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An Attempt at Correlation of Main Climatostratigraphic Units of the Quaternary in the Marginal Zones of Continental Glaciations in Europe

Próba korelacji głównych jednostek klimatostratygraficznego podziału czwartorzędu w brzeżnej strefie zasięgu zlodowaceń kontynentalnych w Europie

INTRODUCTION

Studies of the Quaternary palaeogeographical evolution in the marginal zone of continental glaciations in Europe must be based on good knowledge of rhythmus of climatic changes in that time. Such changes in most cases were expressed by coolings that favoured development of 8 continental glaciations (Fig. 1) and warmings which were typical of climatic conditions during 7 interglacials, all during this part of the Quaternary that is named the Pleistocene (Figs 2-4). From a climatostratigraphic point of view these glaciations and interglacials, together with preceding main coolings and warmings of the Early Quaternary (Prepleistocene) as well as the following – the youngest warming of the Holocene, are considered to be the main units of the inland Quaternary (M. D. Baraniecka 1990; L. Lindner 1991b). These units are more and more frequently correlated with the ^{18}O stages that record the main Quaternary climatic changes in deep-sea sediments (D. Q. Bowen 1989; D. Q. Bowen et al. 1989; L. Lindner 1984, 1988 a, b, 1991 a, b; F. Wiegank 1982; 1987; L. N. Voznyachuk 1985; V. A. Zubakov 1986, 1988, 1990; V. A. Zubakov and I. I. Borzenkova 1990), which enables their mutual correlations (Table 1).

PREPLEISTOCENE

The Prepleistocene in the European Lowland and in the British Isles is totally an ice-free period (Table 1, Figs 2-4). It is indicated by four main units, the first and third of which are cold (Różce = Praetiglian; Otwock = Eburonian) whereas the second and fourth are warm (Ponurzyca = Tiglian; Celestynów = Waalian).

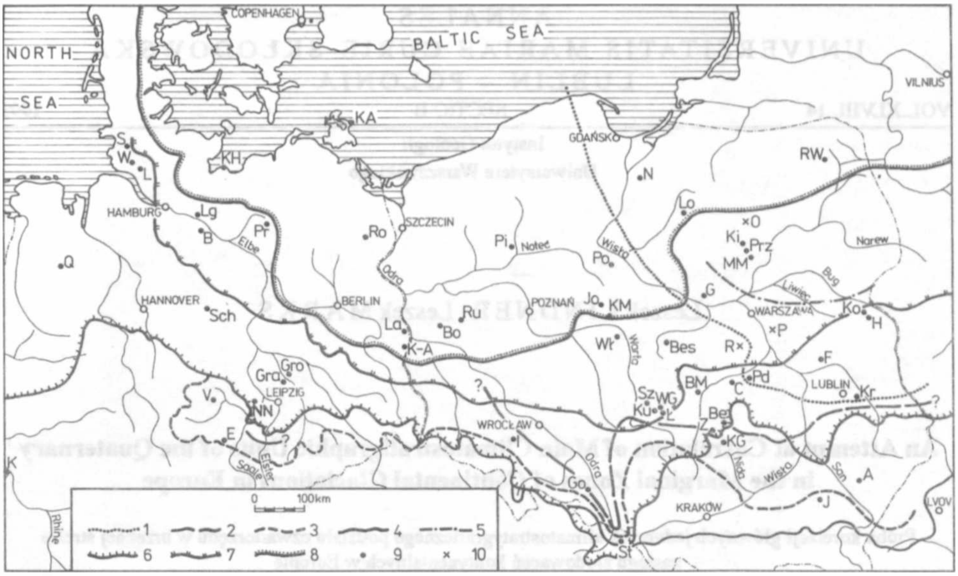

Fig. 1. Extents of Scandinavian glaciations in central Europe against main key sites of interglacial and preglacial sediments; 1 – Narewian Glaciation, 2 – Nidanian Glaciation, 3 – Sanian 1 (Elsterian 1), Glaciation, 4 – Sanian 2 (Elsterian 2) Glaciation, 5 – Liwiecian (Fuhne?) Glaciation, 6 – Odranian (Fuhne? Drenthe?) Glaciation, 7 – Wartanian (Drenthe? Warthe) Glaciation, 8 – Vistulian (Weichselian) Glaciation; 9 – sites with interglacial sediments: A – Adamówka, B – Breetze, Be – Bedlno, Bes – Besiekierz, BM – Barkowice Mokre, Bo – Boczów, C – Ceteń, E – Ehringsdorf, F – Ferdynandów, G – Główczyn, Go – Gościęcin, Gra – Grabschütz, Gro – Gröbern, H – Hrud, I – Imbramowice, J – Jesionka, Jo – Józwin, K – Kärlich, KA – Kap Arkona, KG – Kozi Grzbiet, KH – Klein Höved, Ki – Kijewice, KM – Konin-Marantów, Ko – Komarno, Kr – Krępiec, Ku – Kuców, KA – Kerkwitz-Atterwasch, La – Lawitz, Lg – Lauenburg, Lo – Losy, Ł – Łękińsko, MM – Maków Mazowiecki, N – Nowiny, NN – Neumark-Nord, Pi – Piła, Pd – Podgórze, Po – Popioły, Pr – Pritzwalk, Prz – Przasnysz, Q – Quackenbrück, Ro – Röpersdorf, Ru – Rusinów, RW – Raczki Wielkie, S – Schalkholz, Sch – Schöningen, St – Stonava, Sz – Szczerców, V – Voigtstedt, W – Wacken, WG – Wola Grzymalina, Wł – Władysławów, Z – Zbójno, 10 – sites with preglacial sediments: L – Lieth, O – Opaleniec, P – Ponurzyca, R – Różce

Cold interval – Różce. The studies of L. S t u c h l i k (1987) and M. D. B a r a n i e c k a (1990, 1991) indicated that in Poland this part of the Quaternary starts with a cold period (Różce), correlated with the Praetiglian in the western European Lowland and with Chystopol in the Russian Plain (Table 1). In Germany a deposition of the oldest fluvial series of the Sternhügel terrace (with preserved frost wedges) occurred in that time (L. E i s s m a n n 1975, 1990). In Czecho-Slovakia sediments of the Older Preglacial were deposited (J. M a c o u n 1980, 1985, 1987) and in the British Isles – sediments of the upper Waltonian with sedimentary hiatus in the top (Table 1). In the central and southern Ukraine yellow-brown loessy-like loams of the Siver horizon (sv) with yellow-brown palaeosols were presumably deposited (M. F. V e k l i c h and N. A. S i r e n k o 1976; M. F. V e k l i c h 1979, 1987).

