acta
geologica
polonica

Vol. 38, No. 1-4 Warszawa 1988

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Stratigraphy and extents of Pleistocene continental glaciations in Europe

ABSTRACT: Evidence is presented for subdivision of the Quaternary in Central Europe into 8 continental glaciations (Narew = Menap; Nida = Glacial *A*; San *1* = Glacial *B* = Elster *1*; San *2* = Elster *2*; Liwiec = Fuhne; Odra = Drenthe = Saale *1* + *2*; Warta = Warthe = Saale *3*; Wisła = Weichsel = Vistulian) separated by 7 interglacials (Podlasian = Cromerian *I*; Malopolanian = Cromarian *II*; Ferdynandów = Cromerian *III* + *IV* = Voigtstedt; Mazovian = Holstein *s.s.*; Zbójno = Dömnitz; Lubawa = Rügen; Eemian). All glaciations were expressed by advances of Scandinavian icesheets onto the territory of Poland. There is still no evidence of the presence of one (? or two) earliest glaciations and also of the Liwiec Glaciation in the West European Lowland. During the Liwiec Glaciation the Scandinavian icesheet has not advanced the East European Lowland, similarly as it did not occupy the East Russian Plain during the Nida Glaciation. In the British Isles the first three glaciations were expressed by a development of local ice caps. During the successive glaciations (San *2* = Anglian; Odra = Wolstonian; Wisła = Devensian) these caps expanded so much that they contacted with the Scandinavian icesheet.

INTRODUCTION

Studies of the Quaternary in Europe are mainly focused on investigations of continental (Scandinavian) glaciations and separating interglacials. Separation of these units, their age and extents as well as paleontologic documentation supply with principal data for reconstruction of the rhythm of main climatic changes during the Quaternary (*cf.* KUKLA 1977, ZUBAKOV & BORZENKOVA 1983, LINDNER 1984, BOWEN & *al.* 1986, BRUNNACKER 1986, SHOTTON 1986, ZAGWIJN 1986). They enable, in turn, to present the still more complex stratigraphic subdivisions of the inland Quaternary in Europe and their correlation with the Quaternary climatic changes recorded in deep-sea sediments (*cf.* SHACKLETON & OPDYKE 1973, FINK & KUKLA 1977, MÖRNER 1981, WIEGANK 1982, LINDNER 1984, 1987; ŠIBRAVA 1986, RZECHOWSKI 1986, ZUBAKOV 1986, 1988; MACOUN 1987).

The earliest Quaternary in Central Europe, starting with the Eburonian cooling and correlated with the beginning of the paleomagnetic episode Olduvai (1.87 – 1.67 ka BP), was found to indicate a slight development of icesheets (WIEGANK 1982, LINDNER 1984, 1987; MOJSKI 1985a, b; CEPEK 1986, ZUBAKOV 1986). In Poland this part of the Quaternary is defined as the Protopleistocene (RÓŻYCKI 1980, LINDNER 1984, 1987, 1989), the Eopleistocene (MOJSKI 1985a), or the Preglacial (MOJSKI 1985b). Its upper limit and in the same time the boundary with the Pleistocene, understood by RÓŻYCKI (1980) and by the present author (LINDNER 1984) as the glacial Quaternary, should be correlated with the beginning of the paleomagnetic episode Jaramillo (950–900 ka BP).

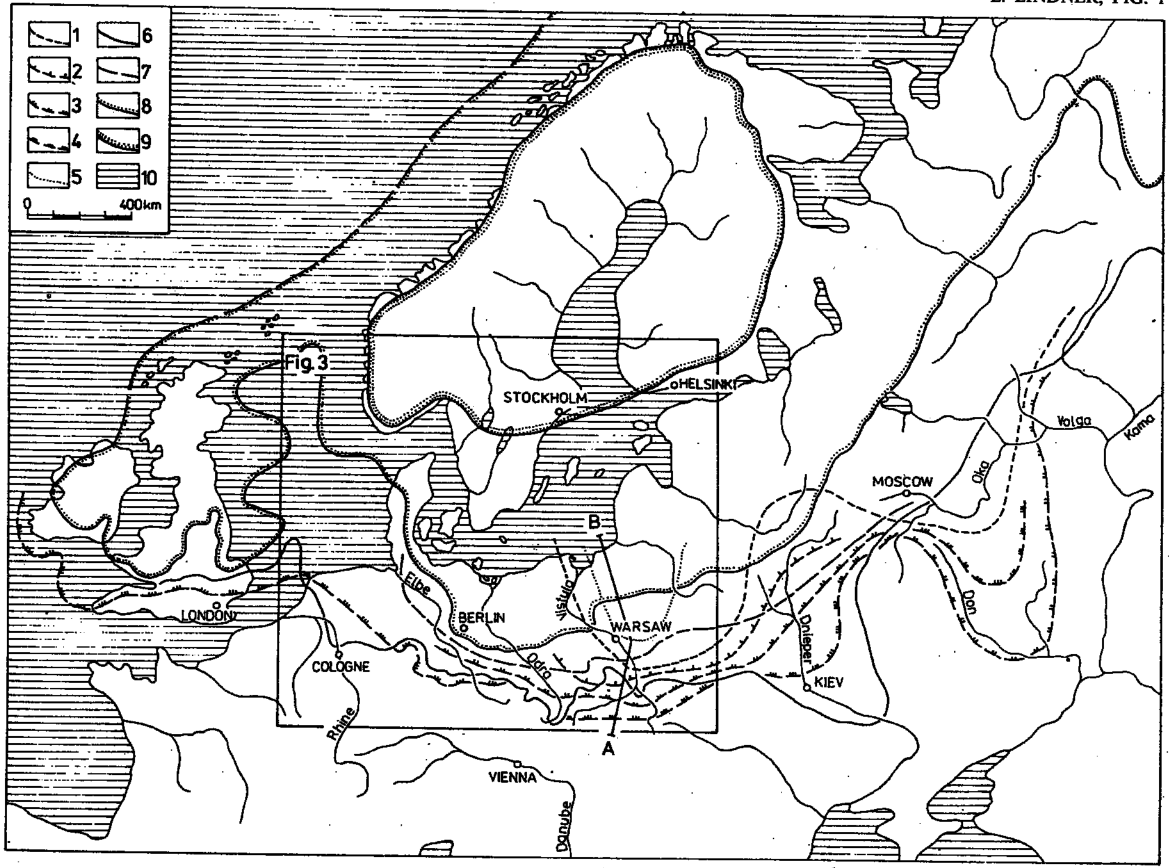
Recent studies on the Pleistocene of Poland, comprising the interval from 950 ka to 10 ka BP (LINDNER 1988a, b, c, 1989), supported the idea of 8 continental glaciations (Narew, Nida, San *1*, San *2* = Wilga, Liwiec, Odra, Warta, Wisła) and 7 interglacials (Podlasian, Malopolanian = Przasnysz, Ferdynandów, Mazovian = Barkowice Mokre, Zbójno, Lubawa = Grabówka, Eemian). These studies have not supported any longer the existence of the Mogielanka Glaciation and the Pilczyca Interglacial (*cf.* LINDNER 1984, 1987).

Similar number of glacial and interglacial units were identified in Byelorussia and Lithuania in the Soviet Union (*cf.* VOZNYACHUK 1985, ZUBAKOV 1986) what is undoubtedly connected with a relief of the Baltic Sea basin that favored advances of the Scandinavian icesheets. To the west of Poland and to the east of Byelorussia the icesheets could not advance so easily or did not develop at all (*cf.* CEPEK 1967, 1986; EHLERS & *al.* 1984, VELICHKO & FAUSTOVA 1986, MACOUN 1987). This is the reason why looking in the North Sea basin, German Lowland and eastern Russian Plain for sediments corresponding with all these glaciations that occurred in the Baltic Sea zone and its southeastern margin, remained unsuccessful (*cf.* Text-figs 1–2). In such a sense, the area of Central Europe is compatible to the southern margin of the North American Great Lakes region where, to the south of the Hudson Bay depression, the Pleistocene continental glaciations generated from the Laurentian icesheet could best develop (*cf.* HALLBERG 1986, FULTON & PREST 1987).

EARLY PLEISTOCENE (950–730 ka BP)

NAREW (MENAP, UNSTRUT, LIKOV, GÜNZ ?) GLACIATION

The Narew Glaciation was the earliest continental glaciation in Europe (Text-figs 1–4). During this glaciation the Scandinavian icesheet entered the European Lowland area through two lobes (Text-fig. 1). The western lobe occupied Lithuania, mid-eastern Poland and northwestern Byelorussia. In Poland it reached as far as the Radom Plain (LINDNER 1988a) and northern foreland of the Lublin Upland (HARASIMIUK & *al.* 1988), leaving there the oldest till, TL dated at about 800 ka BP (RZECHOWSKI 1986). In the Lower Narew drainage basin this till was found older than 890 ka BP (BAŁUK 1986).



Extents of Pleistocene continental glaciations in Europe (based on the referenced data); indicated is the area presented in Text-fig. 3

1 – Narew = Menap Glaciation; **2** – Nida = Glacial *A*; **3** – San *1* = Glacial *B* = Elster *1* Glaciation; **4** – San *2* = Elster *2* Glaciation; **5** – Liwiec = Fuhne Glaciation; **6** – Odra = Drenthe = Saale *1* + *2* Glaciation; **7** – Warta = Warthe = Saale *3* Glaciation; **8** – Wisła = Weichsel = Vistulian Glaciation; **9** – Salpausselkä moraines (Pleistocene-Holocene boundary); **10** – Recent seas and lakes

A-B – Line of schematic cross-section presented in Text-fig. 2

This till forms quite a continuous cover in Lithuania and Byelorussia where also represents the oldest glacigenic episode (VOZNYACHUK 1985). The eastern lobe of this Scandinavian icesheet occupied the Oka drainage basin, probably as far as the Upper Kama drainage basin (Text-fig. 1).

