acta
geologica
polonica

Vol. 45, No. 1-2 Warszawa 1995

LESZEK MARKS

Correlation of the Middle Pleistocene ice-dam lacustrine sediments in the Lower Vistula and the Lower Elbe regions

ABSTRACT: Common occurrence of ice-dam series from the decline of the South Polish Glaciations in northern Poland and from of the Elsterian Glaciation in northwestern Germany, makes them an outstanding correlative horizon. A retreat of the Scandinavian icesheet was accompanied successively by water-damming with occasional draining of ice-dam reservoirs, and by the sea ingression onto a glacioisostatic-depressed area, followed by the regression at the optimum of the Holstein Interglacial that was caused by a gradual isostatic uplifting of the area.

INTRODUCTION

Most stratigraphic schemes of the Quaternary in Central Europe have been formed by correlation of sections that represent only fragmentary records of the geologic past. For this reason, comparison of the key sites between one another and by mutual reference of sections of terrigenic and deep-sea sediments are of primary significance. The latter comprise considerably longer time intervals but their correlation with sections of terrigenous sediments cannot every time be univocal. Such option is firstly due to the "counting from the top" of the assumed representatives of successive cool and warm intervals. Dating of sediments facilitates general correlations but the results of various methods applied to marine and terrigenic sediments may seldom be compatible (*cf.* SARNTHEIN & *al.* 1986).

A large step forward in the Quaternary stratigraphy can be done therefore if correlating the sediments in a transitionary sea-land zone. This kind of analysis has been done in the Lower Vistula region, because in this very area several icesheet advances occurred during the Vistulian Glaciation (MAKOWSKA 1980, 1986) and glacial sediments are underalin by the clearly defined marine sediments, interfingering with fluvial series of the Eemian Interglacial.

Correlation of various sediments of Holstein Interglacial age is much more difficult (SARNTHEIN & *al.* 1986). A sea of that time is the first one which undoubtedly entered the Baltic Basin during the Quaternary (NILSSON 1983). Its sediments have however been considerably removed what is occasionally misinterpreted as an evidence for a limited extent of that sea (*see e.g.* MEYER 1991). Sediments of the Holstein Sea are known from the United Kingdom, France, Belgium, The Netherlands, Denmark, Germany, Russia (Kaliningrad District), Lithuania and, presumably, also from a limited area in northern Poland (*see* Text-fig. 1; *cf. also* KONDRATIENE & GUDELIS 1983, EHLERS & *al.* 1984, KNUDSEN 1987, LONG & *al.* 1988, BER 1988, LINDNER & MARKS 1994). They can relatively be easily identified and they univocally define the stratigraphic setting of over- and underlying series. It is particularly true for underlying ice-dam lake series, the occurrence of which can be considerably greater than that of the marine sediments.

In the Kaliningrad District, the Holstein Sea sediments are composed of two sets of marine silts and clays, up to 20 m thick, separated by the lagoonal and fluvial series (KONDRATIENE & ERIUKHIN 1974); the upper part of marine sediments occupies an area larger than does the lower part. Marine sediments of the Holstein Interglacial occur at 20 m b.s.l. to 25 m a.s.l. at the Polish-Russian border (*see* Text-fig. 2), but at 20 m a.s.l. to 5 m b.s.l. on the

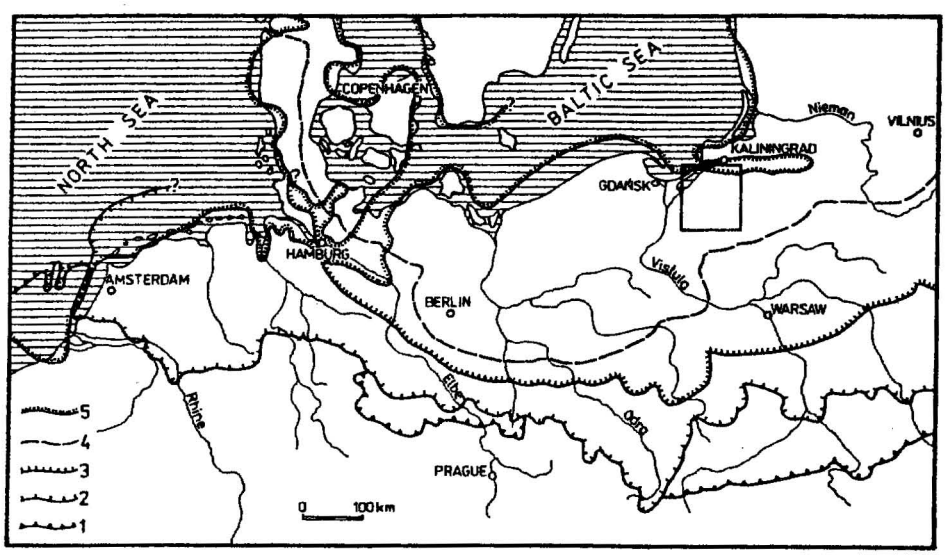


Fig. 1. Location sketch; rectangled is the Lower Vistula region (presented in Text-fig. 3)