Table 1. Attempt at correlation of main climatostratigraphic units of the Quaternary in marginal zone of continental glaciations in Europe (dots mark glacial units indicated with presence of ice sheets) after A. Bałuk (1991), M. D. Baraniecka (1990, 1991), A. B. Bogutsky (1987), A. B. Bogutsky et al. (1980), D. Q. Bowen (1989), D. Q. Bowen et al. (1989), A. G. Cepek (1986), A. G. Cepek and W. Nowel (1991), J. Ehlers et al. (1991), L. Eissmann (1980), L. Lindner (1988b, 1991b), J. Macoun (1980, 1985, 1987), A. Makowska (1992), V. N. Shelkoplyas and T. F. Khristoforova (1987, 1991), M. F. Veklich (1979, 1987), M. F. Veklich and N. A. Sirenko (1976), R. G. West (1977), F. Wiegank (1982, 1987), W. H. Zagwijn (1986), V. A. Zubakov (1986, 1988); ^{18}O stages after D. Q. Bowen et al. (1986)

PALEO-MAGNETIC Age in Ma	^{18}O STAGE	Age in ka	BRITISH ISLES	NETHERLANDS, GERMANY	CZECHO-SLOVAKIA	POLAND	BYELORUSSIA LITHUANIA	RUSSIAN PLAIN	UKRAINE	STRATIGRAPHY
	1	13	[illegible]	HOLOCENE	[illegible]	[illegible]	HOLOCENE	HOLOCENE	HOLOCENE	HOL.
	2–4	75	DEVENSIAN	WEICHSELIAN	WEICHSELIAN	VISTULIAN (WISŁA): BALTIC GL.; KRASTUDY GL. (?); [illegible]	VALDAI	VALDAI	VALDAI	LATE PL. – QUATERNARY
	5	128	[illegible]	[illegible]	EEMIAN	EEMIAN	[illegible]	MGA	PRILUKI (GORODKOV)	
	6		WOLSTONIAN	WARTHE; DRENTHE (SAALIAN)	WARTHIAN	WARTANIAN; ODRANIAN ?	SOZH	KALININ	TYASMIN	MIDDLE PLEISTOCENE
	7		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	8		WOLSTONIAN ?	(DRENTHE ?)	OLDRISOV	ODRANIAN	DNIEPER	DNIEPER	DNIEPER	
0.. Ch	9	287	[illegible]	[illegible]	NEPLACHOVICE	[illegible]	[illegible]	CHEKALIN	ZAVADOVKA (LUTSK)	
	10			[illegible]	PAI HANEC	[illegible]	KOPYSK	KALUGA	LIKHVIN (L)	
	11		[illegible]	HOLSTEINIAN [illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
	12		ANGLIAN	ELSTERIAN 2	KRAVARE	SANIAN 2 (WILGA)	BEREZINA	OKA	(OKA ?) TILIGUL	
	13–15	472	CROMERIAN; WAVERLY WOOD	VOIGTSTEDT; INTERGLACIAL IV	MUGLINOV	FERDYNANDOWIAN	BYELOVEZHA	ROSLAVL	LUBNY (SOKAL ?)	
	16		BEESTONIAN	ELSTERIAN 1	KRAVARE 1	SANIAN 1	SERVETSK	DON	(DON ?) SULA	
	17–19	627	[illegible]	INTERGLACIAL III; GLACIAL B; INTERGLACIAL II (CROMERIAN)	OTICE	MALOPOLANIAN (PRZASNYSZ)	KORCHEVO	ILIN	MARTONOSHA	
0.73	20		[illegible]	GLACIAL A	OPAVA	NIDANIAN	NOVOGOROD	?	PRIAZOVYE	
	21–22	782	[illegible]	INTERGLACIAL I; DORST GL.; [illegible]	SLAVKOV	PODLASIAN (RIJEWICE)	JELIZAROV	TROITSK	SHIROKINO	EARLY PL.
				[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
				WAALIAN		CELESTYNOW	JELINSK	SKIF	KRYZHANOVIAN	PREPLEISTOCENE
	34–38		BAVENTIAN	EBURONIAN	YOUNGER PREGLACIAL	OTWOCK	HOMEL	DOMASHKIN	BEREZAN	
1.67 Ol	40		[illegible]	TIGLIAN	KOBERICKY INTERGLACIAL	PONURZYCA	DVORETSK	KRYZHANOV	BEREGOVO	
Re 2.14			[illegible]	PRAETIGLIAN	OLDER PREGLACIAL	ROZCE		CHYSTOPOL	SIVER	
2.48 GAUSS			WALTONIAN	P L I O C E N E						

Warm interval – Ponurzyca. This period was identified in Poland by L. S t u c h l i k (1975) and M. D. B a r a n i e c k a (1975), and correlated with the Tiglian in the western European Lowland. In the British Isles a younger part of this period is described by climatic fluctuations of Ludhamian, Thurnian and Antian, whereas in Czecho-Slovakia – by sediments of the Kobericky Interglacial (Table 1). In Lithuania and Byelorussia this interval corresponds to the warming Dvoretsk and in the Russian Plain – to the warming Kryzhanov (Table 1). In the central and southern Ukraine this period favoured probably a development of reddish-brown palaeosols of tne horizon Beregovo (br), typical of tropical forests and bushes (M. F. V e - k l i c h and N. A. S i r e n k o 1976; M. F. V e k l i c h 1979, 1987).

Cold interval – Otwock. This period in Poland was also identified by L. S t u c h l i k (1975) and M. D. B a r a n i e c k a (1975), and correlated with the Eburonian in western European Lowland. In the British Isles it is presumably represented by sediments of the

Baventian (Table 1). In Germany fluvial sediments (*Sitteler terrace*) with casts of frost wedges were deposited (L. E i s s m a n n 1975, 1990). In Czecho-Slovakia this interval corresponds to the lower part of the Younger Preglacial (J. M a c o u n 1980). In Byelorussia and Lithuania this climatostratygraphic position is occupied by the Homel horizon and in the Russian Plain – by sediments of the Domashkin horizon (Table 1). In the central and southern Ukraine loessy-like loams of the horizon Berezan (br) were deposited probably in that time (M. F. V e k l i c h and N. A. S i r e n k o 1976, M. F. V e k l i c h 1979, 1987).

