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Warta Glaciation in the Warsaw Region based on recent thermoluminescence datings

Basing on thermoluminescence datings of Quaternary sediments from three well-known key sites in the Warsaw Region (Mochty near Zakroczym, Dębe near Serock and Warka-Winiary), a thick till bed ascribed commonly to the Odra Glaciation, seems to be rather of the Warta Glaciation age and its ice sheet advanced presumably to the south of the Lower Pilica valley. Varved clays that cap the sections at Mochty and Dębe could be deposited during the Wisła Glaciation.

INTRODUCTION

The Central European Lowland has been a principal research region for well-known stratigraphical units of the Quaternary in Europe. In most cases the studies focused however in limited areas and correlations were based on data collected and analyzed according to different methodologic approach. For this reason presented stratigraphical schemes have been many a time compared with one another without sufficient evidence and in spite of general application of similar or even the same terminology, completely different units could be correlated (cf. L. Marks, 1990, 1991a).

Studies of the Quaternary stratigraphy in the recent years ask for reconsideration of the previously published stratigraphical schemes but also for presentation in different areas although elaborated with the same methodology — the key sections, stratigraphical location of which could be univocally defined and which, due to their position in existing stratigraphical schemes, would enable mutual correlation of the

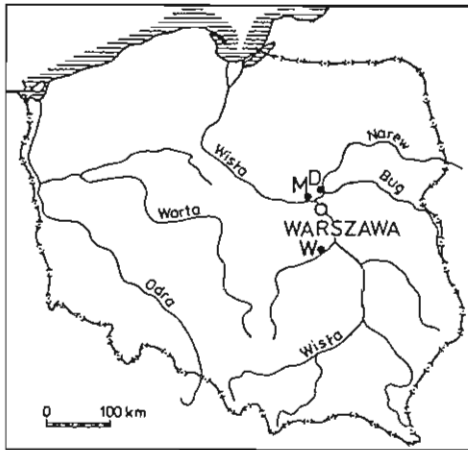


Fig. 1. Location of studied sections: Mochty (M), Dębe (D) and Warka-Winiary (W)
 Lokalizacja opracowanych profili: Mochty (M), Dębe (D) i Warka-Winiary (W)

latter. Particular significance has been gained by the problem of the Warta Glaciation, a key area for which is located in Central Poland.

The present studies focused in three sections of the Middle Pleistocene age, all located in the Warsaw Region (Fig. 1). They occur in escarpments of river valleys, namely: Mochty near Zakroczym — in escarpment of the Wisła (Vistula) valley, Dębe near Serock — in escarpment of the Narew valley and Warka (site Winiary) — in escarpment of the Pilica valley.

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APPLIED METHODOLOGY OF THERMOLUMINESCENCE DATINGS

Thermoluminescence datings were done with the standard method applied in the Thermoluminescence Laboratory of the Gdańsk University (S. Fedorowicz, in press). Collected samples were about 3 kg in weight and 1.5 dm^3 in volume each (Table 1).

The equivalent dose (ED) was determined with reproductive method (A. G. Wintle, D. J. Huntley, 1980), using a polymineral grain size fraction of 88–102 μm in diameter. Residual thermoluminescence was taken into account. Studies of the equivalent dose were carried through with a use of a reader-analyzer, model 770A. Precision of ED is about 10%.

The annual radiation (D_p) was measured with a use of the spectrometer gamma AZAR-82 and calculated with suitable formulae (S. J. Fleming, 1979), considering grain size and sediment moisture. The annual radiation is a total of alpha, beta and gamma radiation, which could be calculated from concentration of uranium, thorium and potassium in a sample. Measuring precision is close to 3%.

