An outline of Pleistocene chronostratigraphy in Poland

ABSTRACT: The Quaternary in Poland consists of the Protopleistocene (1,870,000—850,000 y. BP), the Pleistocene (850,000—100,000 y. BP), and the Holocene (last 100,000 y. BP). Within the Protopleistocene the Otwock Cooling and the Celestynów Warming are distinguished. The Pleistocene includes 9 main glaciations (Narew, Nida, San, Mogielenka, Wilga, Łwów, Odra, Warta, Wisła) separated by 8 interglacials (Przasnysz, Kozi-Grzbiet, Pilczyca, Ferdynandów, Barkowice-Mokre, Zbójno, Gresówka, Ermian). A climatic characteristics and ages of all these episodes are presented on the basis of paleomagnetic, thermoluminescence, FCl/P, and $^{14}$C datings, which also enabled a chronostratigraphic correlation of the distinguished episodes with the equivalent units in the neighboring countries and in deep-sea sediments.

INTRODUCTION

Recent investigations of the Quaternary deposits in Poland have resulted in the recognition of climato- and chronostratigraphic succession, extents of Scandinavian glaciations and of separating interglacials (see Text-fig. 1).

The investigated sections have recently required, but paleontologic data, the absolute datings received by various methods ($^{14}$C, TL, FCl/P, and partly paleomagnetism). These data enable a chronostratigraphic correlation with the Quaternary units in Europe (Text-figs 8 and 9), and with deep-sea sediments that record a full sequence of Quaternary climatic changes (cf. Shackleton & Opdyke 1973, Kellogg 1980, Wysoczański-Minkowicz 1980, Zubakov & Borzenkova 1983).

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Fig. 1. Extents of the Scandinavian icesheets in Poland

1 — Narew Glaciation, 2 — Nida Glaciation, 3 — San Glaciation, 4 — Mogielanka Glaciation, 5 — Wilga Glaciation, 6 — Liwiec Glaciation, 7 — Odra Glaciation, 8 — Warta Glaciation, 9 — Wisła Glaciation, 10 — sea bays during the Barkowice-Mokre (Mazovian = Holstein) Interglacial, 11 — sea bay during the Eemian Interglacial.

Location of sites mentioned in the text:

Bonifay 1980, Nikiforova & al. 1980, Wiegank 1982, Zubakov & Borzenkowa 1983). With reference to the scheme presented by Różycki (1980), the Quaternary of Poland starts with the Protopleistocene, comprising the time interval from 1,870,000 to 950,000 y. BP that is the whole middle part of the Matuyama Epoch, since the beginning of the Olduvai Event to the beginning of the Jaramillo Event (Mankinen & Dalrymple 1979). The Protopleistocene is followed by the Pleistocene, lasting from 950,000 to 100,000 y. BP. The latter is subdivided into three parts: the Early Pleistocene (950,000 to 730,000 y. BP), i.e. the youngest part of the Matuyama Epoch, since the beginning of the Jaramillo Event until the Matuyama/Brunhes boundary; the Middle Pleistocene (730,000 to 128,000 y. BP) which comprises the principal part of the Brunhes Epoch; and the Late Pleistocene (128,000 to 10,000 y. BP) which corresponds to the younger part of the Brunhes Epoch. The youngest part of this epoch, comprising the last 10,000 y. is defined as the Holocene.

PROTOPLEISTOCENE

In the territory of Poland the Protopleistocene supplies no evidences of any Scandinavian glaciations. The section at Ponurzyca near Warsaw (Text-fig. 1) yields a bipartite depositional sequence. Its older part represents the first Quaternary cooling, defined as the Otwock Cooling; the younger part proves a considerably warmer climate and is called the Celestynów Warming (Baraniecka 1975, Stuchlík 1975). Mojski (1982) defined these two parts of the Protopleistocene as the Krasnystaw Formation. In eastern and Central Poland it is composed of clastic deposits which usually fill deep river valleys incised in the Early Tertiary, and the Pliocene sediments of the Kozięnice Formation (Text-figs 2—3).

