STEFAN KOZARSKI *
Poznań

EARLY VISTULIAN PERMAFROST OCCURRENCE IN NORTH-WEST POLAND

Abstract

Ice-wedge casts and fossil frost cracks have been indetified in deposits of Early Vistulian at Stare Kurowo, NW Poland. They are sandwiched between two organic layers; the lower one was formed during the Brørup Interstadial, whereas the upper one became formed during the Odderade Interstadial. The presence of ice-wedge casts in such a clear stratigraphical situation implies that the period between both interstadials was a cold period of stadial rank. It promoted the development of permafrost and it was called the Stare Kurowo Stadial.

INTRODUCTION

A few years ago DYLIKOWA (1978, p. 171) concluded: "Our present state of knowledge of the environmental characteristics included into the notion of periglacial zone, which strongly differentiated in geographical s p a c e, requires the same differentiation as regards the climatic changes in t i m e during the Pleistocene and particularly during the last cold period (Würm)". This conclusion coincided with DYLIK's (1963, 1966) earlier views. DYLIK emphasized also the importance of reconstruction of the history of permafrost and its palaeoclimatic implications. DYLIKOWA's appealing conclusion becomes really significant only if it is compared with information on the evolution of permafrost in central and western Europe during the Vistulian. Facts, especially those concerning the Early Vistulian, are strikingly scarce. Note should also be made that many workers are not able to determine the exact stratigraphical position of structures and/or periglacial deposits because of hiatuses in geological sections.

For instance, it is reported (VANDENBERGHE and KROOK, 1981) that in western Europe there exist strong cryoturbations and large fossil ice wedges related to a very cold climate and the presence of permafrost over a period between Brørup and Hengelo interstadials or in the pre-Amersfoort and post-Amersfoort periods (DE MOOR, 1981). Following MAARLEVELD's (1976) suggestions, the oldest ice-wedge casts identified till now in the Netherlands developed earlier than the Moershoofd Interstadial Complex and later than the

*Adam Mickiewicz University, Quaternary Research Institute, Fredry 10, 61-701 Poznań, Poland.

Early Vistulian. BERGERSEN and FOLLESTAD (1971) as well as HILLEFORS (1974) assigned the age of Early Vistulian to ice-wedge casts found in Scandinavia, using geochronometrical criteria. Those structures are older than 42,000 or 36,000 radiocarbon years BP. Fossil periglacial environment is also traces in the Early Vistulian of Scania (BERGLUND and LAGERLUND, 1981). Its traces are younger than the Slatteröd/Brørup Interstadial.

The problem of age determination is alike if fossil periglacial structures of Early Vistulian in the territory of Poland are dealt with. JAHN (1969, 1975) describes the oldest ice-wedge casts within loess as having been formed immediately after the Brørup Interstadial. In GOŹDZIK's (1973) opinion, involutions and congelifluction lobes developed in the Łódź Upland during that period of the Early Vistulian. In the stratigraphy of Polish loesses, JERSAK (1973) places the first sand wedges before the Brørup Interstadial. On the other hand, MARUSZCZAK (1980) identifies frost cracks of Early Vistulian in loesses but he makes no attempt at defining their stratigraphic position in more detail.

The relative age of periglacial structures mentioned in the above examples was deduced from not always sufficiently clear stratigraphical positions and from the so called general palaeogeographical knowledge of climatic changes during Early Vistulian. In the situation as that described above, reconstruction of palaeogeographical events associated with the presence of permafrost (STARKEL, 1977; KARTE, 1981) during the Early Vistulian must be obscure.

DYLIKOWA'S (1978) appealing statement is thus justified. A search for new sites of periglacial structures in well defined stratigraphical positions among the Vistulian deposits is required as it remains the only means of learning the history of permafrost of that particularly important period of the Pleistocene. Because of that, a report on studies of periglacial structures at the site Stare Kurowo is presented. The structures are developed in a very convenient stratigraphical situation, the study of which has become advanced in the recent years (KOZARSKI, *et al.*, 1980, 1982).

