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The thermoluminescence chronostratigraphy of glacial deposits of the Maximum and Wkra (= I postmaximum) stadials of the Warta Glaciation in southeastern Poland

29 samples of glacial deposits of the Warta (= Saalian II) Glaciation were dated. The deposits of marginal zones of the Maximum and Wkra (= I postmaximum) stadials were analyzied in four selected regions. Presented here results indicate that during the Maximum Stadial, about 185-170 ka BP, the ice sheet has been located in NE Poland within its marginal zone of extent. This stadial could be correlated with the substage 6.6 of the isotopic-oxygen curve of deep-marine deposits. However during the Wkra Stadial the ice sheet advanced, to the maximum extent, about 165-150 ka BP, so it could be correlated with the substage 6.4 of the same curve.

INTRODUCTION

During second half of eighties author has studied the glacial deposits from marginal zones of the Warta ice sheet in northeastern Poland and dated them with the thermoluminescence (TL) method. Beginning of such chronostratigraphic investigations was necessery because on the turn of seventies and eighties the chronostratigraphic position of these deposits was unclear and very general. They were interepreted in various ways in the stratigraphic schemes of Quaternary of Poland (S. Z. Różycki, 1980; J.E. Mojski, 1982, 1985; L. Lindner, 1984, 1988; M. D. Baraniecka, 1990). That time was firstly formulated the chronostratigraphy of the Odra Glaciation (L. Lindner et al., 1985). During the session of the Komitet Badań Czwartorzędu Polskiej Akademii Nauk (KBCzPAN) author has presented his own project of investigations needed to complete actual knowledge of the Pleistocene chronostratigraphy.

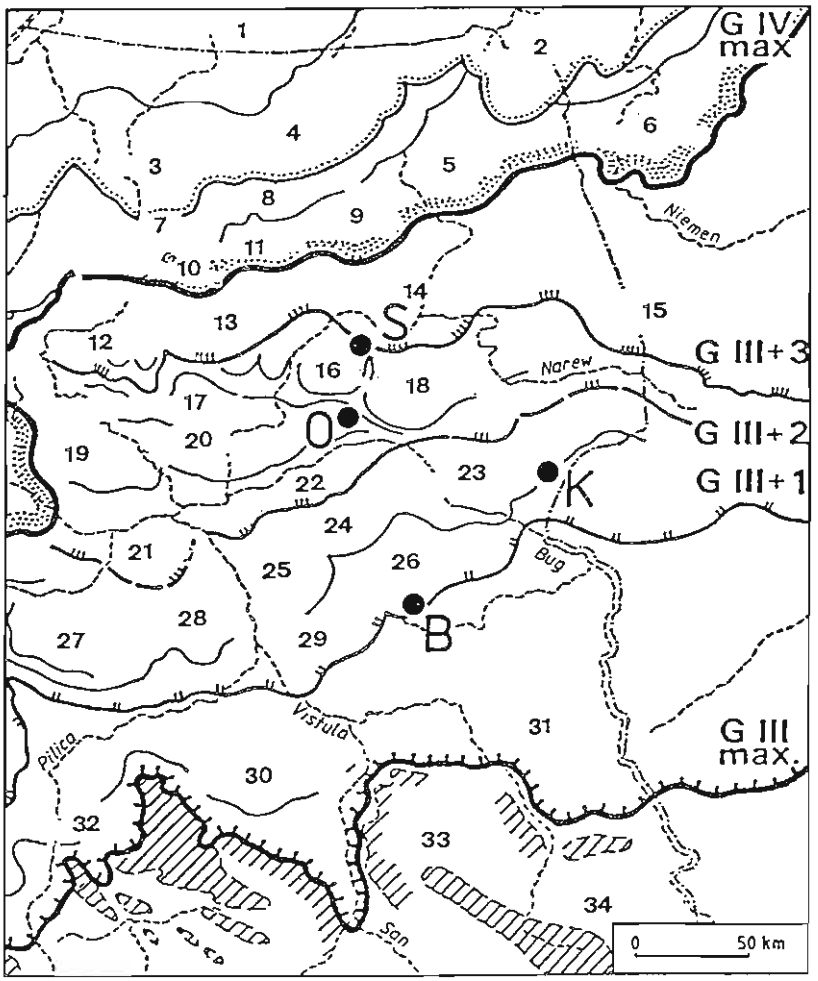

Fig. 1. Location of studied areas and extent of Middle Polish ice sheet in northeastern Poland (extents of ice and name of lobes after S. Z. Różycki, 1972)

Studied areas: B — Biardy, K — Kleszczele, M — Ostrów Mazowiecka, S — Śniadowo, G_{IIImax} — maximum extent of the Middle Polish ice sheet (the Odra one after S. Z. Różycki, 1980); G_{III+1} — the Warta Glacistadial; G_{III+2} — the Wkra Glacistadial; G_{III+3} — the Mława Glacistadial; G_{IVmax} — maximum extent of the Last Glaciation glacier; lobes: 1 — Pregoła, 2 — Szeszupa, 3 — Łyna, 4 — Mrągowo, 5 — Augustów, 6 — Grodno, 7 — Szczytno, 8 — Śniardwy, 9 — Kolno, 10 — Galindery, 11 — Pisz, 12 — Mława, 13 — Omulew, 14 — Łomża, 15 — Puszcza Knyszyńska, 16 — Orz, 17 — Ciechanów, 18 — Zambrów, 19 — Płońsk, 20 — Serock, 21 — Utrata, 22 — Tłuszcz, 23 — Siemiatycze, 24 — Liwiec, 25 — Świder, 26 — Siedlce, 27 — Rawa, 28 — Grójec, 29 — Garwolin, 30 — Radom, 31 — Chełm, 32 — Końskie, 33 — Lublin, 34 — Zamość; oblique dashes mark elevations of older basement, stopping movement of ice sheet

Rozmieszczenie badanych obszarów na tle zasięgów lądolodu środkowopolskiego w NE Polsce (zasięgi lądolodu i nazwy lobów wg S.Z. Różyckiego, 1972)

The Committee (KBCzPAN) has accepted this project and supplied special funds for TL analyses[1]. Studies of thermoluminescence properties for these datings were done by dr J. Butrym in laboratory of the Department of Physical Geography of UMCS.

