# 3. AN OUTLINE OF THE MARINE STAGE OF THE VÄNER BASIN

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## INTRODUCTION

The main ice-marginal zones of western Sweden are well known. As the greater part of the landscape is dominated by bedrock hills and clay-covered lowlands, the moraine deposits in the ice-marginal zones are often pronounced. The previously established Late Weichselian deglaciation chronology in Sweden has been brought up for discussion by Berglund (1979). On the basis of radiocarbon determinations of molluscs, skeletal parts of vertebrates and gyttja samples from limnic deposits, a revision seems to be appropriate. The degree of revision suggested differs depending on the authors. However, all opinions seem to converge the closer one gets towards the end of the Younger Dryas Stadial. It should be noted that the present discussion about the deglaciation chronology deals not only with the stadials themselves but also with the duration of the stadials and interstadials.

## DEGLACIATION CHRONOLOGY OF THE VÄNER BASIN

The main ice-marginal zones are shown in Fig. 3:1. At the present, it seems to be generally accepted that the Billingen moraines were formed at the end of the Younger Dryas Stadial. This is of course an advantage for the discussion of the Pleistocene/Holocene boundary. A review of the opinions of the deglaciation chronology of the Väner basin is also seen in Fig. 3:1. The latest contribution to the discussion is published by Björck and Digerfeldt (1981). According to their opinion radiocarbon determinations from limnic sediments situated above the highest shore line, 133–134 m above sea level, on the Hunneberg hill support Berglund's proposal. The same authors have also established a curve for the shore-line displacement at Hunneberg (Björck and Digerfeldt 1982). Their stratigraphical investigations (diatom and pollen analyses and radiocarbon determinations) of 15 lakes between 129 and 91 m above sea level speak for Berglund's (1979) hypothesis.