OTWOCK COOLING

In the Ponurzyca section this cooling is recorded by lacustrine series that overlies the Tegelen silts. As compared with the Tegelen, this period showed a distinct climatic deterioration. The previous mesophilous deciduous forests were replaced by pine-spruce forests with numerous birch-trees. This interval corresponds to the Eburonian of West Europe. The floristic site at Kaznów, Lublin Upland, and sediments of the Żabia Cave, Polish Jura, with abundant vertebrate remains (Text-figs 1 and 8), are also of the same age. The Otwock Cooling can be correlated with the 18O horizons 36—30 of deep-sea sediments.

CELESTYNÓW WARMING

This warming is represented by sands and silts, underlain in the Ponurzyca section (Text-fig. 1) by the deposits of the Otwock Cooling and overlain by gravels and sands with Scandinavian material, correlated with the Narew Glaciation. From a floristic point of view, the Celestynów Warming is an equivalent of the Waalian Interglacial of the Netherlands. At that time Central Poland was densely forested, whilst in southern Poland the Pełaniec gravels without any Scandinavian material

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**Fig. 2. Territory of Poland during the Pliocene**

**PLIOCENE:** 1 — limits of variegated clays deposition, 2 — main alluvial fans; **QUATERNARY:** 3 — southernmost extent of the Scandinavian erratics
were deposited. Similar gravels fill deep river valleys in the Holy Cross Mts. The warming lasted since about 1,350,000 to 950,000 y. BP and can be correlated with the $^{18}$O horizons 29—25 of deep-sea sediments.


EARLY PLEISTOCENE

NAREW GLACIATION

During this glaciation the Scandinavian icesheet occupied north-eastern and partly western Poland (Text-fig. 1) and could even reach the Lublin Upland. The deposits of this glaciation are best evidenced in the northern and north-eastern Mazovian Lowland. Near Wyszków (Text-fig. 4) and Przasnysz they are represented by two or three tills, separated by silts and sands. The Narew Glaciation lasted since about 950,000 to 900,000 y. BP and can be correlated with the $^{18}$O horizon 24 of deep-sea sediments.


PRZASNYSZ INTERGLACIAL

This interglacial is represented by an almost 30 m thick fluvial series near Wyszków (Text-fig. 4), filling a river valley incised in tills of the Narew Glaciation and in the underlying Miocene deposits. This series is composed of sandy-gravel deposits of several erosive-accumulative cycles.

Fig. 3. Geological section of the Tertiary and Quaternary deposits near Kozienice (adapted from; Mojski 1982)
Tr — older Tertiary, P-Ko — Kozienice Formation of Pliocene age, Kr — Krasnystaw of Proto-Pleistocene age
In the Przasnysz section (Text-fig. 1) this warming is documented by a 50 m thick silty-sandy sequence with pollens of dense deciduous forests which developed during a climatic optimum between two heights of *Abies*. According to some authors, the presence of fir-hornbeam and alder-spuce horizons and TL datings (686 000—615 000 y. BP) seem to refer this interval to a younger interglacial.

Fluvial sediments from the Brus section, Lublin Upland (TL dating: 785 500—761 500 y. BP), are also assigned to the Przasnysz Interglacial. This interglacial is correlated with the $^{18}$O horizons 23—21 of deep-sea sediments.


MIDDLE PLEISTOCENE

NIDA GLACIATION

During this glaciation, previously considered as the older South-Polish Glaciation, the Scandinavian icesheet reached the northern slopes of the Sudetes and of the Central Polish Uplands. The glacial lobes entered the Odra valley upstream Gościęcin and the northern part of the Sandomierz Depression. During a retreat the icesheet deposited a locally bimorphic till, particularly distinct in the central and northern Holy Cross region, in the deeply incised valleys of the Lublin Upland, and throughout the western Sudetic Foreland.

Paleomagnetic determinations (Brunhes/Matuyama boundary) and FCI/P datings of bone remains at Kozi Grzbiet prove the maximum of the Nida Glaciation to have occurred about 730 000—640 000 y. BP. In the same time the earliest loess was deposited (Text-fig. 8) in valleys of the Holy Cross region. In the Lublin Upland the ice-dam sediments of the middle part of this glaciation are known from Wólka Petryłowska (TL dating: 732 000—660 000 y. BP).

The Nida Glaciation is correlated with the $^{18}$O horizon 20 of deep-sea sediments (dated for 729 000—706 000 y. BP).