TL age is a quotient of ED and D_p , and precision of this value is about $\pm 15\%$. Due to very limited comparative datings from different laboratories in Poland, one cannot

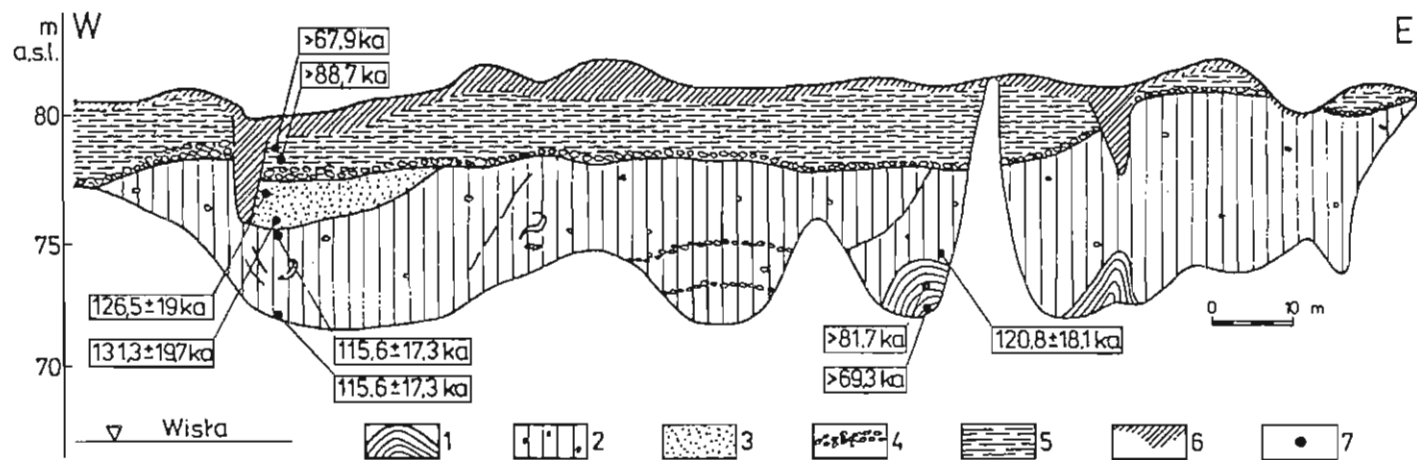


Fig. 2. Escarp section of the Vistula valley at Mochty

1 — dark clays, 2 — brown till, 3 — fine- and medium-grained sands, 4 — lag concentrate, 5 — varved clays, 6 — humus layer of recent soil and overcrept zones, 7 — stapling site to TL dating

Profil krawędzi doliny Wisły w Mochtach

1 — ropy szare, 2 — glina zwalowa brązowa, 3 — piaski drobno- i średnioziarniste, 4 — bruk morenowy, 5 — ropy warwowe, 6 — poziom humusowy współczesnej gleby i fragmenty zapelnione, 7 — miejsca datowań metodą TL

Table 1

Thermoluminescence data of samples from the sections Mochty, Dębe and Warka-Winiary

Name of sample and lithology	Lab. number	$d\alpha$	$d\beta$	$d\gamma$	d_c	D_r	ED	Age [ka]
MOCHTY 31 varved clay	UG-1523	1.62	2.75	1.40	0.12	5.89	>400	>67.9
MOCHTY 32 varved clay	UG-1524	1.26	2.08	1.06	0.11	4.51	>400	>88.7
MOCHTY 33 sand	UG-1525	0.39	0.87	0.45	0.10	1.81	209.2	115.6± 17.3
MOCHTY 34 sand	UG-1526	0.41	0.93	0.41	0.06	1.81	209.4	115.6± 17.3
MOCHTY 35 till	UG-1527	0.71	1.30	0.64	0.06	2.71	342.7	126.5± 19.0
MOCHTY 36 till	UG-1528	0.63	1.23	0.59	0.02	2.47	324.7	131.3± 19.7
MOCHTY 41 till	UG-1529	0.88	1.59	0.79	0.02	3.28	396.4	120.8± 18.1
MOCHTY 42 clay	UG-1530	1.49	2.18	1.20	0.02	4.89	>400	>81.7
MOCHTY 43 clay	UG-1531	1.62	2.71	1.43	0.01	5.77	>400	>69.3
DĘBE 51 varved clay	UG-1532	1.56	2.66	1.39	0.01	5.62	>400	>71.7
DĘBE 52 sand	UG-1533	0.35	0.62	0.30	0.10	1.37	149.0	108.8± 16.3
DĘBE 53 till	UG-1534	0.66	1.22	0.59	0.06	2.53	335.8	132.7± 19.9
DĘBE 54 till	UG-1535	0.71	1.10	0.57	0.04	2.42	332.5	137.4± 20.6

