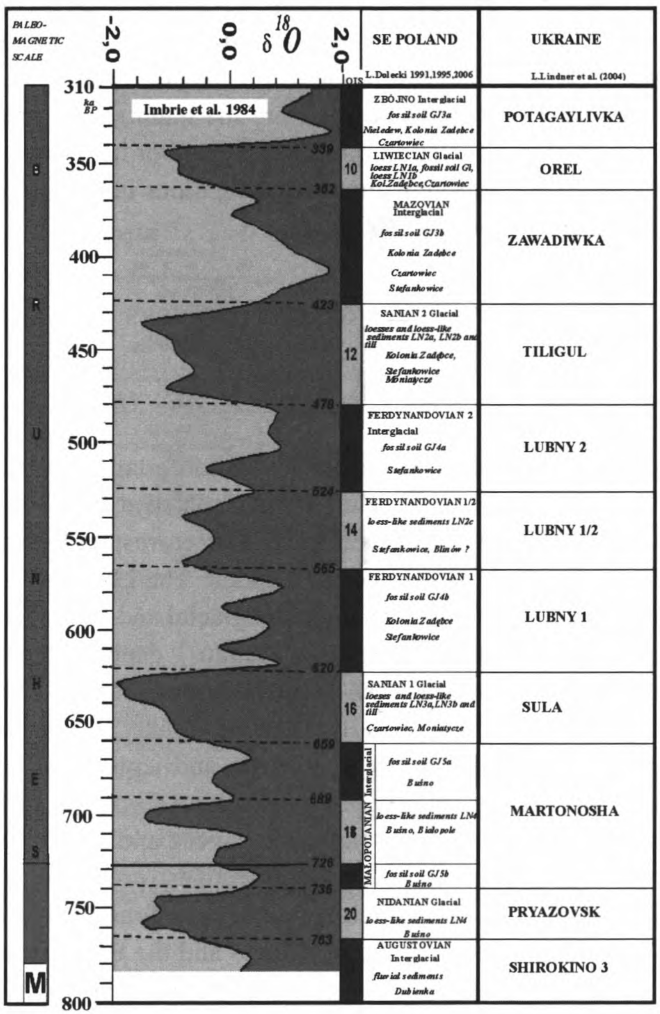

Fig. 4. Stratigraphic scheme of older loesses and loess-like sediments in South-East Poland and stratigraphic correlation with loesses from Ukraine (L. Dolecki, 2004, 2001b)

Schemat stratygraficzny mezoplejstoceńskich utworów lessowych w Polsce SE i korelacja z lessami Ukrainy (L. Dolecki, 2004, 2001b)

LN2 and corresponds to stage 12, the third one (LN3) is correlated with stage 16. The fourth loess bed (LN4), which corresponds to $\delta^{18}O$ stages 18–20, is still insufficiently examined. This code was supplemented with letters which indicate glacial phases during which loess beds were deposited. Loess which occurs under a moraine, formed during ice sheet advance, is denoted with letter “b”. Loess which covers a moraine, i.e., formed during ice sheet recession, is denoted with the letter “a”. Loess from early phase of ice sheet advance is denoted with the letter “c”. The stratigraphic arrangement of loess beds was based on the geological data, the thermoluminescence datings made in the TL laboratory of Maria Curie-Skłodowska University in Lublin, the results of pollen and palaeopedologic analyses. Tills and interglacial paleosols were the main stratigraphic reference layers. The stratigraphic correlation presented by author has been confirmed by the results of subsequent palaeomagnetic investigations in the Kolonia Zadębce profile (J. Nawrocki et al. 1999, 2001), Fig. 5.

PROFILES OF THE OLDEST LOESSES (LN)

Loess deposits (LN4) from the Nidanian Glacial (= Glacial A = OIS 20)

These deposits were found in borings in the borderland of the Horodło Plateau-ridge and the Dubienka Basin. They were TL dated at 689–763 ka BP, i.e. at the interval which in Polish stratigraphic schemes corresponds to the Nidanian Glacial within the Brunhes palaeomagnetic epoch. The LN4 deposits are of residual nature. In places they are covered by the glacial and fluvioglacial deposits of the Sanian 1 Glacial. The LN4 and the Sanian 1 deposits are separated by a probably large hiatus. The yellowish-beige LN4 loess deposits have heterogeneous grain size but silt fraction prevails. They are weakly sorted, with grain size distribution positively skewed, very leptokurtic and leptokurtic. They contain a variable amount of carbonates. These deposits were alimented by the pre-Quaternary bedrock, the Eopleistocene sands and gravels, and also by the Scandinavian gravels coming from the oldest glacial deposits (probably from the older stadial of the Nidanian Glacial) which have not been found till now. A distinct alimentation relationship between the LN4 loess and the Eopleistocene deposits is confirmed by their similar grain size distribution, and heavy minerals composition with the following sequence: zircon (45–46%) > rutile > garnet > tourmaline > staurolite. The contents of amphiboles and pyroxenes are usually only 1%, but amphiboles reach 6–12% and pyroxene – 2% in older layers of the LN4. These features are diagnostic for the discussed deposits.

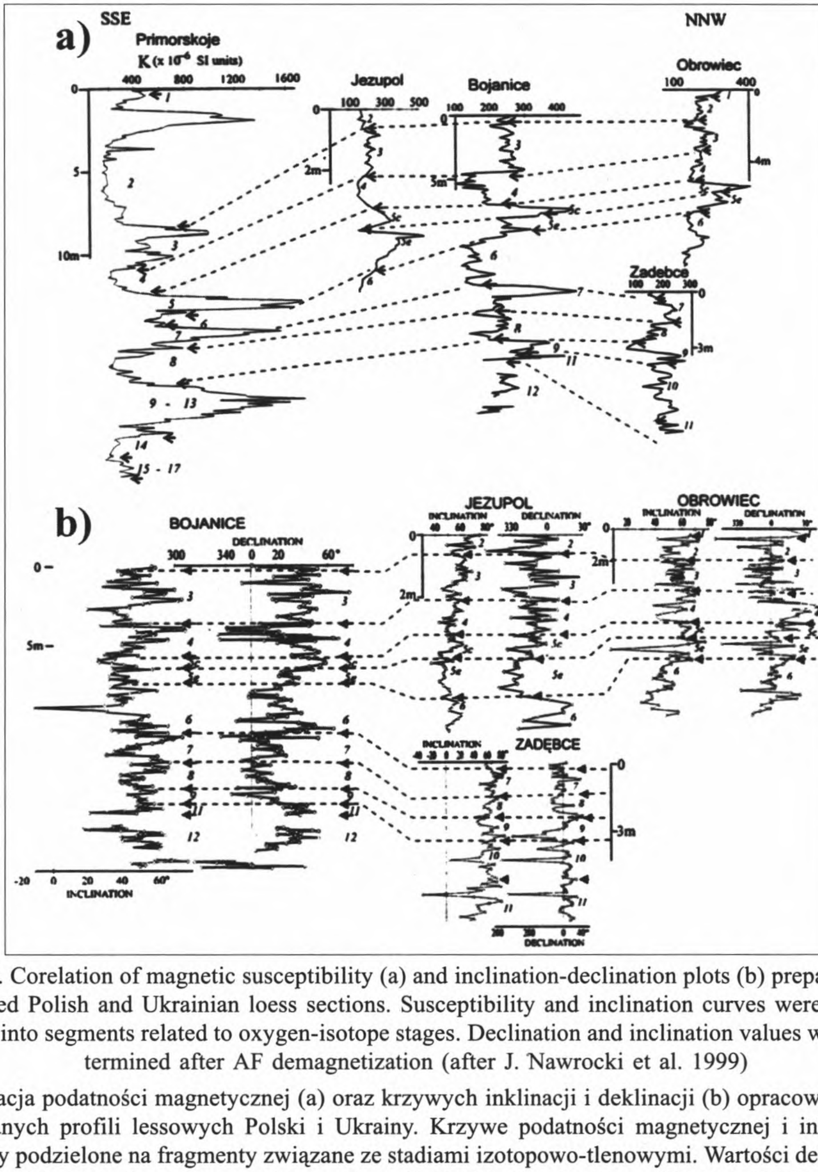

Fig. 5. Corelation of magnetic susceptibility (a) and inclination-declination plots (b) prepared for selected Polish and Ukrainian loess sections. Susceptibility and inclination curves were subdivided into segments related to oxygen-isotope stages. Declination and inclination values were determined after AF demagnetization (after J. Nawrocki et al. 1999)

Korelacja podatności magnetycznej (a) oraz krzywych inklinacji i deklinacji (b) opracowane dla wybranych profili lessowych Polski i Ukrainy. Krzywe podatności magnetycznej i inklinacji zostały podzielone na fragmenty związane ze stadiami izotopowo-tlenowymi. Wartości deklinacji i inklinacji ustalono po demagnetyzacji AF (według J. Nawrocki i inni 1999)

Loess deposits (LN3b) from the ascending phase of the Sanian 1 Glacial (= Glacial B= OIS 16)

In the presented stratigraphic scheme the Sanian 1 Glacial is correlated with oxygen isotope stage 16 (620–659 ka BP). The LN3b loess was found in the Czartowiec (K-6), Moniatycze (K-5) and Kol. Hrebenne (K-2) borings

(Figs. 1, 2), where it covers the Eopleistocene dęposits (TL dated at > 800 ka BP) and is overlain by the Sanian 1 till and fluvioglacial deposits. In the Czartowiec profile the bottom part of this loess was TL dated at 638 ka BP, and the top part – at 612 ka BP. The LN3b deposits contain up to 54% of loess fraction (0.05–0.02 mm), and are facially differentiated. The content of $CaCO_3$ ranges from 6.7 to 16.6 %; eolian facies contains more carbonates. The content of Fe_2O_3 resembles that typical of the younger loesses from the upper Plenivistulian. The LN3b deposits are overlain by the till which was TL dated at 573 ka BP in the Kol. Hrebenne profile, and at 572 ka BP in the Czartowiec profile (Fig. 6).