In period of 1984–1988 was studied marginal zone of the Maximum Stadial of the Warta Glaciation between Wisła and Bug rivers. Very detail sampling (8 samples) was done in selected sites of glacial and fluvioglacial deposits nearby Biardy, in zone of the Siedlce lobe of maximum extent of glacier during this stadial. In 1987–1988 studies (10 samples for datings) were carried on the Siemiatycze lobe of the recessive phase of this glacier in vicinity of Kleszczele, in upper part of the Nurzec drainage-basin. In 1990 year were done investigations (11 taken samples) in extent zone of the Serock and the Orz lobes of the Wkra Stadial in vicinity of Ostrów Mazowiecka and Śniadowo. Location of studied areas is presented on Fig. 1.

PROBLEMS OF TL DATING OF THE GLACIAL DEPOSITS

Results of TL datings are most credible for eolian deposits. Rock grains lost during eolian transport a radiation charge they have got on primary depositional place. During deposition on current place they got a stage comparable to „zero point" (V. N. Shelkoplyas, G. V. Morozov, 1981). Glacial deposits during their long-time transport within ice sheet also acquire features of this stage due to an effect of triboluminescence. But in numerous beds of glacial sediments occurs also significant local component, transported for a short distance, often just from nearness. It causes that the results of TL datings of glacial deposits are more difficult to interpret. They could be critically analyzied only in that case when exist no less than several data for single

Badane obszary: B — Biardy, K — Kleszczele, M — Ostrów Mazowiecka, S — Śniadowo; G_{IIImax} — maksymalny zasięg lądolodu środkowopolskiego (= odrzańskiego wg S.Z. Różyckiego, 1980); G_{III+1} — glacistadiał warty; G_{III+2} — glacistadiał wkry; G_{III+3} — glacistadiał mławy; G_{IVmax} — maksymalny zasięg lądolodu ostatniego zlodowacenia; loby: 1 — Pregoły, 2 — Szeszupy, 3 — Łyny, 4 — mrągowski, 5 — augustowski, 6 — grodzieński, 7 — Szczytna, 8 — Śniardw, 9 — kolneński, 10, Galinder, 11 — piski, 12 — mławski, 13 — Omulwi, 14 — łomżyński, 15 — Puszczy Knyszyńskiej, 16 — Orzu, 17 — ciechanowski, 18 — zambrowski, 19 — płoński, 20 — serocki, 21 — Utraty, 22 — Tłuszcza, 23 — siemiatycki, 24 — Liwca, 25 — Świdra, 26 — siedlecki, 27 — rawski, 28 — grójecki, 29 — garwoliński, 30 — radomski, 31 — chełmski, 32 — konecki, 33 — lubelski, 34 — zamojski; ukośnymi szrafami oznaczono wyniosłości starszego podłoża utrudniające ruch lądolodu

[1] This study was partly financed by the KBCzPAN in two stages. During 1986–1988 were financed the studies of deposits from marginal zone of the Maximum Stadial of the Warta ice sheet and of its one recessive phase; their results were published in „The reports of the scientific investigations of KBCzPAN", no. 8, 1989. In 1990 year were studied deposits of the Wkra Stadial (= I postmaximum) and their results were presented on session of KBCzPAN on 14.11.1990. Up till now similar studies in the zone of the Mława Stadial (= II postmaximum) of the Warta Glaciation have not been done.

profile or site. Results of dating of single sample unable to conclude any stratigraphic opinion (H. Maruszczak, 1985).

Except of interpreting problems very important is a valuation of „characteristics" of technics applied by various laboratories. Among used methods are ones, accepted by phisicists as methodically proper or discussed as improper or seriously doubtful (A. Bluszcz, M. Pazdur, 1985; A. G. Wintle, 1987). Also when are applied methods of first group various results could be obtained. It depends on — among others — size of analyzied grains between 10 and 100 μm. At such large span of grain size also their mineralogical composition could varied and various is their capacity to cumulate radiation.

Author has indicated in his polemic article (H. Maruszczak, 1985) that due to these phenomena the results obtained in various laboratories are in most cases uncomparable. It was confirmed by the experiment of parallel dating by three laboratories the loess samples from the Odonów profile (J. Butrym, 1987; A. Bluszcz, 1989) and lastly of samples from glacial deposits nearby Konin (A. Bluszcz et al., 1991). In the last case the differences of datings were so significant that authors have concluded that „ ... TL method needs further confirming studies". (A. Bluszcz et al., 1991, p. 105). Other scientists more critically comment such large differences and question an useability of results obtained with TL method for stratigraphic interpretations (J. Jersak, 1991).