ST. WARKA 61 varved silt	UG-1536	0.61	1.31	0.62	0.12	2.66	345.5	129.9± 19.5
ST. WARKA 62 varved silt	UG-1537	1.08	1.92	0.96	0.08	4.04	>400	>99.0
ST. WARKA 63 till	UG-1538	0.76	1.47	0.70	0.06	2.99	346.8	115.9± 17.4
ST. WARKA 64 till	UG-1539	0.53	1.14	0.55	0.06	2.28	350.2	153.6± 23.0

Doses of radiation: α — alpha, β — beta, γ — gamma, dc — cosmic, Dr — annual; ED — geologic dose

univocally state that the data from the Gdańsk Laboratory are either „older“ or „younger“.

DESCRIPTION OF PRESENTED SECTIONS

Examined sections as well as areas in which they are located, have been already studied for several dozen of years. Many a time they constituted key sites for earlier stratigraphical works (e.g. S. Z. Różycki, 1961, 1967, 1972; H. Ruszczyńska-Szenajch, 1966; J. Nowak, 1974; Z. Sarnacka, 1990).

MOCHTY

The section of an escarp and a brickyard at Mochty (Fig. 2) is a key exposure for the Quaternary stratigraphy in northern Mazovia. Sediments in this very place have been already studied in the early twenties of this century, and their stratigraphical location was a subject of controversy between J. Lewiński and J. Samsonowicz from one side, and S. Leneewicz from the other (cf. J. Lewiński, 1924). In the end of the forties the section of the Vistula escarp in this area was mapped in detail (cf. S. Z. Różycki, 1978). A sedimentary succession in the section Mochty founded the base to determine the age of the Warsaw Ice-dam Lake and to distinguish the Wkra Stadal of the Middle Polish Glaciation (cf. Z. Michalska, 1961; S. Z. Różycki, 1961, 1967, 1972).

The section starts from the bottom with fine-grained sands (at present completely mantled with slope debris due to diminished erosion capacity of the river in the recent time) that, together with locally overlying grey clays and brown till (Fig. 2), form numerous glacial-dynamic features (cf. S. Z. Różycki, 1970). TL datings of clays (>81.7 and >69.3 ka) have not been univocal, presumably due to presence of residual thermoluminescence signal in sediments during their deposition. A till forms a key bed of the section, being from 5 to over 8 m thick. It is almost homogeneous in its grain size composition and grain roundness, but it contains considerably greater contents of colloidal particles and its grains are better rounded than in a till of the Wisła Glaciation (A. Kostrzewski, 1966). Certain individuality of petrographic composition of this till is also noted (B. Krygow-

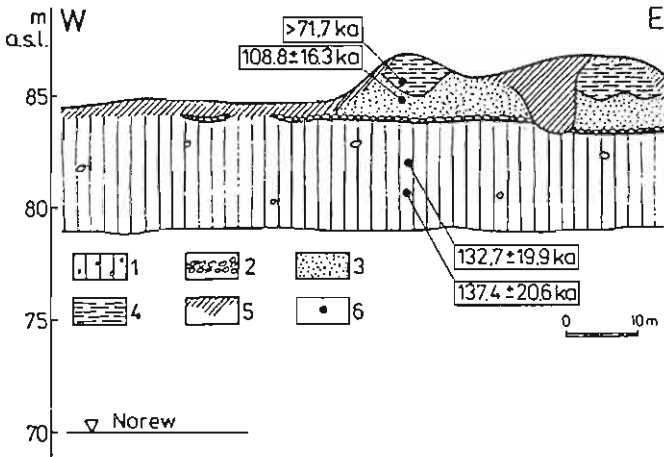


Fig. 3. Escarp section of the Narew valley at Dębe

1 — brown till, 2 — lag concentrate, 3 — sands, 4 — varved clays, 5 — humus layer of recent soil and overrept zones, 6 — sampling site to TL dating

Profil krawędzi doliny Narwi w Dębem

1 — glina zwalowa brązowa, 2 — bruk morenowy, 3 — piaski, 4 — ily warwowe, 5 — poziom humusowy współczesnej gleby i fragmenty zapelnzone, 6 — miejsca datowań metodą TL

ski, 1966). Clast fabric in the till indicates ice sheet movement from W-NW, but there is a distinct re-orientation of clasts in zones with glaciodynamic structures (J. Dzierżek, L. Marks, 1992). Three samples of this till were TL dated at 115.6–120.8 ka (Fig. 2).