Loess deposits (LN3a) from the descending phase of the Sanian 1 Glacial (Glacial B = OIS 16)

Loess-like deposits and loesses of the descending phase of the Sanian 1 Glacial were found in several profiles over the Sanian 1 glacial deposits or directly over the Eopleistocene or Cretaceous rocks. The LN3a deposits were examined in the exposures at Kol. Zadębce (Fig. 7), and in the borings at Moniatycze (K-5) and Stefankowice (K-4, K-3) in the Horodło Plateau-ridge (Fig. 1, 2). These deposits are facially differentiated. The solifluction facies in the Moniatycze (K-5) and Stefankowice (K-4) borings contains the „loess" mollusc – *Succinea oblonga* (Drap.) which prefers open landscape (S. Skompski 1993).

The results of heavy minerals analysis indicate that the LN3a deposits were mainly supplied with mineral components from local bedrock, and an admixture of crystalline, probably Scandinavian material was small.

Pedocomplex (GJ4) from the Ferdynandowian interglacial and the early phase of the Sanian 2 Glacial (= Interglacial III+ Glacial C+ Interglacjal IV= OIS 13-15)

The Ferdynandowian interglacial described by Z. Janczyk-Kopikowa (1991) is correlated with the Voigstedt interglacial in Western Europe (K. Erd 1965), with the Šklov interglacial in Byelorussia (L. N. Vozniačuk, 1978), and with the Byeloveža interglacial in Ukraine (V. N. Šelkoplias, T. F. Christoforova 1987).

In the Horodło Plateau-ridge the Ferdynandowian pedocomplex GJ4 was found in an exposure at Kol. Zadębce (L. Dolecki 1995b,1998a) and in the K-4 boring at Stefankowice (Fig. 8). In Stefankowice this pedocomplex consists of two soils and its thickness reaches 4.2 m. The lower soil (GJ4b) is brown, and its diagnostic features are strongly obliterated by the younger pedogenesis. Carbon-

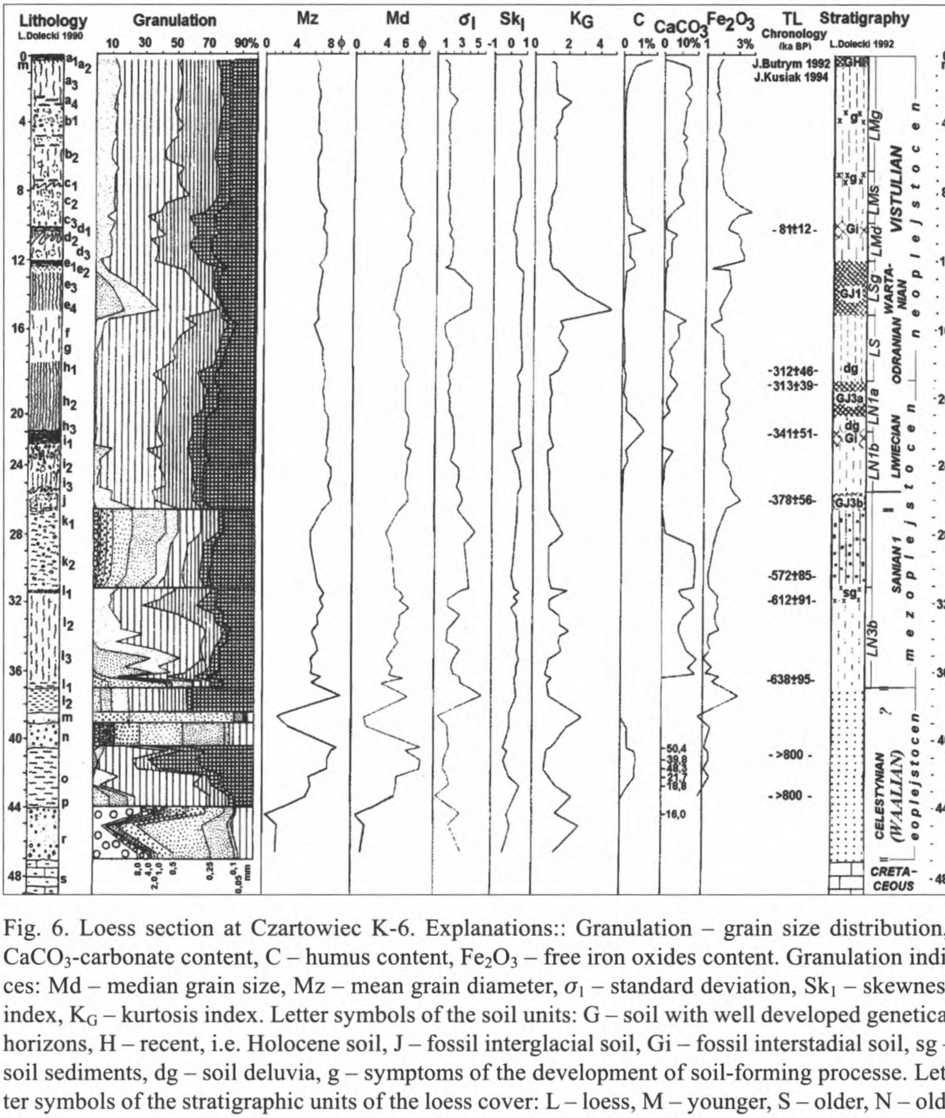

Fig. 6. Loess section at Czartowiec K-6. Explanations:: Granulation – grain size distribution,, $CaCO_3$-carbonate content, C – humus content, Fe_2O_3 – free iron oxides content. Granulation indices: Md – median grain size, Mz – mean grain diameter, σ_I – standard deviation, Sk_I – skewness index, K_G – kurtosis index. Letter symbols of the soil units: G – soil with well developed genetical horizons, H – recent, i.e. Holocene soil, J – fossil interglacial soil, Gi – fossil interstadial soil, sg – soil sediments, dg – soil deluvia, g – symptoms of the development of soil-forming processe. Letter symbols of the stratigraphic units of the loess cover: L – loess, M – younger, S – older, N – oldest, g – upper, s – middle, d – lower, n – the lowest, a – from ascending glaciation, b – from descending glaciation, c – from early glaciation. Diagrams of mineral composition of heavy fraction: Mc I – opaque minerals content; Mc II – composition indices of transparent minerals; Mc III – composition of transparent minerals (%). Letter symbols of transparent minerals: C – zirkon, R – rutile, G – garnet, A – amphiboles, 1(O) – resistant minerals, 2(S) – medium resistant minerals, 3(N) – non-resistant minerals. TL datings (in ka BP) by J. Butrym (Lublin laboratory)

Profil lessowy w Czartowcu K-6. Objaśnienia: Granulacja – diagram uziarnienia, $CaCO_3$ – zawartość węglanów, Fe_2O_3 – zawartość tlenków żelaza, C, humus – zawartość humusu, Wskaźniki uziarnienia: Mz – średnia średnica ziarna (w skali phi), Md – mediana ziarna, σ_I – wskaźnik wysortowania (rozproszenia), Sk_I – wskaźnik skośności rozkładu uziarnienia, K_G – wskaźnik kurtozy. Symbole literowe jednostek glebowych: G – gleby z wykształconymi poziomami genetycznymi, H – holoceńskie, J – interglacjalne, i – interstadialne, sg – sedymenty glebowe, (g) – oznaki rozwoju pedogenezy, dg – produkty denudacji gleb. Symbole stratygraficzne lessów: L – less, M – młodszy, S – starszy, N – najstarszy, g – górny, s – środkowy, d – dolny, n – najniższy, a – z fazy zstępującej zlodowacenia, b – z fazy wstępującej zlodowacenia, c – z wczesnej fazy zlodowacenia. Diagram składu minerałów ciężkich: Mc I – zawartość minerałów ciężkich nieprzezroczystych (%), Mc II – wskaźniki zwietrzenia, Mc III – skład minerałów ciężkich przezroczystych (%). Literowe symbole minerałów ciężkich: C – cyrkon, R – rutyl, G – granat, A – amfibol, O – minerały odporne, S – minerały średnioodporne, N – minerały nieodporne. TL – daty termoluminescencyjne osadów w tys. lat BP wykonane przez J. Butryma w lubelskim laboratorium

ates are absent in this soil, and the top part of its humus horizon is disturbed by solifluction structures and fissure casts which run downwards from the upper soil indicating a probable occurrence of a large hiatus. In the Kol. Zadębce 1 profile the substratum of the lower Ferdynandowian soil was TL dated at 547 ka BP (H. Maruszczak, L. Dolecki, M. Łanczont 1992). In Stefankowice the upper soil (Gi4a) occurs over the silty-clayey deposit (LN2c) which was TL dated at 517 ka BP and correlated with oxygen isotope stage 12. This leached brown soil developed probably during a warm interstadial of the ascending phase of the Sanian 2 Glacial. The deposits of LN2c perhaps represent a separate glaciation (E. Erd 1978, A. Pidek 2000, L. Lindner et al. 2004). Its substratum is distinguished by the very fine mean grain (Mz=7.5 ϕ), extremely weak sorting, grain size distribution positively skewed and mesokurtic (K_G=0.97). A secondary feature, associated with pedogenesis, is the mean content of Fe_2O_3 (1.54%) in the LN2c deposit. The browned horizon of the Gi4a soil contains up to 40% of clay fraction and 2.6% of Fe_2O_3, and the humus horizon – 0.36% of humus. Loess in Medyka environs, covered by the moraine of the Sanian 2 Glacial, and TL dated at 538 ka BP (M. Łanczont 1996), is the stratigraphic counterpart of the LN2c deposits.