Despite of such critical opinions the TL method of dating could not be omitted in studies of the Quaternary. More precise time location of events is necessery not only for stratigraphic aims but also for palaeogeographic analyses. Ignoring of TL datings seems stopping of progress. Such dating ought to be controlled in the highest degree by application of other methods of event ordering in time. It should be also considered defined prineiples, mainly a rule of „non-mixing" of results obtained by various laboratories, without suitable valuation of their technical-methodical charaeteristies.

It should be more detaily describe characteristic of the TL laboratory in Lublin, which results of datings are here presented and discussed. There is applied one of additive dating methods, presented by J. Butrym (1985, 1986). This method is criticized by phisicists preferring the regeneration method (A. G. Wintle, 1987). It could be admitted that there are applied various versions of the regeneration method with different results (L. Zöller, G. A. Wagner, 1990). Irrespective of differences depended on characteristises of both methods the results obtained with this discussed one eommonly are significantly higher than the geologic age of these deposits according to oxygen-isotopic data. In the ease of deposits corresponded with 5 stage of the oxygen-isotopie curve of deep-marine deposits the phisicists have found that TL age was lowered of about 40% (S. Balescu et al., 1991). In the laboratory in Lublin, applying the additive method, the results for Polish loesses corresponding with 5 oxygen-isotopic stage, are similar to their geological age (H. Maruszczak, 1991). For the same loesses the results obtained with the regeneration method are seriously lowered (A. Bluszcz, 1989). For the Late Pleistocene loesses from western part of Middle Europe were noticed also the TL age data, determinated with regeneration method, lowered of 30–50% in relation to results obtained with ^{14}C method (E. H. Juvigné, A. G. Wintle, 1988). Lower values of TL age data in relation to ones of ^{14}C

method, were determinated lastly also for deposits from the Kenia Mt. in Africa (G. W. Berger, W. C. Mahaney, 1990; W. C. Mahaney, 1992).

The TL dating method, applied in the laboratory in Lublin, offers results comparable with obtained with other indirect methods. It allows to take them into account actually without further „confirming" studies of the TL method. Due to fact that this laboratory has the largest in Poland „bank of data", the results of datings could be compared with earlier ones for deposits of analogous (similar) geological age. Also should be admitted that lately in this laboratory were obtained credible — from geological point of view — age data not only for the oldest loesses but also for glacial deposits of over 0.3–0.5 Ma (H. Maruszczak et al., 1992).

THE STUDIED SITES OF GLACIAL DEPOSITS

B i a r d y (between Łuków and Siedlce). This area is located in marginal zone of the Siedlce lobe of the Maximum Stadial of the Warta Glaciation. There occurs the assemblage of forms typical for marginal zone, visible on detail topographic maps. Genetic interpretation of these forms is doubtful in many cases. B. Zaborski (1927) described distinct ridge, perpendicular to general extent of ice sheet as frontal moraine. Recently this form is interpreted by various authors as an osar. The group of hills parallel to ice extent the mentioned author interpreted as an osar. On actual *Geological map of Poland*, scale 1:200 000 (Siedlce sheet) these hills are described as frontal moraines. During his studies on this area in 1985 the author has preliminary interpreted them as kames. Such opinion is confirmed lastly the results of detail studies done by S. Terpiłowski (1992). Occurrence of these and other kame forms northward from Kaczory and Gostchorza indicates that during the deglaciation phase has developed there the broad zone of „dead" ice (Fig. 2). Main morphological forms were presented there on basis of geomorphological map, prepared by S. Terpiłowski in 1983 as his graduate work. There were done some suitable corrections, reflecting later discussions and results of last studies. Samples for the TL datings were taken from following sites:

1 — kame hill in Kaczory (sample from main kame series[2] and two samples from beds covering this series on the hill slope);

2 — kame hill in Gostchorza (sample from main kame series);

3 — low inclined slope in Biardy, composed of glacial till deposits (sample from glacial till);

4 — top of outwash fan southward from Biardy (sample of fluvioglacial sand);

5 — osar in Okniny Nowe (first sample from ablacion sandy-gravel deposits, „implaced" into main osar series and second one from underlaying sands).

[2] As main kame (osar) series are described deposits composing centers of these forms; their relation to other deposits noticed in outcrops is illustrated on Fig. 4.