The till is overlain locally with fine- and medium-grained sands, to 2 m thick and TL dated at 126.5–131.3 ka. These sands and in places where they are absent — the till, are covered with a thin (0.1–0.2 m) lag concentrate. The latter is overlain in turn with 3–4 m thick series of varved clays, considerably weathered in the top. Varved clays are composed of several dozen of varves of varying thickness (cf. J. Dzierżek, L. Marks, 1992). Presumably due to considerable admixture of older material that retained residual thermoluminescence, TL datings of the varved clays have not resulted in univoical results (>88.7 and >67.9 ka).

DĘBE

The escarp section of the Narew valley at Dębe (cf. J. Nowak, 1974) starts in the bottom with a brown till, a thickness of which reaches 5 m and which was TL dated at 132.7–137.4 ka (Fig. 3). The till is discontinuously capped with a lag concentrate, and overlying sands (1–2 m thick) were TL dated at 108.8±16.3 ka. Varved clays in the top of the section are to 2 m thick and strongly weathered in the upper part. Presumable presence of residual thermoluminescence during their deposition resulted in unclear dating of over 71.7 ka.

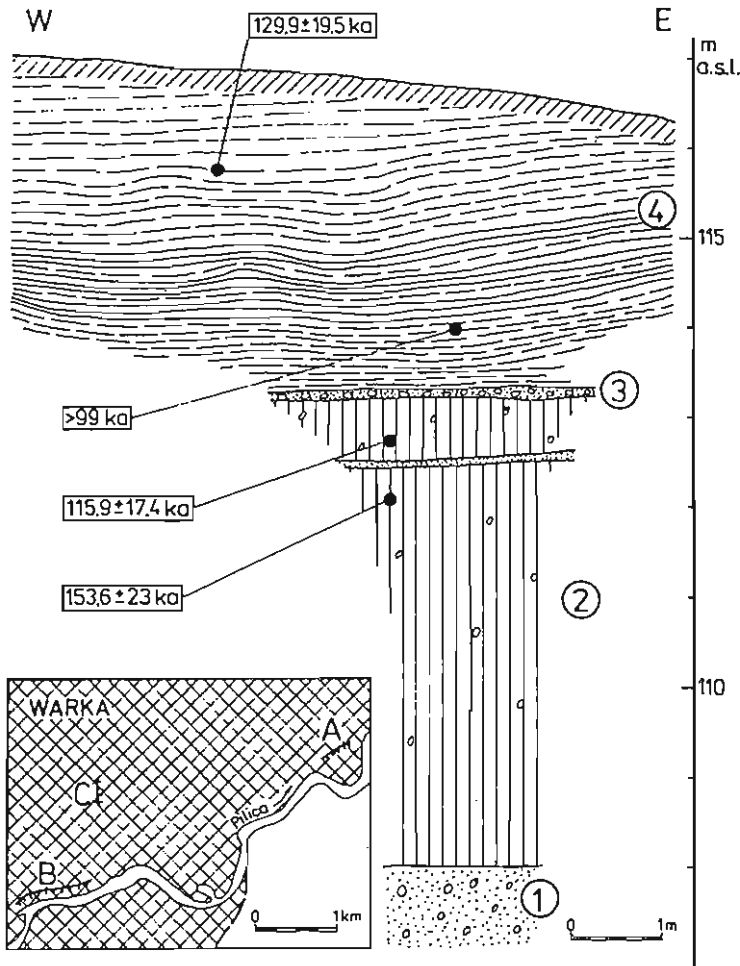


Fig. 4. Location of described exposures at Warka (A — Winiary, B — Niemojewice, C — railway station; cross-hatched is the town area) and section Warka-Winiary with marked sampling sites to TL datings

1 — vari-grained sands with gravel, 2 — grey-brown till, 3 — vari-grained sand with boulders (lag concentrate), 4 — varved clays and silts

Lokalizacja omawianych odsłonięć w rejonie Warki (A — Winiary, B — Niemojewice, C — stacja kolejowa; zakreskowano obszar miasta) i profil Warka-Winiary z zaznaczonymi miejscami datowań metodą TL