KOZI-GRZBIET INTERGLACIAL

This interglacial was identified due to studies over a karst site at Kozi Grzbiet in the Holy Cross Mts (Text-figs 1 and 8). Its speleothems contain, but faunistic remains, feldspars and heavy minerals coming from glacifluvial sediments of the Nida Glaciation. A rich faunistic
Geological section of the Quaternary sediments near Wyszków (adapted from: Straszewska 1968)

- M - Miocene; P - Pliocene; NAREW GLACIATION: 1 tills, sands and silts; PRZASNYSZ INTERGLACIAL: 2 fluvial sands and gravels; NIDA and SAN GLACIATION: 3 ice-dam clays and silts, glacifluvial sands, 4 tills; PILCZYCA INTERGLACIAL: 5 fluvial sands, gravel and silts; MOGIELANKA GLACIATION: 6 till; FERDYNANDÓW INTERGLACIAL: 7 fluvial sands and gravels; WILGA GLACIATION: 8 ice-dam clays and silts; BARKOWICE-MOKRE INTERGLACIAL: 9 fluvial sands, gravels and silts; LIWIEC GLACIATION: 10 till; ZBOJNO INTERGLACIAL: 11 fluvial gravels and sands; ODRA GLACIATION: 12 till; GRABÓWKA INTERGLACIAL: 13 sands and gravels; WARTA GLACIATION: 14 till of the older stadial, 15 interstadial sands and gravels, 16 till of the younger stadial, 17 glacifluvial sands and gravels; EEMIAN INTERGLACIAL and WISŁA GLACIATION: 18 fluvial sands and gravels, 19 aeolian sands; HOLOCENE: 20 fluvial sands and gravels.
assemblage of the speleothems, yielding numerous snail shells, amphibian, reptilian and mammalian remains, proves their Late Cromerian age. A similar conclusion arises from the FCI/P dating of bones (700 000 — 550 000 y. BP), pointing out to the so-called Cromer II of the Netherlands. Paleomagnetic investigations of the speleothem show positive magnetic polarization (Brunhes), and therefore an age younger than the optimum of the Cromer Interglacial of the Netherlands (cf. Montfrans 1971).

A similar conclusion arises from the FClIP dating of bones (700 000 — 550 000 y. BP), pointing out to the so-called Cromer II of the Netherlands. Paleomagnetic investigations of the speleothem show positive magnetic polarization (Brunhes), and therefore an age younger than the optimum of the Cromer Interglacial of the Netherlands (cf. Montfrans 1971).

A floristic characteristics of the Kozi-Grzbiet Interglacial is recorded by organogenic sediments of the Jasionka section near Rzeszów (Text-fig. 1). These sediments enclose pollens of a succession from pine through mixed forests (with small areas covered by deciduous forests) to a very short-lasting subarctic environment and the following, progressive expansion of the Pinus-dominated forests. Outside the extent of the Scandinavian icesheet, in the northern Tatra Foreland, this interglacial is represented by organogenic sediments at Szafary near Nowy Targ (Text-fig. 1). In deep-sea sediments it is correlated with the 18O horizon 19, dated for 706 000—688 000 y. BP.

SAN GLACIATION

During this glaciation, previously considered as the younger South-Polish Glaciation, the Scandinavian icesheet reached the Sudetes and the Carpathians (Text-fig. 1) spreading upslope to about 450 m a.s.l. In southern Poland the icesheet deposited a till underlain by the till of the Nida Glaciation or separated from the latter by fluvial or glacifluvial sediments. In the Łódź and the Central Polish Uplands a bipartition of this till is noted. Its lower part occupies a smaller area and seems to represent the pre-maximum stadial. Such bipartition is exemplified by the section exposed over the Tertiary brown-coal mine at Belchatów (Text-fig. 5) where the till is overlain by sands (TL dating: 558 000 y. BP). In the Holy Gross region the tills of the San Glaciation are underlain by loesses with malaco fauna. In deep-sea sediments the bipartite San Glaciation is correlated with the 18O horizons 18—16, dated for 688 000 to 592 000 y. BP.