The rate of sedimentation and the hydrographical environments for the

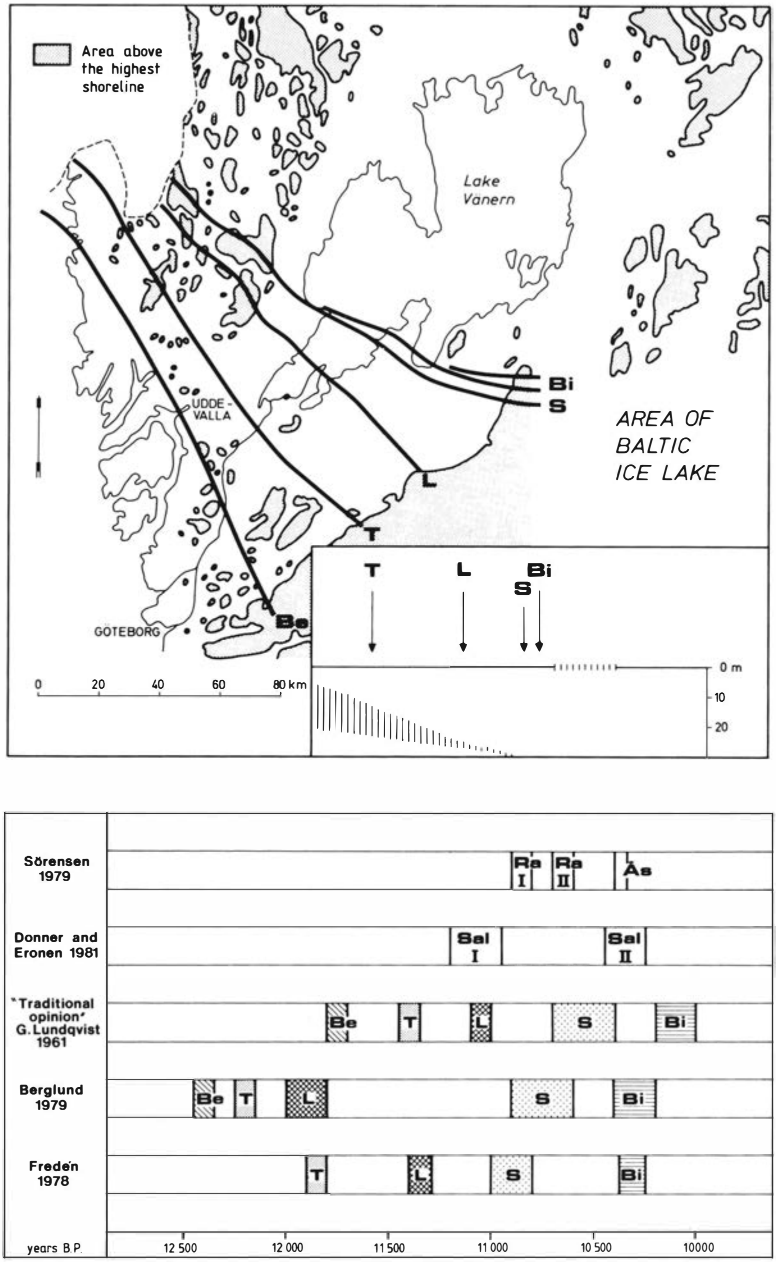


Fig. 3:1. The main features and opinions of the Late Quaternary evolution of western Sweden – in particular, the Väner basin. The extension of the terminal moraines are shown only for the concerned areas. The letters are abbreviations for the main terminal moraine zones, *i.e.* Berghem moraine, Trollhättan moraine, Levene moraine, Skövde moraine, and Billingen moraine. The inset profile shows the stratigraphical occurrence of molluscs in the clay sequences of the Väner basin.

sedimentation along the western coast of Sweden are to a certain degree dependent on the deglaciation chronology, *i.e.* the distance to the ice front at the different distinguished interstadials and stadials as they are recorded in clay sequences. According to previous opinion, based on knowledge before the time of absolute dating, the Trollhättan terminal moraine was formed about 11 500 years ago, see Fig. 3:1. Berglund (1979) maintaines that it was formed *c.* 12 300 years ago, according to radiocarbon determinations carried out on limnic gyttja samples. On basis of radiocarbon determinations of marine molluscs and skeletal parts of vertebrates and the stratigraphical position of these in the clay sequences, Fredén (1978) has suggested that the Trollhättan terminal moraine was formed about 11 800 years ago. With these determinations in mind we have a picture of the maximum (?) and minimum (?) time span, 2 000–1 200 years, between the formation of the Trollhättan and the Billingen terminal moraines, see Fig. 3:1.

The Skövde and the Billingen terminal moraines are part of the Fennoscandian terminal moraines. The continuation of the Skövde and Billingen moraines in Norway are the Ra moraines. Recently, Sörensen (1979) has questioned the previous chronology of the main ice-marginal deposits in the Oslo fiord area. On the other hand, the corresponding moraines in Finland – the Salpaussälkäs – are in good chronological accordance with recent Swedish opinions, see Fig. 3:1.

## OCCURRENCE OF MARINE FAUNA IN THE VÄNER BASIN

To a large extent the present uncertainty of the deglaciation chronology depends on the limited opportunity to find suitable samples for radiocarbon determinations, especially samples in marine clay. The occurrence of molluscs in the clay of the Väner basin is shown in the inset profile of Fig. 3:1; mollusc shells are found at different levels depending on the terrain and it should be read stratigraphically in relation to the top and the bottom of the clay sequence. The same pattern applies for the finds of marine vertebrates. The known occurrences of shell-bearing layers may be summarized as follows (after Fredén, in prep.). In the southern part of the Väner basin the shell-bearing layers are usually 10–20 cm thick and they contain about ten or more species. It is not uncommon that more than one such layer occurs in the same clay sequence. Furthermore, radiocarbon determinations of shells of different species in small, surficial shellbanks show that these sites have been inhabited by different faunas at different times. The difference in radiocarbon age between different shell layers and faunas in the same area has been dated to be approximately 300 to 500 years. The number of species, the occurrence and the thickness of shell-bearing layers decrease the closer one gets to the Skövde terminal moraine zone at the same time as the depth of occurrence increases. The profile in Fig. 3:1 is mainly valid for the vast field areas south-east of Lake Vänern. Note that the greater part of the clay south of the Skövde moraine lacks macrofossils.

North of the Billingen/Skövde terminal moraine zone, shells are only found on or in the most surficial part of the clay sequences west of Lake Vänern. The finds are mainly found in sandy deposits. Radiocarbon ages and localities are shown in Fig. 3:2. East and north of Lake Vänern no finds are known except one of a haddock about 20 km north of Billingen.

The habitats of molluscs reflect fairly stable hydrographical conditions. About 11 000 years ago, and during a period of more than 500 years, optimal conditions prevailed for Arctic and Arctic-Boreal faunas to flourish in the area between the Väner basin and the West Coast. Optimal conditions are defined by the temperature, salinity, clearness, water depth, currents, and nature of the bottom. The supply of nourishment is, of course, dependent upon the same factors. Stable conditions imply that meltwater discharge was low. At times, marine water with a relatively high salinity was most probably in contact with the ice front or quite close to it. The border to saline water both horizontally and vertically is primarily dependent on the meltwater supply and the course of land uplift, which determines the water depth and the palaeogeographical conditions.

