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Correlation of Pleistocene deposits in the area between the Baltic and Black Sea, Central Europe

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The distribution, age and correlation of Pleistocene sediments (1.806–0.01 Ma) is presented for an about 1200 km long geologic cross-section that extends from the Baltic Sea to the Black Sea and crosses the eastern part of the Polish Vistula drainage basin, the Dniester and Upper Pripyat drainage basins of the Ukraine, and also parts of the Russian Kaliningrad District and Moldova. In the vicinity of Warsaw, the oldest Pleistocene deposits comprise preglacial fluvio-lacustrine sediments of the Otvockian (Eburonian) cooling and Celestynovian (Waalian) warming stages that equate in the south with the Berezan and Kryzhaniv horizons, composed of loessy clays, silts and red-brown palaeosol. Along the cross-section, deposits of 8 main glaciations correlate with a similar number of main loesses (Narevian–Ilyichivsk, Nidanian–Pryazovsk, Sanian 1–Sula, Sanian 2–Tiligul, Liviecian–Orel, Krznanian–Dnieper 1, Odranian–Dnieper 2–Tyasmyn, Vistulian–Valday) that are separated by 7 main intra-loess palaeosols that developed during the main interglacial periods (Augustovian–Shirokino, Małopolanian–Martonosha, Ferdynandovian–Lubny–Solotvin, Mazovian–Zavadivka–Sokal, Zbójnian–Potagaylivka, Lubavian–Lublinian–Kaydaky–Korshiv, Eemian–Pryluky–Horokhiv). The first three interglacials are mega-interglacials, which possibly include cool intervals during which ice sheets did not advance beyond Scandinavia. All glaciations and loesses, as well as interglacials and palaeosols that are considered as main climatostratigraphic units of the Pleistocene of Central Europe, are grouped into climatic cycles and megacycles that correlate with corresponding units of Western Europe.

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Key words: Poland, Ukraine, Baltic Sea, Black Sea, Pleistocene, stratigraphic correlation.

INTRODUCTION

In this paper we present the geologic setting and chronologic correlation of Pleistocene deposits (1.806–0.01 Ma) along a synthetic geologic cross-section that extends over a distance of some 1200 km from the Baltic Sea to the Black Sea, and into which control points of an about 100 km wide belt are projected (Fig. 1). This section is based on over 50 boreholes and natural outcrops, half of which represent key sites for Quaternary sediments on which pollen-analyses are available for organic series and palaeosols.

The northern part of the cross-section is composed of two segments (Figs. 2 and 3), which comprise interglacial marine and continental sediments, sandwiched between tills of Scandinavian glaciations (Lindner, 1988*a*; Marks, 2000). These segments cross north-east Poland with only the Domnovo section coming from the Russian Kaliningrad District. The middle part of the cross-section (Fig. 4) transects the San and Upper–Middle Bug drainage basins of south-east Poland and the drainage basins of the Upper Pripyat and Dniester of the northwestern Ukraine, and thus the watershed between the Baltic and the Black Sea. In this area occur not only interglacial organic sediments and tills but also loesses and palaeosols (Lindner and Wojtanowicz, 1997; Łanczont and Boguckyj, 2002). The southernmost part of the cross-section (Fig. 5) comprises only loesses with palaeosols, mostly from the Middle and Lower Dniester drainage basin of the southwestern Ukraine (Gożik *et al*., 1976), with the control points Ivanivtsy (Iva) and Kosautsy (Kos) coming from northern Moldova (Fig. 1).

The presented cross-section is not a detailed representation of a real geological structure. Terrestrial sediments and

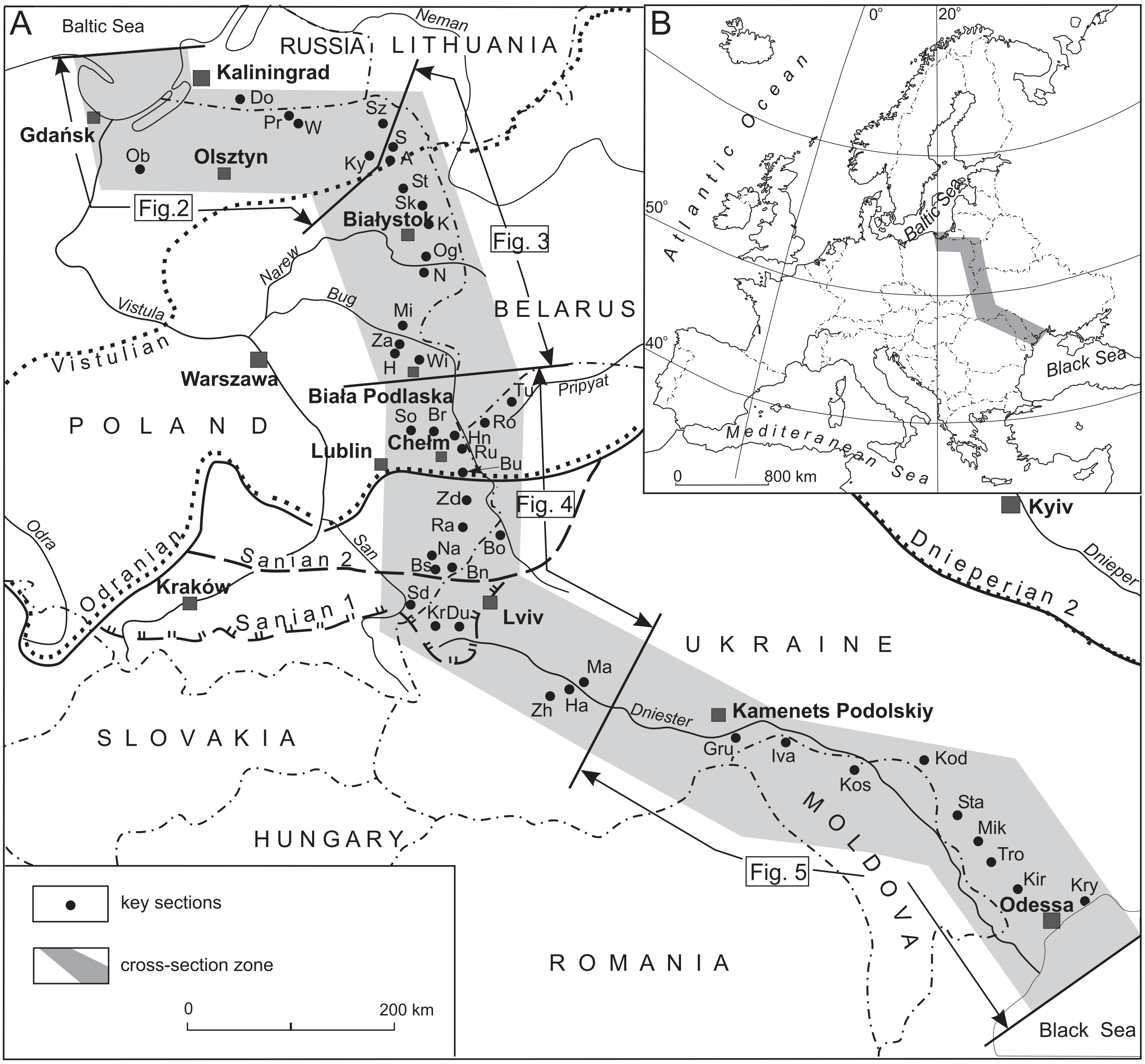

Fig. 1. Location of the presented area between the Baltic and the Black Seas (A), also in Europe (B)

Key sections and the cross-section zone (Figs. 2–5). Indicated are surface maximum limits of the Scandinavian ice sheets during the glaciations: Sanian 1 (Elsterian 1), Sanian 2 (Elsterian 2), Odranian (Saalian, Dnieperian 2) and Vistulian (Weichselian); sections in the cross-section zone: A — Augustów, Bn — Brusno, Bo — Bojanice, Br — Brus, Bs — Buszkowice, Bu — Buśno, Do — Domnovo, Du — Dubaniewice, Gru — Grushevcy, H — Horoszki, Ha — Halich, Hn — Hniszów, Iva — Ivanivtsy, K — Kruszyniany, Kod — Kodyma, Kos — Kosautsy, Kir — Kirovo, Kr — Krukienice, Kry — Kryzhanivka, Ky — Krzyżewo, Ma — Marinopil, Mi — Mielnik, Mik — Mikhailovka, N — Narew, Na — Narol, Ob — Obrzynowo, Og — Ogrodniki, Pr — Prynowo, Ra — Ratyczów, Ro — Rostań, Ru — Ruda, S — Szczebra, Sd — Siedliska, Sk — Sokółka, So — Sosnowica, St — Sztabin, Sta — Stavrovo, Sz — Szwajcaria, Tro — Trostyanets, Tu — Tur, W — Węgorzewo, Wi — Wilczyn, Za — Zawada, Zd — Zadębce Kolonia, Zh — Zahvizdja

among them the glacial ones in particular, are commonly discontinuous and composed, even at short distances, of interfingering sedimentary facies. Therefore, the cross-section reflects rather the general stratigraphy and palaeogeography of the Baltic Sea to the Black Sea transition, based on selected key logs from this area.