PILCZYCA INTERGLACIAL

This interglacial separates the San Glaciation from the Mogielanka Glaciation and has been previously considered as an interstadial in the younger part of the San Glaciation. The borehole data, geomorphologic...
analysis of the area and paleosols under the tills allow to consider this interval as an interglacial warming. Such a conclusion arises also from correlations of the Quaternary climatic changes in Poland and in the neighboring countries (Text-fig. 8) as well as from TL dating for 588 000 y. BP of the supra-till sands in the Belchatów section (Text-fig. 5). This interval is correlated in deep-sea sediments with the \(^{18}O\) horizon 15, defined as a distinct climatic warming from 592 000 to 542 000 y. BP. In the Lublin Upland this interglacial is called the Luszawa Warming.


MOGIELANKA GLACIATION

During this glaciation, previously defined as the younger (post-maximum) stadial of the San Glaciation, the Scandinavian icesheet reached the northern slopes of the Central Polish Uplands and occupied the Belchatów region, and Lower Wieprz drainage basin (Text-fig. 1). It deposited the youngest till of the South-Polish glaciations, noted under the tills of the Middle-Polish glaciations near Belchatów, Podgórze, Ferdynandów and Syrøki on the Wieprz River. In the Lublin Upland (Wólka Petryłowska) the silts under this till were TL dated for 544 400—532 000 y. BP. In the western Holy Cross margins and in the Ferdynandów region a loess was deposited at that time (Text-fig. 8). In deep-sea sediments this glaciation is correlated with the \(^{18}O\) horizon 14, dated for 542 000—500 000 y. BP.


FERDYNANDÓW INTERGLACIAL

This interglacial has been previously considered as an equivalent of the earliest, i.e. the optimum part of the Mavovian Interglacial. The organogenic sediments of this age occur i.a. at Ferdynandów, Podgórze, and Buczyńa near Belchatów (Text-fig. 1) and represent a bi-optimal floristic succession, quite different from that of the Barkowice-Mokre Interglacial (see below). Near Belchatów (Text-fig. 5), the Ferdynandów Interglacial sediments overlie a till of the San Glaciation and the sands of the Pilecyza Interglacial (TL dating: 558 000 y. BP). They are covered there by ice-dam deposits (TL dating: 456 000 y. BP) of the Wilga Glaciation. In northern Poland (Mochowo) this period is represented by a sandy-clayey series (TL dating: 483 700 y. BP). In deep-sea sediments this in-
Geological section of the deposits in the western part of the brown-coal open-mine at Belchatów

(adapted from: Halusczak 1982) with the thermoluminescence dating (after: Butrym & al. 1982, and personal communication)

TERTIARY: 1 sands and silts; SAN GLACIATION: 2 till of the older stadial, 3 interstadial sands and silts, 4 till of the younger stadial with overlying sands of the Pliczycia Interglacial; FERDYNANDOW INTERGLACIAL: 5 fluvial sands and silts with the Buczyna organogenic sequence; WILGA GLACIATION: 6 ice-dam sands and silts; GRABOWKA INTERGLACIAL: 7 fluvial gravels, sands and silts; WARTA GLACIATION: 8 glacifluvial sands, 9 ice-dam clays and silts, 10 glacifluvial sands, 11 lower till, 12 upper till
terglacial is recorded by the $^{18}$O horizon 13 dated for 500 000—472 000 y. BP.


WILGA GLACIATION

During this glaciation the Scandinavian icesheet occupied north-eastern Poland and reached the Lower Wieprz and Lower Pilica drainage basin (Text-fig. 1). It deposited a till, a mineralo-petrographic composition of which differs much from those of tills of earlier glaciations. In the forefield of the icesheet, particularly within the northerly running river valleys, ice-dam lakes were formed at that time, the clays and silts (TL dating: about 456 000 y. BP) of which are noted e.g. in the Belchatów section (Text-fig. 5). In the upper part of the Kozi Grzbiet section a winnowing of older glaciifluvial sands occurred during this period (440 000—400 000 y. BP). In deep-sea sediments this interval is recorded by the $^{18}$O horizon 12, dated for 472 000—400 000 y. BP.