1 — piasek różnoziarnisty z domieszką żwiru, 2 — glina zwalowa szaro-brunatna 3 — piasek różnoziarnisty z gładkami (bruk), 4 — ropy warwowe i mulki

WARKA

Most recent TL datings in this area have concerned sediments in the section Winiary, in escarp of the Pilica valley in the eastern part of Warka (Fig. 4). This section comprises four lithostratigraphic complexes. In the bottom there are yellow-grey

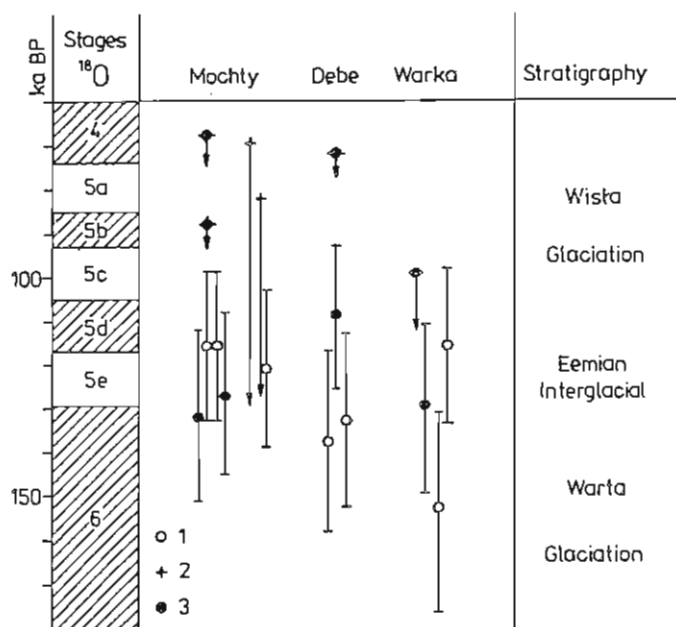


Fig. 5. Attempt of chronostratigraphic correlation of studied sections in connection to isotope stages of deep-sea sediments after D. G. Martinson et al. (1987); marked are measuring error limits of TL data
 1 — sample of till, 2 — sample of sub till deposits, 3 — sample of supratill deposits

Próba korelacji chronostratygraficznej opracowanych profili w nawiązaniu do stadiów izotopowych w osadach głębokomorskich według D. G. Martinsona i in. (1987); zaznaczono zakres błęd pomiarowego metody TL

1 — data z gliny zwalowej, 2 — data z osadów podglinowych, 3 — data z osadów nadglinowych

vari-grained sands with admixture of Scandinavian material and of flint, the latter redeposited from the Preglacial series in the vicinity. Close to Winiary the described sands are up to 14 m thick. In the studied section they have not been TL dated yet.

The overlying grey-brown sandy till, about 5 m thick and decalcified in the bottom, contains in its upper part a thin layer of vari-grained sand. In the top the till indicates rusty illuvial features. The upper part of the till was TL dated at 153.6 ± 23 ka whereas its uppermost part — at 115.9 ± 17.4 ka. The till is overlain with thin layer of vari-grained sand that contains clasts of Scandinavian derivation and is presumably a lag concentrate of denudation origin.

The upper part of the section is composed of ice-dam sediments, silty both in the bottom and in the top, with slightly folded silty and clayey layers in the middle. Sediments from the upper part of the sequence were TL dated at 129.9 ± 19.5 ka, whereas from the lower part — at over 99 ka (Fig. 4). In the studied section the ice-dam sediments are not overlain with a younger till but such has been noted at a plateau surface, about 200 m further to the north (Z. Samacka, 1986). According to M. Roslaniec-Chodnikiewicz (1966) this distance is considerably greater.

DISCUSSION

The Warsaw Region was occupied by an ice sheet of the Warta Glaciation, maximum extent of which has been delimited along the Lower Pilica valley (cf. L. Lindner et al., 1991b). A till of this age was not however noted in most escarp sections of river valleys in this area, what was ascribed to denudation (H. Ruszczyńska-Szenajch, 1966; J. Nowak, 1974). On the other hand, the till was noted at certain distance from the escarp — on a morainic plateau. TL data suggest however that the Warta Glaciation is represented in escarp by this very till which has been previously connected with the preceding Odra Glaciation.