In western Europe this episode is not expressed by icesheet sediments (Text-figs 1–2). In the Elbe drainage basin this interval is represented by sediments of the Unstrut horizon (WIEGANK 1982, CEPEK 1986) whereas in the Lower Rhine valley by gravels of the *Ba* Series (BRUNNACKER 1986). In the Netherlands a flora of the Menap cooling developed (ZAGWIJN 1986) and in the British Isles this period is probably represented by the older pre--Pastonian, during which local glaciers developed in West Midlands and North Wales. The latter fact is supported by erratic gravels from that area, preserved at Stoke Row in the Middle Thames drainage basin (BOWEN & *al.* 1986).

PODLASIAN (CROMERIAN *I* in the Netherlands, ARTERN, JELIZAROV, TROICK, GÜNZ/MINDEL *I*) INTERGLACIAL

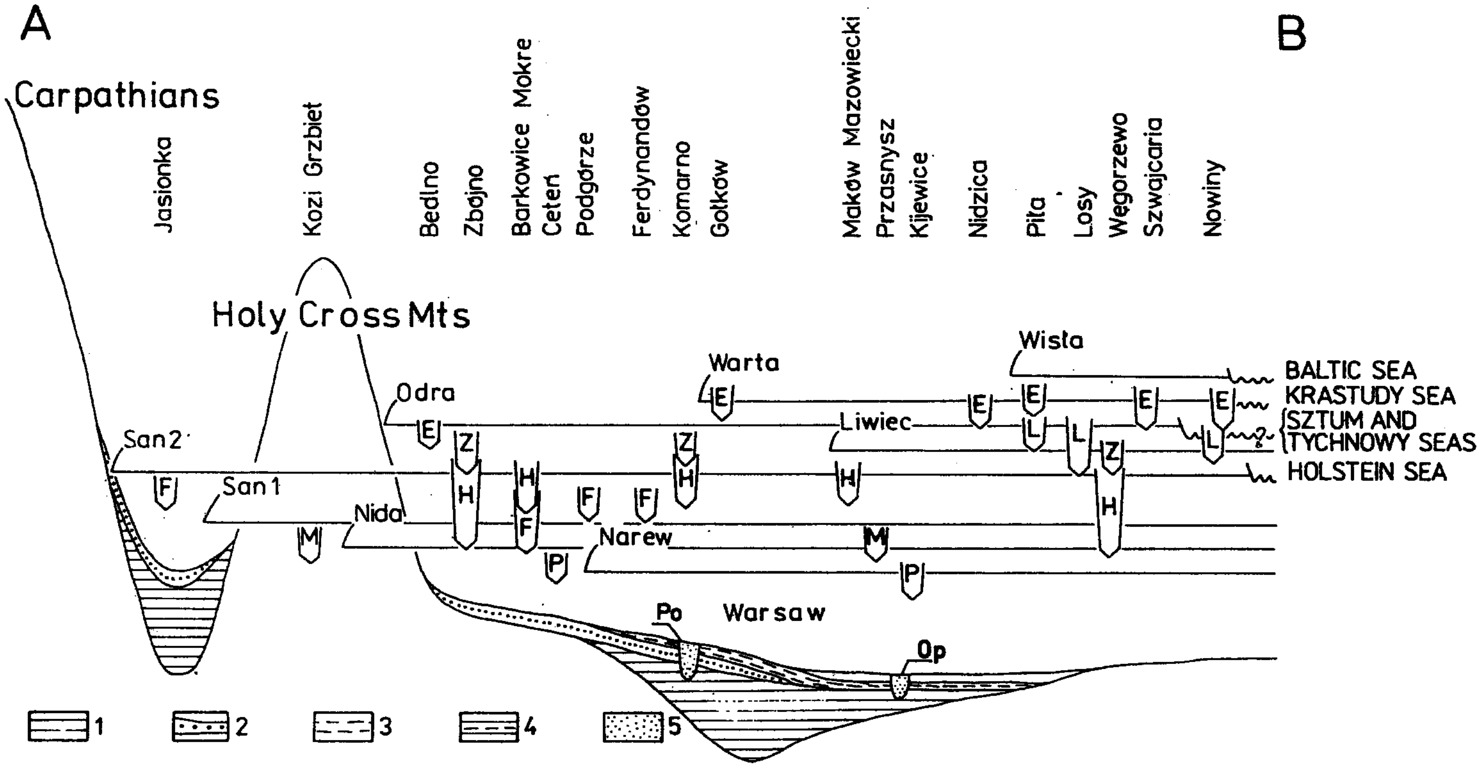
The Podlasian Interglacial is expressed in the mid-eastern European Lowland either by fluvial or lake deposits that fill, among others, the cuts in tills of the Narew Glaciation. In Poland (Text-fig. 2) this interglacial is documented by organic sediments from Ceteń (*cf.* BORÓWKO-DŁUŻAKOWA 1977, LINDNER 1988a) and from Kijewice where they were TL dated at 890–820 ka BP (BAŁUK 1986). In the European part of the Soviet Union this interglacial is documented by the flora from the the Jelizarov horizon and the lower optimum (Troick) in the section Akulovo (*cf.* ZUBAKOV 1986).

In the Upper Elbe drainage basin this interglacial should correspond with sediments of the Artern warming (*cf.* ERD 1978, WIEGANK 1982, CEPEK 1986), in the Lower Rhine drainage basin with development of a paleosol on gravels of the horizon *Ba* (BRUNNACKER 1986) and in the Netherlands with sediments of the Cromerian *I* (Jgl *I*) within the "Cromerian Complex" of that area (ZAGWIJN 1986). In northwestern Germany a stratigraphic position of this intergacial seems to correspond with sediments of the Bavel warming (*cf.* GRUBE & *al.* 1986). In the British Isles there is no convincing evidence for this interglacial.

MIDDLE PLEISTOCENE (730–128 ka BP)

NIDA (GLACIAL *A*, HELME, ELSTER *I*?, OPAVA, NOVOGOROD, MINDEL *I*) GLACIATION

During the Nida Glaciation the Scandinavian icesheet occupied, by its immense lobe, Lithuania, mid-eastern Poland, Byelorussia and probably also the northwestern Ukraine (Text-fig. 1). It entered during its maximum the northern Holy Cross Mts and reached northern slopes of Lublin and Volhynia uplands. In the Holy Cross Mts its presence is proved (but till) by Scandinavian material incorporated into clays at the Kozi Grzbiet cave bottom. These



Schematic cross-section of Poland, to show the extent of successive glaciations (*comp.* Text-fig. 1) and location of interglacial organogenic deposits and marine ingressions (*after* LINDNER 1989; *modified*)

1 — Mio-Pliocene clays; **2** — Middle and Upper Pliocene gravels and sands; **3** — Upper Pliocene silts; **4** — Upper Pliocene clays; **5** — Protopleistocene silts and sands

Po — Ponurzyca section, **Op** — Opaleniec section

Location of interglacial organic deposits of successive interglacials: **P** — Podlasian, **M** — Malopolanian, **F** — Ferdynandów, **H** — Mazovian, **Z** — Zbójno, **L** — Lubawa, **E** — Eemian clays were also found to be correlated with the Brunhes/Matuyama boundary (GŁAZEK & *al.* 1977) dated at about 730 ka BP (*cf.* MANKINEN & DALRYMPLE 1979). The icesheet advanced also onto Moravia where it is documented by deposits of the Opava Glaciation (*cf.* MACOUN 1985, 1987). In the Russian Plain being situated at that time in the icesheet forefield, its close neighborhood is expressed by the cooling that separates two climatic optima in the Akulovo section (*cf.* ZUBAKOV 1986).

In western Europe there was still no decided development of the icesheet. In the Elbe drainage basin this interval is documented by the Helme cooling (CEPEK 1967, 1986; WIEGANK 1982) which certainly corresponds with the lowest (*E 1*) till of the Elster *1* Glaciation (Text-fig. 4). In the Lower Rhine drainage basin the deposition of gravels of the horizon *Bb* and of sediments of the upper "Ville Complex", with marked the Brunhes/Matuyama boundary, occurred during this glaciation (BRUNNACKER & *al.* 1982, BRUNNACKER 1986). In the Netherlands this glaciation should be correlated with the cooling Glacial *A* (Text-fig. 3) which, within the "Cromerian Complex" of this area, separates the Cromerian *I* from the Cromerian *II* (*cf.* ZAGWIJN 1986). In the British Isles a local glaciation developed in West Midlands and North Wales, as proved by erratic gravels of the pre-Pastonian (*a*) from Westland Green, Hertfordshire (BOWEN & *al.* 1986).