BARKOWICE-MOKRE INTERGLACIAL

This interglacial, called also the Mazovian Interglacial, has been described from many sites of organogenic sediments i.a. from Barkowice Mokre, Ciechanki Krzesimowskie, Krępiec, Gościęcin, Węgorzewo, Boczów (Text-fig. 1).

In the Barkowice Mokre section the succession starts with pollen of birch-pine forests, followed by spruce-pine to the climatic optimum with fir-hornbeam forests. A similar succession was noted in the Krępiec section (Text-fig. 6A).

In cave deposits the interglacial optimum is represented by a bonebed with Ursus spelaeus Rosenmüller & Heinroth in the Draby section, Polish Jura (Text-figs 1 and 8), and FCI/P dated for 440 000—320 000 y. BP. In northern Poland (Mochowo) the river deposits were TL dated for 379 000—389 000 y. BP whereas in the Brus section, Lublin Upland, for 384 200 y. BP.

In deep-sea sediments this interglacial is correlated with the $^{18}$O horizon 11, dated for 400 000—367 000 y. BP. According to Müller (1974) it lasted 15 000—16 000 years.

LIWIEC GLACIATION

The Scandinavian icesheet of this glaciation occupied north-eastern Poland and deposited a till to the north-east of Warsaw (Text-fig. 1), among others in the Wyszków area (Text-fig. 4). This till, previously considered for an evidence of the pre-maximum icesheet advance (GIII-2) during the Odra Glaciation, overlies the sands and gravels of the second alluvial cycle of the Mazovian Interglacial (as defined by Różycki 1972).

Fig. 6. Geological sections of the Quaternary deposits at Krępiec (A) and Ciechanki Krzesimowskie (B); adapted from: Harasimiuk & Henkiel (1981)

PROTOPLEISTOCENE: 1 regolith and weathering clays, 2 silts; SAN GLACIATION: 3 till, 4 varved clays; PIŁCZYCA INTERGLACIAL: 5 sandy silts, 6 fluvial sands; MOGIŁANKA GLACIATION: 7 glacifluvial gravels; BARKOWICE-MOKRE INTERGLACIAL: 8 silts and sandy silts, 9 fluvial sands, 10 silts and clays, 11 diatomites, 12 peat and gyttja; ZBOJNO INTERGLACIAL: 13 fluvial sands and gravels, 14 humus sands with peat intercalations; ODRA GLACIATION: 15 tills and glacial sands with gravels; EEMIAN INTERGLACIAL: 16 fluvial sands; WISŁA GLACIATION: 17 sandy-silty elluvial covers with aeolian components, 18 loess; HOLOCENE: 19 muds and peats

P — section with pollen (Janczyk-Kopikowa 1981) and diatomological (Marciniak 1983) analyses
The ice-dam silts deposited in the icesheet forefield (Zbójno section; Text-fig. 1) are TL dated for 380 000 y. whereas the alluvia in the Wąchock section (Text-fig. 1) for 352 000 y. BP. An accumulation of the oldest loess of the Nieledew section (Text-fig. 8) occurred also at that time (TL dating: 367 800 ± 44 00 to 351 600 ± 42 000 y. BP).

In deep-sea sediments this glaciation is correlated with the ¹⁸O horizon 10 dated for 367 000—345 000 y. BP.


ZBÓJNO INTERGLACIAL

During this interglacial the erosion progressed locally through all the deposits of the Liwiec Glaciation down to the underlying sediments of the Barkowice-Mokre Interglacial (Text-fig. 6A). The organogenic deposits are known in the Zbójno section where they are underlain by ice-dam silts (TL dating: 388 000 y. BP) and covered by a till of the Odra Glaciation. A palynological analysis of the Zbójno section proves that during the climatic optimum of this interglacial deciduous forests with Tilia (to 45°/a), Corylus, Quercus and Picea predominated. The organogenic sediments from the Konin-Marantów section seem to be also of the same age.

The TL datings of older loess in the Nieledew section indicate that the oldest paleosol (developed on the loess dated for 367 800 ± 44 000 y. BP) should be correlated with the Zbójno Interglacial. In deep-sea sediments this interglacial is represented by the ¹⁸O horizon 9 dated for 347 000—297 000 y. BP.