Loesses and loess-like deposits (LN2) from the Sanian 2 Glacial (= Elster 2 = OIS 12)

The pedocomplex GJ4 in the Stefankowice K-4 profile, and the fluvial deposits (TL dated at 512 ka BP) in the Moniatycze K-5 profile are covered by the loesses (LN2b) from the ascending phase of the Sanian 2 Glacial. They are overlain by the till 1.5–6.3 m thick from the Sanian 2 Glacial. This till was TL dated at 473 ka BP in the Moniatycze K-5 profile and at 449 ka BP in the Stefankowice K-4 profile. A sample from the top part of the LN2b loess was TL dated at 482 ka BP. The thickness of LN2b in Moniatycze is 7.5 m, and in Stefankowice – 5.3 m. In the latter profile this loess contains 41.5% of the loess fraction 0.05–0.02 mm, and almost 23% of the fraction < 0.002 mm. Its lower part comprises up to 7% of

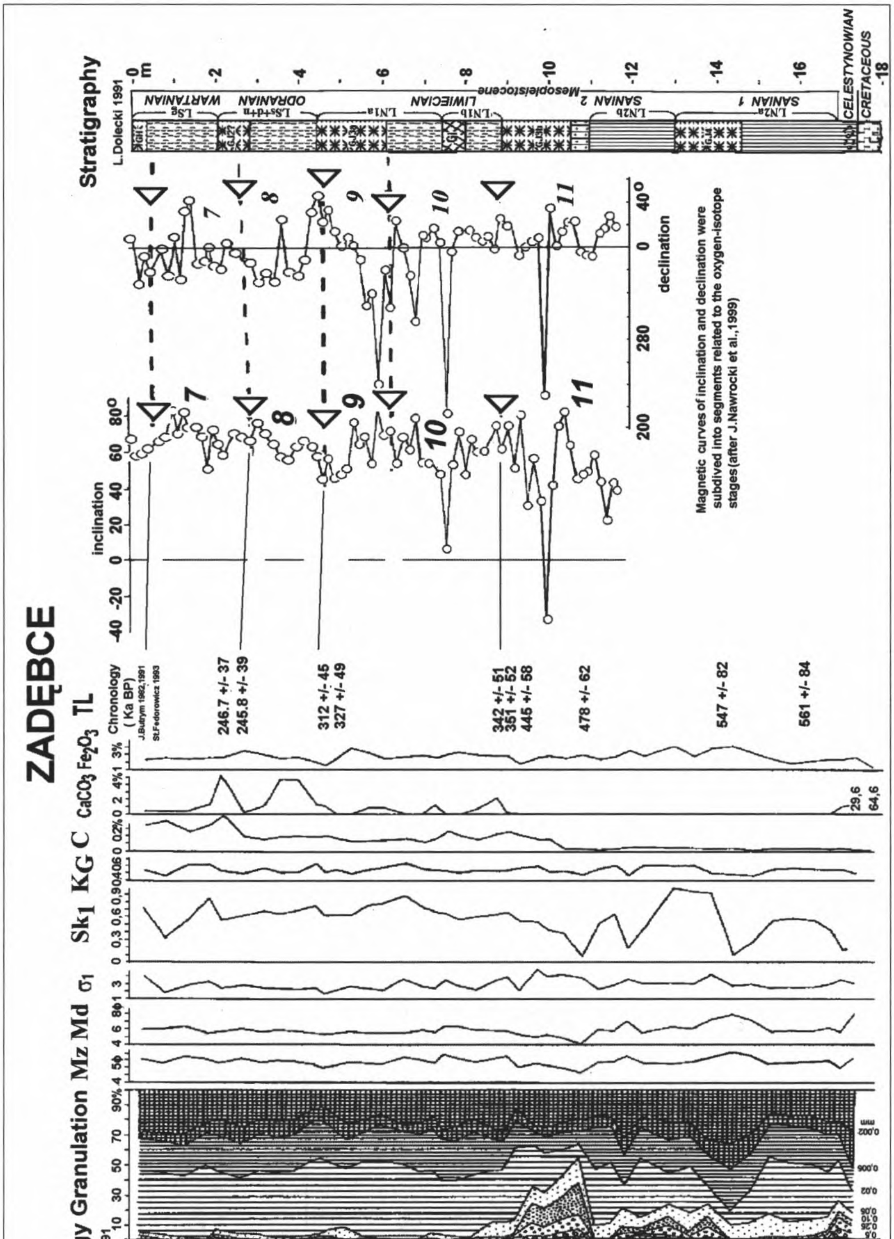

Fig. 7. Synthetic profile of loesses at Kol. Zadębce. Explanation – see Fig. 6

Syntetyczny profil lessów w Kolonii Zadębce. Objaśnienia – patrz ryc. 6

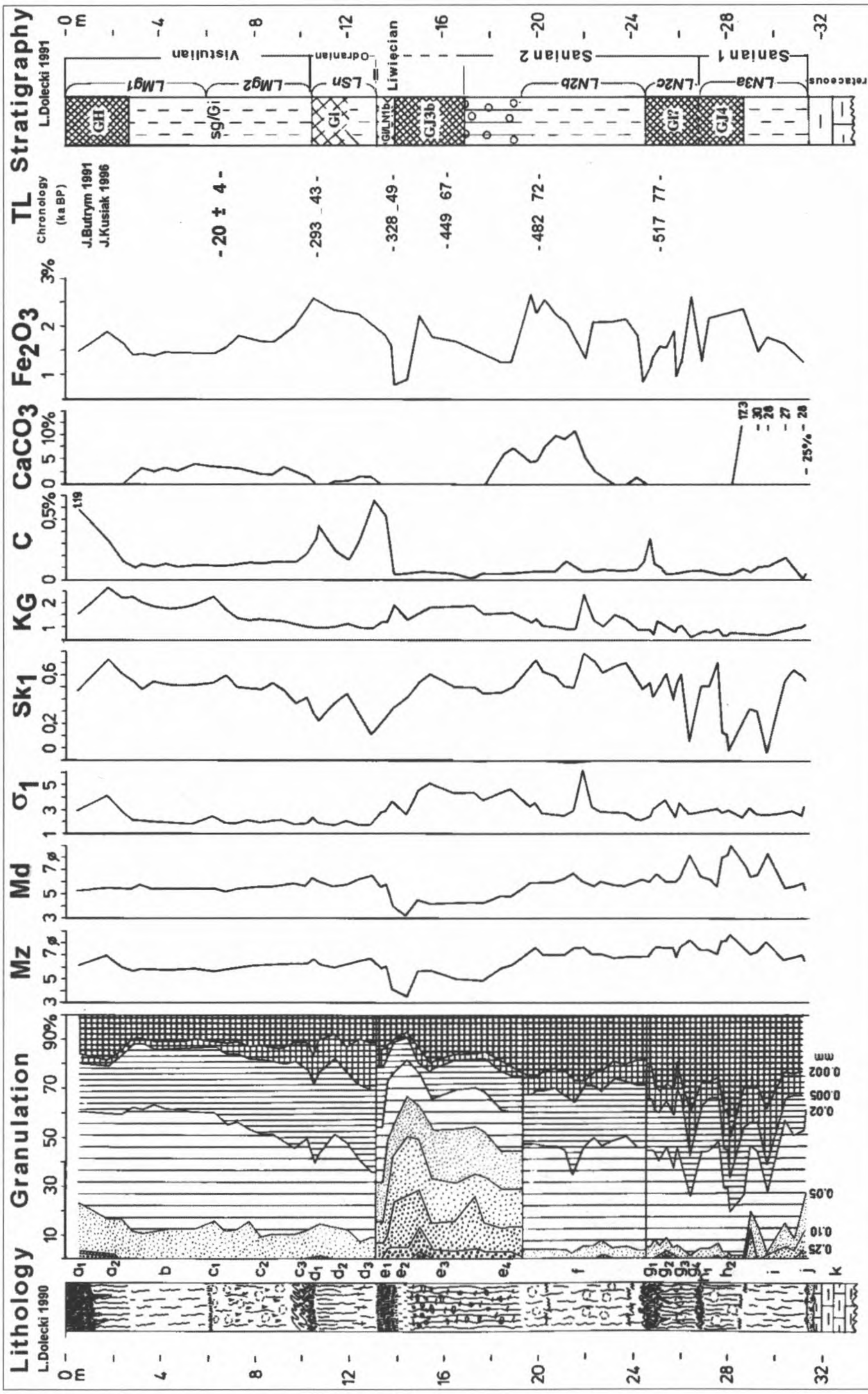

Fig. 8. Loess section at Stefankowice K-4. Explanation – see Fig. 6

Profil lessowy Stefankowice K-4. Objaśnienia – patrz ryc. 6

$CaCO_3$, and the upper part is decalcified. The mean grain size of the LN2b is 7.16 ϕ, thus this deposit is very clayey. The mean content of Fe_2O_3 is 2.11% in the Stefankowice K-4 profile, and 0.94–1.52% in the Moniatycze K-5 profile (Fig. 9). The next loess bed (LN2a) accumulated during the descending phase of the Sanian 2 Glacial. This loess is not preserved as unweathered deposit; it was either denuded during the oldest part of the Mazovian interglacial or affected by pedogenesis and incorporated in paleosols. In the Kol. Zadębce I and II profiles the LN2a loess overlies the till and is wholly affected by pedogenesis of interglacial rank.

Paleosol (GJ3b) from the Mazovian interglacial s.s.(= Holsteinian = OIS 11)

The stratotype profile of the Mazovian interglacial occurs at Krępiec in the Łuszczów Plateau (Z. Janczyk-Kopikowa 1991). In the Horodło Plateau-ridge the Mazovian interglacial is represented by the forest lessivé paleosol (GJ3b), gleyed from the top, which was found in the Kol. Zadębce exposures (L. Dolecki 1981, 1991a, 1995b). This soil is developed on the LN2a loess but pedogenetic processes reached the underlying till from the Sanian 2 Glacial. Only the lower genetic horizons of the GJ3b soil were found in the Czartowiec K-6 boring where its top part was denuded. The substratum of the illuvial horizon contains up to 3.32% of Fe_2O_3. It was TL dated at 378 ka BP. Traces of solifluction processes were found in the upper part of this horizon in the Czartowiec K-6 profile, and an ice wedge cast – in the Kol. Zadębce II profile. The GJ3b paleosol is covered by the thick loess (LN1) from the Liwiecian Glacial. The well developed forest paleosol with thick eluvial horizon was also found over the till in the Stefankowice K-4 boring. This Mazovian soil forms here a pedocomplex together with the overlying interstadial chernozem. The substratum of this chernozem, i.e. the loess form the older stadial of the Liwiecian Glacial, was wholly transformed by interstadial pedogenesis.