Maximum extents of icesheets during the glaciations (*cf.* LINDNER & MARKS 1994): **1** — Elsterian (San 2); **2** — Drenthe (Odra), **3** — Warthe (Warta), **4** — Vistulian (Weichselian); **5** — presumable extent of the Holstein sea in Central Europe

Sambian Peninsula (KONDRATIENE & GUDELIS 1983). At the Lithuanian coast, they are locally considerably thicker (to 120 m) and occur much higher, up to 120 m a.s.l. (KONDRATIENE & GUDELIS 1983). The marine origin of these sediments seems undoubtful, because they contain marine foraminifers, diatoms, ostracodes, and mollusk shells. The water level of the Holstein Sea occurred presumably 30-40 m higher than the present level of the Baltic Sea.

LOWER VISTULA REGION

After retreat of the last icesheet of the South Polish Glaciations (Elsterian), Warmia and western Mazury formed a vast morainic plateau, the surface of which occurred at 20-50 m a.s.l., close to the present coast of the Vistula Bay, and rising southeastwards (MARKS 1988). Damming of water outflow was possibly due to the occurrence of extensive ice masses in the

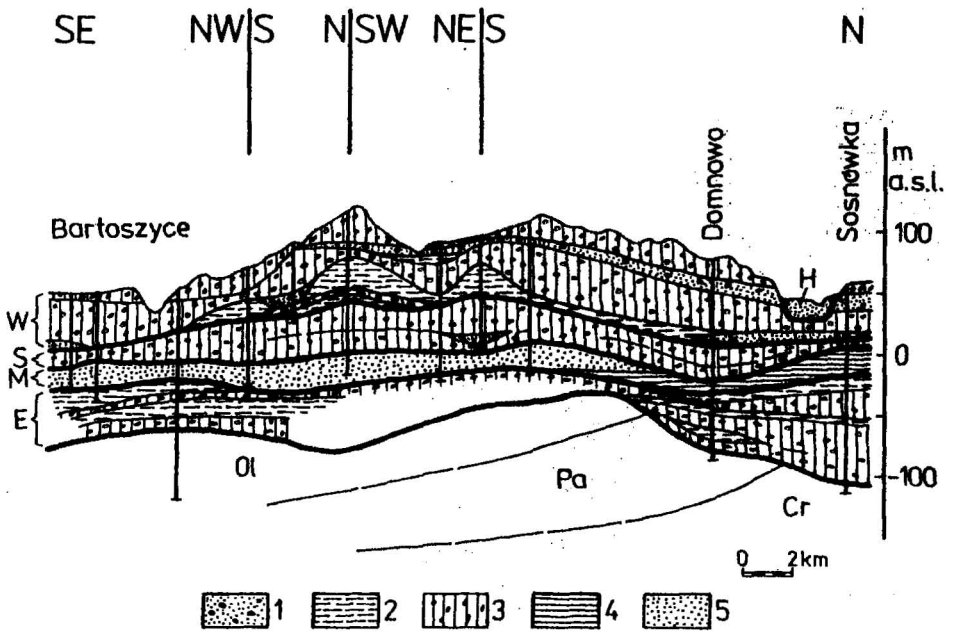


Fig. 2. Schematic geologic section in the vicinity of Bartoszyce at the Polish-Russian border; after MARKS (1988), simplified and slightly modified (*cf.* Text-fig. 3)

Cr — Cretaceous, **Pa** — Paleocene, **Ol** — Oligocene

QUATERNARY: **E** — South Polish Glaciations (Elsterian), **M** — Mazovian Interglacial (Holsteinian), **S** — Middle Polish Glaciations (Saalian), **W** — Vistulian Glaciation (Weichselian), **H** — Holocene

LITHOLOGY: **1** — Glaciofluvial sands and gravels, **2** — ice-dam lacustrine silts, clays and sands, **3** — till, **4** — marine and brackish silts and clays, **5** — fluvial sands and gravels

Gdańsk Bay (*cf.* Text-fig. 1) when depressions on the plateau were occupied by the ice-dam lakes (Text-fig. 3).