ODRA GLACIATION

During this glaciation, defined also as the maximum Middle-Polish Glaciation, the Scandinavian icesheet reached the northern and western forelands of the Central Polish Uplands (Text-fig. 1). It spread upslope to 290—330 m a.s.l. and formed numerous end moraines and outwash plains. Further to the west it occupied a considerable part of the Silesian Upland, passed through the Moravian Gate and stopped at 500—600 m a.s.l. in the Sudetes. In the marginal zone during the maximum extent of the icesheet the glacial deposits were accumulated as the two series. The lower one occupies a smaller area and represents the Krzna Stadial whereas the overlying one corresponds to the Radomka—Kamienna stadial.
In the same time successive loess was deposited in southern Poland (Text-fig. 8). It is best preserved in the Odonów and Nieledew sections where its chronostratigraphic position is supported by the identified Chegan Event, dated for 260 000—298 000 y. BP. In deep-sea sediments this glaciation is represented by the \( ^{18} \text{O} \) horizon 3, dated for 297 000—251 000 y. BP.


GRABÓWKA INTERGLACIAL

This interglacial, previously defined as the Pilica Interstadial or the Lublin Interglacial, separates the older part of the Middle-Polish glaciations (Odra Glaciation) from its younger part (Warta Glaciation). In the Bełchatów section (Text-figs 1 and 5) it is represented by lacustrine and fluvial series (TL dating: 264 000 y. BP), the same as in the Wąchock section (TL dating: 245 000 ± 45 000 y. BP). Sands of the Frombork section (TL dating: 260 000—240 000 y. BP) were supposedly deposited during the same time. In the Grabówka section (Text-fig. 7), the lake sediments between two tills record a relatively warm climate (several percent of Corylus, Tilia, Abies, Ulmus, and over 20% of Quercus in the pollen spectrum).

Fig. 7. Geological section of the Quaternary deposits in the Vistula Valley near Grabówka (adapted from: Makowska 1977)

1 till, 2 gravels, 3 sands, 4 clays, 5 silts, 6 clays, siles and gyttjas with organic matter, 7 marine clays and silts

In the Central Polish Uplands, the Odonów and Nielełew loess sections contain a paleosol of the Nielełew type. At Nielełew this soil is younger than 230 000—240 000 y. BP but older than 221 300 ± 27 000 y. BP.

In deep-sea sediments this interglacial is recorded by the $^{18}$O horizon 7, dated for 251 000—195 000 y. BP.


WARTA GLACIATION

During this glaciation Central Poland was occupied by the Scandinavian icesheet to the south of the Warsaw parallel (Text-fig. 1). In its marginal zone the icesheet deposited two tills of the older (pre-maximum) and younger (maximum) stadials, respectively (Text-fig. 8).

In the Bełchatów section (Text-fig. 5), the sands (TL dating: 147 000 y. BP) separate these tills which overlie the clastic deposits resulting from the icesheet advance during the Warta Glaciation (TL dating: 157 000 and 156 000 y. BP). In the Węgchock section, to the south of the maximum extent of this icesheet, there occur cover deposits (TL dating: 142 550 ± 3 650 y. BP) and in the Nielełew section the loesses (TL dating: 179 000 y. BP). The final part of this glaciation corresponds to the first man’s appearance to the territory of Poland. The artifacts of the Levallois-Mousterian culture in the Zwierzyniec section (Text-fig. 1) were noted within the sands on which a soil of the Eemian Interglacial developed. Such artifacts in the Nietoperzowa Cave (Text-fig. 1) were also found in sediments that were the substrate for Eemian weathering processes.

In deep-sea sediments this glaciation is correlated with the $^{18}$O horizon 6 dated for 185 000—128 000 y. BP, a maximum cooling of which occurred in the North Atlantic 150 000—130 000 y. BP.


UPPER PLEISTOCENE

EEMIAN INTERGLACIAL

This interglacial is the only one during the Pleistocene when the sea entered the territory of Poland (Text-fig. 1). The sediments of this sea are known only in the Lower Vistula area. They are composed of two
clayey-silty series (Text-fig. 7), among which the upper one is correlated with the Eemian optimum and delimits an extent of the Tychnowy Sea.