From a methodologic point of view, the correlations of Pleistocene deposits as presented in this paper, are compatible with previously published synthetic geologic cross-sections for the border areas of Poland and Ukraine (Lindner *et al.*, 1991) and Poland and Belarus (Lindner and Astapova, 2000), as well as for Poland (Lindner *et al.*, 1995). Geologic data summarized in this paper are mostly based on the results of studies that were carried out during the last dozen of years by geologists, geomorphologists, palaeobotanists and palaeopedologists to which reference is made in the following text. In the cross-sections given in Figures 2 to 5 the thickness of Pleistocene sediments and their position with respect to sea

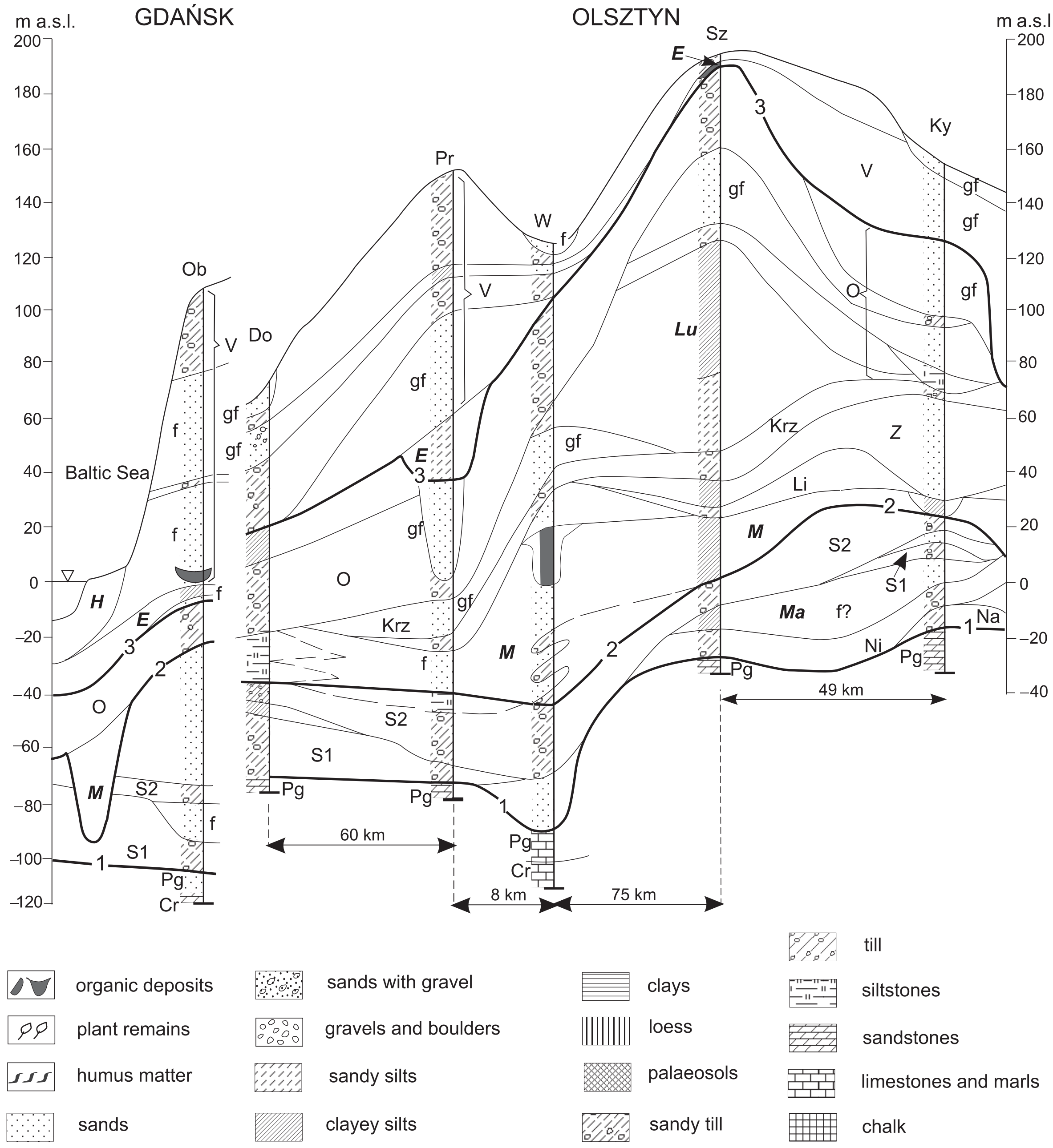

Fig. 2. Geologic cross-section of the Pleistocene deposits between Gdańsk and Olsztyn

Age symbols: Cr — Cretaceous, Pg — Paleogene, Ng — Neogene; **glaciations**: Na — Narevian, Ni — Nidanian, S1 — Sanian 1, S2 — Sanian 2, Li — Liviecian, Krz — Krznanian, O — Odranian, V — Vistulian; **interglacials**: *A* — Augustovian, *Ma* — Małopolanian, *F* — Ferdynandovian, *M* — Mazovian, *Z* — Zbójnian, *Lu* — Lubavian (Lublinian), *E* — Eemian; **loess horizons**: br — Berezan, dn1 — Dnieper 1, dn2 — Dnieper 2 (ts — Tyasmyn), il — Ilyichivsk, or — Orel, pr — Pryazovsk, sl — Sula, sv — Siver, tl — Tiligul, vl — Valday; **palaeosols**: bd — Bogdanov, bv — Beregovo, jr — Yarkov, kd — Kaydaky (ko — Korshiv), kr — Kryzhaniv, l — Luck (Potagaylivka), lb — Lubny (sol — Solotvin), mr — Martonosha, pl — Pryluky (ho — Horokhiv), sh — Shirokino, zv — Zavadivka, H (hl) — Holocene; gf — glaciofluvial, f — fluvial; **top of**: 1 — Paleogene or Neogene, 2 — South Polish Glaciations (Okanian), 3 — Middle Polish Glaciations (Dnieperian); for section names see Figure 1

level is presented to scale whilst the distance between control points is shown at variable horizontal scales. Despite this shortcoming, the picture obtained of the spatial and stratigraphic position of the analysed sediments permits full analysis of the occurrence of the main series along the longest European Pleistocene geologic cross-section. It represents a first attempt at correlating all glacial and interglacial stages in the area occupied by the Scandinavian ice sheets with the loesses and palaeosols of extraglacial areas.

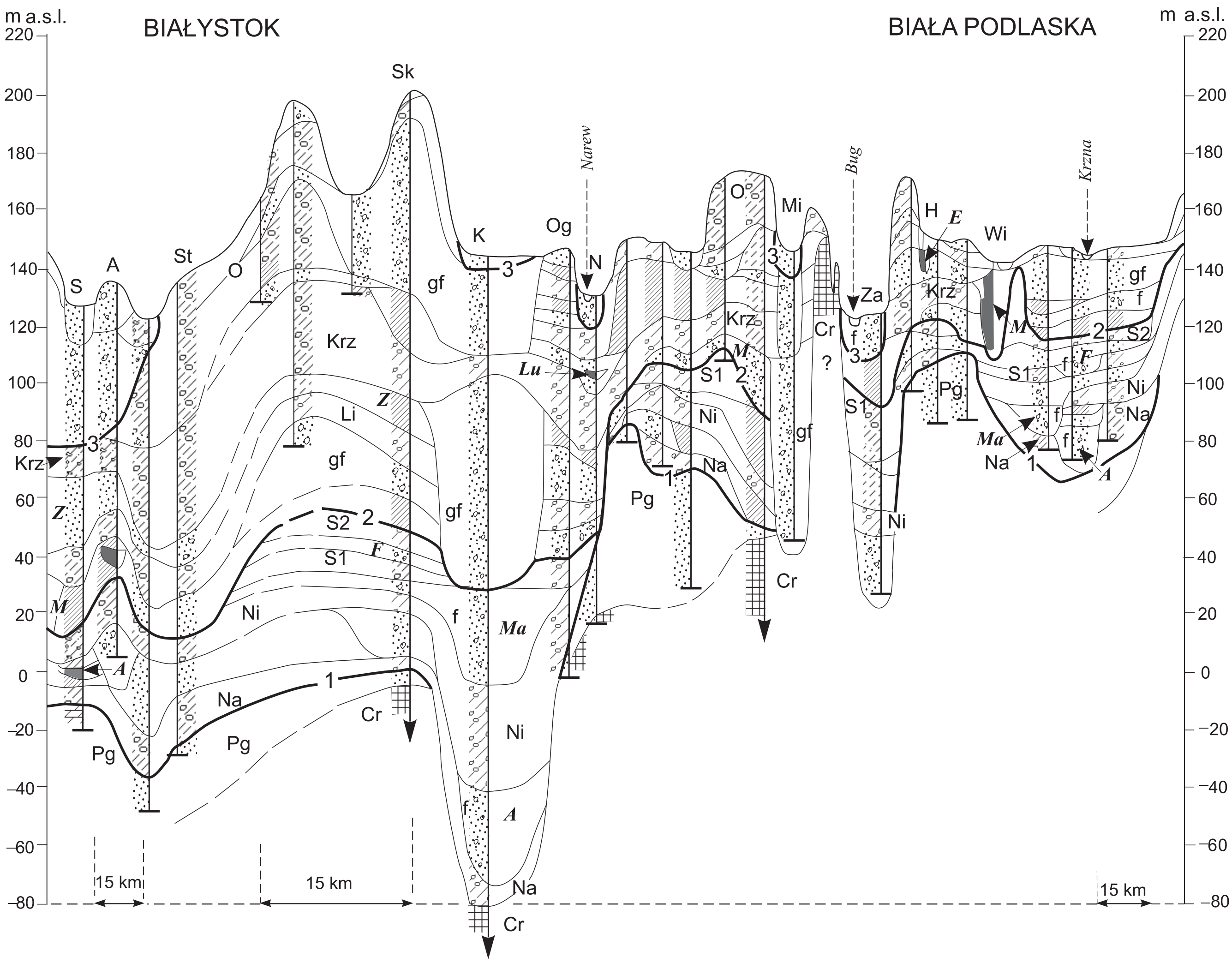

Fig. 3. Geologic cross-section of the Pleistocene deposits between Białystok and Biała Podlaska after Lindner and Astapova (2000), supplemented

For other explanations see Figures 1, 2 and 6

GEOLOGIC SETTING AND CHRONOLOGY

PLEISTOCENE DEPOSITS BETWEEN GDAŃSK AND OLSZTYN (FIG. 2)

This cross-section is over 200 km long and covers the Lower Vistula Region, Warmia, Mazury Lakeland and the western part of the Suwałki-Augustów Lakeland. In this area the land surface reaches elevations to 292 m a.s.l. The Pleistocene deposits are 100–290 m thick and mostly rest on Paleogene terrestrial sediments. Eight successive Scandinavian ices sheets occupied the area covered by this cross-section (Lindner and Marks, 1995), with the resulting sedimentary sequence being represented mainly by glacial, fluvioglacial, fluvial and lacustrine and partly marine deposits.