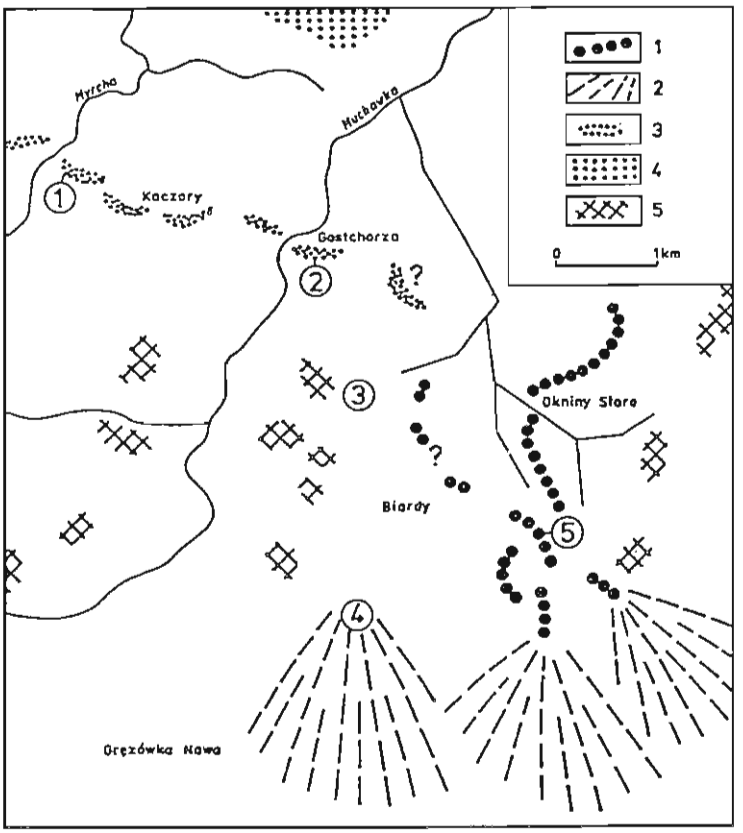

Fig. 2. Location of sites (1-5 in circles) near Biardy on the sketch of distribution of main morphological forms of marginal zone of ice sheet (elab. H. Maruszczak, 1992)

1 — osars; 2 — outwash fans; 3 — kame hills; 4 — kame plain; 5 — low distinct outliers of forms of marginal glacial accumulation

Rozmieszczenie stanowisk (1-5 w kółkach) w okolicy Biard na tle szkicu głównych form rzeźby strefy marginalnej lądolodu (opracował H. Maruszczak, 1992 r.)

1 — ozy; 2 — stożki sandrowe; 3 — pagórki kemowe; 4 — równina kemowa; 5 — słabo wyodrębniające się ostańce form marginalnej akumulacji glacjalnej

K l e s z c z e l e (35 km on northeast from Siemiatycze). This region is located within extent of the Siemiatycze lobe, distinguished by S. Z. Różycki (1972) in recessive phase of the Maximum Stadial of the Warta ice sheet. There occurs typical assemblage of forms characteristic for well developed marginal zones. Some of them have been described about 70 years earlier by B. Zaborski (1927), who has distinguished on his map the osar in Dasze village. It a classic example of the osar ridge with lenght of about 6 km and well marked „mouth" outwash fan. Suitable studies with sampling were there carried on during 1987-1988 period of field works of E. Kojło for her graduate elaboration. The simplified and adequately changed version of her map is presented

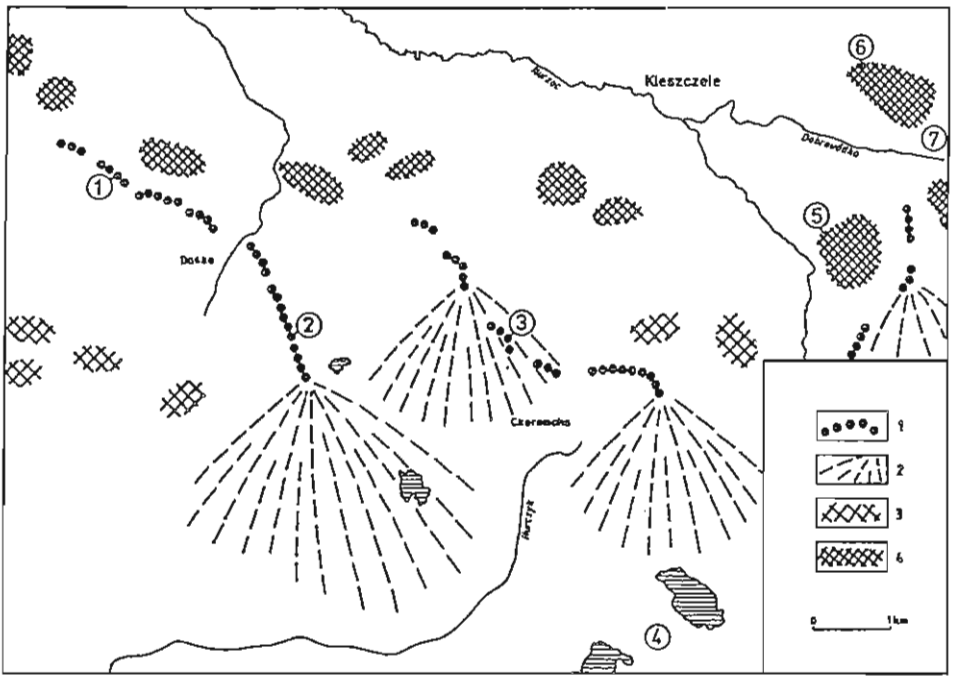

Fig. 3. Location of sites (1-7 in circles) near Kleszczele on the sketch of distribution of main forms of marginal zone of ice sheet (elab. H. Maruszczak, 1992)

1 — osars; 2 — outwash fans; 3 — low distinct outliers of forms of marginal glacial accumulation; 4 — better noticeble outliers of forms of marginal glacial accumulation

Rozmieszczenie stanowisk (1-7 w kółkach) w okolicy Kleszczel na tle szkicu głównych form strefy marginalnej lądolodu (opracował H. Maruszczak, 1992 r.)