In these depressions, deposition of varved clays, silts and sands took place. As the ice-barrier melted out, ice-dam lakes were drained (MARKS 1988), what could be occasionally a catastrophic process. Such draining episodes are indicated by common sandy-gravel interbeds (locally over 20 m thick) within ice-dam lake series (Text-figs 4-5) but also by erosive channel-like depressions at the top of this series (*see* Text-fig. 3; *and* MARKS 1988). Partial or even complete draining was followed by certain stabilisation at a lower water level, accompanied however by gradual displacement of the ice-dam lake onto the

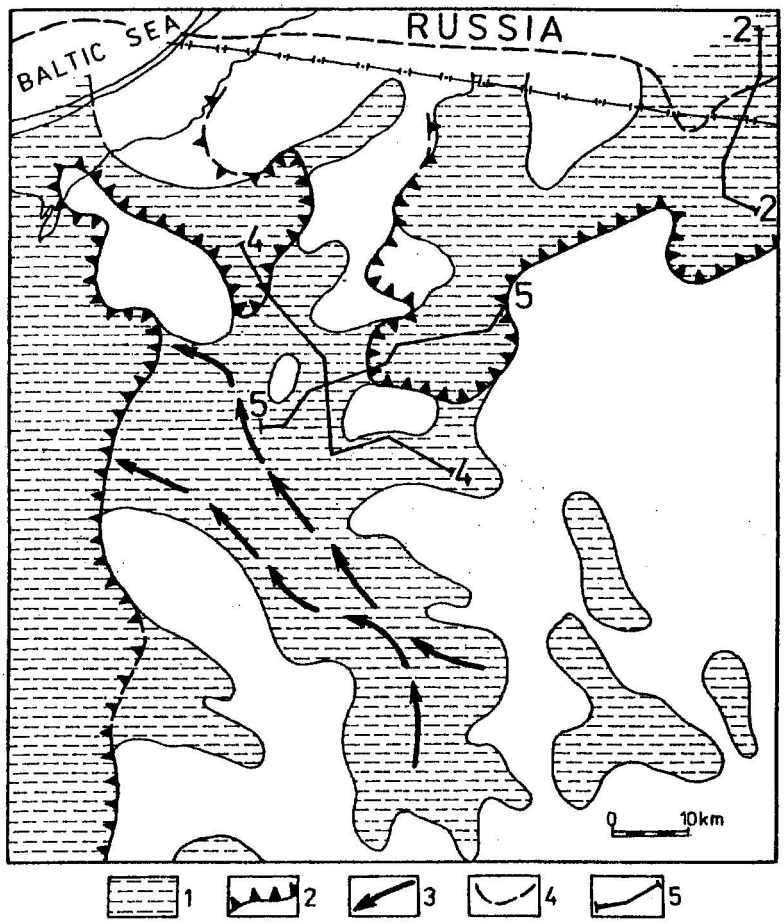
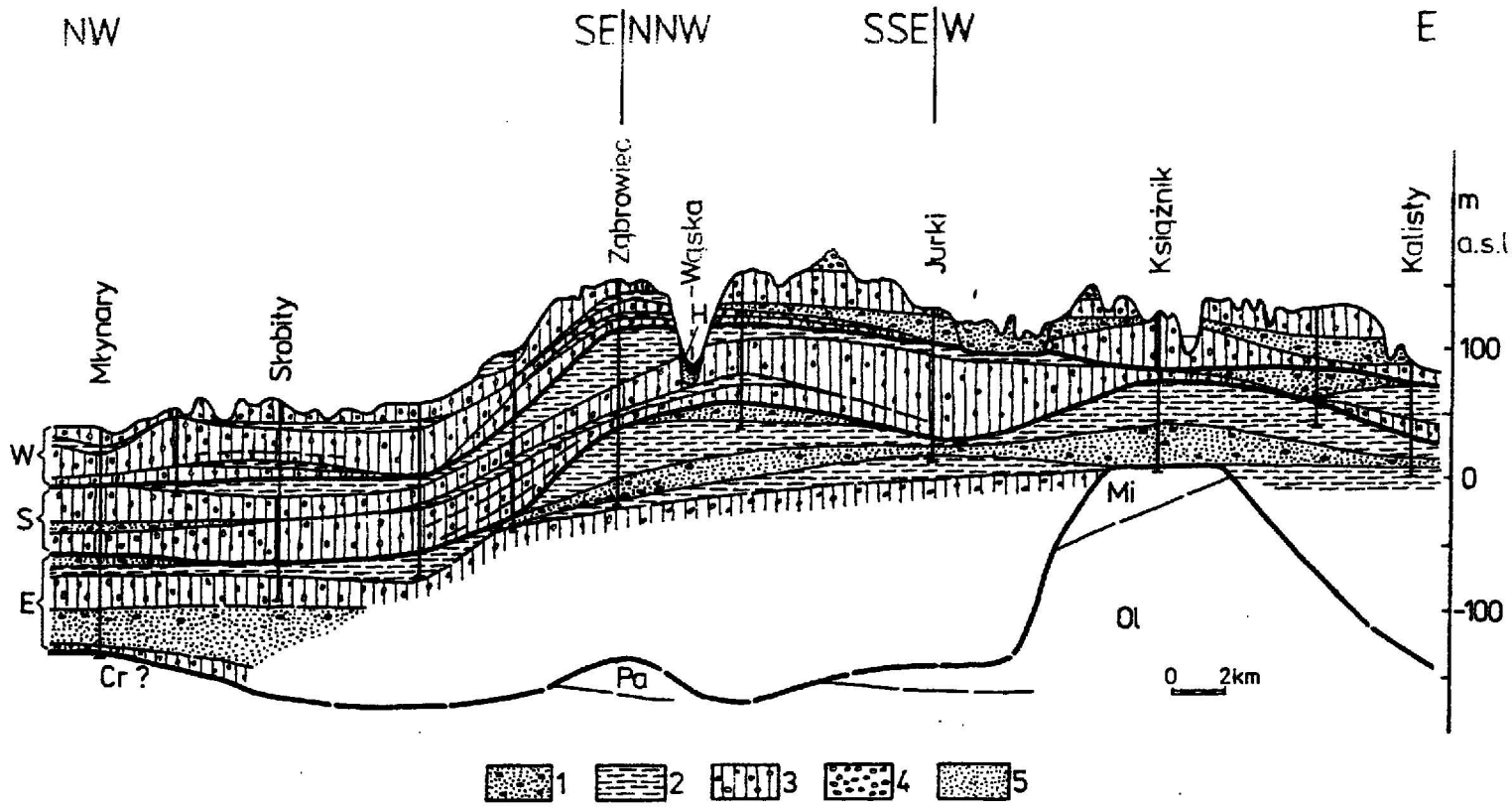