This section plays a significant role in the stratigraphic correlation of Late and Middle Pleistocene sediments in Poland due to occurrence of key sites, both of terrestrial and marine sediments. The latter, which relate to Holstein, Eemian and Holocene seas, occur in the Baltic Basin and along the present seaside, and permit correlations with classical key sites in Western Europe.

A till of the oldest glaciation (Narevian) occurs at Krzyżewo (Ber, 2000) where it is overlain by a till of the Nidanian Glaciation that is also known from Szwajcaria (Ber, 2000). At Szwajcaria and Krzyżewo the Nidanian till is overlain by fluvial(?) sediments of the Małopolanian Interglacial (Ber, 2000). Deposits of the same interglacial presumably occur also at Domuraty (Lisicki and Winter, 2003).

A till of the Sanian 1 Glaciation occurs at Obrzynowo, Domnovo, Prynowo and Krzyżewo (Kondratienė and Gudelis, 1983; *cf*. Marks, 1988; Ber, 2000; Pochocka-Szwarc and Winter, 2001; Head *et al*., 2005). At Prynowo this till is specified by petrographic coefficients O/K, K/W and A/B of 1.7, 0.6 and 1.5, respectively (symbols mean contents of: O — sedimentary rocks, K — crystalline rocks and Scandinavian quartz, W —

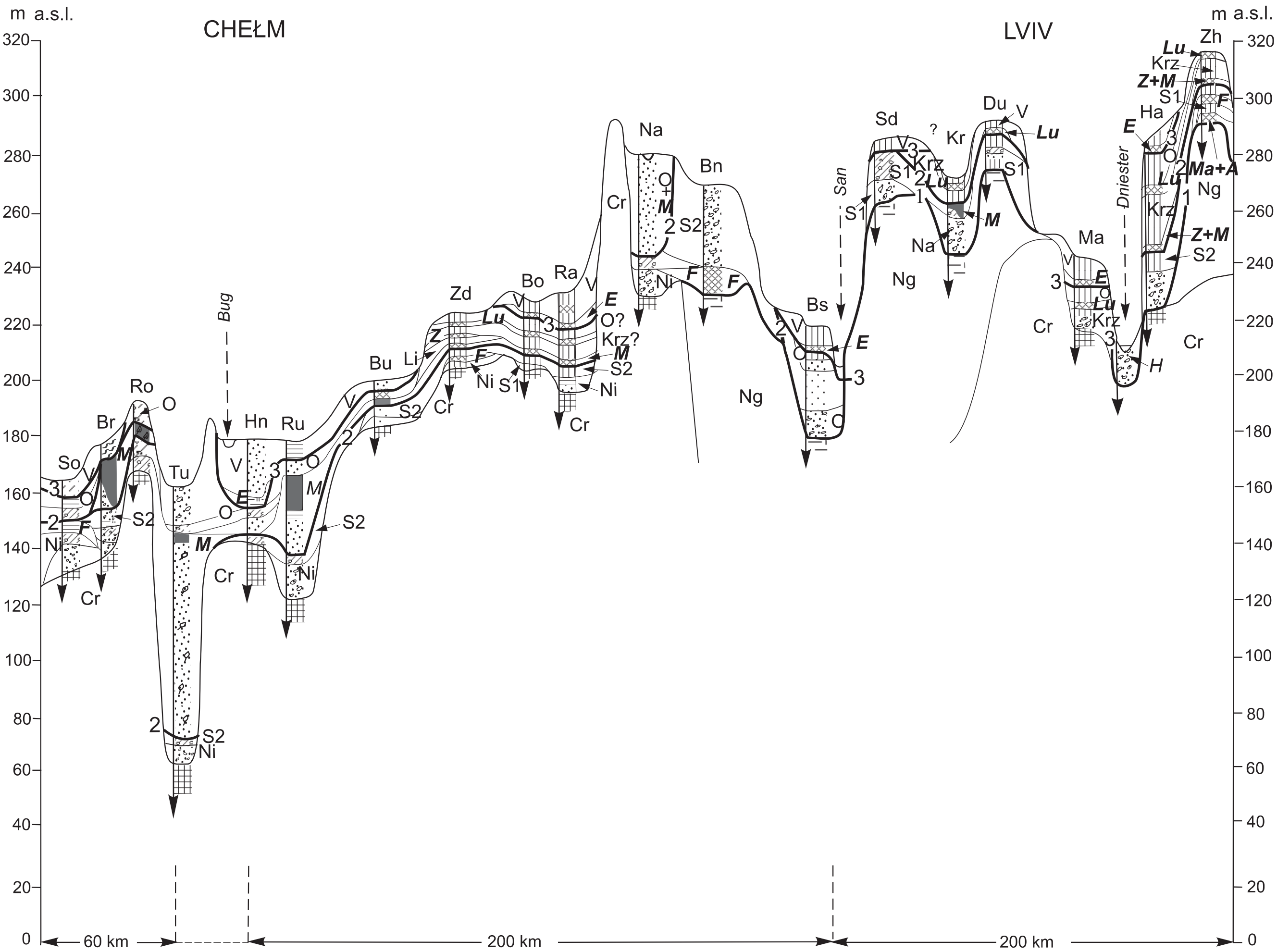

Fig. 4. Geologic cross-section of the Pleistocene deposits between Chełm and Lviv

For other explanations see Figures 1, 2 and 6

carbonate rocks, A — non-resistant rocks *i.e.* limestones, dolomites and shales, B — resistant rocks *i.e.* crystalline, quartz, sandstones and quartzites). Pochocka-Szwarc and Winter (2001) ascribed this till to the Nidanian Glaciation. This till is covered at Domnovo and Obrzynowo by ice-dam clays (Kondratienė and Gudelis, 1983; Makowska, 2001), and at Krzyżewo by glaciofluvial sands (Ber, 2000). The clays are locally varved at Obrzynowo and overlain by fluvial fine-grained sands deposited in a periglacial zone.

A till of the Sanian 2 Glaciation occurs at Obrzynowo, Domnovo, Prynowo, Węgorzewo, Szwajcaria and Krzyżewo (Kondratienė and Gudelis, 1983; Ber, 2000; Makowska, 2001; Lisicki, 2003). It is specified by petrographic coefficients O/K, K/W and A/B of 1.3, 0.8 and 1.2, respectively. The till, which is overlain by late-glacial glaciolacustrine red clays containing abundant sporomorphs and an admixture of silt, is attributed by Pochocka-Szwarc and Winter (2001) to the Wilgian Glaciation.

Lacustrine to marshy sediments of the Mazovian Interglacial occur at Węgorzewo, Krzyżewo and Prynowo (Ber, 2000; Krupiński, 2000; Pochocka-Szwarc and Winter, 2001; Lisicki, 2003). Pollen analysis of interglacial deposits at Prynowo indicated the presence of three local pollen zones, representing the beginning and final part of the interglacial succession. Beneath and above the lacustrine sediments interglacial fluvial deposits occur at Węgorzewo (Lisicki, 2003). From Domnowo (Kaliningrad District) marine and brackish deposits attributed to the Holsteinian Interglacial have been reported (Kondratienė and Gudelis, 1983; Marks, 1988).

A till of the Liviecian Glaciation occurs at Szwajcaria and Krzyżewo and presumably also sediments of the Zbójnian Interglacial (Ber, 2000). A till of the Krznanian Glaciation occurs at Prynowo, Węgorzewo and Krzyżewo (Ber, 2000; Pochocka-Szwarc and Winter, 2001; Lisicki, 2003) where it is specified by petrographic coefficients O/K, K/W and A/B of 2.1, 0.5 and 2.0, respectively. As seen at Szwajcaria, this till is covered by fluvial or lacustrine sands, containing silt and peat intercalations of the Lubavian(?) Interglacial (Pochocka-Szwarc and Winter, 2001; Lisicki, 2003). Fluvioglacial sediments overlay this till at Węgorzewo.