1 — ozy; 2 — stożki sandrowe; 3 — słabo wyodrębniające się ostańce form marginalnej akumulacji glacjalnej; 4 — wyraźniej wyodrębniające się ostańce form akumulacji glacjalnej

on Fig. 3. It indicates that there has occured other type of deglaciation than nearby Biardy because is lack of univocal signs of occurrence of zones with „dead" ice. Samples for datings were taken from following sites:

1 — Dasze osar on north-west from Dasze village (one sample from sandy deposits underlaying the main osar series and two ones from ablation deposits overlaying it on the osar slope — Fig. 4);

2 — Dasze osar on ESE from Dasze village (one sample from sandy-gravel ablation cover and second one from glacifluvial sands of main osar series);

3 — osar on east from Czeremcha (sample of sands from ablation cover, including also beds of glacial tills);

4 — outwash fan plain on SSE from Czeremcha (sample of fluvioglacial sands);

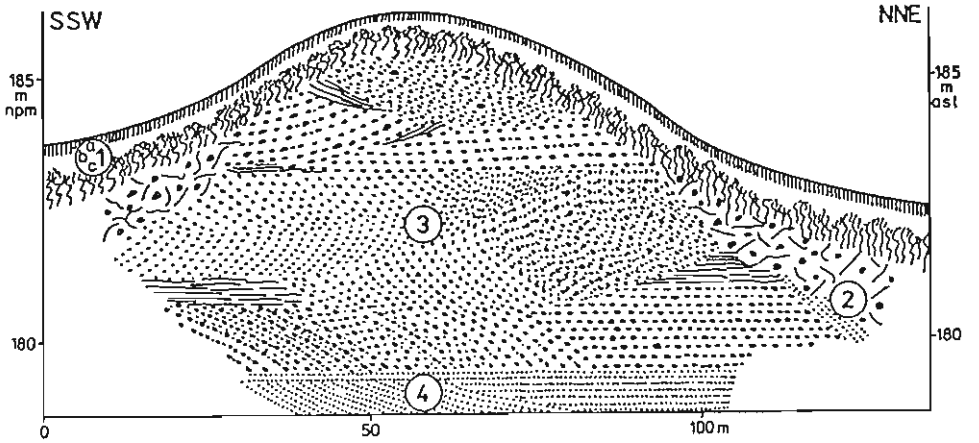

Fig. 4. The osar section in Dasze (site 1 on Fig. 3)

1 — soil-weathered deposits of Holocene age: a — humus horizon, b — podsolization horizon, c — illuvial horizon; the Wkra Stadial: 2 — ablation tills and sands (deposits covering osar slopes), 3 — fluvioglacial sands and gravels (main osar series), 4 — water- deposited vari-grained sands (deposits underlaying the main osar series)

Przekrój poprzeczny ozu w Daszach (stanowisko 1 na fig. 3)

1 — holoceńskie utwory zwietrzelinowo-glebowe: a — poziom humusowy, b — poziom bielicowania, c — poziom iluwialny; 2 — gliny i piaski ablacyjne stadiału wkrzańskiego (= utwory pokrywające na zboczach ozu); 3 — piaski i żwiry fluwioglacjalne stadiału wkrzańskiego (= zasadnicza seria ozowa); 4 — piaski różnoziarniste pochodzenia wodnego stadiału wkrzańskiego (= utwory podścielające zasadniczą serię ozową)

5-7 — hills in villages Dobrowoda and Rzepczyce, composed mainly of fluvioglacial deposits and partly of glacial ones (in any site was taken single sample of fluvioglacial deposits).

Ostrów Mazowiecka and Śniadowo (27 km on NNE from this town). Ostrów Mazowiecka is placed in extent of the Serock lobe of the recessive phase of the Wkra Stadial but Śniadowo is located in extent of the Orz lobe within zone of the next recessive phase (Fig. 1). In last years the detail studies were there carried on by A. Bałuk from Państwowy Instytut Geologiczny. Author would like to thank her for organizing the field trip during which were taken samples for dating from following sites:

1 — southern end of the Czerwony Bór ridge, eastward from Ostrów Mazowiecka (one samle from covering ablation till and two ones from lowerlaying fluvioglacial sands);

2 — outwash fan adjoined from SW on the Czerwony Bór ridge, on east from Ostrów Mazowiecka (two samples from fluvioglacial sands taken from neighbouring outcrops);

3 — large exploited pit within osar on east from Śniadowo (one sample from covering ablation till, two ones from lowerlaying fluvioglacial sands and one from bed of clayey silts within lowest fluvioglacial sandy-gravel deposits);