MALOPOLANIAN (PRZASNYSZ, CROMERIAN *II* in the Netherlands, OTICE, KORCHEVO, ILIN, MINDEL *I*/MINDEL *II*) INTERGLACIAL

This interglacial has a rich paleontologic documentation. In Poland it is first of all indicated by a vertebrate and mollusc fauna from cave clays of Kozi Grzbiet and by a flora from Przasnysz (Text.-fig. 2). At Kozi Grzbiet, the Cromerian characteristic of this fauna was defined what, accompanied by datings of the bones by FCl/P method at 700–550 ka BP and at positive magnetic polarization (Brunhes) of the cave clays (GŁAZEK & *al.* 1976, 1977; SZYNDLAR 1981, SANCHIZ & SZYNDLAR 1984), enables to locate this fauna within the interglacial that post-dates the Nida Glaciation and pre-dates the next (San *1*) glaciation when the cave became filled with glaciofluvial sediments (LINDNER 1988a). An interglacial origin of organic sediments form Przasnysz, preliminarily studied by SELLE (1960), has recently been supported by pollen analysis performed by MAMAKOWA (1983). These sediments were TL dated at 686–615 ka BP (BAŁUK 1983, 1986). In Byelorussia they have equivalents in sediments of the Korchevo = Minsk Interglacial whereas in the Russian Plain by organic sediments of the upper optimum (Illin) in the section Akulovo (ZUBAKOV 1986). In Moravia these sediments should correspond with these of the Otice Interglacial (*cf.* MACOUN 1985, 1987).

In the Elbe drainage basin this interglacial has not been documented yet by good paleontologic evidence. It seems to be represented by a warming within the "Mahlis Complex" (*cf.* WIEGANK 1982, CEPEK 1986). In the Lower Rhine drainage basin it is expressed by a paleosol on gravels of the series *Bb* (*cf.* BRUNNACKER & *al.* 1982, BRUNNACKER 1986) whereas in sections of the Netherlands by sediments of the Cromerian *II* within the "Cromerian Complex" (*cf.* ZAGWIJN 1986). In the British Isles it was presumably represented by the warming defined as the pre-Pastonian *b* (*cf.* BOWEN & *al.* 1986).

SAN *1* (ELSTER *1*, GLACIAL *B*, KRAVARE *1*, SERVECK, DON, MINDEL *II*) GLACIATION

During this glaciation the Scandinavian icesheet displayed a decidedly greater dynamics (Text-fig. 1). In Poland it reached the northern slopes of the Sudetes and the Silesian Upland, passed across the Holy Cross Mts (Text-fig. 2) and the Lublin Upland, coming to the San drainage basin (LINDNER 1988b, 1989). Further to the east it occupied the Volhynia Upland and the Middle Dnieper drainage basin where it is named the Serveck Glaciation (ZUBAKOV 1986). It covered a considerable part of the Don drainage basin (Don Glaciation) and moved as far as the Chopior valley where it delimits the maximum extent of the Pleistocene icesheets (Text-fig. 1). In Poland tills of this glaciation at its maximum extent were TL dated at about 600–580 ka BP (LINDNER 1988b). These tills have also their equivalent in Moravia, defined there as remains of an icesheet of the Kravare *1* Glaciation (*cf.* MACOUN 1985, 1987).

In the Elbe drainage basin this glaciation is represented by sediments of the Elster *1* Glaciation (Text-fig. 4). In that time the Scandinavian icesheet has not advanced further westwards and left the Lower Saxony as well as the Lower Rhine drainage basin ice-free (Text-fig. 1). In the latter region the San *1* (Elster *1*) Glaciation should be referred to a deposition of ice-dam sediments (*C*) and overlying loesses (*D*) in the section Kärlich, and to correlate them with the Glacial *B* in the Netherlands (*cf.* BRUNNACKER 1986, ZAGWIJN 1986). In the British Isles the youngest pre-Pastonian (*c*) local glaciation developed in West Midlands and North Wales, expressed by a supply of gravel erratics to the sites Satwell and Beconsfield in the Middle Thames drainage basin (*cf.* BOWEN & *al.* 1986).

FERDYNANDÓW (CROMERIAN *III* + *IV* in the Netherlands, VOIGTSTEDT, MUGLINOV, BYELOVEZHA, ROSLAVL, MINDEL *II*/MINDEL *III*) INTERGLACIAL

The Ferdynandów Interglacial is well known in Central Europe from numerous sections of intratill organic sediments. In Poland it is best documented in the sections Podgórze and Ferdynandów (Text-fig. 2) where it indicates a bi-optimal floristic succession (*cf.* JURKIEWICZOWA & *al.* 1973, JANCZYK-KOPIKOWA & *al.* 1981). In the Ferdynandów section sediments of this interglacial were TL dated at 546–532 ka BP (RZECHOWSKI 1986). In

Byelorussia this interglacial has the same floristic spectrum (*cf.* MAKHNACH & RYLOVA 1986, KHURSEVICH & LOGINOVA 1986) and is named the Byelovezha Interglacial (VOZNYACHUK 1985), and the Roslavl Interglacial in the Russian Plain (ZUBAKOV 1986). The age setting of this interglacial is sometimes discussed, due to its similarity to the bi-optimal but younger Lubawa = Odintsovo Interglacial (VELICHKO & FAUSTOVA 1986). In Moravia it corresponds with the Muglinov Interglacial (*cf.* MACOUN 1985, 1987).

In the Elbe drainage basin this interval is correlated with the Voigtstedt Interglacial (*cf.* ERD 1978, WIEGANK 1982, CEPEK 1986). In the Lower Rhine drainage basin this period is to be correlated with a development of two paleosols, the older one of which has been formed on the loess *E* and the younger one on the loess *F* (*cf.* BRUNNACKER 1986). The intrasoil loess can evidence a climatic cooling between the two optima of this interglacial. The discussed interglacial seems to correspond as well with the deposition of organic sediments in the site Frimmersdorfer (*cf.* URBAN 1980a) within the terrace series *MT IIb* of the Rhine (*cf.* BRUNNACKER 1986). In the Netherlands the interglacial paleofloras are precised to the Cromerian *III* and *IV*, separated by the Glacial *C* (*cf.* ZAGWIJN 1986). In Denmark such floras probably correspond with the Herreskovian Interglacial (SJØRRING 1983). In the British Isles this horizon is occupied by the Cromer Forest Bed Series (*cf.* WEST 1977) that records a warming of the Pastonian, a cooling of the Baventian (with successive local glaciation of West Midlands and North Wales) and a warming of the English Cromerian itself (*cf.* BOWEN & *al.* 1986).

SAN *2* (WILGA, ELSTER *2*, KRAVARE *2*, BEREZINA, OKA, MINDEL *III*) GLACIATION

An icesheet of the San *2* Glaciation either in the Vistula (LINDNER 1988b, 1989) or in the Elbe drainage basin (CEPEK 1967, 1986), delimits the maximum extent of the Pleistocene continental glaciations (Text-figs 1–3). The TL datings of its sediments in the San drainage basin find this icesheet (*cf.* BUTRYM & GERLACH 1985, WOJTANOWICZ 1985) at a maximum extent about 500 ka BP in the foreland of the Carpathians (Text-fig. 3). In the Dnieper drainage basin a snout of this icesheet has not passed across the parallel of Kiev and its extent was smaller than that of the preceding glaciation in the Don drainage basin (Text-fig. 1). In Moravia this glaciation is named the Kravare *2* Glaciation (MACOUN 1985, 1987) and its extent, similarly as to the west of the Harz Mts, was also smaller than of the overpassing younger Odra Glaciation. In the Lower Rhine drainage basin a deposition of loesses of the *Ga* horizon occurred at that time (BRUNNACKER 1986). In the Netherlands the adjacent icesheet was expressed by development of a vast ice-dam lake in which "ceramic" clays were deposited (ter WEE 1983). On the other side of the North Sea (*cf.* Text-fig. 1) an extent of the icesheet of the San

2 Glaciation is to be correlated with the maximum development of the ice cover in the British Isles during the Anglian Glaciation (*cf.* ZAGWIJN 1979, BOWEN & *al.* 1986, SHOTTON 1986).

MAZOVIAN (BARKOWICE MOKRE, HOLSTEIN *s.s.*, MALOALEKSANDRIA, LIKHVIN *s.s.*, STRONAVA, MINDEL *III*/RISS *I*) INTERGLACIAL

This interglacial is documented in Europe by numerous sites of organic sediments, preserved either within buried fluvial or lake series. Besides, it has been recognized in marine sediments, particularly well preserved at seasides of