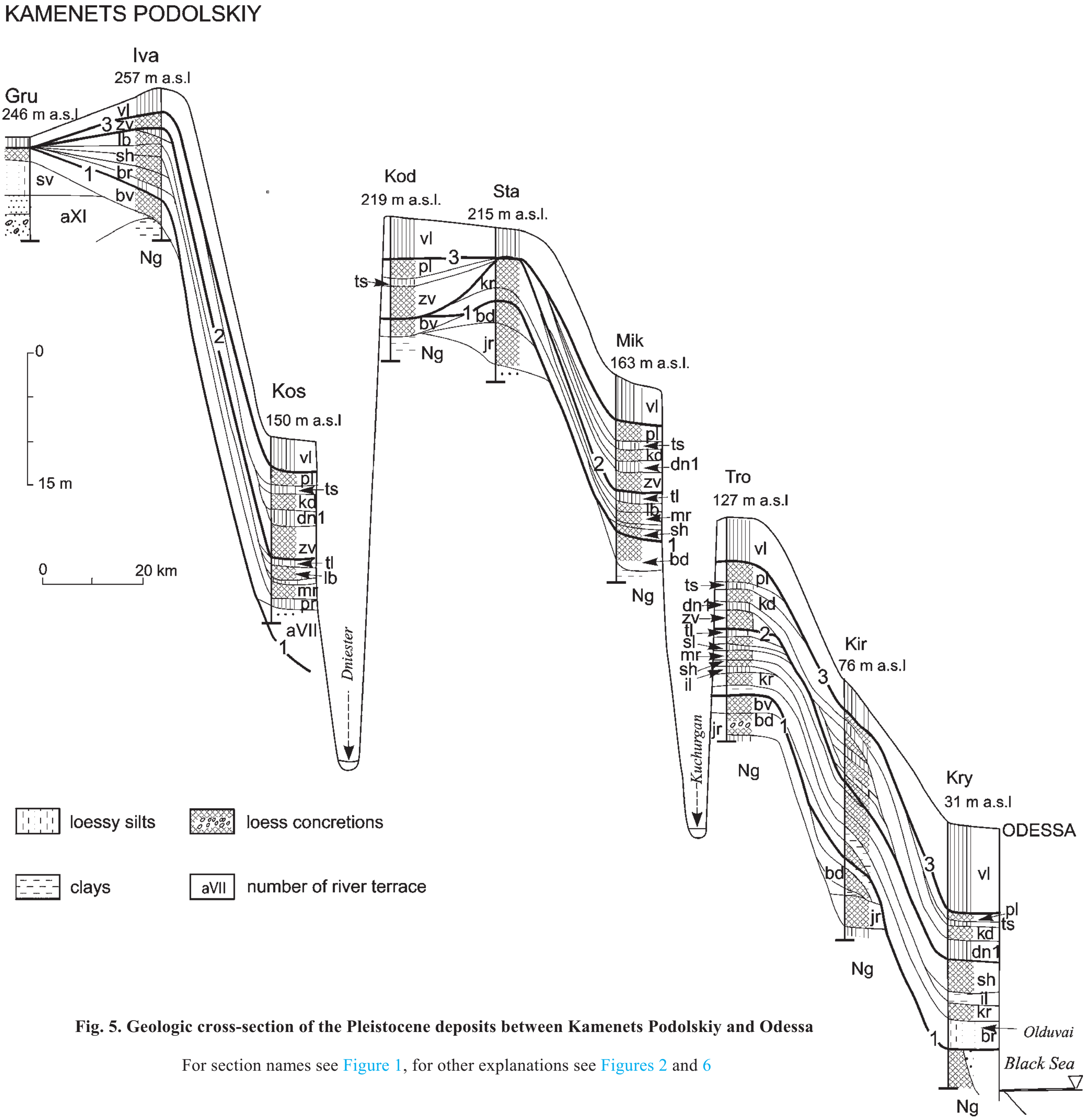

Fig. 5. Geologic cross-section of the Pleistocene deposits between Kamenets Podolskiy and Odessa

For section names see Figure 1, for other explanations see Figures 2 and 6

A till of the Odranian Glaciation occurs at Obrzynowo, Domnovo, Prynowo, Węgorzewo, Szwajcaria and Krzyżewo (Kondratienė and Gudelis, 1983; Ber, 2000; Makowska, 2001; Pochocka-Szwarc and Winter, 2001; Lisicki, 2003). At Prynowo it is represented by petrographic coefficients O/K, K/W and A/B of 1.7, 0.6 and 1.7, respectively. At Szwajcaria this till is composed of two beds that are separated by fluvioglacial sediments. At Obrzynowo this till is overlain by varved clays and silts (Makowska, 2001) and at Prynowo by fluvioglacial sediments.

The Eemian Interglacial is represented at Prynowo by fluvial sands with gravels and silts (Pochocka-Szwarc and Winter, 2001). At Obrzynowo the Eemian sequence starts with a lag concentrate and fluvial sands, containing wood pieces and an admixture of organic matter; heavy minerals contain twice as much amphiboles than garnets. The overlying marine sediments are composed of beach and offshore clays, sands and silts, with mollusc shells (Makowska, 2001), and are in turn covered by peaty silts and shales that were deposited during the terminal part of the Eemian Interglacial. The beginning of the Vistulian Glaciation is represented by a thick series of fluvial vari-grained and fine-grained sands, containing abundant interbeds of lacustrine silts, gyttja and peat. Among heavy minerals, garnet predominates distinctly over amphibole.

Vistulian Glaciation is represented by two tills, which are commonly separated by fluvioglacial sands. The lower till occurs at Obrzynowo, Domnovo, Prynowo, Węgorzewo, Szwajcaria and Krzyżewo (Kondratienė and Gudelis, 1983;

Ber, 2000; Makowska, 2001; Pochocka-Szwarc and Winter, 2001; Lisicki, 2003). At Prynowo it is specified by petrographic coefficients O/K, K/W and A/B of 2.0, 0.5 and 1.6, respectively. Holocene marine sediments occur at the bottom of the Gulf of Gdańsk.

PLEISTOCENE DEPOSITS BETWEEN BIAŁYSTOK AND BIAŁA PODLASKA (FIG. 3, MODIFIED AFTER LINDNER AND ASTAPOVA, 2000)

This cross-section is over 200 km long and covers the eastern part of the Suwałki-Augustów Lakeland and the Podlasie Lowland that are characterized by elevations between 120–200 m a.s.l. The 40–240 m thick Pleistocene deposits mantle sediments of the Middle and Early Palaeogene and Cretaceous. This cross-section is located in an area that was occupied by ice sheets during all Scandinavian glaciations that reached the Polish territory (Lindner and Marks, 1995).

In this section, fluvial and lacustrine deposits separate most of the glacial series. The oldest till is attributed to the Narevian Glaciation and was recognized at Szczebra, Augustów and Sztabin (Ber, 1996). The till of the Narevian Glaciation, which equates with Menapian in Western Europe (Lindner *et al.*, 2004), is characterized by the predominance of carbonate rock fragments over crystalline rocks and by the abundance of dolomites and local rocks (to 32.2%). Its petrographic coefficients O/K, K/W and A/B (Ber, 1996) are equal to 1.23, 0.86 and 1.2, respectively; amongst heavy minerals, garnets and amphiboles predominate (Ber *et al.*, 1998).

Further to the south, the Narevian till occurs in the vicinity of Sokółka where it is to 5–10 m thick and overlies Paleogene sands. At Kruszyniany, it fills a glacial depression and rests on Cretaceous rocks. Moreover, it has been preserved in isolated patches on buried elevations between the rivers Narew and Mielnik, as well as within glacial depressions in the vicinity of Biała Podlaska. In previous publications this till has been commonly treated as an equivalent of the older stadial South Polish Glaciation (Nowicki, 1965, 1969; Ber, 1970) with only Różycki (1961, 1967) and Nowak (1971) connecting it with the Narevian Glaciation. This till is up to 20 m thick, overlies Paleogene sands and marls, and is covered by fluvioglacial sands of the Narevian Glaciation. At Szczebra it is also covered by interglacial organic sediments that document a bi-optimal floristic succession of the Augustovian Interglacial (Janczyk-Kopikowa, 1996; Ber *et al.*, 1998), that is a chronostratigraphic equivalent to the previously distinguished Podlasian Interglacial (Lindner and Yelovicheva, 1998).

Based on recent palynologic investigations the Augustovian Interglacial comprises three warming cycles (Winter, 2003). Preliminary investigations on diatoms determined water level changes in interglacial lakes (Marciniak, 2003). Summing up, this interval can be treated as mega-interglacial with secondary warming and cooling cycles that can be correlated with Bavelian *s.s.*, Linge, Leerdam, Dorst and Cromerian I of Western Europe (Lindner *et al.*, 2004*b*).

The next younger glacial beds in this area correspond to the Nidanian Glaciation (first South Polish Glaciation) that can be correlated with the cooling of the Glacial A in Western Europe (Lindner *et al.*, 2004*b*). They are best developed at Szczebra, Augustów and Sztabin (Ber, 1996) where they are represented by a till, but locally also by underlying fluvioglacial sands with gravels. In this till crystalline components predominate over carbonate ones with locally derived rocks making up between 4.9–5.8% (Ber, 1996). Among heavy minerals there are more garnets, a decreased amphibole content and a lack of biotite (Ber *et al.*, 1998).

Further to the south the Nidanian till forms a continuous bed that rests at Kruszyniany on the alluvia of the Augustovian Interglacial. It is preserved in a similar setting in the vicinity of Biała Podlaska. In both regions it has been previously treated as a relic of a stadial of the South Polish Glaciation (Nowicki, 1969; Nowak, 1971) but has been attributed in more recent papers to the Nidanian Glaciation (Lindner, 1988*b*; Nitychoruk, 1994).