Warm interval – Celestynów. This period is the youngest climatostratigraphic unit of the Prepleistocene (Eopleistocene according to J. E. M o j s k i 1985). In Poland it was defined by L. S t u c h l i k (1975) and M. D. B a r a n i e c k a (1975) and correlated with the Waalian in the western European Lowland (Table 1). After W. H. Z a g w i j n (1979) this period is represented by a sedimentary hiatus in the British Isles. In Czecho-Slovakia this period is connected with deposition of sediments during a middle part of the Younger Preglacial (J. M a c o u n 1980). In Lithuania and Byelorussia this warming is represented by sediments of the horizon Jelińsk and in the Russian Plain – by sediments of the horizon Skif (Table 1). In the central and southern Ukraine red-brown palaeosols of the horizon Kryzhanovian (kr) developed under xerophilus forests and savanna-steppe vegetation (M. F. V e k l i c h and N. A. S i r e n k o 1976; M. F. V e k l i c h 1979, 1987).

EARLY PLEISTOCENE

It seems still reasonable to include into the Early Pleistocene the two successively younger main climatostratigraphic units i.e. Narewian Glaciation and Podlasian Interglacial (cf. L. L i n d n e r 1984, 1991a, b).

Narewian Glaciation. This older unit (Figs 1-2, Table 1) is represented in northeastern and mid-eastern Poland by glacial sediments of the first continental glaciation (K. S t r a s z e w s k a 1968; S. Z. R ó ż y c k i 1980; M. H a r a s i m i u k et al. 1988; L. L i n d n e r 1988a, b, J. W o j t a n o w i c z 1988; L. D o l e c k i et al. 1991). The ice sheet advanced also in Lithuania and Western Byelorussia and reached the Upper Volga basin further to the east where its deposits delimit an extent of the Likov Glaciation (Table 1). In the western European Lowland, being probably in that time outside the extent of this ice sheet, sediments of the cold Menapian were formed: in Germany fluvial sediments of the Grössgorschener terrace, with casts of frost wedges (L. E i s s m a n n 1975, 1990) and in Czecho-Slovakia – sediments of the younger part of the Younger Preglacial (Table 1). In the central and southern Ukraine this interval is presumbaly represented by deposition of brown and bluish-brown loessy-like loams of the horizon Ilyichevsk (il) (M. F. V e k l i c h and N. A. S i r e n k o 1976; M. F. V e k l i c h 1979, 1987).

Podlasian Interglacial. This younger climatostratigraphic unit of the Early Pleistocene (Table 1) is expressed in Poland (Fig. 2-3), among others by deposition of polycyclic alluvial series that indicate long-lasting of this interglacial (K. S t r a s z e w s k a 1968; A. B a l u k 1991). Such evaluation of the Podlasian Interglacial has been supported in the Netherlands not only by identification of two new interglacial (Bavel s.s. and Leerdam) and two new glacial (Linge and Dorst) units within the Bavelian (Table 1) but also by correlation of this interglacial with the Interglacial I of the Cromer Complex (cf. L i n d n e r 1991a, b). In Czecho-Slovakia it corresponds to the Slavkov Interglacial (cf. J. M a c o u n 1985, 1987) which seems to be possibly also the interval when two soil complexes developed (PK, XI, PK, X), separated with the loess horizon K (G. J. K u k l a 1978). In Lithuania and in Byelorussia it should correspond to the Jelizarov Interglacial and in the Russian Plain – to the Troitsk Interglacial (Table 1). In the central and southern Ukraine this interglacial probably corresponds to development of brown palaeosols of the horizon Shirokino (sh), formed under subtropical park-bush vegetation (M. F. V e k l i c h and N. A. S i r e n k o 1976; M. F. V e k l i c h 1979, 1987).

MIDDLE PLEISTOCENE

In the European Lowland the Middle Pleistocene comprises 11 main climatostratigraphic units that are separate glaciations and interglacials within the South Polish (Elsterian) Megaglacial, the Great (Holsteinian *sensu lato*, Likhvin *sensu lato*) Interglacial and the Middle Polish (Saalian) Megaglacial (L. L i n d n e r 1991a, b). J. E. M o j s k i (1985) puts the South Polish Megaglacial (Glaciation) and the Great (Mazovian) Interglacial into the Mezopleistocene.

Nidanian Glaciation. This glaciation is the oldest unit within the South Polish (Elsterian) Megaglacial. During this glaciation the ice sheet advanced for the second time into

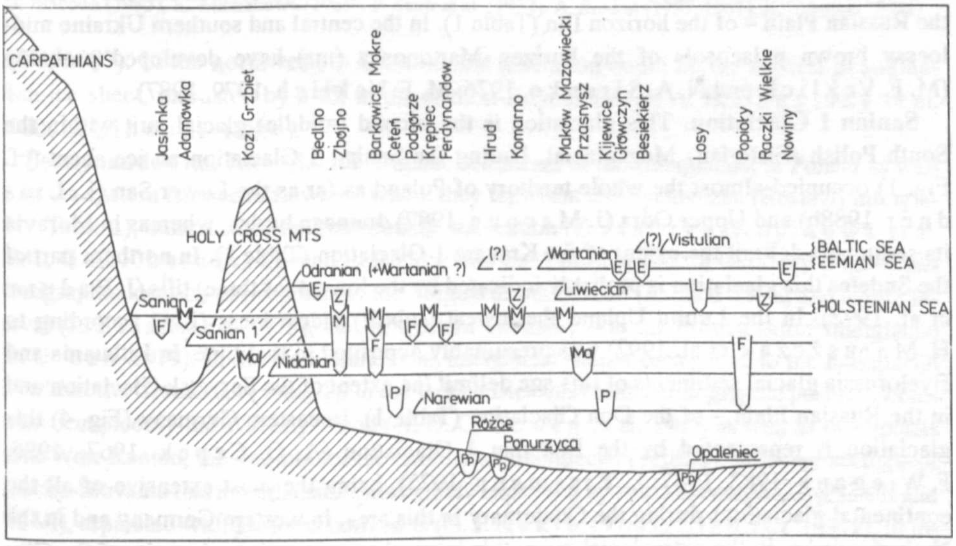

Fig. 2. Extents of Scandinavian glaciations in the Vistula (Wisła) drainage basin against intervening sea ingressions and main kay sites of preglacial (Pp – Prepleistocene) and interglacial sediments (P – Podlasian, Ma – Malopolanian, F – Ferdynandowian, M – Mazovian, Z – Zbójnian, L – Lubawian, E – Eemian); after L. Lindner (1988b), modified; based on data from M. D. Baraniecka (1991), K. Bińka et al. (1987), Z. Janczyk-Kopikowa (1991), J. Jeziorski (in print), H. Klatkowa (1972), K. M. Krupiński, L. Lindner (1991), L. Lindner et al. (1991), J. Niklewski (1968)

