

CHRONOLOGY OF THE VISTULIAN (WEICHSELIAN) GLACIAL EVENTS IN THE LOWER VISTULA REGION, MIDDLE-NORTH POLAND

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Abstract: Stratigraphy of the Vistulian glacial events in the southern part of the Lower Vistula region in the north Poland is presented. Lithostratigraphic units and TL dating of Vistulian deposits exposing along the Vistula valley between Toruń and the Chełmno Lakeland are described in detail. The obtained results indicate that the Vistulian sequences in the Lower Vistula region were deposited during five palaeogeographical episodes. Three glacial events were distinguished: the first at the beginning of the Middle Vistulian (~65–70 ka) and two younger ones during the Late Vistulian. The Middle and Late Vistulian glacial events were separated by a long ice-free period, between 65 and 30 ka.

1. INTRODUCTION

The studies of the Vistulian Glaciation stratigraphy in the southern part of the Lower Vistula (**Fig. 1**) region have been carried out for several recent years (Wysota, 2002; Wysota *et al.*, 1996 and 2000). Thick and not deformed Vistulian stratigraphic sequences exposed along the scarp of the Vistula Valley between Toruń and Chełmno have been the subject of detailed examinations.

Lithostratigraphical and sedimentological researches have been carried out at seven key sites: Rzęczkowo, Łążyn, Unisław, Kiełp, Starogród 1, Starogród 2 and Chełmno (**Fig. 1**). They included: (1) identification and lithofacial analysis of sedimentary units, (2) analysis of directional elements (palaeocurrents, till fabric and kinematic indicators), (3) lithologic and petrographic investigations (grain size composition, carbonate content, quartz grain roundness, petrographic composition of gravels and heavy mineral composition), (4) TL dating of deposits, and (5) spatial analysis of stratigraphic units. Some results of the studies conducted at Rzęczkowo and Łążyn sites have already been published (Wysota *et al.*, 1996 and 2000).

The paper presents the synthesis of the Vistulian Glaciation stratigraphy in the southern part of the Lower Vistula region. The new ideas of chronology and palaeogeography of the Vistulian glacial events have been also put forward.

2. STRATIGRAPHIC UNITS

The lower limit of Vistulian deposits has not been satisfactorily recognized yet. It is supposed that upper fluvial series of the Lower Vistula formation, which so far has been connected entirely with the Eemian (Makowska, 1979 and 1980), represents preglacial period of the Early Vistulian (**Fig. 2**).

The sequence of Middle and Late Vistulian deposits, that overlies the Early Vistulian fluvial sediments, has the thickness of 25–70 m here. Three main stratigraphic units have been distinguished: Chełmno clays formation, Rzęczkowo formation and Starogród formation (**Fig. 2**).

Chełmno clays occur at the bottom of the Middle Vistulian succession. They comprise varved clays and silts up to 20m in thickness, which fill the upper part of the Eemian/Early Vistulian palaeovalley. Overlying it,