Fig. 3. Ice-dam lakes in the Lower Vistula region at the end of the South Polish Glaciations (Elsterian)

1 — Ice-dam lakes, 2 — presumable location of icesheet barrier, 3 — direction of catastrophic channelled meltwater run-off, 4 — extent of the Holstein sea, 5 — geologic sections No. 2, 4 and 5 (presented in Text-figs 2 and 4-5)

Schematic geologic section in northwestern Warmia, northern Poland; for location *see* Text-fig. 3



Cr — Cretaceous, **Pa** — Paleocene, **Ol** — Oligocene, **Mi** — Miocene

QUATERNARY: **E** — South Polish Glaciations (Elsterian), **S** — Middle Polish Glaciations (Saalian), **W** — Vistulian Glaciation (Weichselian), **H** — Holocene

LITHOLOGY: **1** — Glaciofluvial sands and gravels; **2** — ice-dam lacustrine silts, clays and sands; **3** — till; **4** — sands and gravels of end moraines; **5** — fluvial sands and gravels

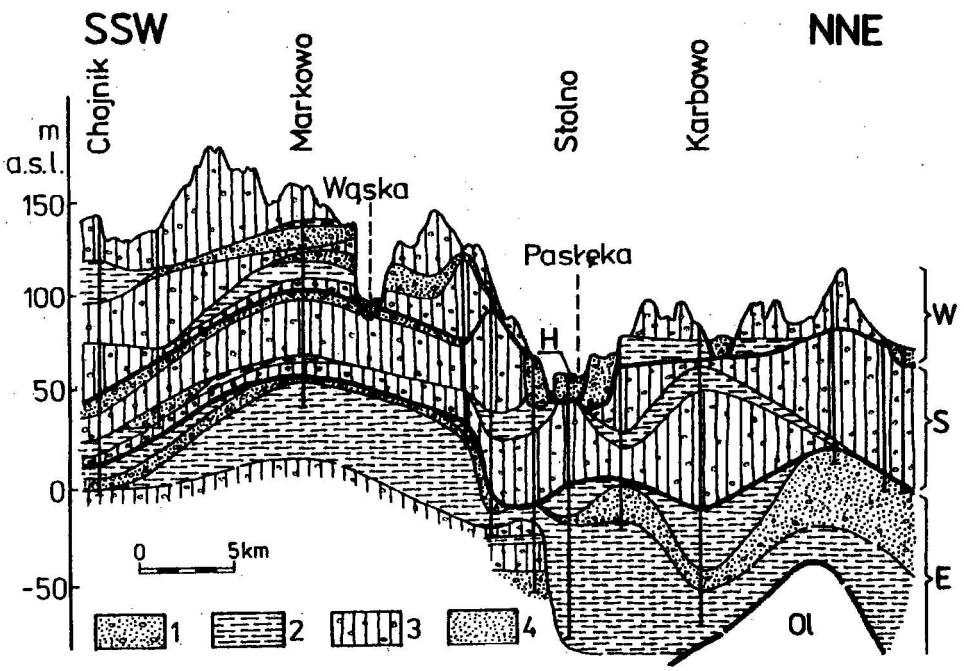


Fig. 5. Schematic geologic section in western Mazury Lakeland, northern Poland; for location *see* Text-fig. 3

Ol — Oligocene

QUATERNARY: **E** — South Polish Glaciations (Elsterian), **S** — Middle Polish Glaciations (Saalian), **W** — Vistulian Glaciation (Weichselian), **H** — Holocene

LITHOLOGY: **1** — Glaciofluvial sands and gravels; **2** — ice-dam lake silts, clays and sands; **3** — till; **4** — fluvial sands and gravels

area, from which the icesheet had just retreated. This process is indicated at present by step-like occurrence of ice-dam sediments (*see* Text-figs 4-5).

LOWER ELBE REGION

After retreat of the icesheet of the Elsterian Glaciation, vast ice-dam lakes have been formed in deep glacial channels in the Lower Elbe region (Grube 1979, Ehlers & *al.* 1984; *see also* Urban & *al.* 1988), in The Netherlands and the North Sea (Long & *al.* 1988), and also in eastern Germany (Gehl 1969). At the very beginning, these channels were filled with sands but later, in the north — by black and red silts or clays of the so-called Lauenburg Clay (Text-fig. 6; *and* Schucht 1908, Wolff 1917, Meyer 1965, Gehl 1969, Woldstedt & Duphorn 1974, Grube & Ross 1982, Ehlers & Linke 1989, Ehlers 1990), to 160 m thick (Kuster & Meyer 1979). In The Netherlands these sediments are known as the "potklei" (Zagwijn 1973). The lithologic composition of the Lauenburg

Clay reflects a variable but progressive disintegration of the icesheet (*cf.* KUSTER & MEYER 1979): the basal layers contain much ice-rafted material, whereas they gradually become laminated (with varves) towards the top. Traces of erosion at the top of the series are considered for a partial subglacial deposition (GRUBE 1984). Deposition of a 110 m thick series of the Lauenburg Clay in the Hamburg area was estimated by the varved counting method at about 2400 years (WÜSTENHAGEN 1984). In Germany, remains of Arctic-Boreal marine fauna are noted in the uppermost part of the sequence, thus indicating a sea ingression (KNUDSEN 1976) which started at the boundary of ^{18}O stages 12 and 11, and lasted about 7000 years only (SARNTHEIN & *al.* 1986). Gradual climatic amelioration during the Holstein Interglacial results in the appearance of thermophilic fauna remains in these sediments (MENKE 1980). On the Dutch