a considerable part of the European Lowland. In Poland it entered the Nida drainage basin in the Holy Cross Mts (Figs 1-2). During its maximal extent it reached northern slopes of the Lublin Upland (M. Harasimiuk et. al. 1988; J. Wojtanowicz 1988; L. Dolecki et al. 1991) and even advanced onto Moravia where its sediments presumably delimit the extent of the Opava Glaciation (Table 1). Deposits of this glaciation are also known from Lithuania and western Byelorussia where they represent the Novogorod Glaciation. In the western European Lowland, being in that time in the extraglacial area, this glaciation corresponds to the Glacial A within the Cromerian (Table 1). In Czecho-Slovakia the loessy horizon I with preserved border Brunhes/Matuyama (G. J. Kukla 1978) has developed, in the central and southern Ukraine – deposition of the horizon Priazovye (pr) occurred (M. F. Veklich and N. A. Sirenko 1976; M. F. Veklich 1979, 1987).

Malopolanian Interglacial. This interglacial in Poland has faunistic evidence in the site Kozi Grzbiet (J. Głazek et al. 1976) and its floristic image is known from Przasnysz (A. Baiuk 1991). In the western European Lowland it corresponds to the warmings of the Interglacials II and III, separated with sediments of the Glacial B within the Cromerian (Table 1). The younger warming was correlated with the Pastonian in the British Isles (W. H. Zagwijn 1979). In Czecho-Slovakia this stratigraphic location is occupied by the Otice Interglacial (J. Macoun 1985, 1987) and probably by two soil complexes (PK IX and PK VIII), with the separating loessy horizon J (G. J. Kukla 1978). In Lithuania and Byelorussia this interglacial corresponds to sediments of the horizon Korchevo and in the Russian Plain – of the horizon Ilin (Table 1). In the central and southern Ukraine mid-loessy brown palaeosols of the horizon Martonosha (mr) have developed probably (M. F. Veklich and N. A. Sirenko 1976; M. F. Veklich 1979, 1987).

Sanian 1 Glaciation. This glaciation is the second (middle) glacial unit within the South Polish (Elsterian) Megaglacial. During the Sanian 1 Glaciation an ice sheet (cf. Fig. 1) occupied almost the whole territory of Poland as far as the Lower San (L. Lindner 1988b) and Upper Odra (J. Macoun 1987) drainage basins, whereas in Moravia its sediments delimit the extent of the Kravare 1 Glaciation (Table 1). In northern part of the Sudetes this glaciation is probably indicated by the lowest (of three) tills (J. Badura et al. 1992). In the Lublin Upland the lowest (subtill) oldest loess (LN3 according to H. Maruszczak et al. 1992) was presumably deposited in that time. In Lithuania and Byelorussia glacial sediments of this age delimit the extent of the Servetsk Glaciation and in the Russian Plain – of the Don Glaciation (Table 1). In eastern Germany (Fig. 4) this glaciation is represented by the Elsterian 1 Glaciation (A. G. Cepek 1967; 1986, F. Wiegank 1982, 1987; L. Eissmann 1975), being the most extensive of all the continental glaciations during the Quaternary in this area. In western Germany and in the Netherlands i.e. in the extraglacial zone, this interval corresponds to deposits of the Glacial C within the Cromerian (Table 1). In the British Isles this stratigraphic position is occupied by deposits of the cold Beestonian and perhaps, also by glacial deposits of the Pre-Cromerian Glaciation (Table 1). In loessy sections of Czecho-Slovakia, loess of the horizon H was deposited (G. J. Kukla 1978), and in the central and southern Ukraine – loess of the horizon Sula (sl) (M. F. Veklich and N. A. Sirenko 1976; M. F. Veklich

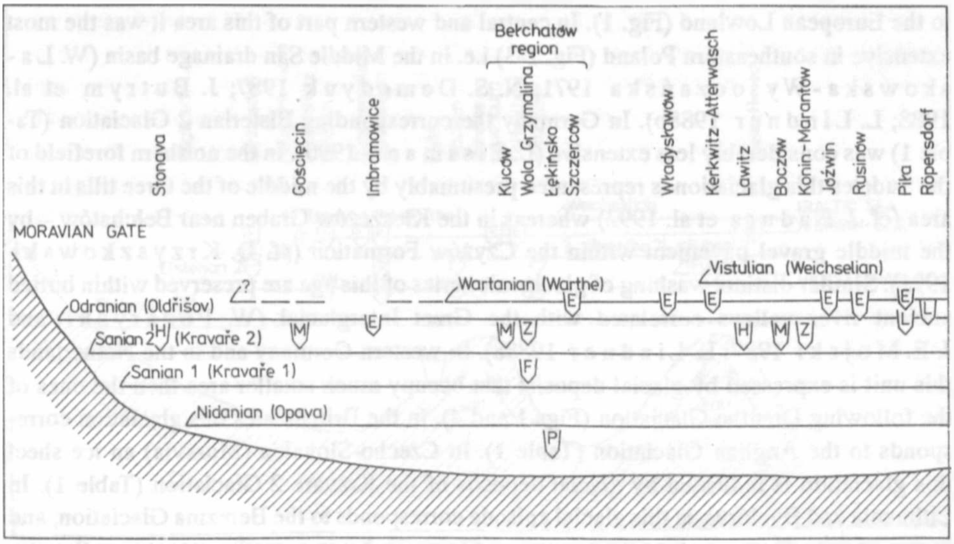

Fig. 3. Extents of Scandinavian glaciations in the Odra drainage basin against main key sites of interglacial sediments (P – Podlasian, F – Ferdynandowian, M – Mazovian, H – Holsteinian, Z – Zbójnian, L – Lubawian, E – Eemian); based on data from Z. Borówko-Dłużakowa (1967), A. G. Cepek (1967), S. Dąbrowski et al. (1987), K. Erd (1987), Z. Janczyk-Kopikowa, S. Skompski (1977), J. Jurkiewiczowa (1961), D. Krzyszkowski (1991), J. Macoun (1985), K. Mamakowa (1989), P. Stark et al. (1932), A. Środoń (1957, 1961), K. Tobolski (1991)

1978, 1987). In the northwestern Ukraine this glaciation could be the earliest Scandinavian ice sheet, indicated by a till in the section Boyaniche (cf. A. B. B o g u t s k y et al. 1980; L. L i n d n e r 1988c).