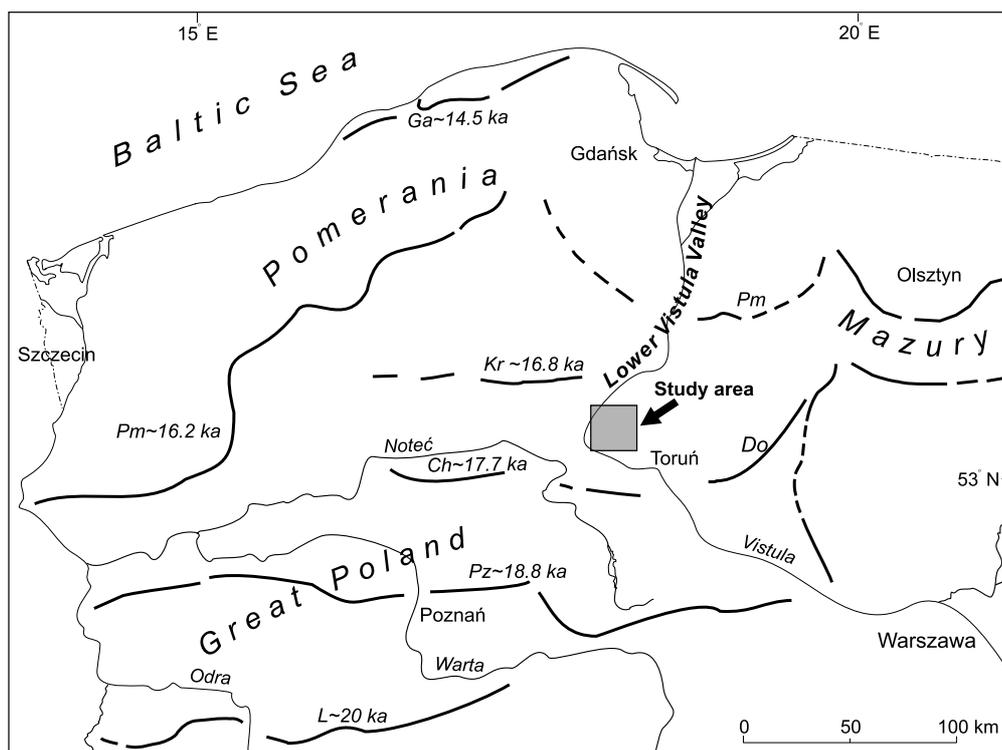


Fig. 1. Study area against the ice sheet margins of the Vistulian Glaciation in the mid-western Poland. L – Leszno phase, Pz – Poznań phase, Ch, Do – Chodzież, Dobrzyń readvance, Kr – Krajna subphase, Pm – Pomeranian phase, and Ga – Gardno phase.

Rzęczkowo formation is 15–25 m thick, and composed mostly of fluvial sands. Lithofacies of planar cross-bedded sands, parallel laminated sands and ripple-laminated sands are predominant.

Starogród formation occurs at the top of the Vistulian sequences. Two separate till units have been distinguished: the lower till member – Łążyn till and the upper till member – Starogród Zamek till. Łążyn till is 1.5–10 m thick and combines sandy and clay-rich massive and stratified diamictos. It comprises three genetic types of subglacial facies: deformation till, melt-out and decoupling till and melt-out till. Till fabric shows NE and NNE ice movement directions. Unisław clays, 2–6 m thick, of glaciolacustrine origin and lying underneath Łążyn till can be found in places. Glaciolacustrine sediments of up to 18-m thickness (Kiełp clays) overlie the lower till member. Glaciofluvial series occur below and above them locally.

Starogród Zamek till constitutes the highest unit of Starogród formation. It consists of massive brownish clay-rich diamicton up to 8–10 m thick. The diamicton usually comprises two facies: lodgement till and melt-out till. Till fabric shows N and NNE ice movement directions.

3. RESULTS OF TL DATING

Two sets of samples were dated by TL method. The first one consisted of four samples related to Kiełp clays: R-4, R-5, St1-1 and St1-2. The other seven samples: K-2, K-3, Ch-1, Ch-2, R-6, Sa2-1 and Sa2-2 were related to Rzęczkowo formation.

The material taken for TL analysis was cleaned and afterwards the quartz grains of specified size were separated and then etched, appropriate to the procedure described earlier (Przegiętka, 1999; Oczkowski *et al.*, 2000a). The bleaching of natural TL signal was performed in a

pecially designed chamber with sunlight simulator (Oczkowski and Przegiętka, 1998a). The bleached samples were used for equivalent dose estimation by the regenerative method. The plateau test was applied to choose the best temperature region. The additive method was also applied for the majority of the samples. The Risø System comprising the calibrated ^{90}Sr source (Oczkowski and Przegiętka, 2000) was used for beta dose irradiation and TL measurements. Details of equivalent dose determination procedures were presented earlier (Oczkowski and Przegiętka, 1998a; Przegiętka, 1999; Wysota *et al.*, 2000). The annual dose rates were determined on the basis of high-resolution gamma spectrum measured with HP germanium detector and Canberra MCA-100 analyser. Details of measurement and computational procedures were published previously (Oczkowski and Przegiętka, 1998b; Oczkowski *et al.*, 2000b). Results are presented in the **Table 1**.

Previously four samples related to Rzęczkowo formation were dated (Wysota *et al.*, 2000). Those dates were analysed together with seven new ones. The mean age value $T = 42.9$ ka with standard uncertainty $\sigma = \pm 1.7$ ka were obtained by the weighted averaging method. The histogram showing the distribution of the eleven TL dates is presented in **Fig. 3**.