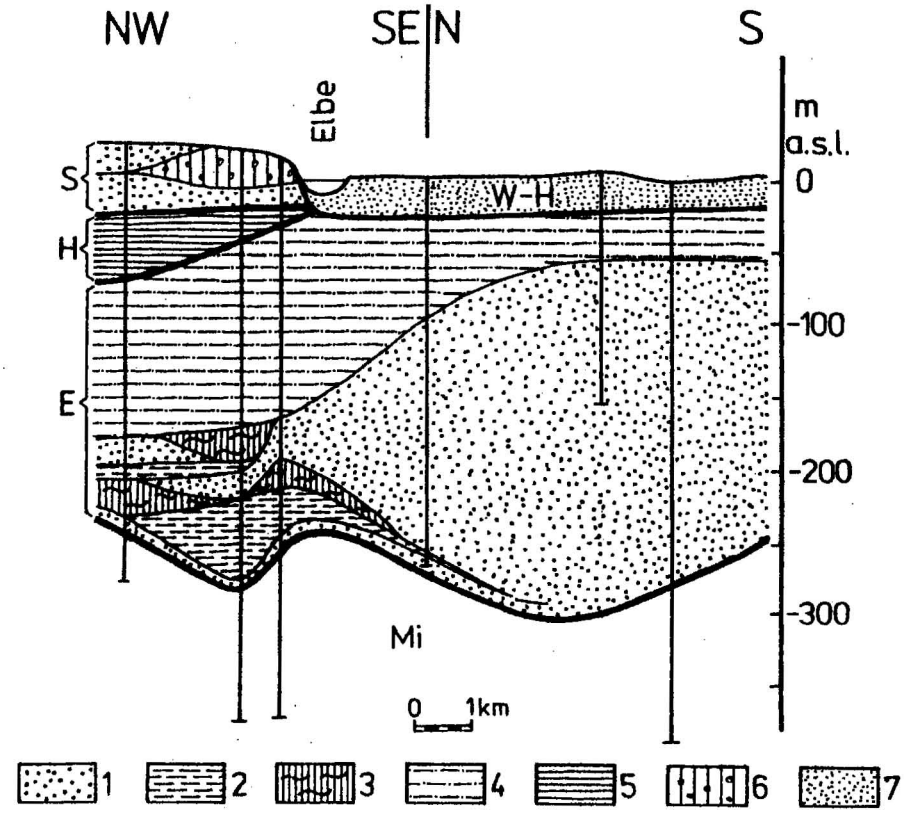


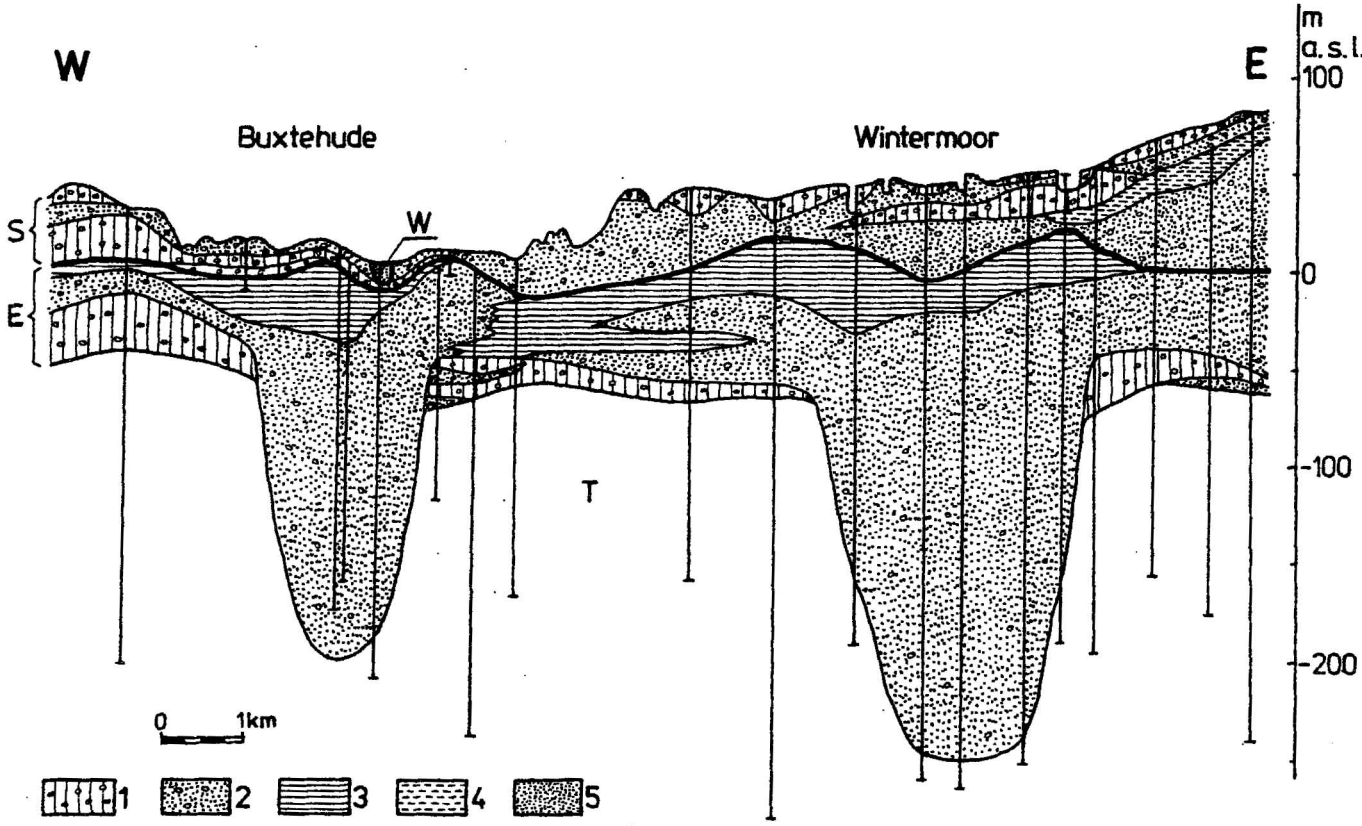
Fig. 7. Schematic geologic section along the Dockenhudener glacial channel in Hamburg; *based on* EHLERS & LINKE (1989), *modified*