Ferdynandowian Interglacial. Organic sediments of this interglacial, in Poland as well as in the eastern European Lowland where they represent the Byelovezha (Roslavl) Interglacial (Table 1), indicate a bi-optimal floristic succession (Z. J a n c z y k - K o p i k o w a et al. 1981; G. K. K h u r s e v i c h and L. P. L o g i n o v a 1986). In eastern Germany (Fig. 4) this stratigraphic location corresponds to the Voigtstedt Interglacial (K. E r d 1978) and Militz Interval (L. E i s s m a n n 1975), and in western Germany – to the Frimmersdorf Interglacial (B. U r b a n 1979). In the Netherlands this interglacial should correspond to the Interglacial IV within the Cromerian (Table 1). In the British Isles this climatostratigraphic position seems to be occupied by the Waverly Wood (cf. D. Q. B o w e n et al. 1989) as well as by deposits from West Runton, the key site for the Cromerian Interglacial (Table 1). In loessy sections of Czecho-Slovakia this interglacial is presumably expressed by two soil complexes (PK VII and PK VI), separated with the loess horizon G (G. J. K u k l a 1978, L. L i n d n e r 1991a). In loessy sections of the central and southern Ukraine it is expressed by palaeosols of the Lubny horizon (lb) (M. F. V e k l i c h and N. A. S i r e n k o 1976; M. F. V e k l i c h 1979, 1987) whereas in the northwestern Ukraine – by the palaeosol VII (Sokal) (A. B. B o g u t s k y et al. 1980; A. B. B o g u t s k y 1987).

Sanian 2 Glaciation. It is the third and the youngest glacial unit within the South Polish (Elsterian) Megaglacial. During this glaciation an ice sheet advanced a fourth time onto the European Lowland (Fig. 1). In central and western part of this area it was the most extensive in southeastern Poland (Fig. 2-3) i.e. in the Middle San drainage basin (W. Laskowska-Wysoczańska 1971; N. S. Demedyuk 1987; J. Butrym et al. 1988; L. Lindner 1988b). In Germany the corresponding Elsterian 2 Glaciation (Table 1) was considerably less extensive (L. Eissmann 1990). In the northern forefield of the Sudetes this glaciation is represented presumably by the middle of the three tills in this area (cf. J. Badura et al. 1992) whereas in the Kleszczów Graben near Bełchatów – by the middle gravel pavement within the Czyżów Formation (cf. D. Krzyszkowski 1991). Similar distinct washing of glacigenic series of this age are preserved within buried ancient river valleys correlated with the Great Interglacial (W. Pożaryski and J. E. Mojski 1987; L. Lindner 1988a). In western Germany and in the Netherlands this unit is expressed by glacial deposits that occupy much smaller area than the ones of the following Drenthe Glaciation (Figs 1 and 4). In the British Isles this glaciation corresponds to the Anglian Glaciation (Table 1). In Czecho-Slovakia (Moravia) an ice sheet this glaciation is indicated by glacial deposits of the Kravare 2 Glaciation (Table 1). In Lithuania and Byelorussia this glacial episode corresponds to the Berezina Glaciation, and in the Russian Plain – to the Oka Glaciation (Table 1), having smaller extent than the preceding Don Glaciation.

In loessy sections of Czecho-Slovakia this glaciation is expressed by deposition of the loess horizon F (G. J. Kukla 1978). In Poland it presumably corresponds to the oldest middle loess (LN2 according to H. Maruszczak 1991). In the central and southern Ukraine the loess Tiligul (ti) was deposited in this time (M. F. Veklich and N. A. Sirenko 1976; Veklich 1979, 1987) whereas in the northwestern Ukraine – glacial deposits, indicated by residual gravel pavement in top of the palaeosol VII in the section Boyaniche (cf. A. B. Bogutsky et al. 1980; L. Lindner 1988c), and the oldest till in the Middle Dnieper valley (V. N. Shelkoplyas and T. F. Khristoforova 1987, 1991).

Mazovian Interglacial. Sediments of this age belong to the best known interglacial-type fluvial, limnic and marine series in the European Lowland. In Poland they represent an older and warm climatostratigraphic unit within the Great Interglacial (according to S. Z. Różycki 1964). In the western European Lowland (Fig. 4) this unit corresponds to the Holsteinian s.s. Interglacial, represented among others by marine sediments (K. D. Meyer 1991) that form uninterrupted sequence with the underlying Late Elsterian ice-dam lacustrine Lauenburger Clays. In Czecho-Slovakia (Moravia) it is to be correlated with the Jaktar Interglacial (Table 1). In the British Isles this climatostratigraphic position is occupied by deposits of the Swanscombe horizon (Table 1), correlated by D. Q. Bowen (1989) with the ^{18}O stage 11, similarly as in the case of the described interglacial in the continent (L. Lindner 1988a, b; F. Wiegank 1982; V. A. Zubakov 1986). In Lithuania and Byelorussia this climatostratigraphic unit is represented by the Maloaleksandria Interglacial whereas in the Russian Plain – by deposits of the Likhvin Interglacial (Table 1).