A pronounced change of the hydrographical conditions is recorded by sedimentation of a clay which is devoid of macrofossils, see Fig. 3:1. Habitats of molluscs in the Väner basin area were buried with great volumes of clay, and the favourable conditions disappeared. Before this change in the deglaciation pattern the ice sheet had retreated to the Billingen terminal moraines during several thousands of years. Slightly more than one thousand years after the retreat from the northernmost Fennoscandian terminal moraine the Scandinavian ice sheet had disappeared entirely. In other words the ice retreat was very rapid without stops other than such caused by higher situated terrain, where the ablation pattern changed from a frontal and surficial to an entirely surficial melting. The discharge of meltwater was enormous during the Preboreal time.

## PALAEOGEOGRAPHICAL CONDITIONS WITH RESPECT TO THE INVESTIGATED LOCALITIES

The palaeogeographical conditions of western Sweden at the end of the Younger Dryas stadial are shown in Fig. 3:3. The map is based upon only few available modern investigations. According to Björck and Digerfeldt (1982) the shore level of Hunneberg at that time would roughly correspond

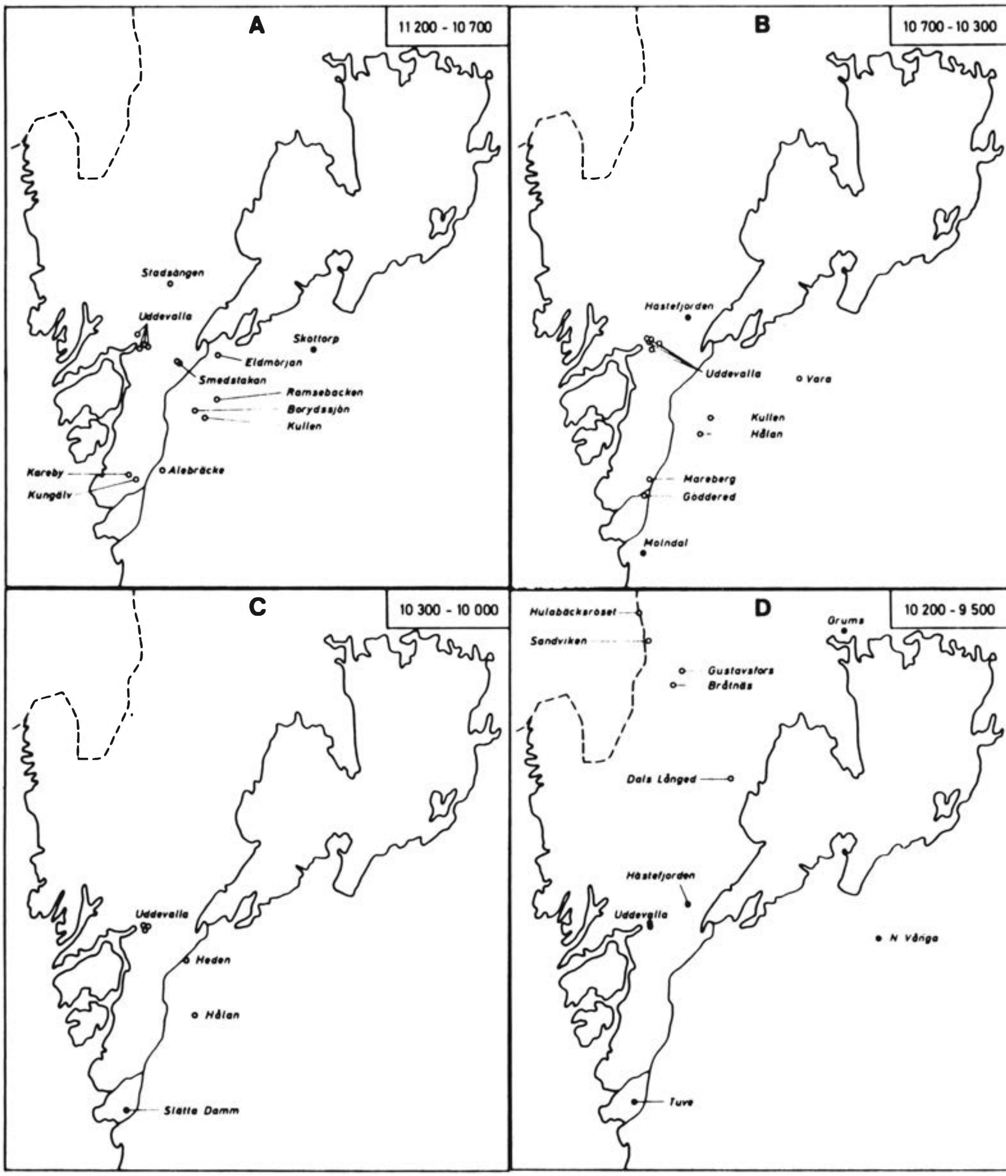


Fig. 3:2. Radiocarbon determinations of mollusc shells and skeletal parts of vertebrates. Sample sites are shown only from the Väner basin and its straits during the time span 11 200–9 500 years B.P. The dates shown include a margin of error and correction for $^{13}C$ and the reservoir age of sea water. Localities of dated molluscs are shown with circles, vertebrates with dots. From Fredén (1975 and in prep.).

to 90–95 m above sea level. Approximate isobases – parallell to those of the highest shore line, (see Chapter 5) – give corresponding levels at Stärkestad of about 105 m and at Tuve of about 60 m above sea level. The purpose of the map is to show the main topographical features of the landscape with respect to the hydrographical conditions in the surroundings of the investigated localities.

The main connections between the Väner basin and the Skagerrak bay of the Atlantic Ocean consisted of the strait at Uddevalla and the Göta River valley. North of the Uddevalla strait a third connection existed, but of a minor importance since the threshold is situated in the eastern part of the valley at a level of 85–90 m above sea level.

In the Munkedal area the influence of meltwater from the two parallell valleys orientated NNE–SSW must have been fairly short-lived. In both valleys deposits of the Fennoscandian terminal moraine zone are built up to and above the highest shore line and form pronounced watersheds. In the valley mouth south of Stärkestad, Fig. 3:3, shells in sandy deposits on the south side have been dated at 10 585±145 years B.P. (St 7119–20). Twelve datings of samples – collected at different levels – in an exploited shellbank on the north side of the valley gave a mean age of 9 980±135 years B.P. (Fredén, unpubl.). The datings range from 10 160±110 (St 7552-53) to 9 820±120 years B.P. (St 7134-35). Both localities are situated at about 75 m above sea level.