LOCATION OF THE SITE

The discussed geological section which reveals periglacial structures of Early Vistulian has been found in a brick-yard pit at Stare Kurowo (Fig. 1). The pit is located in the scarp of the Toruń – Eberswalde Pradolina. The section through Vistulian sediments exposed there reaches down to the depth of 18.5 m (KOZARSKI, *et al.*, 1982). The pradolina scarp cuts there into a morainic plateau covered with ablation sediments on the surface (KASPRZAK, 1981). The sediments date back to a period of recession of the last ice sheet from the extent line of the Poznań Phase to the extent line of the Pommeranian Phase.

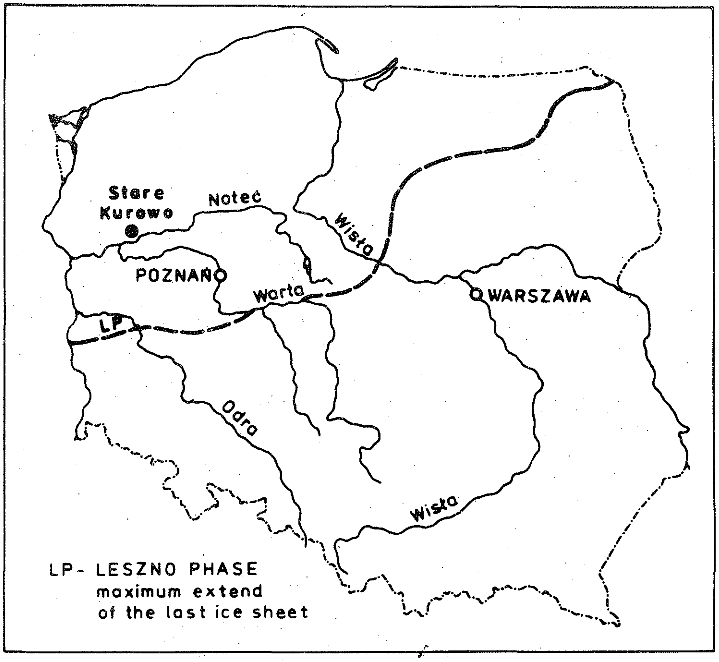

Fig. 1. Location map of site Stare Kurowo

STRATIGRAPHY

With regard to the problem discussed in this paper only the stratigraphy of Early Vistulian deposits exposed in the lower part (14.5 – 18.5 m) of the section (Fig. 2) at Stare Kurowo (KOZARSKI, *et al.*, 1980, 1982) will be presented.

The lower part of the section consists of cross-laminated medium-textured sands that contain organic bands at their top (Fig. 2). The entire thickness of the sands remains unknown. The sands are overlain by a layer of decomposed fen peat. The peat is basically pure as it contains merely thin and sparse sand lenses and/or bands. The thickness of peat approaches 1.0 – 1.2 m. The peat is covered with a thin (0.4 m) layer of laminated fine-textured sands and silts of the flood facies, containing laminae of organic matter. Silt-banded fine sands lie above. The whole layer is up to 1.7 m in thickness and consists of sediments deposited by vertical accretion on the floodplain surface.

Sandy peat and a layer of silt-banded fine sands, in particular, are strongly disturbed by ice-wedge casts and frost cracks (Fig. 2, Pl. 1). Another layer of organic sediments, 0.2 – 0.3 m thick, lies at the top of the fluvial series. It is truncated by an erosional surface (Fig. 2). The base of the organic layer is irregular in pattern (Pl. 4) and the organic matter penetrates sometimes into ice-wedge casts.