Mi — Miocene

QUATERNARY: E — Elsterian, H — Holsteinian, S — Saalian, W-H — Weichselian and Holocene

LITHOLOGY: 1 — Glaciofluvial sands and gravels; 2 — ice-dam lacustrine silts; 3 — flow till; 4 — Lauenburg Clay (ice-dam silts and sands); 5 — marine silts, clays and sands (in bottom locally lacustrine facies); 6 — till; 7 — fluvial sands

Schematic geologic section in the Hamburg area; *after* KUSTER & MEYER (1979), *modified*



T — Tertiary

QUATERNARY: E — Elsterian, S — Saalian, W — Weichselian and Holocene

LITHOLOGY: 1 — Till, 2 — glaciofluvial sands and gravels, 3 — ice-dam clays ("Lauenburger Ton"), 4 — ice-dam silts, 5 — fluvial sands and gravels

and English coasts, a sea ingression has not occurred until the Holstein Interglacial (KNUDSEN 1986). Marine facies of the Holstein Interglacial occur in the southern part of the North Sea and at the present-day seaside of France but also eastwards, as far as Wittenberge in eastern Germany (Text-fig. 1; *cf.* GEHL 1969), where they clearly separate sequences of the Elsterian and the Saalian glaciations (Text-fig. 7). A widespread occurrence of ice-dam sediments in northern Germany was due to vast and long-lasting glacioisostatic subsidence of this area, caused by a long stay of the icesheet cover during the Elsterian Glaciation (*cf.* SARNTHEIN & *al.* 1986).

The ESR datings of aragonite mollusk shells from marine sediments of the Holstein Interglacial of the Hamburg area as well as in Cuxhaven and in the Lower Elbe region, indicate the age of 195-223 ka (LINKE & *al.* 1985). This corresponds to the ^{18}O stage 7 in deep-sea sediments (SHACKLETON & OPDYKE 1973). The U-Th datings of sediments of the Holstein Sea at Wacken suggest them to be older than 350-370 ka, what could correspond to the ^{18}O stage 11 in deep-sea sediments (SARNTHEIN & *al.* 1986). Sediments of the Holstein Sea occur at present up to 23 m a.s.l. in eastern England, 10-12 m a.s.l. in France and Belgium, but due to younger isostatic movements — to 25-40 m b.s.l. in The Netherlands and 13-30 m b.s.l. in northern Germany (*see* LONG & *al.* 1988, EHLERS 1990).

CORRELATION

Damming of meltwater outflow and development of the ice-dam reservoirs occurred at least three times in the Lower Vistula region, *i.e.* at the end of the South Polish (Elsterian), Middle Polish (Saalian) and the Vistulian (Weichselian) glaciations (*see* Text-figs 2-5; *and* ROSZKO 1971, 1976, MAKOWSKA 1990). Precise age reference of ice-dam sediments in this area is possible on the basis of their relation to marine sediments of the Holstein and the Eemian interglacials, and of the Holocene. Marine sediments of Holstein Interglacial age in the Lower Vistula region are however the most questionable item, as they have been recorded herein quite sporadically, in peculiar emplacements as the glacial rafts within tills of the Middle Polish Glaciations (*cf.* MAKOWSKA 1986). In spite of that, they must have really existed in the Gdańsk Bay, but have been eroded repeatedly by icesheets during the following glaciations. Much more precise geologic setting of ice-dam lake sediments could be determined in the adjacent Kaliningrad District where sediments of the Holstein Sea occur quite commonly (Text-fig. 2). Less outstanding development of sediments of the Holstein Sea in the Kaliningrad District than in Germany results from its shorter duration as it formed a secondary branch of the main basin only (*see* Text-fig. 1).