The Eemian Interglacial is characterized by rich vegetation, the relics of which are preserved under deposits of the Wisła Glaciation and outside the icesheet extent (sites at Rusinów, Szeląg, Swarzędz, Imbramowice, Błonie, Nidzica, Szwajcaria; see Text-fig. 1).

In the Central Polish Uplands the older loesses were capped by leached soils. At Wąchock, Odonów, Nieledew and Radymno such soils constitute the lower part of the Nietulisko-I horizon. In the Zwierzyniec section this soil is accompanied by artifacts of the Levallois-Moustierian culture, similarly as in the Nietopierzowa Cave.

The TL datings of the pre- and post-Eemian deposits prove that this interglacial started about 125 000 and ended about 108 000 y. BP. The TL dating of loesses overlying the interglacial soil at Nieledew suggests the interglacial continuation only until 110 000 y. BP. In deep-sea cores this warming is correlated with the $^{18}$O horizon $f_e$ dated for 128 000—118 000 y. BP.

-fig. 7) are the best developed due to oscillations of the iceshet. Two lowest tills are to be connected with the first advance of the Scandinavian icesheet onto the deposits of the Eemian Interglacial, and are dated 110,000—100,000 y. BP. In the same time an accumulation of the oldest loess of the Wisla Glaciation occurred, with the Blake Event symptoms preserved at Nieledew (TL datings: 101,300 ± 12,000 y. BP and 97,700 ± 12,000 y. BP).

A younger warming is evidenced in loesses by a chernozem of the Nietulisko-I horizon and by organogenic sediments at Stare Kurowo (Text-fig. 1), correlated with the Brørup Interstadial. In the Nietoperzowa Cave and neighboring caves the artifacts of the Levallois-Moustierian and Micoquo-Prondnikian cultures of this age were found.

The second icesheet advance of the Wisla Glaciation occupied much larger area. In the Lower Vistula valley it is documented by a till. The TL datings of deposits overlying this till in the Sartowice section (Text-fig. 1) define its age for over 51,000 y. and authorize its correlation with the icesheet advance at the worldwide climatic cooling, recorded in deep-sea sediments by the $^{18}$O horizon 4 dated for 75,000—64,000 y. BP. This cooling is represented in the Zwierzyniec section by silts (TL datings: 71,700—67,600 y. BP) and by the loess at Nieledew (TL dating: 60,800 ± 7,500 y. BP).

A successive, younger warming during the same glaciation is represented at Sartowice by silts (TL datings: 51,000 ± 8,000 y. BP and 43,000 ± 7,000 y. BP) and by two beds of organogenic sediments in the Kônin—Maliniec section (Text-fig. 1). The lower bed of these sediments (Maliniec I; radiocarbon dating 42,900 y. BP and 42,500 y. BP) contains floristic remains of a park tundra and corresponds probably to the Moershoofd Interstadial. The upper bed (Maliniec II; radiocarbon dating 22,230 ± 480 y. BP and 22,050 ± 450 y. BP) yielding remains of a brushy tundra, corresponds to the warming which preceded the maximum extent of the icesheet during the Wisla Glaciation. In southern Poland this warming is identified with the Interpleniglacial of the Netherlands, and it is represented by mid-loessic tundra paleosols (TL datings: 50,000—24,000 y. BP) as well as by a humus horizon in the Nietoperzowa Cave (radiocarbon dating 38,160 ± 250 y. BP). Within and above the latter there occur artifacts of the Jerzmanovician culture. In deep-sea sediments this warming is correlated with the $^{18}$O horizon 3, dated for 64,000—32,000 y. BP.

The third icesheet advance of the Wisła Glaciation (Text-fig. 1) is evidenced by two youngest tills. The lower one, correlated with the Leszno—Poznań Phase, delimits the maximum icesheet extent (about 20,000 y. BP). A retreat of this icesheet during the Mazury Interphase favored an organogenic deposition in the Mazury Lakeland (TL dating 17,800 ± 250 y. BP) and the formation of a paleosol in the Wąchock sec-
tion (TL dating: older than 15 830 ± 1830 y. BP). The last of these dates defines the age of the youngest Wisla Glaciation loess in Poland and it is close to the icesheet-extent time during the Pomeranian Phase. The maximum development of the Wisla Glaciation in Poland is correlated in deep-sea sediments with the $^{18}O$ horizon 2, dated for 32 000—13 000 y. BP.