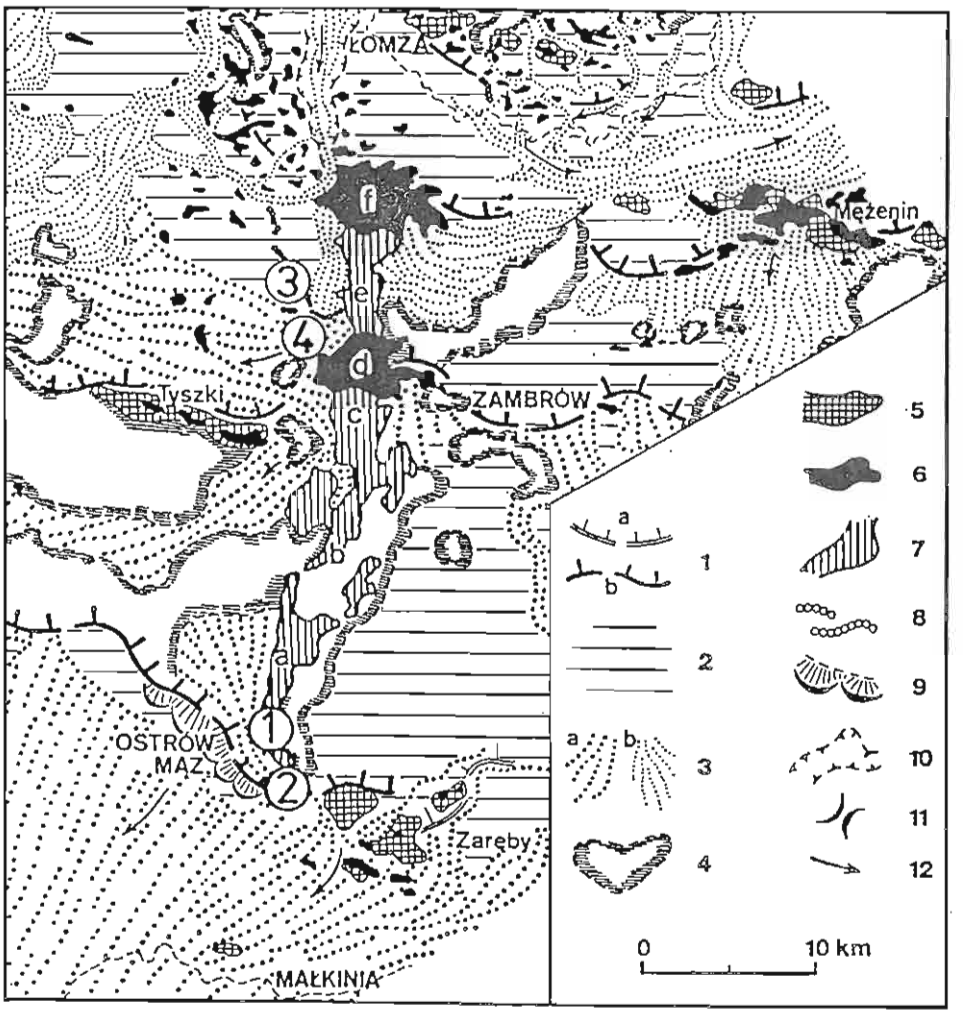

Fig. 5. Location of sites (1-4 in circles) near Ostrów Mazowiecka and Śniadowo on the paleomorphological map of ice sheet recession at the end of the Middle Polish Glaciation (the Warta one) after A. Bałuk (1991)

1 — extent of ice sheet: a — stadial extent, b — extent during the recessive phases; 2 — bottom and ablation moraines; 3 — outwash fans and flow ways of melting waters: a — older, b — younger; 4 — fields of „dead" ice; 5 — zones of marginal accumulation; 6 — frontal moraines (also parts „d" and „f" of the Czerwony Bór Hills as marginal polygenetic forms); 7 — main fracture forms; 8 — osars; 9 — zone of slide till accumulation; 10 — deep marginal trough; 11 — flow gates of melting waters; 12 — flow directions of melting waters

Rozmieszczenie stanowisk (1-4 w kółkach) w okolicy Ostrowi Mazowieckiej i Śniadowa na tle mapy paleogeomorfologicznej obszaru recesji lądolodu u schyłku zlodowacenia środkowopolskiego (= warciańskiego) wg A. Bałuk (1991)

1 — zasięg lądolodu: a — stadialny, b — podczas faz recesyjnych; 2 — morena denna i ablacyjna; 3 — sandry i szlaki przepływu wód roztopowych: a — starsze, b — młodsze; 4 — pola martwego lodu; 5 — strefy akumulacji marginalnej; 6 — moreny czołowe (także części „d" i „f" wzgórz Czerwonego Boru jako formy marginalnej o złożonej genezie); 7 — główne formy szczelinowe; 8 — ozy; 9 — strefa akumulacji gliny spływowej; 10 — głębokie rynny marginalne; 11 — bramy przepływu wód roztopowych; 12 — kierunki odpływu wód roztopowych

Table 1

Results of TL datings for samples of glacial deposits of Maximum and Wkra stadials of the Warta Glaciation in northeastern Poland

Area	Site (number as on Fig. 2, 3, 5) and morphological form	Deposits and sample depth	Results of TL datings (analyses by J. Butrym, 1986, 1988, 1990) and laboratory number sample*
Biardy (Fig. 2)	1. kame in Kaczory	1.1 sands of main kame series	147± 21 ka (Lub-886)
		1.2 till from kame slope	124± 18 ka (Lub-890)
		1.3 sands from kame slope	123± 18 ka (Lub-891)
	2. kame in Gostchorza	2.1 sands of main kame series	188± 28 ka (Lub-884)
	3. morainic elevation in Biardy	3.1 glacial till	140± 21ka (Lub-888)
	4. outwash fan on south from Biardy	4.1 fluvioglacial sands	178± 26 ka (Lub-889)
	5. osar in Okniny Nowe	5.1 clayey deposits from osar slope	123± 18 ka (Lub-885)
		5.2 sands under main osar series	199± 29 ka (Lub-887)
Kleszczele (Fig 3)	1. osar on NW from Dasze	1.1 sands under main kame series	171± 26 ka (Lub-1450)
		1.2 ablation till on slope	164± 24 ka (Lub-1448)
		1.3 sandy deposit under ablation till	167± 25 ka (Lub-1449)
	2. osar on ESE from Dasze	2.1 sands from main osar series	161± 24 ka (Lub-1595)
		2.2 sands on osar slope	153± 22 ka (Lub-1594)
	3. osar northward from Czeremcha	3.1 cover sands(?) on osar slope	137± 20 ka (Lub-1592)
	4. outwash fan on SSE from Czeremcha	4.1 fluvioglacial sands	148± 22 ka (Lub-1591)
	5. hill in Rzepczyce	5.1 vari-grained sands of cover(?)	131± 19 ka (Lub-1593)
	6. hill in Dobrowoda	6.1 fluvioglacial sands	150± 22 ka (Lub-1451)
	7. hill in Dobrowoda	7.1 sands within gravels	143± 21 ka (Lub-1452)
Ostrów Mazowiecka and Śniadowo (Fig. 5)	1. Czerwony Bór ridge eastward from Ostrów Mazowiecka	1A.1 ablation till; 1.3 m	147± 22 ka (Lub-2128)
		1A.2 fluvioglacial sands; 2.5 m	155± 23 ka (Lub-2129)
		1B.1 fluvioglacial sands; 1.9 m	153± 22 ka (Lub-2127)
	2. outwash fan eastward from Ostrów Mazowieeka	2A.1 fluvioglacial sands; 1.9 m	168± 25 ka (Lub-2130)
		2B.1 fluvioglacial sands; 2.5 m	177± 26 ka (Lub-2131)
	3. osar eastward from Śniadowo	3.1 ablation till; 2.1 m	158± 23 ka (Lub-2123)