In the area under consideration occur buried fluvial series of the Małopolanian Interglacial, key sites of which are Kozi Grzbiet (Głazek *et al.*, 1977) and Łowisko (Stuchlik and Wójcik, 2001) located beyond the confines of our study. These series are best developed at Kruszyniany (to 30 m thick) and in the vicinity of Biała Podlaska (to 10 m thick).

Tills of the younger South Polish Glaciations (Sanian 1, Sanian 2 — Wilgian), previously identified with stadials of the South Polish Glaciation (Nowicki, 1965, 1969; Ber, 1970; Nowak, 1971), are preserved mainly in the vicinity of Sokółka, between the Białystok and Biała Podlaska (Fig. 3). Fluvial sands and gravels of the Ferdynandovian Interglacial separate these tills, key sites of which occur at Ferdynandów (Janczyk-Kopikowa *et al.*, 1981) and Zdany (Pidek, 2003) on the Siedlce Plateau.

These tills, and particularly the upper one and the accompanying fluvioglacial sands and gravels, are covered by silty ice-dam lake deposits, which are widespread in north-east Poland and north-west Belarus (Marks and Pavlovskaya, 1998, 2003). In the vicinity of Augustów and Biała Podlaska (section Wilczyn), organic sediments that are attributed to the Mazovian Interglacial cover these silts and sand (Fig. 3); these yielded the characteristic floristic succession presented by Janczyk-Kopikowa (Ber, 1996; Bińka *et al.*, 1997). The Mazovian deposits of Poland are time-equivalents of the Holsteinian Interglacial and Praclaux sediments of Western Europe (Lindner and Marciniak, 1998).

The next younger glacial horizon is represented by sediments of the Liviecian Glaciation that, according to Lindner and Marks (1999), can be considered as the oldest one of the Middle Polish Glaciations. In the vicinity of Augustów, sediments of this glaciation are represented by an up to 12 m thick till and overlying silts (Ber, 1996). Petrographic coefficients of the till are as the following: K/W = 1.27, O/K = 0.83 and A/B = 1.18 whereas the content of locally derived Paleogene rocks is extremely high, amounting to 12.8% (other local rocks make up to 2.3%). In the vicinity of Sokółka a till of the Liviecian Glaciation forms a local elevation and can be traced as far southward as the River Narew, indicating the maximum extent of the ice sheet. Particularly in the northern part of the cross-section (Fig. 3), this till is overlain presumably by sands, sands with gravel and silts from the Zbójnian Interglacial, the key site of which is located in the Holy Cross Mts. that is outside the described area (Lindner and Brykczyńska, 1980).

The second Middle Polish Glaciation is represented by the next younger till that is attributed to the Krznanian Glaciation (Lindner and Marks, 1999). This till occurs in the vicinity of Augustów and in the whole area between Sokółka and Biała Podlaska. It does not extend across the lower Krzna River in the south that delimited the maximum extent of this ice. This till was previously considered as a deposit of the older (pre-maximum, Krzna) stadial of the Middle Polish Glaciation (Nowicki, 1965, 1969; Rühle, 1970; Nowak, 1971). At Narew, sands above this till contain organic deposits that can be equated to the Lubavian?–Lublinian Interglacial (Kupryjanowicz *et al.*, 1999). A key section of this interglacial is located at Losy near Lubawa in the southwestern Mazury Lakeland (*cf.* Krupiński and Marks, 1986).

During the third Middle Polish Glaciation, at present referred to as the Odranian that is composed of Kamienna (maximum) and Warta (post-maximum) stadials (Lindner *et al.*, 2004*a*), a locally bipartite till was deposited. In the vicinity of Augustów, this till represents the youngest one at Szczebra where its petrographic coefficients (K/W = 1.47, O/K = 0.82 and A/B = 1.36) indicate a predominance of crystalline over carbonate components (Ber, 1996). In the middle part of this till a distinct drop in the content of garnets and a rise of amphiboles can be observed, whereas biotite is absent (Ber *et al.*, 1998).

Bipartite nature of this till, noted in the vicinity of Mielnik and Sokółka (Fig. 3), as well as its occurrence at surface from Sztabin in the north to Biała Podlaska in the south, confirm the oscillatory ice sheet retreat, expressed in this part of Poland by 2–3 distinct glacial advances. Thick fluvioglacial deposits beneath this till at Kruszyniany and Zarzecze indicate meltwater erosion and the development deep glaciogenic channel-like depressions.

The following Eemian Interglacial is well indicated by fluvial and organic deposits at Horoszki (Fig. 3), where their upper part represents the Early Vistulian (Granoszewski, 2003). The youngest glacigenic horizon, represented not only by till but also by underlying and overlying fluvioglacial sediments, is attributed to the Vistulian Glaciation. It is only preserved in the vicinity of Augustów (Fig. 3) where it delimits the maximum extent of the Eemian ice sheet.

PLEISTOCENE DEPOSITS BETWEEN CHEŁM AND LVIV (FIG. 4)

This cross-section is over 450 km long and extends from the Polish Polesie Lowland across the eastern part of the Sandomierz Basin (eastern Carpathian Foreland) into the Lublin Upland and then, the Podole Uplands of the Ukraine. Surface elevations range between 160–320 m a.s.l. Whereas the northern parts of the area covered by this cross-section were reached by all Scandinavian glaciations older than the Vistulian, its southern parts mark the important palaeogeographic boundary between the maximum extent of glacial and periglacial zones between Dubaniewice to Marinopol (Figs. 1 and 4).

The Pleistocene series attain thicknesses of up to 100 m and consist of glacial, fluvioglacial, fluvial, lacustrine and aeolian (loess and loess-like) deposits that rest either on Cretaceous or the Lower and Middle Neogene sediments. Generally, periglacial loesses, which are thickest mainly in the upland zone, form together with palaeosols the basis for the stratigraphic subdivision of Pleistocene deposits.

The oldest Pleistocene sediments consist of fluvial deposits that rest in the Carpathian Foreland on Miocene Krakowiec Clays with the most representative sections occurring at Krukienice and Zahvizdja. In the former, fine-grained so-called Eopleistocene or preglacial sands are TL dated at 1036 ka BP (Bogutsky *et al.*, 1999; Boguckij *et al.*, 2001). These calcium carbonate cemented quartz sands (95–97% quartz content) were probably deposited during the Narevian Glaciation. At Zahvizdja fluvial sediments represent a full fluvial cycle, starting with coarse channel gravels that grade upward into sands and ultimately overbank deposits. Amongst heavy minerals resistant components, such as zircone, rutile and garnets predominate (Łanczont and Boguckyj, 2002; Łanczont *et al.*, 2003*a*). As these fluvial sediments occur beneath the palaeomagnetic Brunhes-Matuyama boundary (Nawrocki *et al.*, 2002), they can be correlated with the Augustovian Interglacial (Bavelian) and oxygen isotope stages 33–21 in deep-sea sediments.

Also in foreland of the Lublin Upland at Buśno so-called preglacial deposits consisting of fluvial gravels and medium to coarse-grained sands are underlain by Upper Cretaceous carbonates. They form a system of buried river terraces, undoubtedly older than the Nidanian Glaciation, with TL data suggesting an age of more than 800 ka BP (Dolecki, 1995).

The Nidanian Glaciation was recognized at Sosnowica, Brus, Tur, Ruda and Narol and is represented by fluvioglacial gravels and sands containing Scandinavian material. At Narol they were TL dated at 768 ka BP. Ice sheet of the Nidanian Glaciation advanced far to the south *i.e.* into the Sandomierz Basin (Wojtanowicz, 1995). Loess was deposited in the Lublin Upland where it is 1.8 m thick at Zadębce Kolonia and does not contain any carbonates. In the extraglacial zone at Zahvizdja, the Nidanian Glaciation can be correlated with the lowermost cryoturbation zone, developed in clayey silts.

The Małopolanian Interglacial is well documented at Zahvizdja by two palaeosols that belong to the pedocomplex Zahvizdja that is also deformed by cryoturbations. This complex occurs immediately above the palaeomagnetic Brunhes-Matuyama boundary.

Sediments of the Sanian 1 Glaciation were recorded at Siedliska, Dubaniewice and Zahvizdja. In principal publications dealing with the sections Siedliska (Łanczont, 1997) and Dubaniewice (Boguckyj *et al.*, 2004), the basal part of the Sanian 1 Glaciation deposits was found to consist of sandy-gravel alluvia that contain exclusively material derived from the Carpathians and are exceptionally rich in garnets (up to 85%). Loess and silts also accompany these fluvial deposits. On the other hand, tills and fluvioglacial sands occurring in these sections have been related to the Sanian 2 Glaciation.

However, in this paper we relate them to the Sanian 1 Glaciation, as this is consistent with the opinion of Lindner (2001) and suggestions drawn from the publication of Wójcik *et al*. (2004), according to which the Sanian 1 Glaciation is the most widespread Scandinavian Glaciation in Southern Poland and the southwestern Ukraine. Petrographic coefficients of a till at Siedliska are dominated by a locally derived component (>40%). Scandinavian dolomites and Palaeozoic shales are absent. Amongst transparent heavy minerals garnets and amphiboles predominate (Łanczont, 1997). At Krukienice, petrographic coefficients of fluvioglacial sediments are O/K = 0.73, K/W = 2.42 and A/B = 0.31 (Nowak, 2000). At Zahvizdja, that is already located beyond the maximum limit of Scandinavian glaciations, about 3 m thick loess (Mz = 7.0, δ_1= 1.98) was deposited during the Sanian 1 Glaciation.