In loessy sections of Czecho-Slovakia this interglacial is expressed by a soil complex PK V (G. J. Kukla 1978). In Polish loesses it corresponds presumably to the palaeosol GJ3b according to H. Maruszczak (1991a, b). In the central and southern Ukraine it is represented by palaeosols of the horizon Zavadovka (zv) (M. F. Veklich and

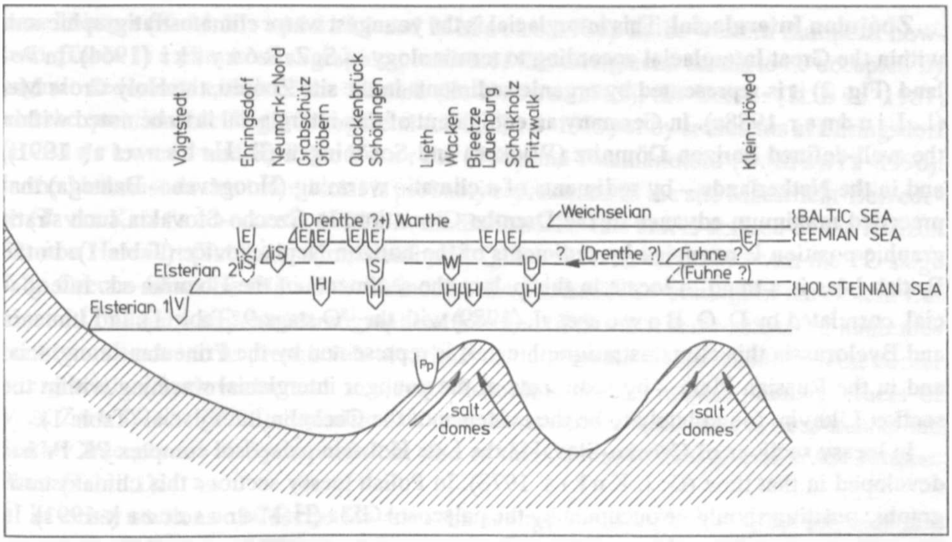

Fig. 4. Extents of Scandinavian glaciations in the Elbe drainage basin against intervening sea ingressions and main key sites of preglacial (Pp – Prepleistocene) and interglacial sediments (V – Voigtstedt, H – Holsteinian, W – Wacken, D – Dömnitz, S – Schöningen, iS – intra-Saalian, E – Eemian); based on data from L. Benda, K. D. Meyer (1973), B. Blackwell, H. P. Schwarcz (1986), W. von Bülow (1992), A. G. Cepek (1986), K. Kuphorn et al. (1973), K. Erd (1978, 1987), T. Litt (1990), D. Mania (1990), B. Menke (1980a, b, c), K. D. Meyer (1965), G. Steinich (1992), B. Urban at al. (1991), S. Wansa, R. Wimmer (1990), P. Woldstedt, K. Duphorn (1974)

N. A. Sirenko 1976; Veklich 1979, 1987) and in the northwestern Ukraine – by the lower part of the soil complex VI (Lutsk) (cf. A. B. Bogutsky et al. 1980; A. B. Bogutsky 1987).

Liwiecian Glaciation. This glaciation is expressed by glacial sediments that have been noted in northeastern Poland only (L. Lindner 1984, 1988a, b; M. D. Baraniecka 1990) and thus indicating the fifth, limited advance of an ice sheet (Figs 1-2). In the remaining part of the European Lowland this unit is defined as a cold interval in the middle part of the Holsteinian s. lato (Likhvin s. lato) Interglacial (Fig. 4) In Germany this unit is generally represented by periglacial and glaciofluvial sediments (cf. B. Urban et al. 1991) but in Meklenburg presumably also by a till (W. von Bülow 1992) of the Fuhne (Mehlbeck) interval. In Czecho-Slovakia (Moravia) it corresponds to the sediments of the horizon Palhanec (Table 1). In the Netherlands and the British Isles this unit has not been univocally defined yet. In Lithuania and Byelorussia it is an equivalent of the cool interval Kopysk and in the Russian Plain – of the cooling Kaluga (Table 1).

In loessy sections of Czecho-Slovakia this glaciation corresponds to the loessy horizon E (cf. G. J. Kukla 1978) and in Poland – to the oldest upper loess LN1 (L. Dolecki et al. 1991; H. Maruszczak 1991a, b). In the central and southern Ukraine its equivalents are to be found in the middle part of the soil complex Zavadovka (zv) (M. F. Veklich and N. A. Sirenko 1976; M. F. Veklich 1979, 1987), and in the northwestern Ukraine – within the middle part of the soil complex VI (Lutsk) (cf. A. B. Bogutsky et al. 1980; A. B. Bogutsky 1987).

Zbójnian Interglacial. This interglacial is the youngest warm climatostratigraphic unit within the Great Interglacial according to terminology of S. Z. Różycki (1964). In Poland (Fig. 2) it is represented by organic sediments in the site Zbójno, the Holy Cross Mts (L. Lindner 1988a). In Germany an equivalent of this interglacial is to be noted within the well-defined horizon Dömnitz (Wacken) and Schöningen (B. Urban et al. 1991), and in the Netherlands – by sediments of a climatic warming (Hoogeven – Bantega) that preceded maximum advance of the Drenthe Glaciation. In Czecho-Slovakia such stratigraphic position is occupied by sediments of the horizon Neplachovice (Table 1). In the British Isles is a trend to locate in this palace the sediments of the Hoxnian s.s. Interglacial, correlated by D. Q. Bowen et al. (1989) with the ^{18}O stage 9 (Table 1). In Lithuania and Byelorussia this climatostratigraphic unit is represented by the Prineman Interglacial and in the Russian Plain – by sediments of the younger interglacial warming within the section Likhvin, found lately to be the evidence of the Chekalin Interglacial (Table 1).

In loessy sections of Czecho-Slovakia the Late Holstein palaeosol complex PK IV has developed in that time (G. J. Kukla 1978). In Polish loessy sections this climatostratigraphic position should be occupied by the palaeosol GJ3a (H. Maruszczak 1991). In the central and southern Ukraine this soil corresponds to a younger part of the soil complex Zavadovka (zv) (M. F. Veklich and N. A. Sirenko 1976; M. F. Veklich 1979, 1987), and in the northwestern Ukraine – to the upper part of the soil complex VI (Lutsk) (A. B. Bogutsky et al. 1980; A. B. Bogutsky 1987).