Ostrów Mazowiecka and Śniadowo (Fig. 5)	3. osar eastward from Śniadowo	3.2 sands of main osar series; 3.2 m	163± 24 ka (Lub-2124)
		3.3 sands of main osar series; 7.4 m	175± 26 ka (Lub-2125)
		3.4 clayey sands within gravels; 11.5 m	182± 27 ka (Lub-2126)
	4. outwash fan in Ratowo Stare	4.1 sands within fluvioglacial gravels; 2.3 m	167± 25 ka (Lub-2132)
		4.2 sands within fluvioglacial gravels; 4.2 m	172± 25 ka (Lub-2133)

*Here are placed arithmetic mean values of results of TL analyses of microsamples (microprobes) (about 30 in any sample) from all studies sites. Such calculated averages of oldest series of samples (nearby Biardy) were so dispersed that in this case were determinated for them the medial valuers. They have differed from arithmetic values in some cases significantly. Because these medial values have seemed to be more representative from geological point of view they were published in preliminary report of such results. This other way of interpretation of series of samples from area nearby Biardy was indicated in text of that report (*vide* The reports of investigations of the Comittee of Quaternary Studies, Polish Academy of Sciences, No. 8, 1989, p. 26).

4 — outwash fan plain adjoined from south on the Śniadowo osar in Ratowo Stare (two samples from sandy-gravel deposits).

Location of these sites is presented on the sketch (Fig. 5), based on the paleogeomorphological map of A. Bałuk (1991). This map indicates that deglaciation conditions were there other than ones from diseussed above areas. The most significant proof of this differenee is an oecurrence of huge ridge of Czerwony Bór, deseribed by A. Bałuk as large fracture form.

CHRONOSTATIGRAPHIC INTERPRETATION OF RESULTS OF TL DATINGS

The results of TL datings are presented in Tab. 1. Any studied area was interpreted separetely. Further in text is eommented only definited in laboratory the average age of individual sample (average value of 30 mierosample data) but technical range of confidenee, presented in table, was not discussed.

The marginal zone of the Maximum Stadial in vieinity of Biardy. The oldest deposit was sandy fluvioglacial sediment, underlaying main osar series in Okniny (199 ka). Age of two samples from main kame series is quite different — 188 ka in Gostchorza and 147 ka in Kaczory. Age of the sample from top of the outwash fan southward from Biardy (178 ka) corresponds to the average age of three mentioned samples. The oldest sample probably represents a phase preceeding the ice advance but the last three document the stagnation phase within marginal zone. The ice sheet has occured there probably in period of 185–170 ka BP. Three next samples, taken from deposits interpreted as covering main kame and osar series, were dated for 125 ka (two samples) and 124 ka (one sample) and they probably indicate the deposits of slope type. They were presumably accumulated during the Late Wartanian phases of transformations of slopes of kame and osar hills. During displacement in subaerial conditions their primary radiation charge — from phase of deposition in glacial environment — could be reduced due to atmospheric factors. Age of glacial till from Biardy (140 ka) indicates that it could be also displaced along the slope after finishing of the glacial deposition. It is possible

that this till could be interpreted as facies of deposits connected with long-lasted remains of „dead" ice.

The marginal zone nearby Kleszczele. The oldest one was the sample from fluvioglacial sands underlaying main series of the Dasze osar (171 ka); the sample taken from this series was younger (161 ka). The samples collected from ablation deposits, covering main osar series, were of 167–164 and 153 ka. It seems that the ice sheet has stopped in this zone during period of 165–150 ka. The fluvioglacial deposits, accumulated during the stage of retreat and decline of glacier, were dated for 150–143 ka; similar age had sample from outwash fan southward from Czeremcha (148 ka). Age of cap deposits from the osar northward from Czeremcha (137 ka) and of sands in Rzepczyce (131 ka) indicates that they represent the phase of redeposition of glacial deposits in subaerial conditions of the Late Wartanian.

The Wkra Stadial of glaciation in vicinity of Ostrów Mazowiecka and Śniadowo. Age of samples from lowermost beds of main osar series (182 and 175 ka) could indicate that their accumulation was connected with the Maximum Stadial of discussed glaciation. Such interpretation should be confirmed with special sedimentological studies. Author has considered the results of datings of one sample from upper part of main osar series from Śniadowo (163 ka) and of two samples from fluvioglacial sands from the Czerwony Bór ridge (155 and 153 ka). According to these datings the ice stagnation on this area could be related with, as in vicinity of Kleszczele, the period of 165–150 ka. It could correspond to age data of samples from ablation tills from the Śniadowo osar (158 ka) and from the Czerwony Bór ridge (147 ka). Age of samples from outwash fan in front of the Śniadowo osar (Ratowo Stare — 172 and 167 ka) and of older one of two samples from southern margin of the Czerwony Bór ridge (168 and 155 ka) could be regarded as lowest value of lower limit of mentioned period. It is possible that the age of these last four samples is too high due to differences of petrographic composition resulted from an occurrence of strange source material (for instance — from parts of ice sheet with large admixture of local material from Older Pleistocene deposits).