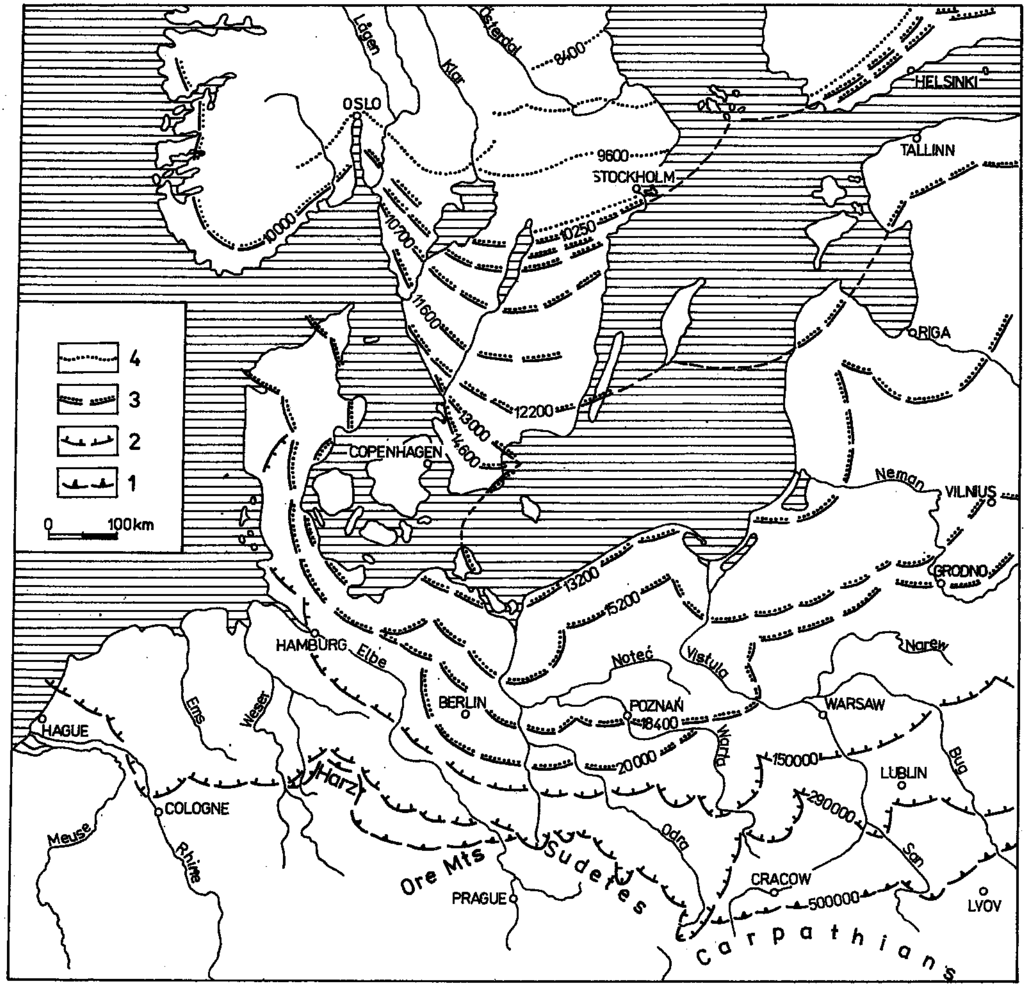


Fig. 3. Location and age (in years BP) of the main, readable in morphology, marginal zones of the continental Scandinavian icesheets in the Central European Lowland and southern Scandinavia (based on the referenced data) at the time of:
1 — San *2* = Elster *2* Glaciation; **2** — Odra = Drenthe and Warta = Warthe glaciations; **3** — Wisła = Weichsel = Vistulian Glaciation; **4** — Holocene

the southern North Sea and the southeastern Baltic Sea (*cf.* MILLER 1986). In Poland organic sediments of the Mazovian Interglacial in the section Krępiec, Lublin Upland (*cf.* JANCZYK-KOPIKOWA 1981, MARCINIAK 1983), were TL dated at 400–350 ka BP (RZECHOWSKI 1986). In Lithuania, Byelorussia and the Russian Plain they correspond in age with sediments of the Maloaleksandria = Likhvin *s.s.* Interglacial (Text-fig. 4) that were defined in the section Chekalin (previously Likhvin) as *Lh1* and TL dated at 459 ka BP (SUDAKOVA & ALESHINSKAYA 1974).

In the Elbe drainage basin this interglacial is documented by numerous sites of lake and marine sediments (MÜLLER 1974, ERD 1973, CEPEK 1986, CEPEK & ERD 1975) with key series in Schleswig-Holstein (MENKE 1970, GRUBE & *al.* 1986, MILLER 1986). In Denmark they correspond with sediments of the Vejlby Interglacial (ANDERSEN 1965, SJØRRING 1983) and in Sweden with sediments of the Hyby *I* Interglacial (MILLER 1977, 1986; LUNDQVIST 1986a). In the Lower Rhine drainage basin this interglacial corresponds among others with deposition of the organic series from the Kempen-Krefeld section (KEMPF 1966), whereas in loessy sections with deposition of sediments of the Leutesdorfer Interglacial (BRUNNACKER 1986). In the Netherlands this interval is represented by fluvial sediments and by deposits that delimit the southern extent of the Holstein sea (ter WEE 1983a, b; ZAGWIJN 1986). In the British Isles this interval presumably corresponds with the older part of the Hoxnian Interglacial, documented by vegetation phases *Ho I* and *Ho II* (*cf.* WEST 1977).

LIWIEC (FUHNE, PALHANEC, KOLYSK, KALUGA) GLACIATION

During this glaciation the Scandinavian icesheet occupied mid-eastern Poland only (Text-fig. 1) and deposited there a separate till, running from the Węgorzewo area as far southwards as Warsaw (Text-fig. 2). In a forefield of this icesheet a deposition of loessy and ice-dam silts occurred at that time, dated in numerous sections of the northwestern foreland of the Holy Cross Mts at about 390–380 ka BP (LINDNER 1984, 1988a). In Byelorussia and Russian Plain, constituting in that time the extraglacial zone of the icesheet, sediments of the horizons Kolysk and Kaluga were deposited (*cf.* ZUBAKOV 1986). In the section Chekalin these sediments (*Lh 2*) contain frost structures, TL dated at 370–330 ka BP (SUDAKOVA & ALESHINSKAYA 1974). In Moravia, deposited at that time were sediments of the Palhanec unit (*cf.* MACOUN 1985, 1987).

In the extraglacial zone that covered the Elbe drainage basin, sediments with a cold flora of the unit Fuhne were deposited (ERD 1978, WIEGANK 1982, CEPEK 1986) whereas in the Lower Rhine drainage basin loesses of the horizon *Gb* were formed with preserved frost structures and cold-phased molluscs (BRUNNACKER 1986). In Denmark this cooling has not been accompanied by icesheet advance but only by ice-dam deposition, among others known from above the Holstein series it the section Vejlby (SJØRRING 1983). In the British Isles this period seems to be indicated by deforestation at the end of the upper part of the phase *Ho II* in palynologic spectra of the Hoxnian Interglacial *s.l.* (*cf.* WEST 1977).

ZBÓJNO (DÖMNITZ, NEPLACHOVICE, PRINEMAN, CHEKALIN) INTERGLACIAL

At present, this interglacial has a relatively small number of studied floristic sites. In Poland it is best represented by a flora from the Zbójno section in the Holy Cross Mts (LINDNER & BRYKCZYŃSKA 1980) and similar flora from the section Konin-Marantów, ascribed formerly (BORÓWKO-DŁUŻAKOWA 1967) to a considerably lower stratigraphic position. As proved by TL datings from the section Zbójno, this flora is younger than 388 ka BP and older from the overlying till, dated in adjacent sections at 300—260 ka BP (LINDNER 1988a). In Byelorussia interglacial sediments of the Chekalin horizon (*Lh 3*) were TL dated at 330—318 ka BP (SUDAKOVA & ALESHINSKAYA 1974, ZUBAKOV 1986).

In the Elbe drainage basin this interval corresponds with the Dömnitz Interglacial that constitutes the final warming during Holstein Interglacial *s.l.* (ERD 1978, WIEGANK 1982, CEPEK 1986) and named in northwestern Germany the Wacken Interglacial (MENKE 1968; GRUBE & *al.* 1986). In Denmark the described stratigraphic setting can be occupied by two warmings (Vejlby *I*, *II*), younger that the Vejlby Interglacial and older from the overlying glacial sediments (SJØRRING 1983). In the Lower Rhine drainage basin this poriod is represented by a paleosol of the Ariendorfer Interglacial (BRUNNACKER 1986) and in the Netherlands by two warmings (Hoogevan and Bantega) that precede a maximum of the younger glaciation (ter WEE 1983b). In Moravia this interval corresponds with deposition of sediments of the unit Neplachowice (MACOUN 1985, 1987). In the British Isles the described interval should be correlated with the younger part of the Hoxnian Interglacial, represented in a limnic-fluvial facies by the forest phases *Ho III* and *Ho IV* (*cf.* WEST 1977).

ODRA (DRENTHE, SAALE *1* + *2*, OLDRISOV, DNIEPER, MOSCOW ?, RISS *I*) GLACIATION

An icesheet of this glaciation reached its maximum in the Upper Odra drainage basin in Moravia, in the Dnieper drainage where it passed over the parallel of Kiev, and in the Lower Rhine drainage basin where it stopped to the north of Cologne (Text-fig. 1). In higher part of the Lower Rhine drainage basin this time favored a deposition of loesses of the horizon *H* with preserved frost structures (BRUNNACKER 1986). In Poland, in the Małopolska and Lublin uplands a till that delimits the maximum extent of this icesheet has been TL dated at about 290 ka BP (Text-fig. 2). New studies indicate that an icesheet of this glaciation has not entered the Don drainage basin (*cf.* VELICHKO & FAUSTOVA 1986) whereas its maximum extent in the eastern

Russian Plain could be close to that of the Moscow Glaciation (*cf.* ZUBAKOV 1986). In the British Isles this glaciation seems to be represented by the maximum extent of an icesheet of the Wolstonian Glaciation (BOWEN & *al.* 1986).

LUBAWA (GRABÓWKA, RÜGEN, KÄRLICHER, POSTSAALE, SHKLOV, ODINTSOVO ?, MIKULINO ?, RISS *I*/RISS *II*) INTERGLACIAL

In the German-Polish Lowland and in the European part of the Soviet Union this interglacial is documented in numerous floristic sites (*cf.* ERD 1973, 1978; YELOVICHEVA 1971, 1979; URBAN 1983; KRUPIŃSKI & MARKS 1985, 1986) that seem to indicate its bi-optimal characteristics (KRUPIŃSKI & *al.* 1987, LINDNER 1987). It is also documented by paleosols (STREMME 1982, MARUSZCZAK 1985, 1987; BRUNNACKER 1986, ZÖLLER & *al.* 1987), marine sediments from the section Kap Arkona on the Island of Rügen (ERD 1978, CEPEK 1967, 1986; WIEGANK 1982) and travertines, among others from Bilzingsleben (GŁAZEK & *al.* 1980). In that time two successive sea transgressions (Sztum and Tychnowy) with Lusitanian malacofauna in the Lower Vistula valley occurred (*cf.* Text-fig. 2). They have recently been considered by MAKOWSKA (1986) as an equivalent of the Eemian, in spite of their location above the marine sediments from Suchacz, TL dated at over 180 ka and over 210 ka BP. A possible older age of sediments of the Sztum sea is however also suggested by MAKOWSKA (1986, p. 47), when citing their TL age equal to 217 ka BP (PRÓSZYŃSKI 1980).