Odranian Glaciation. This glaciation is the youngest glacial episode within the Middle Polish (Saalian) Megaglacial. According to J. E. Mojski (1985) it starts the Neopleistocene. During the Odranian an ice sheet advanced for the sixth time onto the European Lowland (Fig. 1). Glacial deposits of this age delimit a maximum extent of a continental glaciation in most places of southwestern Poland (A. Szponar 1986; J. Lewandowski 1987), in southwestern Germany and in the Netherlands (D. Long et al. 1988; J. Ehlers 1990; M. Rappol et al. 1989) where it is named the Drenthe Glaciation, and in northwestern Czecho-Slovakia – defined as the Oldrisov Glaciation (Table 1, Fig. 3). Lately a possibility that the Drenthe Glaciation is an older glacial episode within the younger Warta glaciation is taken into account (L. Marks 1991). In the British Isles a development of this ice sheet could occur during the poorly expressed Wolstonian Glaciation (Table 1). In the eastern European Lowland, in Lithuania, Byelorussia an the Russian Plain (V. A. Zubakov 1986) but also in the northern and central Ukraine (V. N. Shelkoplyas and T. F. Khristoforova 1987), glacial sediments of the Dnieper Glaciation were deposited (Table 1).

In loessy sections of Czecho-Slovakia this glaciation is indicated by the loessy horizon D (G. J. Kukla 1978) and in Poland – by the older lower loess LSd (H. Maruszczak 1991a, b). In the central and southern Ukraine deposition of loesses of the horizon Dnieper (dn) occurred (M. F. Veklich and N. A. Sirenko 1976; M. F. Veklich 1979, 1987) and in the northwestern Ukraine – of the lower horizon of the Middle Pleistocene loesses (cf. A. B. Bogutsky et al. 1980; A. B. Bogutsky 1987).

Lubawian Interglacial. This interglacial, named in Poland also the Lublin (Grabówka, Pilica) Interglacial (Fig. 2), is best represented by organic sediments in the section Losy near Lubawa (K. M. Krupiński and L. Marks 1986). In the western European Lowland (Table 1) a climatostratigraphic position of this interglacial seems to be occupied by organic sediments either of the Kärlich (B. Urban 1983), the Uecker (K. Erd 1987) and the questionable Rugia Interglacial (cf. K. Erd 1973) or by sediments at Ehringsdorf (B. Blackwell and H. P. Schwarcz 1986) and Neumarknord (D. Mania 1990). In the Netherlands this interglacial is probably represented in the site Maestricht-Belvedere (T. van Kolfschotten 1990). In the British Isles this unit is defined by the horizon Stanton Harcourt (Table 1), correlated by D. Q. Bowen et al. (1989) with the ^{18}O stage 7. In Czecho-Slovakia this unit is defined by the Postsaalian warming. In the eastern European Lowland a rank and stratigraphical location of this unit is the subject of numerous controversies due to its presumable bioptimal character what makes it similar to the earlier interglacials (Byelovezha and Roslavl). According to the opinion, among others of V. A. Zubakov (1986), a position of this climatostratigraphic unit corresponds to the Shklov Interglacial in Byelorussia but also to the Odintsovo Interglacial in the Russian Plain (Table 1).

In loessy sections of Czecho-Slovakia this interglacial is indicated by the soil complex PK III (G. J. Kukla 1978). In Poland a mid-loessic soil complex of the "Tomaszów" type (J. Jersak 1973, 1988), named GJ2 (H. Maruszczak 1991a, b), developed in that time. On loesses of the central and southern Ukraine the soil complex Kaydak (kd) was formed (M. F. Veklich, N. A. Sirenko 1976; M. F. Veklich 1979, 1987) whereas in the northwestern Ukraine – the soil complex V (Korshev) (cf. A. B. Bogutsky et al. 1980; A. B. Bogutsky 1987).

Wartanian Glaciation. This glaciation is the youngest glacial unit within the Middle Polish (Saalian) Megaglacial. An ice sheet advanced onto vast areas of the central and eastern European Lowland (Fig. 1). Not only southern Poland but also western Germany and the Netherlands remained ice-free (Figs 1-4, Table 1). In the British Isles this interval is represented by the pre-Ipswichian cooling, indicated probably by development of local glaciers only (D. Q. Bowen et al. 1986). Also in the eastern European Lowland an ice sheet had a more limited extent. In Lithuania and Byelorussia it corresponds to the Sozh Glaciation and in the Russian Plain – presumably to the Kalinin Glaciation (Table 1).

Numerous ice sheet advances between the Mazovian (Holsteinian) and the Eemian interglacials in Poland and in Lusatia (A. G. Cepek and W. Nowel 1991) were probably due to location of this part of Europe at main directions of ice sheet movement from Scandinavia during the Saalian Megaglacial. On the other side it cannot be excluded that both the Odranian and the Wartanian glaciations distinguished in Poland create, similarly as in most part of Germany, only the phases of the same glaciation (cf. L. Marks 1991; S. Fedorowicz et al. 1993), corresponding to the ^{18}O stage 6 in deep-sea sediments. It seems also reasonable that this is just the location for the Wolstonian Glaciation in the British Isles (Table 1). If such is the case, then the above described Liwiecian Glaciation should be correlated with the ^{18}O stage 9 in deep-sea sediments whereas the sediments of the Zbójnian and Mazovian interglacials would not be separated from each other by a glacial sequence. If so, also a till from Meklenburg, correlated with the Fuhne cooling (W. von Bülow 1992) would be respectively younger (cf. Table 1).

During the Warta Glaciation loesses of the horizon C in Czecho-Slovakia (G. J. K u k l a 1978), and the older upper loess LSg in Poland (H. M a r u s z c z a k 1991a, b) were deposited. In the central and southern Ukraine they correspond to the loess Tyasmin (ts) (M. F. V e k l i c h and N. A. S i r e n k o 1976; M. F. V e k l i c h 1979, 1987) and in the northwestern Ukraine – to the upper horizon of the Middle Pleistocene loesses (cf. A. B. B o g u t s k y et al. 1980; A. B. B o g u t s k y 1987).

LATE PLEISTOCENE

The Late Pleistocene consists of two main climatostratigraphic units i.e. of the Eemian Interglacial and the Vistulian (Wisla, Weichselian) Glaciation.

Eemian Interglacial. It is the best known interglacial in the European Lowland due to ancient marine ingressions and numerous sites with organic sediments of this age, with shallow or even surficial occurrence (Figs 2-4). For this reason it is concordantly distinguished in the whole area of western and central European Lowland, being a warm and relatively short-lasting climatostratigraphic unit, correlated with the ^{18}O stage 5e (Table 1). New evidence suggests that also sediments of the so-called Rugia Interglacial are of the Eemian Interglacial age (cf. G. S t e i n i c h 1992). In the British Isles this unit corresponds to the Ipswichian Interglacial (Table 1). In Lithuania and Byelorussia sediments of this unit represent the Mga (Mikulino) Interglacial (Table 1).