Loess deposits (LN1) from the Liwiecian Glacial (= Fuhne Glacial= OIS 10)

These deposits were found at Nieledew in the Horodło Plateau-ridge by J. E. Mojski (1965), but L. Lindner (1991) was the first who defined their real stratigraphic position. Loess of that age was also found in the Kol. Zadębce II exposure (L. Dolecki 1991a, 1995b). It is 4.5 m thick, contains a weakly developed interstadial paleosol, and occurs between two paleosols of interglacial rank, i.e. over the GJ3b soil from the Mazovian interglacial (= oxygen isotope stage 11), and under the GJ3a soil from the Zbójnian interglacial (=oxygen isotope stage

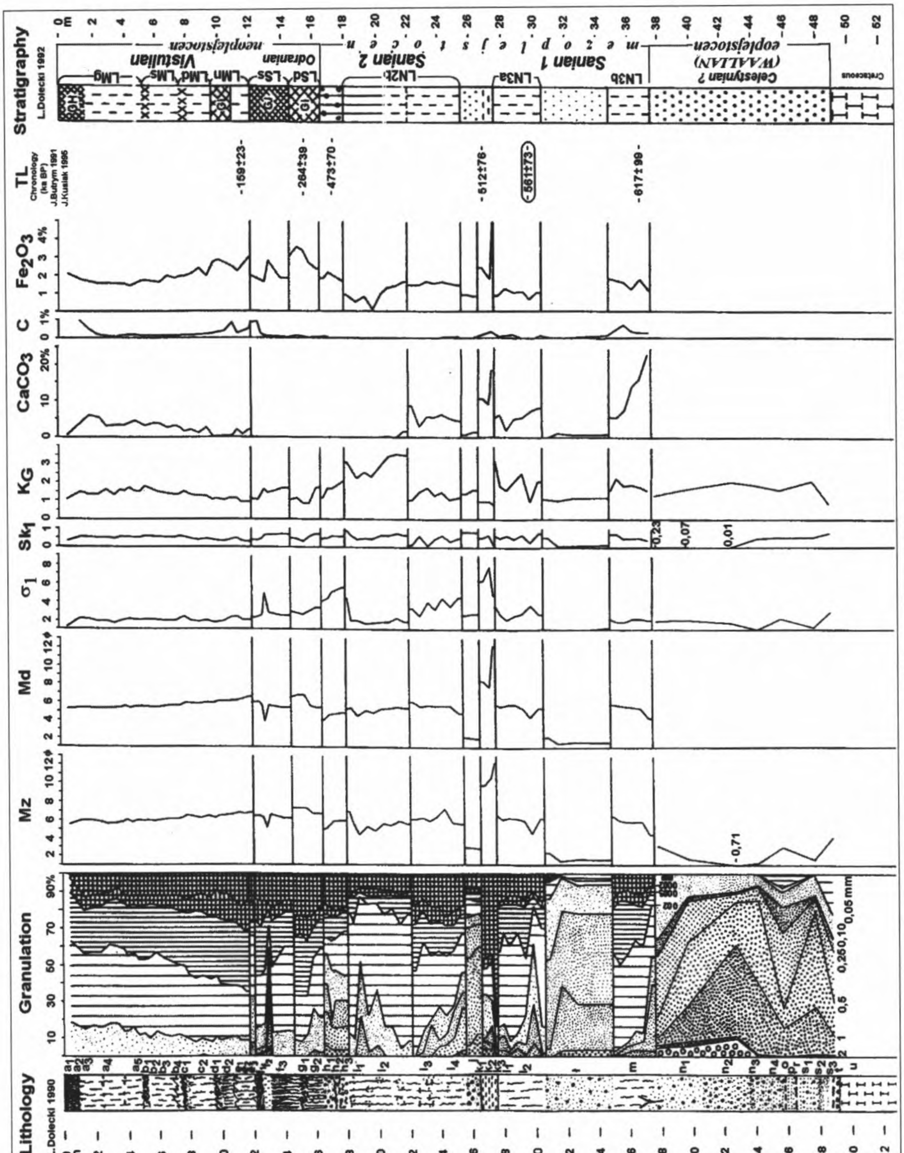

Fig. 9. Loess section at Moniatycze K-5. Explanation – see Fig. 6

Ryc. 9. Profil lessowy Moniatycze K-5. Objaśnienia – patrz ryc. 6

9). A similar stratigraphic sequence was recorded in the Czartowiec K-6 boring where the LN1 loess is 6.5 m thick and divided into two parts by the very well developed paleosol. This interstadial soil, with the sequence of A_1–A_1C–C horizons, is almost 2.5 m thick, and its humus horizon contains up to 1.4% of humus. The substratum of this soil was TL dated at 341 ka BP. In the Stefankowice K-3 boring, the same interstadial of the Liwiecian Glacial is represented by the turf soil developed on thin loess-like deposit which lies on the erosion surface of the till (TL age: 483 ka BP) from the Sanian 2 Glacial (Fig. 10). Preliminary pollen analysis of the turf paleosol substratum revealed the occurrence of the following pollen: *Pinus* (31.8%), *Betula* (18.1%), *Alnus* (3.98%), *Picea* (3.58%), *Corylus* (2.65%), *Carpinus* (1.32%), *Salix* (1.32%), *Quercus* (0.44%0, *Tilia* (0.44%). Cyperaceae (21.68%, Gramineae (7.08%) and *Artemisia* (4.86%) are dominant among herbs. It may be supposed that boreal climatic conditions prevailed during the development of this interstadial soil. The overlying LN1a loess accumulated during the upper stadial of the Liwiecian Glacial. The upper, pedogenetically altered part of this deposit was TL dated at 313 ka BP. The whole LN1 loess was deposited in the time interval which was determined by the TL method at 336.4–367.8 ka BP in the Nieledew profile (J. Butrym, H. Maruszczak 1983), and at 312–342 ka BP in the source of loess material, and supply from the Mesopleistocene glacial deposits was of less importance.

Paleosol (GJ3a) from the Zbójnian interglacial (= Reinsdorf Interglacial = OIS 9)

Zbójnian interglacial has been distinguished in Poland on the basis of palynologic profile at Zbójno (L. Lindner, E. Brykczyńska 1980). It corresponds to the Dömnitz (=Ariendorf) interglacial (K. Erd 1978, K. Brunnacker et al. 1982) in Western Europe. This period is correlated with oxygen isotope stage 9.

The GJ3a paleosol was found not only at Zbójno but also in the Kol. Zadębce II and Teratyn exposures (L. Dolecki 1981, 1991a), as well as in the Stefankowice K-4 and Czartowiec K-6 borings in the Horodło Plateau-ridge (L. Dolecki 1995a). This paleosol was developed as forest brown or lessivé soil, with distinct traces of gleying from the top and of permafrost occurrence. In the Kol. Zadębce II profile the GJ3a paleosol is cut by an ice wedge cast filled with the carbonate lowest older loess (LSn) from the Odranian Glacial (= oxygen isotope stage 8).

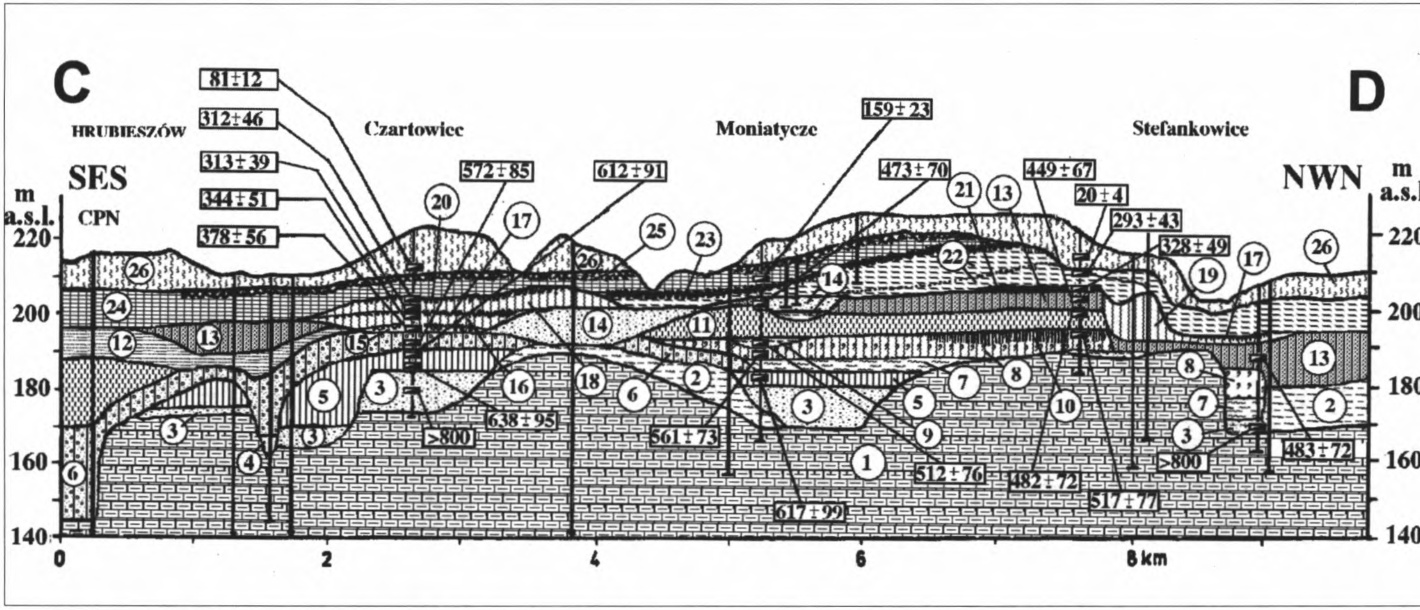

Fig. 10. Geological cross-section C–D: Hrubieszów CPN–Stefankowice K-3. Upper Cretaceous: 1 – marls and chalk; Eopleistocene, Kozienice level: 2 – clayey muds and sands with gravels of Cretaceous rocks; Krasnystaw level: 3 – gravels, sands and muds; Mesopleistocene, Podlasian Interglacial: 4 – fluvial sands and gravels with Scandinavian material; Sanian 1 Glacial: 5 – loesses and loess-like deposits LN3b, 6 – till, 7 – sands and gravels, 8 – loesses and loess-like muds LN3a; Ferdynandowian Interglacial and early Sanian 2 Glacial: 9 – fluvial sands and lacustrine clays, 10 – pedocomplex GJ4; Sanian 2 Glacial: 11 – loesses and loess-like deposits LN2b, 12 – muds and varved clays, 13 – till, 14 – fluvioglacial sands with gravels and sandy muds; Masovian Interglacial (San/Liwiec): 15 – paleosol GJ3b; Liwiecian Glacial: 16 – loess and loess-like deposits of lower stadial, 17 – interstadial paleosol, 18 – loess and loess-like deposits of upper stadial, 19 – undivided loesses and loess-like deposits LN1; Zbójnian Interglacial (Liwiec/Odra): 20 – pedocomplex and paleosols GJ3a without upper genetic horizon, 21 – chernozem from interglacial decline, 22 – lowest, lower and middle older loesses with interstadial soils; Lublinian (Lubawian) Interglacial: 23 – paleosol GJ2 and fragments of its genetic horizons; Wartanian Glacial: 24 – upper older loess of different facies; Eemian Interglacial and early Vistulian Glacial: 25 – pedocomplex GJ1; Vistulian Glacial: 26 – undivided younger loesses of different facies with interstadial paleosols and interphase soil sediments. In frames – TL datings in ka BP (Lublin laboratory)