The majority of the mentioned sites of organic sediments, travertines and paleosols have been also TL or U/Th dated. The age reported as 230–180 ka BP seems to support their pre-Eemian stratigraphic location (LINDNER 1989) in spite of a considerable similarity to the Eemian floristic succession (presumably in the case of the lower optimum) or to the lower optimum from Ferdynandów (probably in the case of the upper optimum). Also amino--acid datings of some sites of marine sediments considered to be the Eemian (Fjösanger, Nowiny) in age, make them possible to represent the pre--Eemian and the post-Holstein interglacial (*cf.* MILLER & MANGERUD 1985). In Denmark the discussed interglacial is documented by a paleosol on the Drenthe till in the section Oksbøl (SJØRRING 1983) and in southwestern Sweden by marine sediments of the inter-Saalian interglacial from the section Margreteberg (PÅSSE & *al.* 1988). In the Netherlands and in the British Isles no sediments of this interglacial have been noted until the present, although in the Atlantic sediments at 48° to 78°N a warming of this age (225–150 ka BP) is expressed by a considerable lesser extent of polar waters (RUDDIMAN & *al.* 1977).

WARTA (WARTHE, SAALE *3*, SOZH, KALININ ?, MOSCOW ?, RISS *II*) GLACIATION

During this glaciation the Scandinavian icesheet advanced onto the Lower Elbe drainage basin, Central Poland as well as northern Byelorussia and the Russian Plain (Text-fig. 1). In Poland tills of this icesheet were TL dated at

180–150 ka BP (*cf.* LINDNER 1989) and maximum of its extent was estimated for about 150 ka BP (Text-fig. 2). In the European part of the Soviet Union, a maximum extent of this icesheet is delimited by the Sozh = Moscow Glaciation although the other opinions speak for a correlation of this glaciation with the Kalinin one (*cf.* ZUBAKOV 1986) and finding the Moscow Glaciation to be a stadial within the Dnieper Glaciation (*cf.* VELICHKO & FAUSTOVA 1986). In Poland a similar opinion is represented by MOJSKI (1985a) who takes the Warta Glaciation for a retreat stadial of the Odra Glaciation only.

The area of Lower Saxony and the Lower Rhine drainage basin were in that time completely ice-free (Text-fig. 1). In the Lower Rhine drainage basin a deposition of the loess *Ja* (BRUNNACKER 1986) and of the loesses TL dated in the Riegel section at 184–153 ka BP (ZÖLLER & *al.* 1987) occurred. A problem of an ice cap (local glaciation ?) of that time in the British Isles has not been solved yet. The Basement Till that is to represent the pre-Ipswichian glaciation (*cf.* BOWEN & *al.* 1986), may be regarded as its remains.

UPPER PLEISTOCENE (128–10 ka BP)

EEMIAN (EEM, MURAVINO, MGA, RISS *II*/WÜRM) INTERGLACIAL

This interglacial has the best paleontologic documentation amongst all the other distinguished interglacial episodes. In the zone of Scandinavian glaciations it is represented by numerous sites of organic sediments (*cf.* ANDERSEN 1965, CHEBOTAREVA 1972, FORSSTRÖM 1984, BEHRE & LADE 1986, LUNDQVIST 1986a, MAMAKOWA 1986) and many locations of marine deposits (MAKOWSKA 1986, MILLER 1986, ZAGWIJN 1986). In Poland in the section Błonie near Warsaw, organic sediments of this interglacial (JANCZYK-KOPIKOWA 1974) were TL dated at 125–108 ka BP (KARASZEWSKI 1974). In the Lower Vistula valley the Eemian Interglacial is represented by sediments of the Krastudy sea (Text-fig. 2) with the Lusitanian fauna, similar to that noted within the underlying sediments of the Sztum and Tychnowy seas (*cf.* MAKOWSKA 1986).

Loess sections of western and central Europe comprise this interglacial as represented by illuvial horizon of a lessivé soil that forms a lower part of the soil complex, being developed also at the beginning of the Wisła Glaciation (MARUSZCZAK 1987). In the Lower Rhine basin during this interglacial a paleosol developed in a top of the loessy horizon *Ja* (BRUNNACKER 1986) whereas in the Netherlands a deposition of typical marine and organic sediments occurred in the Eem River basin. The latter sequence indicates a sedimentary continuity during the preliminary part of the last glaciation (ZAGWIJN 1979, 1986). In the British Isles this interglacial is also represented in marine and inland facies, and named the Ipswichian Interglacial (BOWEN & *al.* 1986).

WISŁA (VISTULIAN, WEICHSEL, VALDAI, WÜRM) GLACIATION

This glaciation is the last Scandinavian glaciation of the European mainland. Its maximum extent (Text-fig. 1) runs from the Jutland Peninsula across the eastern part of the Lower Elbe drainage basin to the south of Berlin (Brandenburg Stade) and further to the east (Leszno Phase). In the Lower Vistula region the icesheet of this glaciation reached the Płock area (Poznań Phase *after* KOZARSKI 1986) and then to the east its snout advanced slightly northwards, tightly adhering to the elevations of older morainic plateaux (MARKS 1984) or developing vast outwash plains (MICHALSKA 1961, BER 1974). In the European part of the Soviet Union a maximum extent of the icesheet during this glaciation (Text-fig. 1) is delimited by location of its sediments in the Upper Neman drainage basin, at the watershed of the Dnieper

^{18}O Stage	WEST EUROPE (Cepek 1986, Brunnacker 1986, Zagwijn 1986)	ka (TL)	POLAND (Lindner 1984, 1988a)	SOVIET UNION (Zubakov 1986): Baltic regions, Byelorussia, NW. Ukraine	SOVIET UNION (Zubakov 1986): Russian Plain
	Glaciations: Interglacials:		Glaciations: Interglacials:	Glaciations: Interglacials:	Glaciations: Interglacials:
2-5d	WEICHSEL	10, 100	WISŁA	VALDAI	VALDAI
5e	Eem		Eemian	Muravino	Mga
6	WARTHE		WARTA	SOZH	KALININ
7	Rügen (Kärlicher)	200	Lubawa (Grabówka)	?Shklov	Mikulino (?) (Odintsovo?)
8	DRENTHE		ODRA	DNIEPER	DNIEPER (MOSCOW?)
9	Dömnitz	300	Zbójno	Prineman	Chekalin (Likhvin s.l.)
10	FUHNE		LIWIEC	KOLYSK	KALUGA
11	Holstein	400	Mazovian	Maloaleksandria	Likhvin
12	ELSTER 2		SAN 2 (WILGA)	BEREZINA	OKA
13-15	Voigtstedt (Jgl. III+IV)	500	Ferdynandów	Byelovezha	Roslavl
16	(Cromerian Complex) ELSTER 1 (GLACIAL B)	600	SAN 1	SERVECK	DON
17-19	Jgl. II		Małopolanian	Korchevo	Ilin (Akulovo)
20	GLACIAL A (ELSTER 1?)	700	NIDA	NOVOGOROD	?
21-23	Jgl. I	800	Podlasian	Jelizarov	Troitsk
24	MENAP	950	NAREW	NAREW	LIKOV

Fig. 4. Correlation of glaciations and interglacials in the marginal zone of the continental icesheets in Europe

and Dzvina as well as in the drainage basin of the Upper Dvina and Pechora. In the northern part of the North Sea (Text-fig. 1) this icesheet contacted with the ice cap of the British Isles, named there as that of the Devensian Glaciation (BOWEN & *al.* 1986).

The radiocarbon datings of organic sediments that underlie such furthest extent of glacial deposits of this glaciation or corresponding extraglacial series, prove that its maximum development occurred in the British Isles about 18–17 ka BP (BOWEN & *al.* 1986) and about 21–20 ka BP in Lithuania, northern Byelorussia and in the Russian Plain (ZUBAKOV 1986).

During the pre-maximum stage of this glaciation the meridional part of the Baltic Sea basin and its southeastern margin underwent 2 or 3 advances of the Scandinavian icesheet (*cf.* MAKOWSKA 1976, DROZDOWSKI 1980, MOJSKI 1980, ZARRINA 1982, LINDNER 1987). The TL datings of tills of these advances deposited in the Vistula valley suggest their possible further extents than previously expected (*cf.* BRYKCZYŃSKI & *al.* 1987, MARKS 1988).

During this glaciation its extraglacial zone has commonly been subjected to deposition of several beds of the so-called younger loesses, separated from one another by several interstadial paleosols and TL dated at 100–28 ka BP (MARUSZCZAK 1985, 1987). In the Lower Rhine basin these loesses are represented by the horizon *Jb* (BRUNNACKER 1986).

The melting of the icesheet was indicated by the development of several standstill zones, expressed in most cases by systems of destinct morainic landforms. These zones, both in northern Poland and southern Scandinavian Peninsula (KOZARSKI 1986, LUNDQVIST 1986b) were quite precisely dated by the radiocarbon method and by the analysis of the varved clays. The turn of the last glaciation and the Holocene was defined by a location of a snout of the Scandinavian icesheet about 10 ka BP *i.e.* at its standstill along the Salpausselkä moraines to the north of Helsinki and to the south of Stockholm (Text-fig. 3).