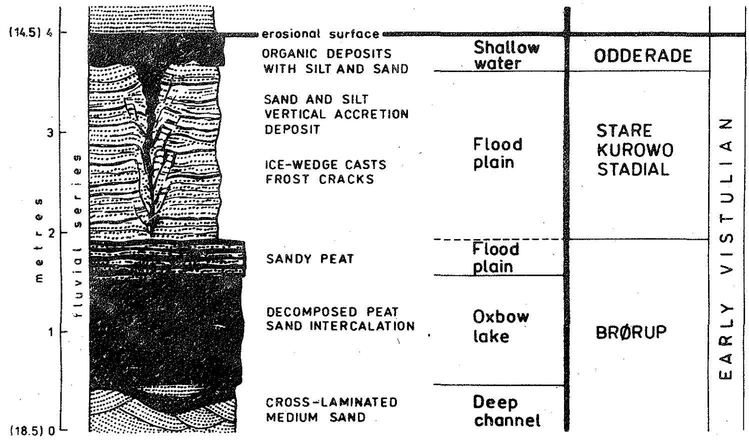

Fig. 2. Stratigraphical position of Early Vistulian ice-wedge casts and fossil frost cracks at Stare Kurowo

From palaeobotanical studies including pollen analysis and macrofossil analysis carried out by TOBOLSKI it can be inferred (KOZARSKI, *et al.*, 1981, 1982; KOZARSKI, 1980, 1981) that the lower organic layer was formed during the Brørup Interstadial, whereas the upper organic layer accumulated during the Odderade Interstadial. Thus, this permits the exact determination of the stratigraphical position of ice-wedge casts and fossil frost cracks occurring between both organic layers at the site Stare Kurowo (Fig. 2). In such a situation as that described above, periglacial phenomena alone are of major stratigraphic and palaeogeographic significance. Evidence of the statement that their development is related to the presence of permafrost is only required.

DESCRIPTION OF PERIGLACIAL PHENOMENA

Periglacial phenomena have been studied in vertical and horizontal planes. One of the basic requirements (BLACK, 1976; DYLIK, 1963) for correct analysis of thermal contraction structures has thus been fulfilled. The above structures are developed in the main layer of flood deposits (Fig. 2) as epigenetic and intraformational structures. In the vertical plane they have the shape of: (1) narrow cracks, about 0.5 – 2.0 m in lenght, with wedge-like widening by 5 – 10 cm in the upper parts, (2) sharply marked wedges, up to 1.5 m long, the upper parts of which contain the slump zone with a width ranging from 0.5 to 0.8 m at the most (Pl. 1), and (3) irregular sacks bent at the bottom which, together with an expanding vein, are over 1.5 m in length (Pl. 2).

Structures under (2) and (3) were filled from the top and sides. Evidence for the filling of wedge structures in top parts is provided by organic matter derived from