Przekrój geologiczny C–D: Hrubieszów CPN – Stefankowice K-4. Objaśnienia: kreda górna: 1 – margle i kreda pisząca; eoplejstocen, poziom kozienicki: 2 – mułki ilaste i piaski ze żwirami skał kredowych, poziom krasnystawski: 3 – żwiry, piaski i mułki; Mezoplejstocen, interglacjał podlaski (?): 4 – piaski i żwiry rzeczne z materiałem skandynawskim; zlodowacenie san 1: 5 – lessy i utwory lessopodobne LN3b, 6 – glina zwałowa, 7 – piaski i żwiry wodnolodowcowe, 8 – lessy i mułki lessopodobne LN3a; interglacjał ferdynandowski i wczesny san 2: 9 – piaski rzeczne i iły jeziorne, 10 – kompleks glebowy GJ4; zlodowacenie san 2: 11 – lessy i utwory lessopodobne LN2b, 12 – mułki i iły zastoiskowe, 13 – glina zwałowa, 14 – piaski ze żwirami i mułki piaszczyste wodnolodowcowe; interglacjał mazowiecki (san 2/liwiec): 15 – gleba kopalna GJ3b; zlodowacenie liwca: 16 – less i utwory lessopodobne stadiału dolnego, interstadiał: 17 – gleba kopalna Gi/LN1b, stadiał górny: 18 – less i utwory lessopodobne LN1a, 19 – less i utwory lessopodobne LN1 nierozdzielone; interglacjał zbójna (liwiec/odra): 20 – kompleks glebowy i pozbawione górnego poziomu genetycznego gleby kopalne GJ3a, 21 – gleba darniowa z fazy schyłkowej interglacjału; zlodowacenie odry: 22 – lessy starsze najniższe, dolne i środkowe (LSn+d+s) rozdzielone glebami interstadialnymi; interglacjał lubelski (lubawski): 23 – gleba kopalna GJ2 i fragmenty jej poziomów genetycznych; zlodowacenie warty: 24 – less starszy górny (LSg) w różnych facjach; interglacjał eemski i wczesna wisła: 25 – kompleks glebowy (GJ1+Gi); zlodowacenie wisły: 26 – lessy młodsze (LMd+s+g) w różnych facjach i rozdzielające je gleby kopalne interstadialne. W ramkach podano daty TL (J. Butrym, laboratorium lubelskie)

PROFILES OF THE OLDER LOESSES (LS)
(= Saalian loesses)

Loesses accumulated during the period from the Zbójno Interglacial until the Eemian Interglacial are defined here as the older ones. Cycles of their accumulation correspond to oxygen-isotope stages 6–8. Loesses from the Odranian, Wartanian and Vistulian glaciations were classified according to the stratigraphic scheme after H. Maruszczak (1991).

The lowest older loess (LSn) is characterized by very fine mean grain diameter – from 6.5 phi[1] in Stefankowice K-4, and 6.92 phi in Teratyn to 7.38 phi in Czartowiec. Grain sorting is extremely weak, and grain size distribution is positively skew. This loess was accumulated in much wetter conditions than the overlying older loesses. It contains variable amounts of carbonates, mainly secondary ones, and usually a high content of organic material. These features are diagnostic for this loess, and especially important are large carbonate concretions which occur in the bottom of this stratigraphic unit in the examined area. Heavy fraction of this loess contains on the average 44% of opaque minerals. Among transparent heavy minerals the following association predominates: garnet > epidote > zircon > rutile > tourmaline. The paleomagnetic Chegan event was recorded in this loess (H. Maruszczak 1985, 1991, H. Maruszczak, J. Nawrocki 1991).

Traces of pedogenesis – usually thin gley horizons – are preserved in the top of the lowest older loess. Gley soils disturbed by cryogenic structures occur in places. Their formation is correlated with an interstadial representing 280–270 ka BP interval (H. Maruszczak 1991).

Lower older loess (LSd) was accumulated during the first post-maximum stadial of the Odra Glaciation in 270–225/250 ka BP interval (H. Maruszczak 1991). It occurs as a carbonate deposit (up to 7% of $CaCO_3$), and as a carbonate-free one. It contains rather large amounts of free iron and humus. This loess is up to 2.6 m thick in flat interfluve areas, and up to 8 m on the Pleistocene river terraces. Loess occurring in the interfluve areas was submitted to pedogenesis and cryogenic processes. The following assemblage predominates among transparent heavy minerals of this loess: garnet > zircon > amphibole > rutile > epidote > tourmaline > staurolite. The deposit is strongly weathered what is reflected in the values of weathering indices. It is characterized by fine mean grain diameter (6–7 phi, i.e. 0.0156–0.0078 mm), just as the lowest younger loess. These features suggest rather "wet" conditions of loess accumulation

[1] Granulometric indices were calculated in phi scale according to Folk and Ward (1957).

when comparing with accumulation conditions of strongly carbonate loesses. Therefore, lower older loess was sedimented near front of the Odranian ice sheet which probably stayed in the northern part of Polesie Lubelskie, where the Odranian till was dated to 277 ka BP at Jabłoń (L. Dolecki et al. 1995); thus, the obtained datings of loess and till accumulation time are similar. Heavy minerals composition indicates that the lowest and lower older loesses came from the Upper Cretaceous rocks mainly, in which the following association predominates: garnet > rutile > epidote > zircon > topaz. High contents of amphibole, tourmaline, disthene and staurolite indicate that the fluvial Eopleistocene deposits were also the source material for these loesses.

Paleosols (Gi/LSd)

Weakly developed paleosols (Gi/LSd) or soil sediments found on lower older loess were formed between 255/250 and 245 ka BP (H. Maruszczak 1991) during the retreat of the first postmaximum stadial of the Odra Glaciation. Weakly developed chernozem with (A)–(A)C horizons occurring in Nieledew contains 0.26% of humus, and carbonates as pseudomycelia. H. Maruszczak (1976) considers that its morphological features resemble humic pararendzina. Only lower horizons of the interstadial degraded black soil are preserved in Moniatycze. Interstadial soil with A–(A)C–C horizons was found in the Lipice-brickfield profile. The age of the soil with A_1–B_g–C_{Ca} horizons from Rogalin is the same. Its illuvial horizon contains up to 26% of clay fraction and 3.36% of iron oxides. These paleosols were destroyed by solifluction processes in most of the known profiles, and their remnants occur as soil deluvia. As regards the morphology and typology, the paleosols occurring on lower older loess are very similar to the lower soil of the Korshov pedocomplex in the Volhynia loesses in Ukraine (A. Bogucki 1987).

Middle older loess (LSs)

Middle older loess was accumulated during the interval 245–230/225 ka BP (H. Maruszczak 1991), i.e. during the second postmaximum stadial of the Odra Glaciation (J. Buraczyński 1986) correlated with oxygen isotope stage 7.5 which was dated at 238 ka BP by I. Imbrie et al. (1984). Glacial deposits of this period occurring on the Włodawa Height in Sosnowica were TL dated at 244 ka BP (L. Dolecki et al. 1990, 1995). At that time a marginal zone of ice-sheet reached Puławy – Niemce – Włodawa line. Middle older loess is carbonate or non-carbonate. Its mean grain diameter ranges from 5.6 ϕ in the near-valley profiles to

6.10 ϕ in the profiles situated on flat interfluve areas. Mean grain diameter and other granulometric indices are spatially differentiated depending on relief. Association of zircon > garnet > epidote > amphibole > rutile > tourmaline > staurolite > chlorite > biotite is characteristic of the transparent heavy minerals. Loess is considerably weathered, which is confirmed by the values of weathering indices. Parent material of middle older loess was distinctly different from that of upper older loess accumulated during the Warta Glaciation. Middle older loess (LSs) on the Horodło Plateau-ridge contains almost two times more of opaque minerals (46.2–47.6%) in heavy fraction than upper older loess (LSg). The composition of the heavy minerals assemblage in the Upper Cretaceous weathered rocks indicates that these rocks could be the source material for middle older loess; it especially concerns zircon, garnet, epidote, rutile, and perhaps also biotite. Other minerals could have come from the exposed deposits of the South Polish Glaciations.

Paleosols from the Lublin Interglacial (GJ2) (= Schöningen Interglacial = OIS 7) are preserved only in certain places. Among them the following soils prevail: weakly developed forest soils, leached chernozems or chernozems with traces of leaching. Pedocomplexes of forest soil from the Lublin Interglacial covered by one or more chernozem or turf soils from interstadials of the Early Warta Glaciation were also found. Soils of this period are poorly preserved within the loesses of alluvial facies, and they are usually represented by weakly developed swampy and gley soils, e.g. in the loess profiles in Obrowiec (L. Dolecki 1991b) and in Lipice-brickfield. In respect of typology, the soils from the Lublin Interglacial are spatially differentiated. Humic rendzina occurs in the Horodło III and V profiles, chernozem with leaching signs – in the Kolonia Zadębce II profile, pedocomplex with A–A_3–B_{tg} horizons – in the Moniatycze K-5 profile. Similar pedocomplex, consisting of brown soil covered by chernozem soil, was found in the Kolonia Zadębce III boring. Pollen analysis evidences boreal climate of this period, thus it was a cold interglacial or warm interstadial. Soils were developing in two stages. First of them was rather warm, so forest and brown soils were formed then, but they were less developed than the Eemian soils. During the second stage, probably after a period of strong denudation, steppe or meadow soils developed towards the close of the Lublin Interglacial. Distinct climate fluctuations conditioned changes of soil-forming processes at the end of this interglacial. The Lublin Interglacial is correlated with oxygen isotope stage 7.