FINAL REMARKS

The presented stratigraphy in Central Europe results from correlations of glacial and interglacial units distinguished in the marginal zone of the Scandinavian icesheet (Text-figs 1–3).

The distinguished eight glaciations and seven interglacials document rhythms of the main climatic variation during the Pleistocene of Europe. These rhythms correlate well with global climatic variation, recorded by the ^{18}O stages in deep-sea sediments (Text-fig. 4).

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REFERENCES

ANDERSEN, S. T. 1965. Interglacialer og interstadialer i Danmarks kvarter. *Medd. Dansk Geol. Foren.*, **15**, 486–506. København.

BAŁUK, A. 1983. Nowe profile czwartorzędu okolic Przasnysza. *Kwart. Geol.*, **27** (2), 414–415. Warszawa.

— 1986. Czwartorzęd i jego podłoże w rejonie dolnej Narwi. Unpublished Ph. D. thesis; *Państw. Inst. Geol.*, Warszawa.

BEHRE, K.-E. & LADE, U. 1986. Eine Folge von Eem und 4 Weichsel-Interstadialen in Oerel/Niedersachsen und ihr Vegetationsablauf. *Eiszeitalter u. Gegenwart*, **36**, 11–36. Hannover.

BER, A. 1974. The Quaternary of the Suwałki Lake District. *Biul. Inst. Geol.*, **269**, 23–105. Warszawa.

BORÓWKO-DŁUŻAKOWA, Z. 1967. Palaeobotanical studies of Late Pleistocene deposits (Brørup) in the Konin-Marantów area. *Prace Inst. Geol.*, **48**, 81–136. Warszawa.

— 1977. Diagram palinologiczny z profilu Ceteń nad Drzewiczką. *In*: L. LINDNER & Z. MICHALSKA (*Eds*), Czwartorzęd zachodniej części regionu świętokrzyskiego. *Wyd. Geol.*; Warszawa.

BOWEN, D. Q., ROSE, J., Mc CABE, A. M. & SOUTHERLAND, D. G. 1986. Correlations of Quaternary glaciations in England, Ireland, Scotland and Wales. *In*: V. ŠIBRAVA, D. Q. BOWEN & G. M. RICHMOND (*Eds*), Quaternary Glaciations in the Northern Hemisphere. *Quatern. Sci. Rev.*, **5**, 299–340. *Pergamon Press*; Oxford.

BRUNNACKER, K. 1986. Quaternary Stratigraphy in the Lower Rhine Area and Northern Alpine Foothills. *In*: V. ŠIBRAVA, D. Q. BOWEN & G. M. RICHMOND (*Eds*), Quaternary Glaciations in the Northern Hemisphere. *Quatern. Sci. Rev.*, **5**, 373–380. *Pergamon Press*; Oxford.

— , LÖSCHER, M., TILLMANS, W. & URBAN, B. 1982. Correlation of the Quaternary terrace sequence in the lower Rhine Valley and North Alpine Foothills of Central Europe. *Quatern. Res.*, **18**, 152–173. *Academic Press*; New York.

BRYKCZYŃSKI, M., FEDOROWICZ, S. & OLSZAK, I. J. 1987. First TL datings of Vistulian sediments in the Vistula valley near Włocławek. *Zesz. Nauk. Polit. Śląskiej*, **56** (*Matematyka – Fizyka*; *Geochronometria*, **4**), 93–100. Gliwice.

BUTRYM, J. & GERLACH, T. 1985. Contribution à la chronostratigraphie des dépôts de glaciation Cracovienne (Mindel) dans l'avant-pays de Dynów. *Studia Geomorph. Carpat.-Balcanica*, 19, 29–35. Kraków.

CEPEK, A. G. 1967. Stand und Probleme der Quartärstratigraphie im Nordteil der DDR. *Ber. Deutsch. Ges. Geol. Wiss. A. Geol. Paläont.*, **12** (3/4), 375–404. Berlin.

— 1986. Quaternary Stratigraphy of the German Democratic Republic. *In*: V. ŠIBRAVA, D. Q. BOWEN & G. R. RICHMOND (Eds), Quaternary Glaciations in the Northern Hemisphere. *Quatern. Sci. Rev.*, **5**, 359–364. *Pergamon Press;* Oxford.

— & ERD, K. 1975. Das Holstein-Interglacial im Raum Neuruppin – ein neues pollenstratigraphisches Richtprofil und seine quartärgeologische Bedeutung. *Zt. Geol. Wiss.*, **3** (9), 1151–1178. Berlin.

CHEBOTAREVA, N. S. 1972. Die interglazialen Mikulino-Schichten in Nordwestern der Russischen Tafel; Teil I. *Ber. Deutsch. Ges. Geol. Wiss.*, *A*, **17** (3), 377–399. Berlin.

DROZDOWSKI, E. 1980. Chronostratigraphy of the Vistulian Glaciation on the Lower Vistula River. *Quatern. Studies in Poland*, **2**, 13–20. Warszawa–Poznań.

EHLERS, J., MEYER, K.-D. & STEPHAN, H.-J. 1984. Pre-Weichselian glaciations of North-West Europe. *Quatern. Sci. Rev.*, **3**, 1–40. *Pergamon Press*; Oxford.

ERD, K. 1973. Pollenanalytische Gliederung des Pleistozäns der Deutsches Demokratischen Republik. *Zt. Geol. Wiss.*, **1** (9), 1087–1103. Berlin.

— 1978. Pollenstratigraphie im Gebiet der Skandinavischen Vereisungen. *Schriftenr. Geol. Wiss.*, **9**, 99–119. Berlin.

FINK, J. & KUKLA, G. J. 1977. Pleistocene climates in Central Europe: At least 17 interglacials after the Olduvai Event. *Quatern. Res.*, **7** (3), 363–371. *Academic Press*; New York.

FORSSTRÖM, L. 1984. Eemian and Weichselian correlation problems in Finland. *Boreas*, **13**, 301–318. Oslo.

FULTON, R. J. & PREST, V. K. 1987. Introduction: The Laurentide Ice Sheet and its significance. *Géogr. Phys. et Quatern.*, **41** (2), 181–186. Montréal.

GŁAZEK, J., HARMON, R. S. & NOWAK, K. 1980. Uranian-series dating of the hominid-bearing travertine deposits of Bilzingsleben, GDR, and its stratigraphic significance. *Acta Geol. Polon.*, **30** (1), 1–14. Warszawa.

—, KOWALSKI, K., LINDNER, L., MŁYNARSKI, M., STWORZEWICZ, E., TUCHOŁKA, P. & WYSOCZAŃSKI-MINKOWICZ, T. 1977. Cave deposits at Kozi Grzbiet (Holy Cross Mts., Central Poland) with vertebrate and snail faunas of the Mindelian *I*/Mindelian *II* Interglacial and their stratigraphic correlations. *Proc. 7th Intern. Speleolog. Congr.*, 211–214. Sheffield.

—, LINDNER, L. & WYSOCZAŃSKI-MINKOWICZ, T. 1976. Interglacial Mindel *I*/Mindel *II* in fossil-bearing karst at Kozi Grzbiet in the Holy Cross Mts. *Acta Geol. Poln.*, **26** (3), 376–393. Warszawa.

GRUBE, F., CHRISTIANSEN, S., VOLLMER, T., DUPHORN, K., KLOSTERMANN, J. & MENKE, B. 1986. Glaciations in North West Germany. *In*: V. ŠIBRAVA, D. Q. BOWEN & G. M. RICHMOND (*Eds*), Quaternary Glaciationis in the Northern Hemisphere. *Quatern. Sci. Rev.*, **5**, 347–359. *Pergamon Press*; Oxford.

HALLBERG, G. R. 1986. Pre-Wisconsin glacial stratigraphy of the Central Plains Region in Iowa, Nebraska, Kansas and Missouri. *In*: V. ŠIBRAVA, D. Q. BOWEN & G. M. RICHMOND (*Eds*), Quaternary Glaciations in the Northern Hemisphere. *Quatern. Sci. Rev.*, **5**, 11–15. *Pergamon Press*; Oxford.

HARASIMIUK, M., MARUSZCZAK, H. & WOJTANOWICZ, J. 1988. Quaternary stratigraphy of the Lublin region, southeastern Poland. *Quatern. Studies in Poland*, **8**, 15–25. Warszawa–Poznań.

JANCZYK-KOPIKOWA, Z. 1974. The Eemian Interglacial sediments at Błonie near Warsaw. *Bull. Acad. Polon. Sci., Sér. Sci. Géol. Géogr.*, **22** (3/4), 147–150. Warszawa.

— 1981. Pollen analysis of the Pleistocene sediments at Kaznów and Krępiec. *Biul. Inst. Geol.*, **321**, 249–258. Warszawa.

— MOJSKI, J. E. & RZECHOWSKI, J. 1981. Position of the Ferdynandów Interglacial, Middle Polland, in the Quaternary stratigraphy of the North European Plain. Rept. 6 on the Session IGCP Project 73/1/24, Quaternary Glaciations in the Northern Hemisphere, pp. 146–162. Prague.

JURKIEWICZOWA, I., MAMAKOWA, K. & RÜHLE, E. 1973. Middle Pleistocene deposits south of Wyśmierzyce near Nowe Miasto on the Pilica River. *Folia Quatern.*, **43**, 1–26. Kraków.

KARASZEWSKI, W. 1974. Age of the Warsaw ice-dammed lake sediments. *Bull. Acad. Polon. Sci., Sér. Sci. Géol. Géogr.*, **22** (3/4), 151–154. Warszawa.