The Ferdynandovian Interglacial was confirmed at Sosnowica by palynologic data where it is represented by an over 5 m thick layer of lake deposits, TL dated as 537 ka BP (Dolecki *et al*., 1991). The observed pollen succession is typical for this interglacial and very close to the key section at Ferdynandów and other sections (see discussion in Pidek, 2003). During the older climatic optimum (of the two distinguished elsewhere) only one was recorded at Sosnowica, reflecting a temperate climate with deciduous forest.

The probable occurrence of the Ferdynandovian Interglacial was noted in lacustrine silts at Brusno and in the Solotvin pedocomplex at Zahvizdja, the latter TL dated as 586–644 ka BP. These palaeosols correspond to the oxygen isotope stages 13–15 and developed during the longest and the most intensive Middle Pleistocene pedogenesis (Łanczont and Bogucki, 2002).

The Sanian 2 Glaciation is documented by tills and fluvioglacial deposits, noted not only at Siedliska and Dubaniewice in the Carpathian Foreland, but also at Brus, Ruda (Wojtanowicz, 1995) and Buśno (Malicki and Pękala, 1972) in the northern foreland of the Lublin Upland where thin layers of till were TL dated as 430–530 ka BP.

The Mazovian Interglacial was palynologically analysed at Brus (Pidek, 2003) and Krukienice (Łanczont *et al*., 2003*b*). The pollen spectrum proved uniform climatic conditions in vast areas of Central Europe. Well-documented are also interglacial series with lake-marshy deposits at Ruda and Buśno (Wojtanowicz, 1995). Almost all loess sections contain brown, leached or chernozem palaeosols (Kolonia Zadębce, Bojanice, Ratyczów) or pedocomplexes composed of two superimposed soils from the Mazovian and Zbójnian interglacials (Halich, Zahvizdja). The interval of the Liviecian Glaciation is indicated in the described cross-section by slope deposits, *e.g.* at Zahvizdja, and by insignificant silt deposition, incorporated into the Zbójnian Interglacial soil and intensively transformed by soil processes.

Sediments of the Middle Polish Glaciation are, in agreement with the opinion of Lindner *et al*. (2004), generally attributed to the Odranian Glaciation. Tills of this glaciation occur at Sosnowica and Rosta, and fluvioglacial sediments at Ruda. In loess sequences, the Middle Polish Glaciations are represented by thick loess beds (e.g. at Halich), which are subdivided by the Lublinian (-Lubavian) interglacial soil.

Evidence for the Eemian Interglacial occurs at Hniszów in the Bug River valley where a fluvial series contains clays with fine humus laminas, peat and mollusc shells. These sediments were TL dated as 106 and 114 ka BP (Wojtanowicz, 1993). In loess sections at Bojanice, Ratyczów, Marinopil and Halich there is commonly a well-developed Eemian soil of the Horokhiv type.

The Vistulian Glaciation is represented by fluvial channel (Hniszów) and flood deposits (Sosnowica), as well as by loess (Bojanice, Ratyczów, Buszkowice, Siedliska, Dubaniewice, Halich).

PLEISTOCENE DEPOSITS BETWEEN KAMENETS PODOLSKIY AND ODESSA (FIG. 5)

This cross-section is over 450 km long and extends across the southwestern and eastern parts of the Dniester drainage basin, including the Podole Upland, Moldavian Plateau and Black Sea Lowland. Surface elevations range between 257–31 m a.s.l. Pleistocene deposits are 14–30 m thick and consist mainly of loess with thick palaeosols. In two cases (Grushevcy and Kosautsy) Dniester fluvial deposits underlay the loess. The Pleistocene sequence rests on Lower and Middle Neogene marine sediments and the Pliocene Yarkov and Bogdanov horizons (Veklich, 1979, 1982).

At Grushevcy the Neogene is presumably also represented by fluvial deposits of the XIth Dniester terrace that is composed of sands and gravels containing fragments of freshwater mollusc shells (*Unio sturi* M. Horn, *etc*.), typical for the Pliocene/Pleistocene boundary in Eastern Europe (Gożik, 1982). Overlying loessy silts or clays of the Siver Horizon span, according to Veklich (1979), the time interval of 2640–2430 ka. Based on palynological studies these silts contain pollen of herbaceous plants. The Beregovo pedocomplex is composed of two superimposed red soils of the younger warming. Palynological data indicate that these soils developed in a subtropical forest-steppe environment, ascribed to 2430–1900 ka (Veklich, 1979).

At Ivanivtsy, loess of the Berezan horizon is the oldest Pleistocene series above this palaeosol. It was deposited at about 1900–1620 ka (Veklich, 1979), under a cool climate as indicated by palynologic data. At Kirovo and Kryzhanivka, there occur clays or loessy silts that comprise at Kryzhanivka the palaeomagnetic Olduvai episode (Tretjak and Volok, 1976; Tretjak *et al*., 1987) that is dated as 1960–1780 ka (Heller and Evans, 1995). At Trostyanets, Kirovo and Kryzhanivka these deposits are overlain by the Kryzhaniv pedocomplex that is up to 3.5 m thick and composed of two red-brown palaeosols that developed in a subtropical forest-steppe environment. These soils are characterized by the reverse magnetic polarization of the Matuyama epoch (Tretjak *et al*., 1987) and are dated as 1620–1400 ka (Veklich, 1979).

The younger cooling, defined in the Ukraine as the Ilyichivsk horizon, is represented in our cross-section at Trostyanets, Kirovo and Kryzhanivka by loess or clays. These sediments, 0.7–4 m thick, were deposited in a steppe environment during the Matuyama epoch (Tretjak *et al*., 1987). Veklich (1979) determined the age of these deposits as

1400–1290 ka. At Ivanivtsy, Mikhailovka, Trostyanets, Kirovo and Kryzhanivka, successive warming is indicated by the Shirokino horizon, a 3.5–4 m thick pedocomplex that developed in subtropical environment during 1290–1000 ka (Veklich, 1979). Most probably the fluvial Dniester VIIth terrace sediments, preserved in the lowermost part at Kosautsy, were deposited at the same time.

At Kosautsy and Mikhailovka, successive cooling is represented by loess of the Pryazovsk horizon that is up to 2 m thick and contains pollen indicative for a temperate climate steppe environment with rare trees in river valleys. The age of this horizon was estimated by Veklich (1979) to be in the range of 1000–920 ka. At Ivanivtsy, Kosautsy, Mikhailovka, Trostyanets and Kirovo, the Pryazovsk horizon in overlain by the Martonosha pedocomplex that is up to 3.5 m thick and consists of 2–3 superimposed palaeosols, the age of which is estimated by Veklich (1979) to be about 920–700 ka. At Roxolany, SW of Odessa, the palaeomagnetic Matuyama-Brunhes boundary, dated at 780 ka (Heller and Evans, 1995), is located in the lower parts of this complex (Gozhik *et al*., 2000).

At Kosautsy, Trostyanets and Kirovo, the younger Sula horizon is composed of loess and loessy silts that, based on palynological data, were deposited under distinctly periglacial conditions in a cool steppe. Deposits of the Sula horizon are characterized by a normal (Brunhes) magnetic polarization (Tretjak *et al*., 1987) and their age was determined as 700–650 ka (Veklich, 1979). At Ivanivtsy, Kosautsy, Mikhailovka, Trostyanets and Kirovo, the following warming period is represented by the pedocomplex of the Lubny horizon that consists of two chernozems, locally separated by thin loess. These soils developed in a warm steppe whereas the separating loess was deposited during a distinct cooling period. Deposits of the Martonosha horizon are 1.5–3.5 m thick and their age was estimated at 650–470 ka (Veklich, 1979).

The subsequent cooling period is represented by the loess of the Tiligul horizon that is preserved above the Lubny palaeosols at Kosautsy, Mikhailovka and Trostyanets. It is 1–4 m thick, widespread at the northern seaside of the Black Sea, and has normal (Brunhes) magnetic polarization. Veklich (1979) estimated its age at 470–370 ka, whereas TL data suggest an age of 510–420 ka (Shelkoplyas *et al*., 1986; Gozhik *et al*., 1995). The Tiligul loess and older deposits are overlain by the pedocomplex of the Zavadivka horizon that consists of two brown forest soils separated locally by the thin loess of the Orel horizon. Palynological data show that these soils developed in a subtropical forest and that they contain abundant exotic (Early and Middle Neogene) pollen. The separating loess indicates a short return to a cool steppe environment. Within the younger soil of the Zavadivka horizon (Potagaylivka) the palaeomagnetic zone V (Biva III) of the Brunhes episode was identified (Gozhik *et al*., 2000). Veklich (1979) estimated the age of the Zavadivka pedocomplex at 370–250 ka. TL data ascribe the older soil to 440–380 ka and the younger to 390–340 ka (Shelkoplyas *et al*., 1986; Gozhik *et al*., 1995).