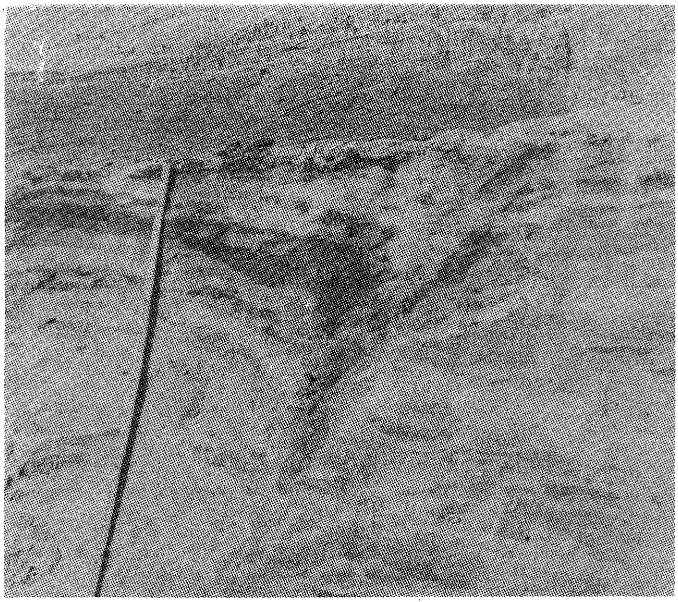

Photo by L. Kasprzak

Pl. 1. Ice-wedge cast between deposits of Brørup and Odderade Interstadials

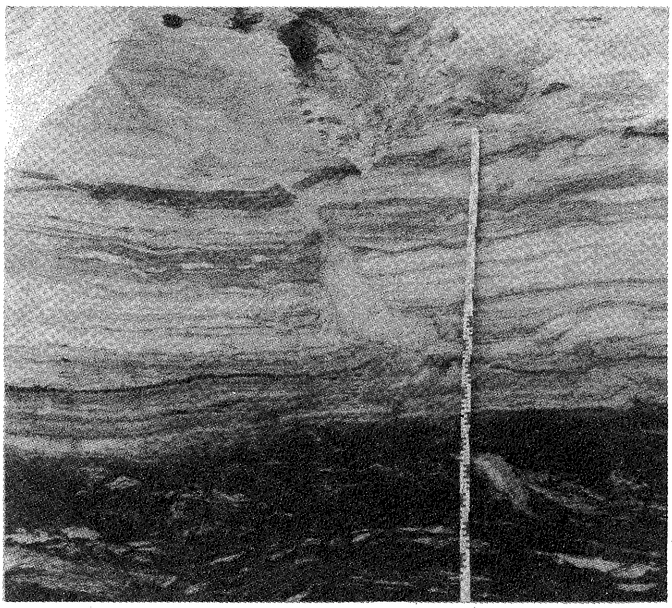

Photo by S. Kozarski

Pl. 2. Sack-like structure in flood deposits

Photo by S. Kozarski

Pl. 3. A fossil frost crack in horizontal plane

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Pl. 4. Slightly cryoturbated bottom part of Odderade Interstadial organic layer the upper layer (Odderade). It penetrates into the topmost parts of wedges. On the other hand, filling from the sides following the melting out of fissure ice becomes apparent in the form of many small gravity faults in the host material (Pl. 1). The mineral fill of sack-like structures is entirely foreign to the host material and unconsolidated. The particle-size distribution of sandy fill (coarse sand) differs from that of flood deposits (fine sands and silts) in which the above structures are present.

The structures under consideration were also studied in the horizontal plane (Pl. 3). The distance between wedge structures that are first order structures exceeds 5 m whereas the distance between frost cracks is smaller than 5 m. The structures are organized in a distinct polygonal pattern, as can be inferred from the study of their exposed parts.

All the features of fossil periglacial structures identified and described here are of diagnostic value (BLACK, 1976; JAHN, 1975, 1978; ROMANOVSKIJ, 1973; GOŹDZIK, 1973, 1978; WASHBURN, 1979) and permit the structures to be recognized as phenomena produced in permafrost.

Small-scale deformations at the base of the upper organic layer are also thought to be cryoturbate origin (Pl. 4). They reveal features of deformations associated with the active layer that was formed after the deposition of the upper organic layer. Thus it is the remainder of a younger active layer compared with ice-wedge casts and fossil frost cracks discussed above. That active layer was formed during a cold period following the Odderade Interstadial.

DISCUSSION AND CONCLUSIONS

In the past decade many workers studying periglacial phenomena (BLACK, 1976; FRENCH, 1976; JAHN, 1975, 1978; GOŹDZIK, 1973, 1978; ROMANOVSKIJ, 1973; WASHBURN, 1979) have been in agreement on at lest two points concerning ice-wedge casts, namely on that of: (1) origin of ice-wedge casts that grow as thermal contraction progresses, and that of (2) their role as unquestionable indicators of permafrost.