KEMPF, E. K. 1966. Das Holstein-Interglacial von Tönisberg im Rahmen des Niederrheinischen Pleistozäns. *Eiszeitalter u. Gegenwart*, **17**, 5–60. Öhringen.

KHURSEVICH, G. K. & LOGINOVA, L. P. 1986. Vozrast y paleogeographicheskye uslovya formirovanya drevnyeozernykh otlozheny Rechitskovo Pridnyeprovya (po danym uzuchenya diatomey). *In*: Pleistotsen Rechitskovo Pridnyeprovya Belorussy, pp. 76–142. *Nauka y Tekhnika*; Minsk.

KOZARSKI, S. 1986. Timescales and the rhytm of Vistulian geomorphic events in the Polish Lowland. *Czasop. Geograf.*, **57** (2), 247–270. Wrocław.

KRUPIŃSKI, K. M. & MARKS, L. 1985. Interglacial site at Losy near Lubawa in the Mazury Lakeland (preliminary report). *Kwart. Geol.*, **29** (3/4), 767–779. Warszawa.

— & — 1986. Interglacial sediments at Losy, Mazury Lakeland. *Bull. Polon. Acad. Sci., Earth Sci.*, **34** (4), 375–386. Warszawa.

—, — & SZYNKIEWICZ, A. 1987. Three new sites of the Middle Pleistocene fossil floras from the Bełchatów Mine, Central Poland. *Bull. Polon. Acad. Sci., Earth Sci.*, **35** (4), 359–377. Warszawa.

KUKLA, G. J. 1977. Pleistocene land-sea correlations; *I*. Europe. *Earth Sci. Rev.*, **13**, 307–374. Amsterdam.

LINDNER, L. 1984. An outline of Pleistocene chronostratigraphy in Poland. *Acta Geol. Polon.*, **34** (1/2), 27–49. Warszawa.

— 1987. Main stratigraphic problems in the Pleistocene of Poland. *Bull. Polon. Acad. Sci., Earth Sci.*, **35** (4), 343–358. Warszawa.

— 1988a. Glacial and interglacial units of the Pleistocene in the Holy Cross Mts. *Przegl. Geol.*, 1 (417), 31–39. Warszawa.

— 1988b. Glacial and interglacial units of the Pleistocene of the MiechówUpland and Nida Basin. *Przegl. Geol.*, 3 (419), 140–148. Warszawa.

— 1988c. An outline of Pleistocene stratigraphy of Biała Podlaska region (Eastern Poland) and attempt of correlation with neighboring area of the Soviet Union. *Przegl. Geol.*, 11 (427), 637—647. Warszawa.
— 1989. Main units of subdivision of the Pleistocene in Poland. *Geografia. A. Mickiewicz University Press*; Poznań.
— & BRYKCZYŃSKA, E. 1980. Organogenic deposits at Zbójno by Przedbórz, western slopes of the Holy Cross Mts and their bearing on stratigraphy of the Pleistocene of Poland. *Acta Geol. Polon.*, **30** (2), 153—163. Warszawa.
LUNDQVIST, J. 1986a. Stratigraphy of the Central Area of the Scandinavian glaciations. *In*: V. ŠIBRAVA, D. Q. BOWEN & G. M. RICHMOND (*Eds*), Quaternary Glaciations in the Northern Hemisphere. *Quatern. Sci. Rev.*, **5**, 251—268. *Pergamon Press*; Oxford.
— 1986b. Late Weichselian glaciation and deglaciation in Scandinavia. *In*: V. ŠIBRAVA, D. Q. BOWEN & G. M. RICHMOND (*Eds*), Quaternary Glaciations in the Northern Hemisphere. *Quatern. Sci. Rev.*, **5**, 269—292. *Pergamon Press*; Oxford.
MACOUN, J. 1985. Stratigraphie des Mittelpleitozäns Mähren in bezug auf das Quartär Europas. *Čas. Slez. Muz. Opava* (*A*), **34**, pp. 125—143 and 219—238. Opava.
— 1987. Stratigraphy of Middle Pleistocene continental glaciations in central and north--west Europe. *Sbor. Geol. Ved, Antropozoikum*, **18**, 159—169. Praha.
MAKHNACH, N. A. & RYLOVA, T. B. 1986. Stratigraphicheskoye razchlenenye drevnyeozernykh otlozheny Rechitskovo Pridneprovya (po materialam novykh palinologicheskykh isledovany). *In*: Pleistotsen Rechitskovo Prodnieprovya Belorussy, pp. 56—75. *Nauka y Tekhnika*; Minsk.
MAKOWSKA, A. 1976. Stratigraphy of tills exposed along the valley of the Lower Vistula area. *In*: W. STANKOWSKI (*Ed.*), Till its genesis and diagenesis. *Geografia*, **12**, 239—242. *A. Mickiewicz University Press*; Poznań.
— 1986. Pleistocene seas in Poland — sediments, age and palaeogeography. *Prace Inst. Geol.*, **120**, 1—74. Warszawa.
MAMAKOWA, K. 1983. Wstępne wyniki badań palinologicznych osadów z Przasnysza. *Kwart. Geol.*, **27** (2), 415—418. Warszawa.
— 1986. Lower boundary of the Vistulian and the Early Vistulian pollen stratigraphy in continous Eemian — Early Vistulian pollen sequences in Poland. *Quatern. Studies in Poland*, **7**, 51—63. Warszawa—Poznań.
MANKINEN, E. A. & DALRYMPLE, G. B. 1979. Revised geomagnetic polarity time scale for the interval 0—5 m.y. BP *J. Geophys. Res.*, **84** (2), 615—625. Washington.
MARCINIAK, B. 1983. Diatoms in the Mazovian Interglacial of the Lublin Upland. *Bull. Acad. Polon. Sci., Sér. Sci. Terre*, **30** (1/2), 77—85. Warszawa.
MARKS, L. 1984. Extent of ice sheet of Baltic (Würm) Glaciation in the vicinity of Dąbrówno and Uzdowo (western part of the Mazury Lakeland). *Biul. Geol. Univ. Warsz.*, **28**, 133—176. Warszawa.
— 1988. Relation of substrate to the Quaternary paleorelief and sediments, western Mazury and Warmia (northern Poland). *Geologia*, **14** (1), 1—76. *Akad. Górn.-Hutn. Press*; Kraków.
MARUSZCZAK, H. 1985. Problems of the stratigraphy and paleogeography of loesses in Poland. *In*: H. MARUSZCZAK (*Ed.*), Guide-book Intern. Symposium "Problems of the stratigraphy and paleogeography of loesses", pp. 63—80. *M. Curie-Skłodowska University Press*; Lublin.
— 1987. Stratigraphy of European loesses of Saalian Age: Was the Inter-Saalian a warm interstadial or a cold interglacial? *In*: M. PÉCSI (*Ed.*), Loess and environment. *Catena, Supplement*, **9**, 67—80. Braunschweig.
MENKE, B. 1968. Beiträge zur Biostratigraphie des Mittelpleistozäns in Norddeutschland (pollenanalytische Untersuchungen aus Westholstein). *Meyniana*, **18**, 35—42. Kiel.
— 1970. Ergenbnisse der Pollenanalyse zur Pleistozän-Stratigraphie und zur Pliozän-Pleistozän--Geneze in Schleswig-Holstein. *Eiszeitalter u. Gegenwart*, **21**, 5—21. Öhringen.
MICHALSKA, Z. 1961. Stratigraphy of the Pleistocene and paleomorphology of the northeastern part of Mazowsze (Central Poland). *Studia Geol. Polon.*, **7**, 1—102. Warszawa.
MILLER, U. 1977. Pleistocene deposits of the Alnarp Valley southern Sweden — Microfossils and their stratigraphical application. *University of Lund. Dept. Quatern. Geol., Thesis*, **4**, 1—125. Lund.
— 1986. An outline of the Nordic natural landscape in the Late Pleistocene. *Striae*, **24**, 9—14. Uppsala

MILLER, G. H. & MANGERUD, J. 1985. Aminostratigraphy of European marine interglacial deposits. *Quatern. Sci. Rev.*, **4**, 215–278. *Pergamon Press*; Oxford.

MOJSKI, J. E. 1980. Vistulian stratigraphy in the glaciated area of the Polish Lowlands. *Quatern. Studies in Poland*, **2**, 77–98. Warszawa–Poznań.

— 1985a. Geology of Poland, *1*, Stratigraphy *3b*, Cainozoic, Quaternary, pp. 1–244. *Wyd. Geol.*; Warszawa.

— 1985b. Czwartorzęd. *In*: W. POŻARYSKI (*Ed.*), Tablica stratygraficzna obszaru Polski i krajów ościennych na tle Europy Centralnej. *Wyd. Geol.*; Warszawa.

MÖRNER, N.-A. 1981. Eustasy, paleoglaciation and palaeoclimatology. *Geol. Rundschau*, **70** (2), 691–702. Stuttgart.

MÜLLER, H. 1974. Pollenanalytische Untersuchengen und Jahres schichtenzählung an der Holstein-zeitlischen Keiselgur von Munster-Breloh. *Geol. Jb.*, *A*, **21**, 107–140. Hannover.

PÅSSE, T., ROBERTSSON, A.-M., MILLER, U. & KLINGEBERG, F. 1988. A Late Pleistocene sequence of Margreteberg, southwestern Sweden. *Boreas*, **17**, 141–163. Oslo.

PRÓSZYŃSKI, M. 1980. Termoluminescencyjne wskaźniki wieku. *Komitet Badań Czwart. PAN, Sprawozd. z Bad. Nauk.*, 3, 65–103. Warszawa.