Upper older loess (LSg)

Upper older loess from the Warta Glaciation was investigated on the Horodło Plateau-ridge mainly in samples taken from drill cores (Fig. 11); detailed description of interstadial and stadial units distinguished by H. Maruszczak (1991) was impossible. However, some general features of upper older loess can be presented on the basis of several near-valley exposures and few borings situated on the flat interfluve areas. Loesses in the interfluve profiles are rather thin: from 0.9 m in Rogalin to 3 m in Czartowiec. Eemian paleosols were found in most of the investigated profiles. The granulometric features of upper older loess (LSg) are similar to those of upper younger loess (LMg). Grains in peripheries of this loess patch are distinctly coarser than in its flat interfluve parts. Sorting index σ_1 exceeds 1.5 in all studied profiles, deposits show positive skewness. The content of carbonates can reach even more than 16% in thick loess profiles. Thin loess beds are wholly weathered and have usually been changed by pedogenesis.

Upper older loess is brownish and spotted due to high content of iron oxides. Typical assemblage of main transparent heavy minerals is the following: zircon > garnet > epidote > amphibole > rutile > tourmaline. In several samples garnet is dominant. The content of opaque minerals ranges from 24.7% to 50.4%; mean value is 31.2%. Weathering indices are higher than those of the younger loesses. All these features are important for recognition of this loess on the Horodło Plateau-ridge. The older loesses differ from the younger ones, and a change of the content of resistant heavy minerals is especially distinct. This feature is very important for discernment of older loesses from the younger ones if the pedocomplex from the Eemian and Early Vistulian is absent in the top of the older loesses.

The Pedocomplex from the Eemian Interglacial and Early Vistulian Glaciation (GJ1+Gi) (= OIS 5e+ 5a–d) occurs commonly in loesses of the Horodło Plateau-ridge. In the profiles studied in borings and wells this pedocomplex is usually found at the depth of 13–14 m. It is up to 3 m thick in certain places, but in many profiles only its lower genetic horizons survived denudation processes. H. Maruszczak (1991) distinguished the interglacial soil (GJ1) covered by the interstadial one (Gi) within the pedocomplex which developed during the interval 130/125–100 ka BP on loesses from the Wartanian Glaciation, and also on other older deposits of various genesis occurring on the ground surface at that time.

Genetic horizons of this pedocomplex (A_1–A_3–B_t–C) indicate that this is a forest soil with thick humus horizon – not typical of forest soils. As generally

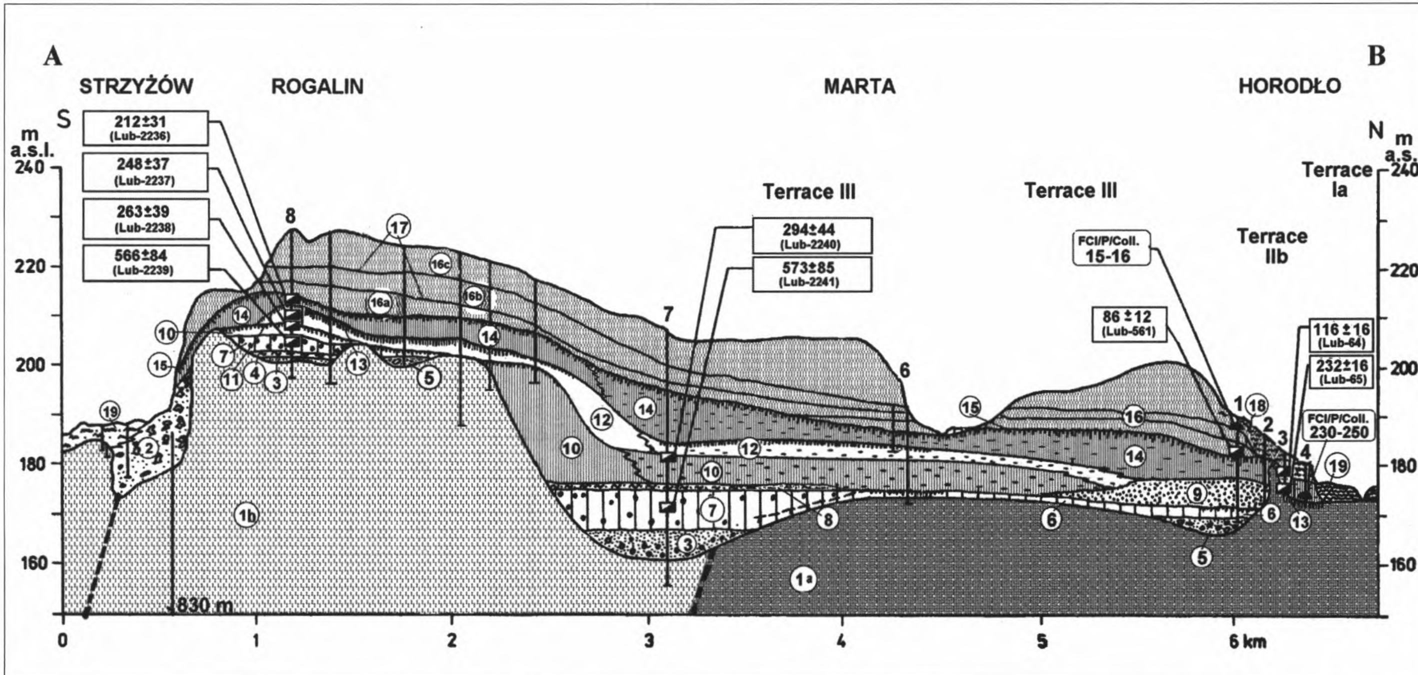

Fig. 11. Geologic cross-sections Strzyżów – Horodło (A – B). Cretaceous: 1a – Campanian marls; 1b – Maestrichtian chalk; (Eopleistocene): 2 – weathered local rocks, 3 – fluvial sands and sands with gravels, 4 – fluvial muds; Sanian 1 Glacial: 5 – fluvioglacial sands and gravels, 6 – fluvioperiglacial loess-like muds, 7 – till; Zbójnian Interglacial: 8 – fluvial loamy sands with shells of molluscs, 9 – fluvial sands; Odranian Glacial: 10 – lower older loess of different facies and loess-like alluvial deposits, 11 – gley soil of interstadial rank, 12 – middle older loess of different facies; Lublinian Interglacial and early stadial of Wartanian Glacial: 13 – GJ2 pedocomplex; Wartanian Glacial: 14 – upper older loess of different facies; Eemian Interglacial and early stadials of Vistulian Glacial: 15 – GJ1 pedocomplex; Vistulian Glacial: 16 – younger loesses: a – lower, b – middle, c – upper, 17 – interstadial soils and signs of pedogenesis within younger loesses; decline of Vistulian Glacial: 18 – deluvia and colluvia of younger loesses; Holocene: 19 – sandy muds and alluvial soils in valley bottoms. In rectangular frames – TL datings (J. Butrym, Lublin), in oval frames – datings determined by FCL/P/Coll method (T. Wysoczański-Minkowicz, Warszawa). All datings in ka BP

Przekrój geologiczny Strzyżów – Horodło (A–B). Kreda, mastrycht dolny: 1a – kreda pisząca i margle, kampan górny: 1b – kreda pisząca. Eoplejstocen: 2 – wietrzeliny i rumosze margli i kredy piszącej; 3 – piaski i piaski ze żwirami, rzeczne, 4 – mułki rzeczne; zlodowacenie sanu 1: 5 – piaski i żwiry wodnolodowcowe, 6 – mułki fluwioperyglacjalne lessopodobne (LN3b ?), 7 – glina zwałowa; interglacjał zbójna: 8 – piaski gliniaste z fauną mięczaków, rzeczne, 9 – piaski rzeczne; zlodowacenie odry: 10 – less starszy dolny (LSd) zróżnicowany facjalnie, 11 – interstadialna gleba, glejowa (Gi/LSd), 12 – less starszy środkowy (LSs) zróżnicowany facjalnie; interglacjał lubelski: 13 – pedokompleks GJ2, zlodowacenie warty: 14 – less starszy górny (LSg) zróżnicowany facjalnie; interglacjał eemski – wczesna wisła: 15 – pedokompleks GJ1; zlodowacenie wisły: 16a – less młodszy dolny (LMd), 16b – less młodszy środkowy (LMs), 16c – less młodszy górny (LMg), 17 – gleby interstadialne i pedolity w obrębie lessów młodszych, 18 – deluwia i koluwia lessów młodszych; holocen: 19 – mułki piaszczyste i mady den dolinnych. W ramkach prostokątnych podano daty TL w tys. lat BP (J. Butrym – Lublin), w owalnych – daty wyznaczone metodą fluoro-chloro-kolagenową (T. Wysoczański-Minkowicz – Warszawa) believed, this humus horizon can be composed of as many as three paleosols of interstadial rank. The change of the pedogenesis type occurred during the earliest period of the Vistulian Glaciation. Turf processes developing on the Eemian interglacial soil in park forests of boreal type were interrupted by cooling periods. Each subsequent turf horizon was formed on the substratum consisting of the preceding turf horizon and thin loess accumulated during each of successive coolings. Thick humus horizon, with three layers of silt material inside, was thus formed over the interglacial soil. In some profiles these silt layers are well visible, but in many other they were transformed by pedogenesis. Three generations of contraction fissure casts with seasonal filling run from the silt layers deep into the soil profile. Occurrence of this pedocomplex and its structural features make the stratigraphic separation of older loesses from the younger ones possible.

The substratum of the pedocomplex is characterized by the following ranges of granulometric indices: Mz = 5.14–5.84 phi, σ_1 = 1.60–2.08, Sk_1 = 0.15–0.41, K_G = 0.36–0.53. Heavy fraction contains 31.9–36.7% of opaque minerals. Among transparent heavy minerals the resistant ones predominate, especially zircon (16.3–22.5%), but less resistant garnet is most abundant (19.6–35.9%) in some samples. In the second place there is rutile or epidote, and next amphibole. Weathering indices of deposit were calculated as C/G+A for two samples. Their values (0.71 and 0.38) directly evidence advanced weathering processes.