Deposition of a till, present in the escarp of the Vistula valley near Mochty, was connected previously with the South Polish Glaciation (S. Z. Różycki, 1972) or with the maximum (Radomka) stadial of the Middle Polish Glaciation (J. Nowak, 1974). The overlying lag concentrate has been considered for residuum of a till of the Radomka, Warta and Wkra stadials of the Middle Polish Glaciation whereas varved clays in top of the section should represent deposition in the Warsaw Ice-dam Lake, formed during advance of an ice sheet of the Wkra Stadial (S. Z. Różycki, 1972). Some authors suggested that varved clays in the Warsaw Region had been formed in ice-dam lakes of varying ages (cf. T. Merta, 1978). TL dating of sediments in the escarp of the Vistula valley near Mochty suggests that the till was deposited during the Warta Glaciation whereas the overlying sands — already during the Eemian Interglacial. Glaciotectionic deformations of a till in the escarp of the Vistula valley to the northwest of Warsaw were considered by M. Brykczyński (1982) for younger than deposition of the till. In light of TL datings these deformations could develop during retreat of an ice sheet of the Warta Glaciation, presumably during a small readvance of the ice front. On the other hand a lag concentrate in top of a till or overlying sands, seems to have been formed by denudation acting in the escarp zone before deposition of the overlying varved clays. A non-univocal significance of TL datings of the latter does not exclude a possibility of their deposition during the initial phase of the Wisła Glaciation (Fig. 5; cf. W. Karaszewski, 1974).

Deposition of a till in the section Dębe has been connected with the Radomka Stadial whereas the overlying sands and varved clays — with the Warta Stadial of the Middle Polish Glaciation (J. Nowak, 1974). Basing on TL datings, this till is to be connected with the Warta Glaciation, whereas the overlying sands and varved clays — probably with a preliminary phase of the Wisła Glaciation (Fig. 5) what seems possible if all datings of ice-dam sediments in the Warsaw Basin are taken into account (cf. L. Marks, 1988, 1991b).

Sands in the lower part of the section Winiary form a very distinct stratigraphical horizon in exposures along the escarp of the Pilica valley near Warka, and were generally connected with the Mazovian Interglacial (cf. K. Grzybowski, 1966; M. Rosłaniec-Chodnikiewicz, 1966; H. Ruszczyńska-Szenajch, 1966; L. Lindner, K. Grzybowski, 1982; Z. Sarnacka, 1990). Such sands at Niemojewice, about 4 km to the west from the studied section (Fig. 4), have been previously TL dated at 560 ± 80 ka (cf. L. Lindner et al., 1987, 1991a) and therefore, they would be older than the Mazovian

Interglacial and correspond rather to the Ferdynandów Interglacial (cf. L. Lindner, 1991).

Two tills in top of the described sands near Warka were connected with the Radomka and Warta stadials of the Middle Polish Glaciation (K. Grzybowski, 1966; M. Rosłaniec-Chodnikiewicz, 1966; H. Ruszczyńska-Szenajch, 1966; Z. Sarnacka, 1990) or with corresponding Odra and Warta glaciations (L. Lindner, K. Grzybowski, 1982). TL datings of samples from the studied section suggest that the lower till represents the Warta Glaciation and its uppermost part (connected presumably with late melting of ice) was deposited during the interval which, according to the commonly accepted stratigraphical schemes (cf. L. Lindner, 1991), already belonged to the Eemian Interglacial. Acceptance of such hypothesis contradicts the conclusions of the above cited authors who prepared geological maps of the Warka Region. On the other hand it seems noteworthy that tills at northern edge of the Pilica valley near Warka have not been TL dated yet. In the Warka morainic plateau TL datings of a till, correlated with the till in the Pilica escarp (Z. Sarnacka, 1990) were equal to 230.3 ka in the borehole Dębówka and 230.2 ka in the borehole Gołębiów, and they deal with samples collected about 3 km and about 8 km respectively to the north-northwest from the escarp zone. In a railcut at the Warka station between the mentioned boreholes and the studied section the upper till is overlain by analogous sediments (K. Grzybowski, 1966). A lag concentrate noted between a till and ice-dam series was connected with an interphase within the maximum stadial of the Warta Glaciation. It seems therefore reasonable that in the area close to the section described in this paper, a till of the Odra Glaciation has been at least partly destroyed during the Lubawa Interglacial (cf. L. Lindner, 1991); if so, then the sampled till and the overlying lag concentrate really represent the Warta Glaciation.