Sedimentary sequences presenting termination of the Elsterian Glaciation and the following Holstein Interglacial in the Lower Elbe and the Lower Vistula regions, indicate considerable similarities. In both these areas, ice-dam lake sediments are key horizons, even if not overlain by sediments of the Holstein Sea (*cf.* Text-fig. 8).

CONCLUSIONS

Ice-dam lake sediments from the decline of the South Polish Glaciations in northern Poland and of the Elsterian Glaciation in northwestern Germany are presumably of the same age. They form an outstanding Middle Pleistocene correlative horizon.

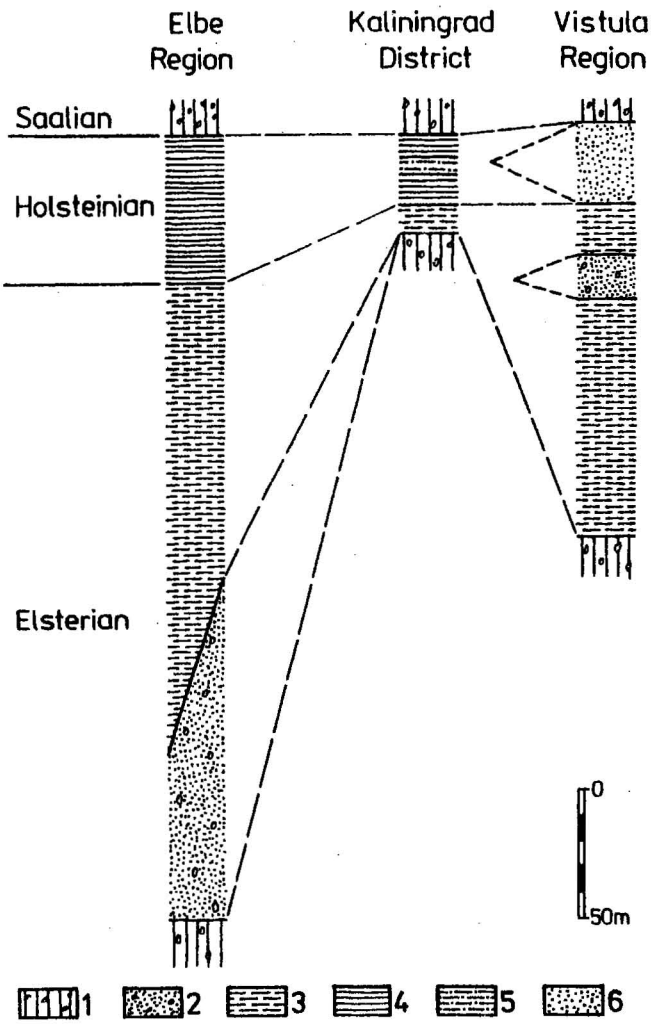


Fig. 8. Correlation of the Late Elsterian–Holsteinian sediments in the Lower Elbe and the Lower Vistula regions

1 — Till; 2 — glaciofluvial sands and gravels; 3 — ice-dam lacustrine silts, clays and sands; 4 — marine silts and clays; 5 — brackish sands; 6 — fluvial sands and gravels

Widespreading of thick synchronous ice-dam series at a distance of about 1000 km (from the North Sea through The Netherlands, the Lower Elbe and the Lower Oder to the Lower Vistula region and the Kaliningrad District) indicates that the icesheet retreat was accompanied by a sequence of similar processes, as follows:

— water-damming in front of the retreating icesheet;

— occasional (catastrophic?) draining of ice-dam reservoirs, connected with a withdrawal of the ice front;

— sea ingression, locally in two phases separated by a short regression, onto a glacioisostatic-depressed area; this ingression lasted about 7000 years (*cf.* SARNTHEIN & *al.* 1986);

— sea regression at the optimum of the Holstein Interglacial, being due to a gradual isostatic uplifting of the area, caused by complete disappearance of the Scandinavian icesheet (probably long before the interglacial optimum).

Acknowledgements

The present author's studies in Germany were possible due to the assistance of the A. von Humboldt Foundation. The paper could be finished due to a financial support from the National Committee of Scientific Research (Grant No. 6 P202 062 03). Comments on the manuscript by Michael HOUMARK-NIELSEN (University of Copenhagen) and Eric LAGERLUND (University of Lund) are also gratefully acknowledged.

Institute of Geology
of the University of Warsaw,
Al. Żwirki i Wigury 93,
02-089 Warszawa, Poland

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