In loessy sections of Czecho-Slovakia soil processes during the Eemian Interglacial formed an older part of the soil complex PK II (G. J. K u k l a 1978, J. M a c o u n 1980, 1985). In Polish loesses these processes are recorded in the horizon B (H. M a r u s z c z a k 1991a, b) by a lower part of the soil complex of the "Nietulisko I" type (J. J e r s ą k 1973, 1988). In the central and southern Ukraine the Eemian soil processes are represented by a lower part of the mid-loessic soil complex Priluky (pl) (M. F. V e k l i c h and N. A. S i r e n k o 1976; M. F. V e k l i c h 1979, 1987) and in loesses of the northwestern Ukraine – by a lower part of the soil complex Gorokhov (A. B. B o g u t s k y et al. 1980; A. B. B o g u t s k y 1987).

Vistulian Glaciation. This is the last glacial episode of the Pleistocene when ice sheets several times advanced onto a considerable part of the European Lowland (Fig. 1), namely northern Poland, northeastern Germany (Figs 3-4) but also Lithuania, northern Byelorussia and Russian Plain where this episode is known as the Valdai Glaciation (Table 1). In northern Poland (Lower Vistula drainage basin) an older part of the Vistulian Glaciation has been found lately to comprise marine sediments of the Krastudy Interglacial which is separated from the Eemian Interglacial (Sztum and Tychnowy seas) by glacial deposits of the Toruń Glaciation (A. M a k o w s k a 1986, 1992). A younger part of the Vistulian Glaciation was there defined as the Baltic Glaciation (Table 1). During the Vistulian Glaciation icefree areas occurred in Czecho-Slovakia, western Germany, the Netherlands and most of the North Sea (Table 1). The British Isles were covered with local ice cap of the Devensian Glaciation that could eventually contact with the Scandinavian ice sheet but in a relatively narrow zone of the northern North Sea.

In loessy sections of Czecho-Slovakia this glaciation presumably corresponds to an upper part of the soil complex PK II and the loessy horizon B with a preserved soil complex PK I (G. J. Kukla 1978). In Poland a loess of this age, named the younger loess (LM after H. Maruszczak 1991a, b), is developed in 1-5 separate beds with interstadial soils in between (H. Maruszczak 1976, 1987; L. Lindner 1980, 1991a). In the central and southern Ukraine a loess of the last glaciation age is expressed with three beds: Uday (ud), Bug (bg) and Prichernomorye (pc), separated with two palaeosols: Vitachev (vt) and Dofinovka (df) (M. F. Veklich and N. A. Sirenko 1976; M. F. Veklich 1979, 1987). In the northwestern Ukraine a tripartity of this Upper Pleistocene loess is expressed by its lower, middle and upper horizons, separated with palaeosols Dubno and Krasilov (A. B. Bogutsky et al. 1980; A. B. Bogutsky 1987).

HOLOCENE

It is the youngest, postglacial and warm climatostratigraphic unit of the Quaternary that comprises the last 10,250 years and is concordantly distinguished in the whole Europe. This unit is treated as a key one for climatic conditions as well as diversity of geomorphological, geological and biological process that are typical for interglacials (L. Starkel 1990).

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STRESZCZENIE

Badania geologiczne, geomorfologiczne i paleontologiczne wykazały, że w brzeżnej strefie zasięgu zlodowaceń kontynentalnych w Europie można zidentyfikować co najmniej 20 głównych jednostek klimatostratygraficznych (tab. 1). We wczesnym czwartorzędzie, określanym na obszarze Polski jako preglacjał (preplejstocen), jednostkami tymi są dobrze korelujące z analogicznymi jednostkami na pozostałym obszarze Niżu Europejskiego dwa poważne ochłodzenia (Różce = Pretegelenian, Otwock = Eburonian) oraz dwa poważne ocieplenia (Ponurzyca = Tegelenian, Celestynów = Waalian). W środkowym i młodszym czwartorzędzie obszar Polski znajdował się w głównej strefie ruchu lądolodów skandynawskich i dlatego tu właśnie można wyróżnić największą liczbę jednostek klimatostratygraficznych, które nie zawsze mogą być jednoznacznie skorelowane z odpowiednimi jednostkami na pozostałym obszarze Niżu Europejskiego i Wysp Brytyjskich. Wyróżniono 8 zlodowaceń skandynawskich: Narewian (Menapian), Nidanian, Sanian 1 (Elsterian 1, Don), Sanian 2 (Elsterian 2, Anglian, Berezina, Oka), Liwiecian, Odranian (Saalian?, Dnieper), Wartanian (Saalian, Wolstonian?) i Vistulian (Weichselian, Devensian, Valdai) oraz 7 oddzielających je interglacjałów: Podlasian, Malopolanian (Korchevo), Ferdynandowian (Voigtstedt, Cromerian, Byelovezha), Mazovian (Holsteinian, Likhvin), Zbójnian (Dömnitz,

Wacken, Hoxnian), Lubawian (Shklov) i Eemian (Ipswichian, Muravino, Mga). Najmłodszą jednostką klimatostratygraficzną czwartorzędu jest holocen, traktowany jako wzorzec warunków interglacjalnych.

Przedstawiono także próbę korelacji zasięgów czwartorzędowych zlodowaceń kontynentalnych w środkowej Europie i główne stanowiska osadów interglacjalnych w dorzeczach Wisły, Odry i Łaby – z ich jednoczesnym zaklasyfikowaniem wiekowym (ryc. 1-4). Najwięcej niejasności budzi korelacja zlodowacenia Saalian w Niemczech (gdzie występują stadiały Drenthe i Warthe) ze zlodowaceniem Wolstonian na Wyspach Brytyjskich oraz ze zlodowaceniami Odranian i Wartanian w Polsce, a także ewentualne występowanie odrębnych interglacjałów w obrębie tego piętra zimnego (tab. 1). Istotnym problemem jest korelacja jednostek klimatostratygraficznych w obszarze objętym zlodowaceniami kontynentalnymi z odpowiednimi ochłodzeniami i ociepleniami zarejestrowanymi na obszarze ekstraglacjalnym w profilach lessowych Czecho-Słowacji i Ukrainy.

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