Ice-dam sediments near the studied section have been connected with advance of an ice sheet of the Warta Glaciation (M. Rosłaniec-Chodnikiewicz, 1966; Z. Sarnacka, 1990). TL dating of the upper part of this till enables however correlation with sediments of the already mentioned exposure at the railway station. These sediments have been probably deposited during ice sheet retreat of the Warta Glaciation (L. Lindner, K. Grzybowski, 1982). If, however, a chronostratigraphic scheme of L. Lindner (1991) is taken into account, then the age of these sediments corresponds already to the beginning of the Eemian Interglacial.

In the section Niemojewice (Fig. 4) glaciofluvial sands on a till of the Warta Glaciation (K. Grzybowski, 1966) were TL dated at 159 ± 23 ka (cf. L. Lindner et al., 1991a). At Rytomoczydła (about 12 km to the northwest from the section Winiary) silts of the same glaciofluvial complex (K. Grzybowski, 1970) were TL dated by W. Stańska-Prószyńska and M. Prószyński at 185 ka (fide Z. Sarnacka, 1990). These varying age data (coming however from different laboratories) can be the effect of analytic errors but they also suggest that geological processes during the Warta Glaciation were much more complex than accepted by the above cited authors.

CONCLUSIONS

TL datings of Pleistocene sediments from the Warsaw Region allow to draw the following conclusions:

— a thick till in this area, previously correlated with the Odra Glaciation, seems to be of the Warta Glaciation age;

— a till which commonly occurs in surface of a morainic plateau and was previously correlated with maximum of the Warta Glaciation, seems to be deposited during minute readvance of an ice sheet when it was already generally retreating;

— an ice sheet of the Warta Glaciation advanced most probably considerably further to the south than to the present Lower Pilica valley (cf. A. Makowska, 1969; Z. Sarnacka, 1990; M. Żarski, 1990); sporadic end moraines in this area were formed during ice sheet retreat;

— varved clays at Mochty and Dębe could be deposited already during the Wisła Glaciation.

Results of TL datings in the Warsaw Region call for a broad discussion of extent and correlation of the Warta Glaciation in central Poland.

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ZŁODOWACENIE WARTY W REJONIE WARSZAWY W ŚWIETLE DATOWAŃ METODĄ TERMOLUMINESCENCJI

Streszczenie

Metodą termoluminescencji datowano osady plejstoceny w trzech stanowiskach w rejonie Warszawy, położonych w krawędziach dolin rzecznych: Mochty k. Zakroczymia, Dęba k. Serocka i Warka-Winiary (fig. 1, tab. 1). Miększa glina zwałowa, która występuje we wszystkich stanowiskach (fig. 2-4), była dotychczas korelowana ze zlodowaczeniem odry, lecz w świetle datowań TL wydaje się, że odpowiada raczej zlodowaczeniu warty (fig. 5). Z drugiej strony glina zwałowa, która występuje w powierzchni wysoczyzny polodowcowej położonej powyżej wspomnianych krawędzi dolin rzecznych i była dotychczas korelowana ze stadiątem maksymalnym zlodowaczenia warty, została prawdopodobnie osadzona w czasie recesji lądolodu tego zlodowaczenia.

Występowanie tak miększego i jednolitego pokładu gliny zwałowej zlodowaczenia warty w rejonie Warszawy sugeruje, że lądolód tego zlodowaczenia dotarł przypuszczalnie znacznie dalej na południe niż tylko do rejonu Doliny Dolnej Pilicy (por. Z. Sarnacka, 1990). Jeśli tak było w rzeczywistości, to należałoby poddać krytycznej ocenie także wyznaczony dotychczas zasięg zlodowaczenia odry i korelacje jego osadów.

Datowania metodą TL ilów warwowych występujących w strefie analizowanych profili w Mochtach i Dębem nie wykluczają możliwości, że tzw. zastoisko warszawskie (por. T. Merta, 1978) przynajmniej częściowo powstało dopiero w początkach zlodowaczenia wisły.

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