Apparently these dates represent rather a continuous process stretched over a certain period of time than a single event (**Fig. 4**). Hence the mean age value is not suitable parameter for describing such a process. We assumed that the set of eleven investigated samples was good enough for the representation of Rzęczkowo formation. The shape of the histogram (**Fig. 4**) may suggest that the deposition lasted for the period of *ca.* 35 ky. Hence, we concluded that sedimentation of Rzęczkowo formation deposits started *ca.* 65 and ended about 30 ka ago.

Table 1. TL dates of deposits from southern part of the Lower Vistula region.

No	Section	Stratigraphic Unit	Sample Name	Lab. No.	Material	Age [ka]	Equivalent Dose [Gy]	Dose Rate [Gy/ka]
1.	Rzęczkowo	Kielc clays	R-4	TOR-35	Glaciolacustrine silts	19 ± 3	35 ± 6	1.863
		Kielc clays	R-5	TOR-36	Glaciolacustrine silts	20 ± 2	36 ± 4	1.805
		Rzęczkowo Fm.	R-6	TOR-37	Fluvial sands	33 ± 3	34 ± 3	1.023
		Rzęczkowo Fm.	R-2*	TOR-25	Fluvial sands	49 ± 6	51 ± 6	1.045
2.	Łążyn	Rzęczkowo Fm.	L-3*	TOR-28	Fluvial silts	50 ± 8	104 ± 17	2.078
		Rzęczkowo Fm.	L-2*	TOR-27	Fluvial sands	63 ± 20	126 ± 40	2.000
		Rzęczkowo Fm.	L-1*	TOR-29	Fluvial sands	65 ± 20	130 ± 40	2.000
3.	Kielc	Rzęczkowo Fm.	K-2	TOR-31	Fluvial sands	39 ± 6	61 ± 9	1.564
		Rzęczkowo Fm.	K-3	TOR-32	Fluvial sands	57 ± 7	57 ± 7	1.008
4.	Starogród 1	Kielc clays	St1-2	TOR-41	Glaciofluvial sands	21 ± 3	41 ± 5	1.931
		Kielc clays	St1-1	TOR-40	Glaciofluvial sands	27 ± 5	36 ± 6	1.329
5.	Starogród 2	Rzęczkowo Fm.	Sa2-1	TOR-38	Fluvial sands	47 ± 7	62 ± 9	1.325
		Rzęczkowo Fm.	Sa2-2	TOR-39	Fluvial sands	49 ± 5	60 ± 6	1.221
6.	Chelmno	Rzęczkowo Fm.	Ch-1	TOR-33	Fluvial silts	45 ± 5	76 ± 8	1.685
		Rzęczkowo Fm.	Ch-2	TOR-34	Fluvial sands	46 ± 5	47 ± 5	1.028

*) The data obtained prior to the present project and published in Wysota et al. (2000).