Differences in views between them include temperature conditions controlling the origin of thermal contraction cracks and the development of ice wedges, substratum characteristics and a relationship between mean annual air temperature (MAAT) and the formation of thermal contraction cracks. PÉWÉ (1966, 1973) used the −6°C to −8°C isotherm of mean annual air temperature (MAAT) as a boundary marking the occurence of active ice wedges in North America. In his studies from Siberia ROMANOVSKIJ (1973) reported that ice veins are present in alluvial fine sands near rivers and on floodplains when the ground temperature is −5°C, −6°C, or most probably, even colder. The mean ground temperature in clayey-sandy sediments is −7 and −8°C. Yet, ROMANOVSKIJ states that thermal contraction cracks are generated in alluvial sandy-silty and sandy-clayey sediments when ground temperatures range between −2 and −4°C. BLACK (1976) and WASHBURN (1979) accept that the activity of ice wedges is conditioned by the temperature of − 5°C. BLACK's comments are of special importance. In his opinion, regions of continuous permafrost where temperature at the depth of no annual change is lower than −5°C contain active layer that is thin enough to permit rapid drops of temperature at the top of permafrost during early winter. Besides, from a discussion of mean annual air temperatures and ground temperatures in permafrost regions, BLACK (1976) draws a conclusion that "the changes of 4 to 8°C that can induce thermal contraction cracking in supersaturated fine-grained sediments are controlled more by local surface conditions and individual cold spells than by annual temperatures". This view is consistent with the conclusion presented recently by HARRIS (1981) who remarks that the boundary of the continuous permafrost zone crosses the mean annual air temperature isotherm (MAAT).

Perhaps palaeogeographic objectives will rather require the use of both mean annual air temperature (MAAT) and temperature of the permafrost top and not only of the former that is used by KARTE and LIEDTKE (1981) for determining threshold climatic values controlling the distribution of periglacial phenomena.

In view of KARTE and LIEDTKE'S (1981) concept, data provided by them and values given by BLACK (1976), threshold climatic values for the site Stare Kurowo through a period between the Brørup and Odderade Interstadials are as follows:

MAAT (mean annual air temperature): −4 to −8°C, additional climatic indication: permafrost temperature at the depth of no annual change: −5°C; rapid temperature drops in early winter by at least 4 to 8°C.

MAP (mean annual precipitation): 50 to 500 mm.

The above estimated threshold climatic values permit the period between the Brørup and Odderade Interstadials to be recognized as a cold one and to be ranked as a stadial. In view of an exceptionally clear stratigraphical situation of the above palaeoclimatic indicators, the use of the term "Stare Kurowo Stadial" for the designation of that period (Fig. 2) appears valid from at least the regional viewpoint (KOZARSKI, 1980, 1981). The Stare Kurowo Stadial can be correlated with a period recognized by WELTEN (1981) on the basis of the palaeobotanical record and termed "Die dritte Frühwürm-Kaltphase" (FW-St. 3) and with a sub-Arctic phase proposed by MENKE (1982) to define a period between Brørup and Odderade Interstadials in NW Germany.

From palaeobotanical data (KOZARSKI, *et al.*, 1980, 1982) and sedimentological facts obtained from the geological section at site Stare Kurowo it can be inferred that climate deteriorated gradually during that stadial. The pollen diagram (KOZARSKI, *et al.*, 1980, 1982) first shows forest retreat and at the same time shrubs and herbaceous plants expansion at the top of Brørup sediments. This part of the section is remarkably distinguished by sand intercalations which mean a change in deposition due to the changed runoff conditions. Above the peat strongly interbedded with sand the deposition of organic matter ceases completely. Merely, mineral deposition of fluvial sediments of the flood facies takes place. Vegetation must have then disappeared to a larger extent from the river basin since over bankfull discharges were frequent. The floodplain remained entirely unvegetated. During the deposition of sediments by vertical accretion aggradation of permafrost occurred, resulting in intraformational frost cracks and ice-wedge casts. When ice was still present in wedges, accumulation of the upper organic layer began. It was the beginning of climate amelioration associated with the Odderade Interstadial already. Fossilization of ice wedges occurred then, as can be inferred from the presence of organic matter derived from the upper layer in their topmost parts. Thus, it appears that the site Stare Kurowo represents a rather complete record of a cold climatic change ranked as a stadial between the Brørup and Odderade Interstadials.

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