RÓŻYCKI, S. Z. 1980. Principles of stratigraphic subdivisions of Quaternary of Poland. *Quatern. Studies in Poland*, **2**, 99–106. Warszawa–Poznań.

RUDDIMAN, W. F., SANCETTA, C. D. & Mc INTYRE, A. 1977. Glacial – interglacial response rate of subpolar North Atlantic waters to climatic change: the record in oceanic sedements. *Phil. Trans. R. Soc.*, *B*, **280**, 119–142. London.

RZECHOWSKI, J. 1986. Pleistocene till stratigraphy in Poland. *In*: V. ŠIBRAVA, D. Q. BOWEN & G. M. RICHMOND (*Eds*), Quaternary Glaciations in the Northern Hemisphere. *Quatern. Sci. Rev.*, **5**, 365–372. *Pergamon Press*; Oxford.

SANCHIZ, B. & SZYNDLAR, Z. 1984. Pleistocene amphibian fauna from Kozi Grzbiet in the Holy Cross Mts. *Acta Geol. Polon.*, **34** (1/2), 51–62. Warszawa.

SELLE, W. 1960. Das Interglacial von Praschnitz. *Geol. Jb.*, **77**, 319–327. Hannover.

SHACKLETON, N. J. & OPDYKE, N. D. 1973. Oxygen isotope and paleomagnetic stratigraphy of equatorial Pacific core V28–238: Oxygene isotope temperatures and ice volumes on a 10^5 and 10^6 years scale. *Quatern. Res.*, **3** (1), 39–55. *Academic Press*; New York.

SHOTTON, F. W. 1986. Glaciations in the United Kingdom. *In*: V. ŠIBRAVA, D. Q. BOWEN & G. M. RICHMOND (*Eds*), Quaternary Glaciations in the Northern Hemisphere. *Quatern. Sci. Rev.*, **5**, 293–298. *Pergamon Press*; Oxford.

SJØRRING, S. 1983. The glacial history of Denmark. *In*: J. EHLERS (*Ed.*), Glacial deposits in North-West Europe, pp. 163–179. *A. A. Balkema*; Rotterdam.

STREMME, H. E. 1982. Pedostratigraphie in Schleswig-Holstein. IGCP Project 24: Quaternary Glaciations in the Northern Hemisphere, Rpt. 7, 223–231. Prague.

SUDAKOVA, N. G. & ALESHINSKAYA, Z. V. 1974. Ranny y sredny pleistotsen. *In*: Geokhronologya SSSR, 3, pp. 49–55. Leningrad.

SZYNDLAR, Z. 1981. Early Pleistocene reptile fauna from Kozi Grzbiet in the Holy Cross Mts. *Acta Geol. Polon.*, **31** (1/2), 81–101. Warszawa.

ŠIBRAVA, V. 1986. Correlation of European glaciations and their relation to the deep--sea record. *In*: V. ŠIBRAVA, D. Q. BOWEN & G. M. RICHMOND (*Eds*), Quaternary Glaciations in the Northern Hemisphere. *Quatern. Sci. Rev.*, **5**, 433–441. *Pergamon Press*; Oxford.

URBAN, B. 1980a. Zur Stratigraphie des Frimmersdorf-Interglazials und Krefeld-Interglazials in der Niederrheinischen Bucht. *Decheniana*, 133, 224–228. Bonn.

— 1980b. Paläoökologische Untersuchungen zum Krefeld-Interglazial am Niederrhein. *Eiszeitalter u. Gegenwart*, **30**, 73–88. Hannover.

— 1983. Biostratigraphic correlation of the Kärlich Interglacial, Northwestern Germany. *Boreas*, **12** (2), 83–90. Oslo.

WEE, M. W. ter 1983a. The Elsterian Glaciation in the Netherlands. *In*: J. EHLERS (*Ed.*), Glacial deposits in north-west Europe, pp. 413–415. *A. A. Balkema*; Rotterdam.

— 1983b. The Saalian Glaciation in the northern Netherlands. *In*: J. EHLERS (*Ed.*), Glacial deposits in north-west Europe, pp. 405–412. *A. A. Balkema*; Rotterdam.

WEST, R. G. 1977. Pleistocene geology and biology with expecial reference to the British Isles, pp. 1–440. *Longman*; London–New York.

WIEGANK, F. 1982. Ergebnisse magnetostratigraphischer Untersuchungen im höheren Känozoikum der DDR. *Zt. Geol. Wiss.*, **10** (6), 737—744. Berlin.
WOJTANOWICZ, J. 1985. The TL dated of the Quaternary deposits at Giedlarowa (Sandomierz Basin) and its palaeogeographic importance. *Studia Geomorph. Carpat.-Balcanica*, **19**, 37—44. Kraków.
VELICHKO, A. A. & FAUSTOVA, M. A. 1986. Glaciations in the East European Region of the USSR. *In:* V. ŠIBRAVA, D. Q. BOWEN & G. M. RICHMOND (*Eds*), Quaternary Glaciations in the Northern Hemisphere. *Quatern. Sci. Rev.*, **5**, 447—461. *Pergamon Press*; Oxford.
YELOVICHEVA, J. K. 1971. Kharakteristika mezhlednikovykh otlozheni vskritikh skvazhinoy Nizhninsky-Rov-30. *Dokl. AN BSSR*, **15** (9), 833—836. Minsk.
— 1979. Shklovskye (Roslavlskye) mezhlednikovye otlozhenya Belorussy y smezhnykh territory, pp. 1—184. *Nauka y Tekhnika*; Minsk.
ZAGWIJN, W. H. 1979. Early and Middle Pleistocene coastlines in the southern North Sea basin. *In*: E. OELE, R. T. E. SCHUTTENHELM & A. J. WIGGERS (*Eds*), The Quaternary History of the North Sea. *Acta Univ. Ups. Symp. Univ. Ups. Annum Quinqentesimum Celebrantis*, **2**, 31—42, Uppsala.
— 1986. The Pleistocene to the Netherlands with special reference to glaciation and terrace formation. *In*: V. ŠIBRAVA, D. Q. BOWEN & G. M. RICHMOND (*Eds*), Quaternary Glaciations in the Northern Hemisphere. *Quatern. Sci. Rev.*, **5**, 341—346. *Pergamon Press*; Oxford.
ZARRINA, E. P. 1982. Stratigraphy and chronology of the Upper Pleistocene in the glacial region of the European part of the USSR. *Quatern. Studies in Poland*, **3**, 147—155. Warszawa—Poznań.
ZÖLLER, L., STREMME, H. & WAGNER, G. A. 1987. Thermolumineszenz-Datierung an Löss-Paläoboden-Sequenzen von Nieder-, Mittel- und Oberrhein. *Max-Planck-Inst. f. Kernphysik*, **29**, 1—25. Heidelberg.
ZUBAKOV, V. A. 1986. The global climatic events of the Pleistocene, pp. 1—287. *Gidrometeoizdat*; Leningrad.
— 1988. Climatostratigraphic scheme of the Black Sea Pleistocene and its correlation with the oxygen-isotope scale and glacial events. *Quatern. Res.*, **29**, (1), 1—24. *Academic Press*; New York.
— & BORZENKOVA, I. I. 1983. Paleoclimates of the Upper Cenozoic, pp. 1—214. *Gidrometeoizdat*; Leningrad.

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STRATYGRAFIA ZLODOWACEŃ I ZASIĘGI LĄDOLODU PLEJSTOCEŃSKIEGO W EUROPIE

(Streszczenie)

W pracy przedstawiono następstwo plejstoceńskich zlodowaceń kontynentalnych udokumentowanych w Europie poziomami osadów lodowcowych w brzeżnych strefach zasięgu lądolodu skandynawskiego (fig. 1). Podstawowych danych dla identyfikacji tych zlodowaceń i oddzielających je interglacjałów dostarczył obszar Niżu Środkowoeuropejskiego, a zwłaszcza obszar Polski (fig. 2). Wyróżniono 8 zlodowaceń (Narwi = Menap; Nidy = Glacial *A*; Sanu *1* = Glacial *B* = Elster *1*; Sanu *2* = Elster *2*; Liwca = Fuhne; Odry = Drenthe = Saale *1* + *2*; Warty = Warthe = Saale *3*; Wisły = Weichsel = Vistulian) oddzielonych 7 interglacjałami (podlaski

= Cromerian *I*; małopolski = Cromerian *II*; ferdynandowski = Cromerian *III* + *IV* = Voigtstedt; mazowiecki = Holstein *s.s.*; Zbójna = Dömnitz; lubawski = Rügen; eemski). Nie potwierdzono możliwości wyróżnienia wcześniej wydzielanego (*por.* LINDNER 1984, 1987) zlodowacenia Mogielanki i interglacjału Pilczycy. Wykazano, że zarówno w basenie Morza Północnego, na Niżu Niemieckim oraz we wschodniej części Równiny Rosyjskiej nie należy doszukiwać się osadów lodowcowych odpowiadających tym wszystkim zlodowaceniom kontynentalnym, jakie miały miejsce w strefie południowowschodniego obramowania Morza Bałtyckiego. Dzięki licznym datowaniom metodami TL i radiowęgla osadów lodowcowych oraz podścielających i przykrywających je serii organogenicznych przedstawiono próbę określenia wieku głównych stref brzeżnych lądolodu skandynawskiego w środkowej Europie i w południowej Skandynawii (fig. 3). Przedstawiono korelację wyróżnionych zlodowaceń i dzielących je interglacjałów na kontynencie europejskim (fig. 4), a także próbę ich korelacji z analogicznymi jednostkami na obszarze Wysp Brytyjskich.