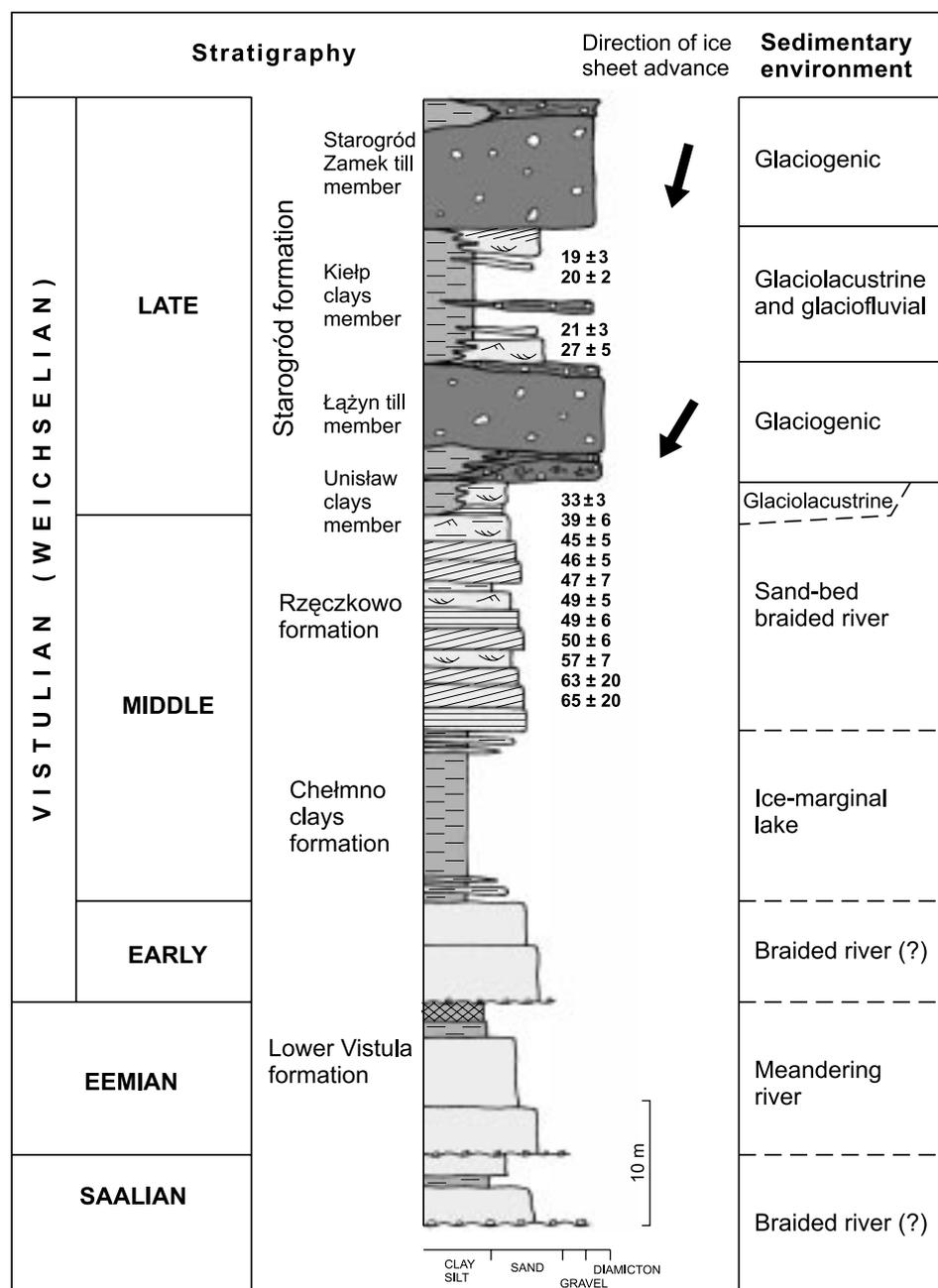


Fig. 2. Synthetic section and sedimentary environments of Vistulian deposits in the southern part of the Lower Vistula region. The numbers column means TL dates in ka.

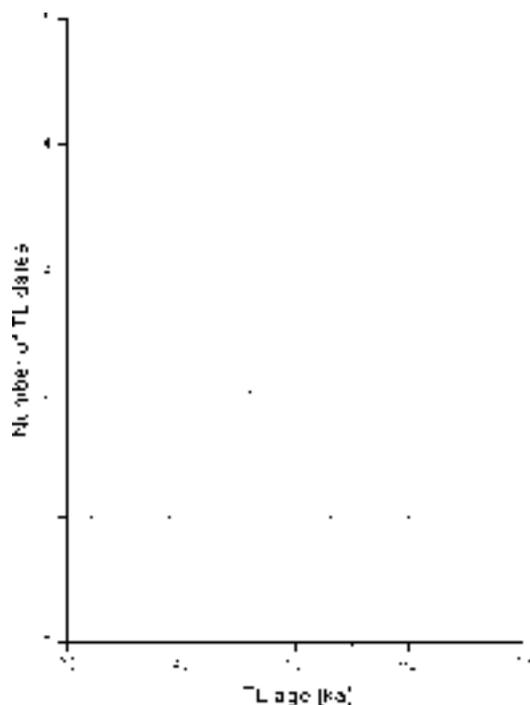


Fig. 3. Histogram of eleven TL dates obtained for samples representing Rzęczkowo formation, the bar width is 7 ka.