A deglaciation of the area during the Pomeranian Phase and the younger icesheet standstills are defined as the Late Glacial. In Poland this period is recorded by numerous sites with organogenic sediments (Witów, Mikołajki, Brzozowica, Przedni Staw Lake, Woryty, Niechorze; see Text-fig. 1). A palynological analysis proved that most Late Glacial-Holocene lacustrine and bog sediments had been deposited already before the Alleröd.


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Fig. 9. Correlation of the Quaternary units in Europe, based on the 1 — biostratigraphic, 2 — paleomagnetic data, and 3 — absolute datings
Datings of deposits of the Kozi Grzbiet section by FCl/P (KG2 — 700 000—550 000 BP after Glazek & al. 1976) and thermoluminescence (KG1 — 440 000—400 000 BP after Lindner 1982) methods
PLEISTOCENE CHRONOSTRATIGRAPHY


HOLOCENE

The Holocene is considered by some authors as the warming of the interglacial rank. This time favored the deposition of lacustrine-bog, fluviial, aeolian and slope sediments. Studies over these sediments laid the foundations for a subdivision of the Holocene into several phases with a climatic optimum of the Atlantic Period at 8,400—5,100 y. BP.


CONCLUSIONS

The Ice Age in Poland starts in the Early Pleistocene with the Narew Glaciation (GI according to Różycki, 1961) and the following Przasnysz Interglacial (J/II). The three Middle Pleistocene glaciations (Nida, San, Mogielanka) together with the separating interglacials (Koźi-Grzbiet, Pilczyca) represent the climatic warmings and coolings of the South-Polish glaciations (GII). The successive Great Interglacial (II/III) with its four climatic warmings distinguished by Różycki (1984), in the presented chro-nostratigraphical approach comprises three interglacials (Ferdynandów, Barkowice-Mokre, Zbójno), two glaciations (Wilga, Liwiec) and a warming of the lower rank (Podlesie) which took place already in the anagalcial part of the Odra Glaciation. The Middle-Polish glaciations (GIII) include the older (Odra) and the younger (Warta) glaciations, separated by the Grabówka Interglacial. The Upper Pleistocene is represented by the Eemian Interglacial (III/IV) and the following Wiśla Glaciation (GIV).

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ZARYS CHRONOSTRATYGRAFII PLEJSTOCENU POLSKI

(Streszczenie)

Przedstawiono czas trwania i podział czwartorzędu Polski na protoplejstocen (1 870 000—850 000 lat BP), plejstocen (850 000—10 000 lat BP), oraz holocen (ostatecznie 10 000 lat). W obrębie protoplejstocenu wydzielono ochłodzenie Otwocka i ocieplenie Celestynowa. W plejstocenie dzielącym się na trzy części (dolny, środkowy, górny) wyróżniono większą niż dotychczas ilość epizodów glacialnych i interglacialnych (patrz fig. 1--6). Dolny plejstocen (850 000—730 000 lat BP) reprezentowany jest przez najstarsze złodowacenie (Narwii) i następujący po nim interglacjał (Przasnysza). W obrębie środkowego plejstocenu (730 000—128 000 lat BP), jego starsza część obejmuje trzy złodowacenia południowopolskie (Nidy, Sanu, Mogielanksi) oddzielone od siebie dwoma interglacjami (Koziego Grzbietu, Pilczycy), część środkowa obejmuje trzy epizody interglacjalne (Ferdynandowa, Barkowic Mokrych, Zbójna) wraz z dzielącymi je złodowaceniami (Wilgi, Lwówca), a część młodsza składa się z dwóch złodowaceń środkowopolskich (Odry, Warty) oddzielonych przedostatnim epizodem interglacjальным (Grabówka). Górný plejstocen (128 000—10 000 lat BP) reprezentowany jest przez ostatni interglacjał (eemski) i najmłodsze złodowacenie (Wisły). Dzięki danym paleontologicznym, paleomagnetycznym i datowaniem bezwzględnym podjęto próbę korelacji wymienionych epizodów z jednostkami podziału czwartorzędu w krajach sąsiednich (patrz fig. 8 i 9).