Above the Zavadivka pedocomplex, the Dnieper (Dnieper 1) horizon loess is preserved at Kosautsy, Trostyanets and Kryzhanivka. It is 2–3 m thick and, south-west of Odessa, comprises at Roxolany the palaeomagnetic Chegan episode (Gozhik *et al*., 2000) of the Brunhes epoch. Veklich (1979) estimated the age of the Dnieper loess at 250–175 ka whilst TL data indicate an age of 290–240 ka (Shelkoplyas *et al*., 1986). At Kosautsy, Mikhailovka, Trostyanets, Kirovo and Kryzhanivka, this loess forms the substrate of the Kaydaky pedocomplex that is 1.2–3.5 m thick and consists of two superimposed palaeosols that developed in a forest-steppe environment (Sirienko, 1974; Matviishina, 1982). They are characterized by normal magentic polarization (Brunhes) and their age is estimated at 175–115 ka (Veklich, 1979) or, based on TL data, at 280–180 ka (Shelkoplyas *et al*., 1986; Shelkoplyas and Khristophorova, 1996).

At Kosautsy, Kodyma, Mikhailovka, Trostyanets and Kryzhanivka, the Kaydaky pedocomplex is overlain by the 0.5–2.0 m thick loess of the Tyasmyn (Dnieper 2) horizon, which was deposited in a cool steppe, influenced by a periglacial climate. At the northern seaside of the Black Sea this loess displays normal polarization (Brunhes) and its age is estimated at 100–115 ka (Veklich, 1979) or, based on TL data, at 190–140 ka (Shelkoplyas *et al*., 1986, Gozhik *et al*., 1995). This loess is covered by the Pryluky horizon palaeosol that is well developed at Kosautsy, Kodyma, Mikhailovka, Trostyanets, Kirovo and Kryzhanivka where it is 1.8–3.2 m thick. It is composed of an illuvial layer of a forest soil that is covered by a chernozem. At Roxolany, NW of Odessa, the upper part of this soil comprises the palaeomagnetic Blake episode (Gozhik *et al*., 2000). Veklich (1979) estimated the age of the Pryluky horizon at 100–70 ka and TL data suggest that it has developed between 140–90 ka (Shelkoplyas *et al*., 1986; Gozhik *et al*., 1995).

The Pryluky palaeosol overlies the loess of the Valday horizon. This is the thickest (up to 10 m) of all loesses and is composed of three separate beds (Uday, Bug, Prichernomorye) that are subdivided by initial palaeosols (Vitachiv, Dofinovka). Veklich (1979) estimated their age at 70–10 ka, whilst TL and C^{14} data suggest 90–10 ka (Shelkoplyas *et al*., 1986; Gozhik *et al*., 1995). The Valday loess is overlain by the Holocene chernozem.

CORRELATION

Our review of the regional distribution and chronology of Pleistocene sediments comes along with a controversial proposal for a new Cainozoic stratigraphic chart and time scale that suggests cancelling the "Tertiary" and "Quaternary" as stratigraphic units of the Cainozoic (Gradstein *et al*., 2004), and introducing the "Pleistocene" and "Holocene" as subunits of the Neogene. The boundary Holocene/Pleistocene is retained at about 10 ka, and the boundary Pliocene/Pleistocene at 1806 ka *i.e.* within the palaeomagnetic Olduvai episode (Fig. 6). This hasty proposal got immediate response in the global chronostratigraphical correlation table for the last 2.7 million years (Gibbard *et al*., 2004), treated as the "unofficial alternative base of the Quaternary (Pleistocene)". It supports a use of the term "Quaternary", comprising Pleistocene and Holocene, and starting either from 1806 ka or from 2580 ka *i.e.*

the boundary Gauss/Matuyama. This point of view has been reflected also in our recent publications (Marks, 2000, 2004; Lindner *et al*., 2004*b*).

Proposed (Fig. 6) shorter duration of the Pleistocene (1806–10 ka) is compatible with earlier suggestions for the territory of Poland (Lindner, 1992; Mojski, 1993) and the recent ones for the Ukraine (Gozhik, 2000). Correlation of the main stratigraphic units of the Pleistocene, taking into account glaciations, interglacials, loesses and palaeosols in Poland and Ukraine, and main stratigraphic units from Western Europe will be discussed below (Fig. 6).

In our study area, the oldest Quaternary unit is the Berezan horizon of the southwestern Ukraine. The equivalents of this horizon are formed in Poland by fluvial-lacustrine deposits lacking Scandinavian material that represented the Otvockian cooling (Lindner *et al*., 2004*b*). Based on palynological investigations, these sediments are correlated by Stuchlik (Baraniecka, 1991) with the Eburonian of the Netherlands (e.g. Zagwijn, 1989).

The next younger unit is the Kryzhaniv horizon of the SW Ukraine and the warming Celestynovian of Poland. The latter is characterized by fluvio-lacustrine deposits, correlated by Stuchlik (Baraniecka, 1991) with the Waalian of the Netherlands and ascribed to the Kozienice and Krasnystaw series in Poland (Mojski, 1985).

In Western Poland, sediments of the cooling Otvockian, the warming Celestynovian, the Narevian and Nidanian glaciations, and the separating deposits of the Augustovian Interglacial are ascribed to the Lower Pleistocene (Fig. 6). The Middle Pleistocene starts with the sediments of the Małopolanian Interglacial. These are overlain by deposits of the successively younger glaciations, namely the Sanian 1, Sanian 2, Liviecian, Krznanian and Odranian and the separating interglacials: Ferdynandovian, Mazovian, Zbójnian and Lubavian. The Upper Pleistocene comprises the Eemian Interglacial and the following Vistulian Glaciation,

The oldest glaciation (Narevian) correlates with the Ilyichivsk horizon of the Ukraine and the Menapian of Western Europe (e.g. Zagwijn, 1989). During this glaciation the Scandinavian ice sheet did not reach beyond the territory of Poland. Therefore, the “Narevian Glaciation” reported from Belarus (Velichkevich *et al*., 2001) must presumably be older (Lindner *et al*., 2004*a*). The post-Narvenian interglacial, previously referred to in Poland as the Podlasian Interglacial (Lindner,

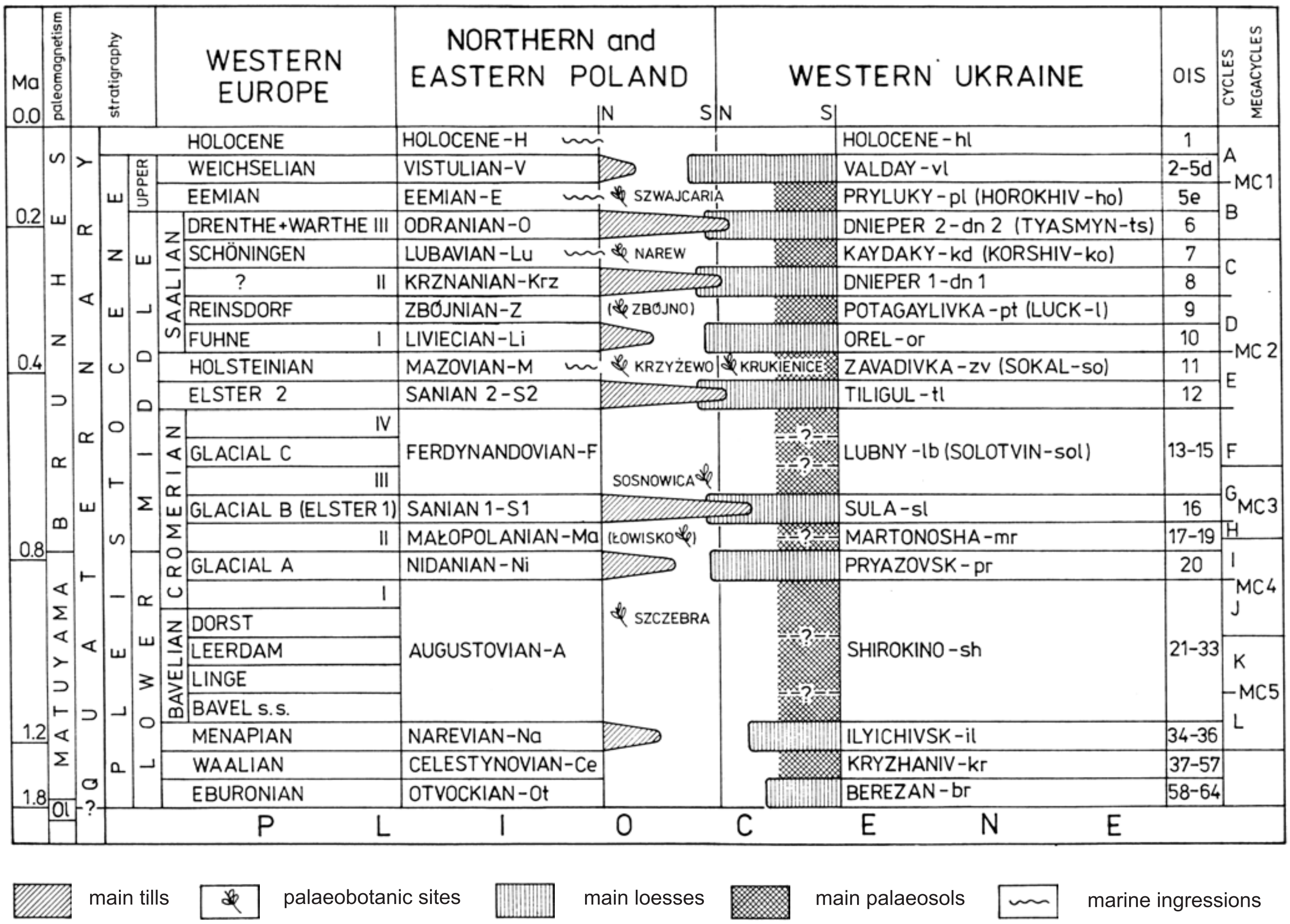

Fig. 6. Main glaciations and interglacials, loesses and palaeosols in the Pleistocene of Poland and Ukraine and their correlation with stratigraphic units in western Europe after Eissmann (1994), Urban (1995), Zagwijn (1996) and Gibbard *et al.* (1998), and with oxygen isotope stages (OIS) (Paepe *et al*., 1996); climatic cycles and megacycles after Lindner *et al*. (2002, modified)

1992), corresponds to the Augustovian mega-interglacial. In the Ukraine it correlated with the Shirokino horizon and in Western Europe, probably not only to Bavelian *s.l.* (Bavel *s.s.*, Linge, Leerdan, Dorst), but also to Cromerian I (Waardenbug) in Dutch schemes (e.g. Zagwijn, 1985, 1989).