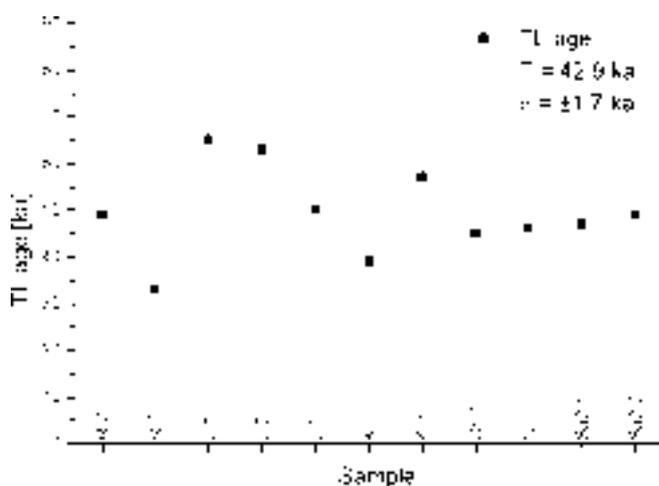


Fig. 4. The set of eleven TL dates obtained for Rzęczkowo formation and the weighted average value with its uncertainty, $T \pm \sigma$.

4. PALAEOGEOGRAPHIC EPISODES

The Vistulian deposits in the Lower Vistula region were deposited during five palaeogeographical episodes (Fig. 2). During the preglacial period of the Early Vistulian Upper fluvial series of the Lower Vistula Formation was accumulated. Deposition of deposits was developed in a braided river environment.

During the next stage Chełmno clays were formed. Sedimentary processes took place in a glaciolacustrine environment. The environment was formed as a result of the first ice sheet advance in the Lower Vistula region at the beginning of the Middle Vistulian (~65–70 ka). It is supposed that the ice sheet reached the Grudziądz Basin.

As the ice sheet was retreating, depositional processes were gradually changing their character from glaciolacustrine sedimentation to fluvial deposition. Rzęczkowo formation was deposited in the environment of a sand-bed braided river (Wysota *et al.*, 1996 and Wysota, 2002). The obtained TL dating suggests that the deposition of Rzęczkowo formation developed during a long ice-free period of the Middle Vistulian, between 65 and 30 ka.

Glacial, glaciolacustrine and glaciofluvial sedimentation characterised the succeeding depositional episodes. They were connected with two ice sheet advances, which covered the studied area during the Late Vistulian. The older glacial event was related to the first Late Vistulian maximum, ca 22–20 ka (the Leszno Phase). The younger one represented ice sheet readvance connected with the second Late Vistulian maximum, ca 19–18 ka (the Poznań Phase).

5. CONCLUSIONS

The obtained results of the studies indicate that there was no glacial event in the southern part of the Lower Vistula region during the Early Vistulian as it had previously been assumed (Makowska 1980, 1992 and 1994). Palaeogeographical and especially palaeoclimatological conditions recently recognized in the Polish Lowland, also deny ice sheet existence on the Lower Vistula at that time (Mojski, 1999).

The first glacial advance in this area occurred as late as at the beginning of the Middle Vistulian. This advance corresponds to the Toruń glacial horizon distinguished earlier by Makowska (1979, 1980, 1992 and 1994) in the Lower Vistula region. The collected lithostratigraphic data have not confirmed that the ice sheet reached Toruń, as she presumed. The Middle Vistulian ice sheet advanced to the northern, and probably to the middle part of the Lower Vistula region. Only proglacial deposits (Chełmno clays) are related to this advance in the southern part of the Lower Vistula region.

The obtained TL dates substantiated higher chronostratigraphic position of the younger Vistulian units than it had previously been stated (Makowska 1980, 1992 and 1994; Wysota *et al.*, 1996). It is presumed that Rzęczkowo Formation linked before to the Gniew Interstadial of the Early/Middle Vistulian period, represents a younger warm unit – the Grudziądz Interstadial of the Middle Vistulian. Overlying it, the lower glacial horizon of Starogród formation (Łążyn till), which formerly has been interpreted as the Middle Vistulian glacial episode unit (the Świecie stadial), is related to the first Late Vistulian maximum (ca. 22–20 ka). The ice sheet readvance connected with the second Late Vistulian maximum (ca. 19–18 ka) has not been recognized in the Lower Vistula region yet.

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