PROFILES OF THE YOUNGER LOESSES (LM)
(= Vistulian (Weischselian) Glacial= OIS 2+3+4+5a–d)

The younger loesses (LM) from the Vistulian Glaciation are the youngest Pleistocene stratigraphic unit on the Horodło Plateau-Ridge; the Holocene soils developed on them. These loesses were largely deposited on the surface of older loesses (Odranian and Wartanian) topped with the interglacial pedocomplex from the Eemian and early Vistulian. Initial accumulation surface of the younger loesses is an undulated denudation plain, so in places these loesses are directly underlain by old deposits, even Mesozoic ones.

As it was found in borings, the younger loesses are separated by soil sediments and paleosols of interstadial and interphase rank. The intensity of pedogenesis was changing with time. Interstadial soils from the early Vistulian are much better developed than the interpleniglacial soils and sediments from warmer climatic fluctuations of the upper pleniglacial of the Vistulian Glaciation. The substratum of these paloesols is also considerably differentiated in respect of the selected chemical features such as carbonate, free iron and humus contents. With the ageing of the younger loesses the amount of carbonates decreases and the content of iron oxides and humus increases. It is an evidence of more favourable climatic conditions during the initial stage of glaciation. It is also confirmed by a sequence of soil types: from forest soils, through meadow or steppe to arctic ones. Warmings during the upper Plenivistulian were recorded only as pedogenesis traces. Conditions favouring loess accumulation were also changing with time. It seems to be evidenced by a variable thickness of loess in the flat interfluve area, because denudation processes influenced it only slightly.

Loesses from early stadials of the Vistulian Glaciation, i.e. silt deposits of periglacial type, were mostly incorporated in chernozem and turf soils (formed during the Amersfoort and Brörup Interstadials) belonging to the Eemian and Early Vistulian pedocomplex. The lowest younger loess with paleosol from the Odderade Stadial in the top is well visible in some profiles; however, in most profiles this soil belongs to the pedocomplex and is not recognizable morphologically.

The lowest younger loess (LMn) on the Horodło Plateau-ridge is 0.26–2.0 m thick. It was identified in eight profiles in different hypsometric situations. Loess occurring in the SE and S parts of the loess patch is thicker than in the N part. Its minimum thickness, usually less than 0.6 m, is found in patch margins. This loess is largely carbonate, and in all profiles it contains a considerable amount of humus: from 0.3% at Moniatycze to 0.48% in the Feliks brickfield at Hrubieszów. The high content of iron oxides ranges from 1.14 to 3.20%. The dominant assemblage of transparent heavy minerals is the following: garnet > zircon > epidote > rutile > amphibole > staurolite. It seems to indicate that the source material came from older loess covers and the Eopleistocene deposits. Usually weakly developed and thin (up to 0.6 m) brown soils or chernozem-like soils were formed over this loess during the Odderade Interstadial. Gley soil with A_1–G–CG horizons occurs in Kułakowice II, chernozem with A_1–A_1C–C horizons in Marta-1 and Czartowiec, and with A–(B)C–C horizons in Moniatycze. In other profiles only traces of pedogenesis were found.

Lower younger loess (LMd)

Lower younger loess commonly occurs on the Horodło Plateau-ridge and its thickness reaches usually 1.5–3 m only. It is characterized by dark yellowish-grey colour indicating a low content of carbonates and a large amount of iron oxides. Weakly developed soils or rather soil sediments of interphase rank occurring within the lower younger loess divide it into four beds: LMd_1, LMd_2, LMd_3, LMd_4. These stratigraphic units are well visible in the Marta 1 profile near the Bug river valley (Fig. 12). Mean grain diameter of this loess ranges from 5.8 to

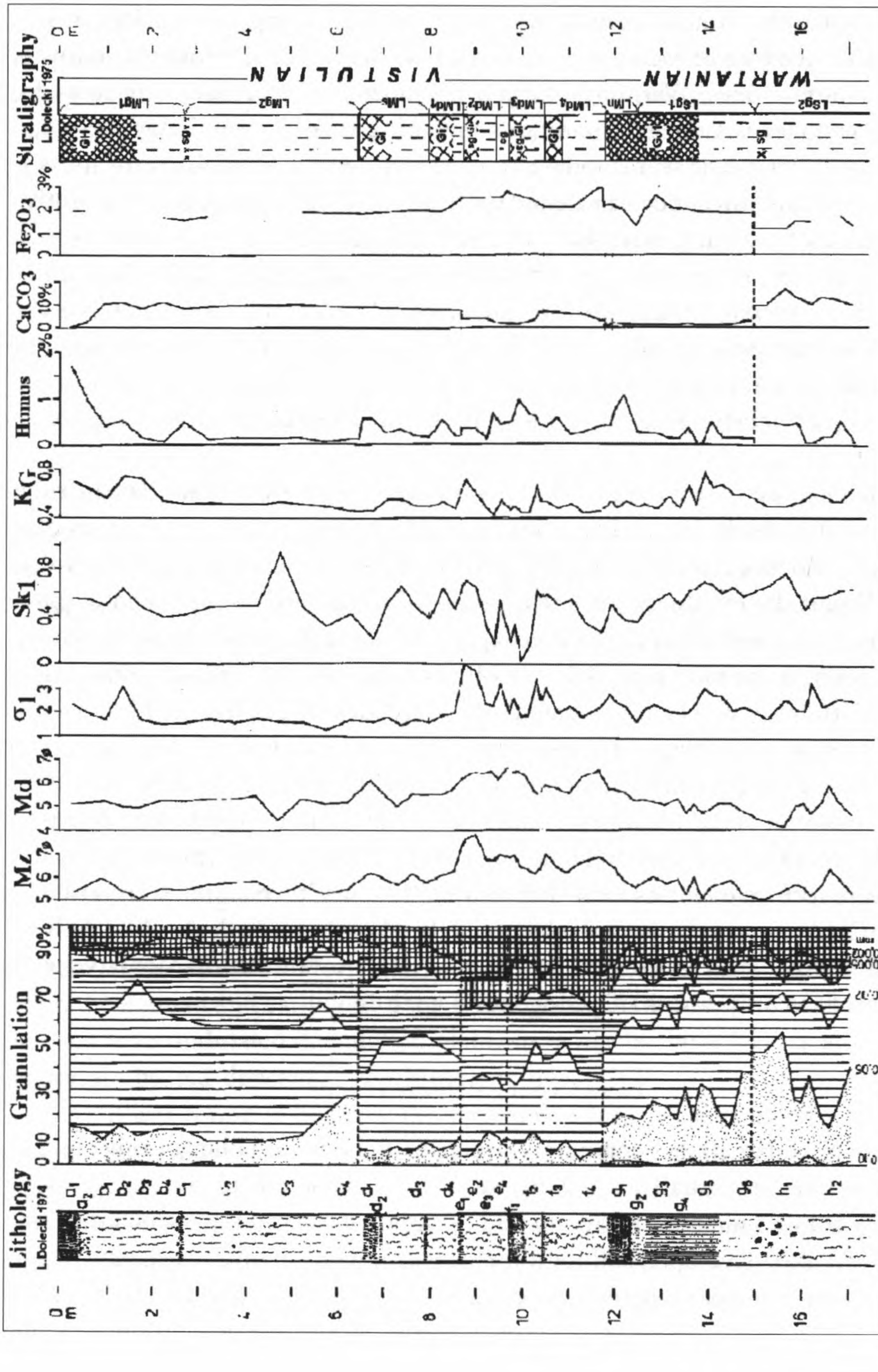

Fig. 12. Loess section at Marta I. Explanation – see Fig. 6

Ryc. 12. Profil lessowy Marta 1. Objaśnienia – patrz ryc. 6

6.8 phi in the studied profiles; finer mean grain occurs in the central part of the flat interfluve area, and coarser – in the near-valley profiles. Mean humus content in this loess is 0.23% and mean content of Fe_2O_3 – 2.42%. Heavy fraction contains almost 30% of opaque minerals. Among transparent heavy minerals zircon and garnet predominate considerably. Minerals less resistant to weathering are here more abundant than in the older and oldest loesses on the Horodło Plateau-ridge; their presence indicates that the lower younger loess came from rather fresh, non-weathered glacial deposits.

Interstadial soil (Gi/LMd)

Interstadial soils (Gi/LMd) which developed on the lower younger loess are typologically differentiated; these are subarctic brown, gley and boggy soils or only traces of pedogenesis preserved as gleying horizons. Genetic horizons of these soils are more completely preserved in valley and near-valley sites than in the flat interfluve areas where they were probably destructed by deflation, and on inclined surfaces – by solifluction processes. In some places these soils are as mature as those from the Early Vistulian period. This fact and also the dating results of the substratum of these soils indicate that they cannot be correlated with the "cold" Denekamp-Hengelo (= Komorniki = Briansk) interstadials, but they were formed during the Glinde or Oerel interstadial of the stratigraphic schemes adopted in Western Europe. Such stratigraphic interpretations result from the use of different techniques of dating deposits, i.e., C^{14} and TL.

Middle younger loess (LMs)

Middle younger loess reaches its maximum thickness (up to 5 m) on the heights of interfluve areas in the central and NE parts of the loess patch. The mean thickness calculated on the basis of data from 16 profiles is 2.34 m. Mean granulometric indices of this loess are: $Mz = 6.22$, $\sigma_1 = 1.94$, $Sk_1 = 0.43$, $K_G = 1.08$. The mean content of carbonates in this loess is 8.48%. Humus content is a little higher than in LMg, and its mean value in the examined profiles is 0.16%. This loess is darker than the upper younger loess due to the greater mean amount of free iron oxides, which is 1.82%.

Heavy fraction contains 28.1% of opaque minerals. The following association of transparent minerals predominates in the studied profiles: garnet > zircon > amphibole > rutile > epidote > tourmaline. Middle younger loess contains smaller amounts of garnet and zircon, and it is less weathered than the upper younger loess.

Soils on the middle younger loess (Gi/LMs)

Soils on the middle younger loess (Gi/LMs) were formed in cold and dry conditions, so these are weakly developed gley or brown arctic soils. Sometimes only traces of pedogenesis are visible in the form of gleying horizons, which are distinguishable in the profiles by colour. These horizons are also characterized by a low content or lack of carbonates, unlike the parent loess which is rich with them. Iron-manganese concretions also occur in these horizons. Soil sediments are distinguishable by yellow-brownish colour in their upper parts, usually with denudation traces. Strips and rust-coloured streaks occur commonly in their lower parts. Horizons affected with pedogenesis are characterized by a higher content of humus and free iron. Carbonates occur usually as pseudomycelia which form a complicated pattern in the upper parts of these horizons; the carbonate content can reach even 9%. Some soil sediments are gleyed at the top, their colour is grey and genetic horizons are difficult to distinguish. The grain-size is usually different than in non-weathered loess; a greater admixture of sand fraction occurs in the top of soil sediment.