The successive three younger glaciations are represented in Poland by the South Polish Glaciations (Nidanian, Sanian 1 and Sanian 2) and in the NW Ukraine by the glacial deposits of the Sanian 1, also referred to as the Donian Glaciation. Each of these glaciations is represented in the SW Ukraine by the successive Pryazovsk, Sula and Tiligul loess horizons (Fig. 6). In Western Europe, these glaciations equate to the Glacial A, Glacial B (Elster 1?) and Elster 2 cooling phases that are distinguished in the Netherlands (e.g. Zagwijn, 1985; Zagwijn and Hager, 1987) and Germany (e.g. Wiegank, 1982; Cepek, 1986; Eissmann, 1994). The Nidanian, Sanian 1 and Sanian 2 glaciations and corresponding loesses are separated in Poland by the Małopolanian and Ferdynandovian mega-interglacials, respectively, that correlate in the Ukraine with the pedocomplexes of the Martonosha and Lubny (Solotvin) horizons. During both mega-interglacials cooling periods occurred that presumably reflect so-called small glaciations during which ice sheets were confined to Scandinavia. Based on recent studies, the Małopolanian and Ferdynandovian mega-interglacials and corresponding palaeosols correlate in Western Europe with the Cromerian II (Westerhoven), Cromerian III (Rosmalen) and Cromerian IV (Noordbergum) warming episodes of the Netherlands (among others Zagwijn, 1985, 1996), and with warmings preceding the Elster 2 Glaciation in Germany (Erd, 1978; Grüger, 1996; Hahne, 1996).

The Mazovian Interglacial, represented in the northern part of the cross-section at Domnovo by marine sediments of the West European Holsteinian (Marks, 1988, 2000; Marks and Pavlovskaya, 2003), correlates in the Ukraine with the Zavadivka (Sokal) horizon palaeosols. During the Middle Polish Glaciations (Saalian) with three glacial advances referred to as the Liviecian, Krznanian and Odranian, the Scandinavian ice sheets extended over progressively wider areas (Lindner *et al.*, 2004*b*), with the youngest one (Dnieper 2) reaching the northwestern Ukraine. These three glaciations in Poland (Fig. 6) correspond in the southwestern Ukraine to the three Orel, Dnieper 1 and Tyasmyn (Dnieper 2) loesses. In Western Europe, there are no univocal traces of the older two of these glaciations. It does seem probable that their chronology should be referred in Germany to cooling periods that separate the interglacials Holstein/Reinsdorf and Reinsdorf/Schöningen (Urban, 1995). In Poland the Krznanian Glaciation separates the organic deposits of the Zbójnian (Reinsdorf) and Lubavian (Lublinian, Schöningen) interglacials, that find their equivalents in France as the Landos and Le Bouchet interglacials (Reille *et al.*, 2000), as well as the Norwegian Trench Interglacial (OIS 9 after Sejrup and Knudsen, 1993) and the Grødeland Interglacial (OIS 7 after Sejrup *et al.*, 1999) in the North Sea. The younger of these interglacials can correspond in Poland with sediments of the so-called "Sztum Sea", discovered by Makowska (1986) and preserved in the lower Vistula valley (Lindner and Marks, 1999). In the Ukrainian loess sequences these interglacials are represented by the palaeosols of the Luck (Potagaylivka) and Korshiv (Kaydaky) horizons.

Global warming during the Eemian Interglacial is reflected in the lower Vistula valley by sediments of the so-called "Tychnowy Sea" (Makowska, 1986). These sediments have been subjected to detailed palaeontologic studies (Head *et al.*, 2005) and their correlation with equivalent sediments of the youngest interglacial of Western Europe is beyond doubt (Lindner and Marciniak, 1998). In Southern Poland, this interglacial is expressed by an illuvial horizon of a palaeosol of the type "Nietulisko I" (Jersak, 1973). In the Ukraine it corresponds to the palaeosol of the Horokhiv (Pryluky) horizon. The last glaciation is referred to as Weichselian in Western Europe (e.g. Zagwijn, 1989), as Valdaynian in Eastern Europe (and Ukraine) and as the Vistulian Glaciation in Poland. In the northern part of our cross-section it is represented by sediments deposited by the Scandinavian ice sheet and in the northwestern and southwestern Ukraine by loess of the Valday horizon.

All referred to glaciations and separating palaeosols permit to define 12 glacial-interglacial and loessy-soil climatic cycles that in turn can be grouped into 5 megacycles (Fig. 6) as reported earlier (Lindner *et al.*, 2002). Such a presentation corresponds to the proposed reconstruction of Pleistocene climatic changes (*cf.* Kukla and Cilek, 1996) and univocally indicates that each of these cycles comprised a glaciation and the following interglacial (Holocene included). Analysis of number and duration of these cycles supports their correlation with astronomic cycles, 110–90 thousand years long each. In our opinion the suggestion of Kukla and Cilek (1996) that 2–4 Pleistocene climatic cycles are grouped into mega-cycles is most probably based on the shorter duration of some interglacials (*e.g.* Eemian) and glaciations (*e.g.* Liviecian).

CONCLUSIONS

Data presented here on the distribution and chronology of Pleistocene deposits in the area between the Baltic Sea and the Black Sea are of great importance for the reconstruction of climatic conditions and the natural environment of Central Europe during the last 2 million years.

In the northern part of the study area, the preglacial cold (Eburonian) and the subsequent warm (Waalian) intervals were followed by 8 main Scandinavian glaciations (Narevian, Nidanian, Sanian 1, Sanian 2, Liviecian, Krznanian, Odranian, Vistulian). These were interrupted by 7 main interglacials (Augustovian, Małopolanian, Ferdynandovian, Mazovian, Zbójnian, Lubavian–Lublinian, Eemian), the first three of which were mega-interglacials. During the Sanian 1 (Elsterian 1, Donian) Glaciation the Scandinavian ice cover reached its largest extent with the ice sheet extending southward as far as the Upper Dniester drainage basin. Subsequently, in deglaciated areas an over 400 ka old glacial landscape was created in which dead-ice holes (Krukienice) were filled with organic sediments during the Mazovian (Likhvin) Interglacial. These deposits correlate with palaeosols of the Ukrainian Zavadivka (Sokal) horizon. The area described is the zone where the main watershed between the Baltic and Black Seas was established during the Mazovian–Zavadivka interglacial stage.

To the north of this zone, which covers southeastern Poland and the northwestern Ukraine, Sanian and younger glacial deposits partly interfinger with loess series that contain interglacial palaeosols. This permits to correlate these series with the glacial deposits and interglacial lake-marshy series of northeastern Poland, and to establish the chronology of these sediments by relating them to the 8 superimposed main loess horizons of the Ukraine (Ilyichivsk, Pryazovsk, Sula, Tiligul, Orel, Dnieper 1, Dnieper 2 — Tyasmyn, Valday) that are separated by 7 palaeosols (Shirokino, Martonosha, Lubny–Solotvin, Zavadivka–Sokal, Luck–Potagaylivka, Kaydaky–Korshiv, Pryluky–Horokhiv), most of which are represented by pedocomplexes.

The resulting correlations show, that all Scandinavian glaciations recognized in Poland equate in the Ukraine with loess horizons, and that the Ukrainian palaeosols (pedocomplexes) find their climatic-chronologic equivalents in the Polish interglacial lake-marshy sediments. Correlation of these sediments plays a very important role in terms of the occurrence of marine sediments of the Mazovian (Holstein) Interglacial (Domnovo) and Eemian Interglacial (Obrzynowo) in the Peri-Baltic domain and the results of palaeomagnetic investigations in several sections (Kryzhanivka, Zahvizdja) of the Ukraine. Of particular importance are the "long" loess sections of the Ukraine that provide a continuous record of the Late Pliocene and Pleistocene climate changes during the last 2–3 million years.

The main units (horizons) of the Pleistocene climatostratigraphic subdivision that was established in the area under discussion could be successfully correlated with similar units of Western Europe (Fig. 6). The resulting correlation suggests a close similarity in the number and rank of the main climatic changes in Europe during the last 2 million years. These changes reflect 12 climatic cycles (A–L), each of which comprised a cooling (glaciation) and a warming (interglacial) phase, and that can be grouped into 5 megacycles. This made it possible to establish a close link between the classical scheme of the Alpine glaciations, and also with Pleistocene climatic changes on other continents. In the case of the Augustovian Mega-interglacial and the corresponding Shirokino horizon, the Małopolanian Mega-interglacial and the corresponding Martonosha horizon, as well as the Ferdynandovian Mega-interglacial and the corresponding Lubny (Solotvin) horizon, the occurrence of possible limited glaciations within cool units is suggested. These could be related to intervals during which Scandinavian ice sheets did not reached areas south of the Baltic Basin.

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