Analysis of dating results indicates that the studied deposits in vicinity of Kleszczele should be connected rather with the transgressive Wkra Stadial than with the recessive phase of the Maximum Stadial of the Warta Glaciation. The Maximum Stadial seems to be much older than it was supposed by L. Lindner (1988) who definited its age for 150 ka. It should be dated for 185–170 ka and correlated with the substage 6.6 of the oxygen-isotopic curve for deep-marine deposits after J. Imbrie et al. (1984). The Wkra Stadial should be dated for 165–150 ka and compared with the substage 6.4 of this curve. Similar ones to discussed results of datings of glacial deposits of the Wartanian were obtained in the laboratory in Lublin from other areas of Poland. Some of these results have been just published, for instance — data from surroundings of Szamotuły (W. Gogolek, 1991), from Inowrocław (J. Jeziorski, 1991) and from Ryki (M. Żarski, 1991).

CONCLUSIONS

1. The results of TL datings indicate that the Maximum Stadial of the Warta ice sheet in NE Poland should be correlated with the period of 185-170 ka BP and with the substage 6.6 of the oxygen-isotopic curve for deep-marine deposits. With this period were connected early beds of older upper loesses from southern Poland, signed in the stratigraphic scheme of H. Maruszczak (1991) as LSg3. The Wkra Stadial should be correlated with the period of 165-150 ka BP and with the substage 6.4 of mentioned curve. During this period were accumulated middle beds of older upper loesses (LSg2). Because up till now have not been realized the chronostratigraphic studies of deposits of the Mława Stadial of the Wartanian, it could be only suggested that in age they are comparable with the substage 6.2 of the isotopic curve and correlable with late beds of older upper loesses LSg1 from southern Poland.

2. The results of datings of glacial deposits from the marginal zone nearby Kleszczele indicate that they should be correlated rather with the Wkra Stadial than with the recessive phase of the Maximum Stadial of glaciation. Such interpretation is confirmed with an occurrence of the assemblage of marginal forms of glacial accumulation, resulted rather from transgression than retreat of the ice.

3. Among the Middle Pleistocene glacial deposits the most useful for the chronostratigraphic analyses are these ones occuring within well developed osar forms. Separately should be considered and dated the main series, forming osar centers, the deposits underlaying as well as covering them, for instance — ablation deposits (Fig. 4). They sometimes differ significantly in age. Datings of single samples as not allow to define osar chronology.

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CHRONOSTRATYGRAFIA TERMOLUMINESCENCYJNA GLACJALNYCH UTWORÓW MAKSYMALNEGO I WKRZAŃSKIEGO (= I POSTMAKSYMALNEGO) STADIAŁU ZLODOWACENIA WARTY W NE POLSCE

Streszczenie

Metodą TL datowano 29 próbek utworów glacjalnych zlodowacenia warty (= Saalian II) w Polsce północno-wschodniej. Badano utwory ze stref marginalnych stadiału maksymalnego i stadiału wkry tego zlodowacenia (fig. 2, 3, 5). Analizy TL wykonał J. Butrym w laboratorium Zakładu Geografii Fizycznej UMCS w Lublinie, stosując jedną z odmian metody addytywnej datowania (J. Butrym 1985, 1986). Wykonane tą metodą liczne datowania różnowiekowych warstw lessów europejskich są zbieżne z określeniami ich wieku geologicznego (H. Maruszczak, 1991). Preferowana przez fizyków metoda regeneracyjna TL datowania daje natomiast wyniki znacznie zaniżone w stosunku do wieku geologicznego (S. Balescu i in., 1991). Dzięki temu, że lubelskie laboratorium TL datowania ma największy w Polsce „bank danych", prezentowane wyniki można porównać z wynikami wcześniej uzyskanymi dla utworów glacjalnych tego samego wieku z innych regionów Polski.

Na podstawie tych datowań stadiał maksymalny zlodowacenia warty w Polsce północno-wschodniej należy wiązać z interwałem 185-170 ka BP, a więc paralelizować go z substadium 6.6 krzywej izotopowo-tlenowej osadów głębokomorskich (standaryzowana krzywa wg J. Imbrie i in., 1984). Z tym interwałem zostały powiązane, występujące w Polsce południowej, wczesne warstwy lessów starszych górnych, oznaczone w schemacie stratygraficznym H. Maruszczaka (1991) symbolem LSg3. Utwory glacjalne stadiału wkry (= pierwszy postmaksymalny stadiał zlodowacenia warty) należy wiązać z interwałem 165-150 ka BP, a więc paralelizować z substadium 6.4 krzywej izotopowo-tlenowej. W tym interwale były akumulowane średnie warstwy lessów starszych górnych LSg2. Datowania wykonane dla rejonu Kleszczel (fig. 1) wskazują, że górna część dorzecza Nurca (prawy dopływ Bugu) była w zasięgu lądolodu stadiału wkry, a nie na zewnątrz tego zasięgu.