Upper younger loess (LMg)

The thickness of the upper younger loess can reach even 9.5–11.5 m in places where accumulation conditions were favourable (J. Jersak 1969, 1973). The greatest thickness of this loess was found in the following borings: Stefankowice K-4 (10.5 m), Hrebenne (9.05 m, bottom not reached), Kułakowice K-2 (7.44 m), Turkołówka (7.23 m), Rogalin K-1 (7.0 m), Marta 1 (6.51 m), Hrubieszów-Feliks (6.10 m). In other examined borings the thickness of LMg was from 1.8 m in Poraj (at northern edge of the Horodło Plateau-Ridge) to 6 m in Stefankowice K-3, and only 2.19 m in Szpikłosy and 2.59 m in Janki 1. This shows that the thickest loesses occur in the interfluve heights, especially in the NE and E parts of the Horodło Plateau-Ridge. The mean thickness of LMg (calculated from the values measured in 16 profiles) is 5.9 m. The mean grain diameter in the bottom part of LMg is up to 5 phi, and in the upper part – up to 4.1 phi; the mean value is 5.48 phi. The sorting expressed by σ_1 index ranges from 1.2 to 2, thus it is very weak, the grain size distribution is positively skew ($Sk_1 > 0.3$), and the kurtosis shows mesokurtic distributions.

The distribution of carbonates does not exhibit any distinct regularities, except a higher content of them in the profiles situated on the flat heights of the interfluve area. The maximum values of mean carbonate content calculated for particular profiles were found in the central part of loessial plateau: Rogalin

(12.5%), Czartowiec K-6 (12.08%), Kułakowice 1 (12.22%), Janki 1 (11.93%). Smaller amounts of carbonates occur in the profiles on slopes, e.g.: Kol. Hrebenne (4.5%), Stefankowice K-4 (2.9%), Moniatycze (3.68%). The mean carbonate content in this loess is 8.76%.

Humus is distributed in loess rather uniformly and its content ranges from 0.06% to 0.21%. The higher content of humus occurs in the profiles situated on the heights of flat interfluve areas, and the lowest – on slopes. The mean humus content in this loess is 0.12%.

Iron oxides in flat interfluve areas and slopes are not very differentiated and their amount ranges from 1.06% (Hrebenne) to 1.79% (Moroczyn); the mean content, calculated for 16 profiles, is 1.61%. A similar content of iron oxides was found in the upper younger loess accumulated on higher terraces, e.g. 1.51% in Zosin 1 profile.

The composition of heavy minerals of the upper younger loess was studied in the following profiles of the Horodło Plateau-ridge: Czartowiec K-6, Moniatycze K-5, Stefankowice K-3, Rogalin K-1 and Kol. Hrebenne K-2. Heavy fraction contains 26% of opaque minerals. After calculating the mean content of each kind from the group of transparent minerals in all studied profiles, we obtain the following sequence: garnet > zircon > amphibole = epidote > rutile > tourmaline > staurolite > disthene, and in minor amounts: apatite > biotite > chlorite, pyroxene and titanite. A quantitative differentiation is visible when comparing the mineral composition of different samples; garnet is usually the main component but the content of other dominant minerals, i.e. epidote, amphibole, zircon, rutile, are variable. The mean values of weathering indices are strangely high: $C/(G+A) = 0.43$, and $O/(S+N) = 0.49$. They are even somewhat higher than those calculated for the middle and lower younger loess, which were submitted to mechanical and chemical disintegration for a longer period than the upper younger loess.

The results of loess investigations in borings presented here add new information to the knowledge about the Neopleistocene loesses. These data can be the basis for assignation of diagnostic features in loess research, and for stratigraphic and paleogeographic studies. They provide possibilities for a comparison of loesses studied in the near-valley profiles (such as Nieledew, Obrowiec, Horodło, which have been the basis for the construction of stratigraphic schemes of loesses from the Horodło Plateau-ridge with loesses occurring on flat interfluve areas, where the conditions of accumulation and transformation of deposits were somewhat different. Therefore, this work brings new data about the facial variability of the Neopleistocene loesses, especially loesses and paleosols from the Vistulian Glaciation. If loess cores are studied and described in detail, and adequate methods of laboratory analyses are used, we obtain results similar to those when studying loesses in exposures. Of course, it is difficult to define, on the basis of borings, structural features of the deposit, horizontal facial variability, spatial changes of paleosol structure, cryogenic structures and other features. However, the results obtained from borings in loess areas are noteworthy, because they allow us to construct geological cross-sections and study relief development in different paleogeographical stages. Most of the physicochemical features of different loess facies can be the basis for stratigraphic correlations and descriptions of the spatial variability of physico-geographical processes.

CONCLUSION

In the south-eastern part of the Lublin Upland there are thick loess and loess-like formation covers which are stratigraphically varied. In general, one can distinguish the oldest loess from the South Polish Glaciations, older loess from the Middle Polish Glaciations and younger loess of the Vistulian Glaciation. In Central Europe, with its highest concentration of glaciation traces, the covers of the oldest loess have been preserved only in the form of isolated and incomplete patches covered by younger deposits.

A relatively extensive stratigraphic sequence of the oldest loess and the fossil soils of various stratigraphic rank separating it was distinguished in the exploration holes in Kolonia Zadębce in Grzęda Horodelska as well as in the cartographic drillings made for the Detailed Geological Map of Poland 1:50000 in the sheets Kopyłów and Horodło. An important stratigraphic benchmark for these drillings was provided by the boulder clay, separating the loess, correlated with oxygen-isotope stages 12 and 16. The results of the geological mapping made it possible to present, for the first time on the basis of Polish profiles, a stratigraphic scheme of the oldest loess in South-Eastern Poland (L. Dolecki 1991a, 1995a, 1995b, 2001a, 2001b, 2004)

This scheme uses a numerical code to stratigraphically order the loess beds in accordance with their age. The youngest bed of the oldest loess corresponding to stage 10 in the scale $\delta^{18}O$ was designated with the symbol LN1. The oldest loess 2 designated with the symbol LN2 is paralleled with stage 12, the oldest loess 3 with the symbol LN3 was accumulated in the period corresponding to stage 16, while the largely unexplored oldest loess 4 with the symbol LN4 – corresponds to stages 18–20 in the scale $\delta^{18}O$. To stratigraphically order the loess formations, the geological and paleogeological methods were used together with results of palynological and paleopedological analyses and thermoluminescence dating performed at the Lublin laboratory of the Maria Curie-Skłodowska University. The main stratigraphic benchmarks were boulder clay and interglacial fossil soils. The stratigraphic parallelisation presented by the author was later confirmed with further results of paleomagnetic resarch made for profiles in Kol. Zadębce and Obrowiec (J. Nawrocki et al. 1999, 2001). The degree to which the loess from the Middle Polish, South Polish, and Old Pleistocene Glaciations has been preserved is naturally much worse that in the case of the loess from the last, Vistulian Glaciation.

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STRESZCZENIE

Na Grzędzie Horodelskiej badano lessy mezoplejstoceńskie nazwane najstarszymi (LN) (Maruszczak 1972,1976,1991) przy pomocy wierceń oraz w odsłonięciach (Dolecki 1977, 1981, 1991a). Na skałach górnokredowych zachowały się pokrywy piasków, żwirów i mułków oraz iłów eoplejstoceńskich datowanych metodą TL na > 800 ka BP. Wyżej leżą miejscami lessy najstarsze z fazy wstępującej zlodowacenia Nidy (daty TL <Lublin> 638, 612, 617 ka BP). Przykryte są gliną zwałową datowaną TL w trzech profilach: 572, 566 i 573 ka BP paralelizowaną ze zlodowaceniem Nidy (Dolecki 1991a). Utwory lessopodobne (LN3) z fazy zstępującej tego zlodowacenia stwierdzono w centralnej części obszaru w Moniatyczach i Stefankowicach. W Moniatyczach w stropie LN3 wykształcony jest ferdynandowski kompleks glebowy GJ4 (Dolecki 1991a) datowany metodą TL na 517 ka BP. Synchroniczne rozwojowi najmłodszej gleby kompleksu są datowane na 512 ka BP osady rzeczne nawiercone w Moniatyczach. Ze zlodowacenia Sanu są lessy najstarsze LN2 (podmorenowe), oddzielone od LN3 kompleksem GJ4 i datowane w górnej części 482 ka BP. LN2 to utwory eoliczne z fazy wstępującej zlodowacenia Sanu. W innych facjach stwierdzono je w Kol. Zadębce. Powyżej lessów LN2 leży glina zwałowa zlodowacenia Sanu 2 datowana TL 473 ka (Moniatycze), 449 ka (Stefankowice K-4), 483 ka (Stefankowice K-3) oraz 445 ka i 478 ka w Kol. Zadębce. Z interglacjału mazowieckiego (San 2/Liwiec) znaleziono w Kol. Zadębce i Czartowcu gleby kopalne (GJ3b) rozwinięte na glinie zwałowej i małomiąższych pokrywach pylastych zlodowacenia Sanu 2. Lessy ze zlodowacenia Liwca (LN1) stwierdzono pomiędzy dwiema glebami interglacjalnymi w profilu Kol. Zadębce. Akumulacja ich zachodziła w okresie 342–312 ka BP. Na LN1 w Kol. Zadębce rozwinięta jest gleba (GJ3a) rangi interglacjalnej paralelizowana z interglacjałem Zbójna (Liwiec/Odra). Glebę tego wieku wcześniej rozpoznano w Nieledwi oraz w Teratynie (Dolecki 1981). Należą tu zapewne także gleby wykształcone na osadach glacjalnych w otworach wiertniczych w Czartowcu oraz w Stefankowicach K-3. Substrat ich datowano odpowiednio: 312 ka i 328 ka. Powyżej leżą miąższe lessy neoplejstoceńskie rozdzielone glebami kopalnymi w różnym stadium rozwojowym, sklasyfikowane zgodnie ze schematem stratygraficznym lessów H. Maruszczaka (1972, 1976).