## BALTIC ICE LAKE

On the inset map of Fig. 3:4 the extension of the Baltic Ice Lake is shown. The traditional opinion is that the lake was dammed by the ice sheet and the topography until the icefront passed the northern point of the Billingen hill. There is a prevalent uncertainty about the circumstances concerning the draining event. However, the event as such is not questioned.

The uncertainty of the evolution at Billingen depends on several factors. According to the traditional opinion the youngest Fennoscandian terminal moraines are found at least 5 km south of the northern point, which implies that the event occurred some tens of years after the formation of the Billingen moraines. The relation between the northern point and the terminal moraines is shown on Fig. 3:1. Furthermore, the event implied a lowering of the lake surface of 26 m and a connection was established between the Baltic basin and the Atlantic Ocean. The circumstances about the so-called Billingen event itself have been discussed by Strömberg (1977). A review of the history of the Baltic Ice Lake was published in 1979 (Fredén).

On basis of pollen-analysed and radiocarbon dated isolation sequences of nine localities in south-eastern Sweden, Björck (1979) has recorded a sudden drop of the Baltic Ice Lake surface at about 10 300–10 200 years B.P. The lowering amount was recorded to be at least 26 m. A rapid lowering of the surface of the Baltic Ice Lake has been reported from many other places in the Baltic basin. In Finland (Alhonen 1979, pp. 103–107), for example, an approximate 28 m drop in the water level is recorded. It can be observed morphologically in several places on Salpaussälkä II, which was formed at the year ±0 in the Finnish varve chronology – corresponding to the year 8 213 B.C. in the revised Swedish varve chronology.

The lowering of the Baltic Ice Lake surface has been related to the sudden outflow at the Billingen hill. However, at the northern part of the Billingen hill there is an annoying lack of erosional phenomena from this presumably dramatic and violent event. One may summarize that a regional lowering of the Baltic Ice Lake surface is recorded and that the event is dated to about 10 200–10 300 years B.P. Whether the total lowering, or part of it, occurred at the Billingen hill, or not, is not fully known.

## YOLDIA SEA STAGE

When the land ice receded from the Billingen hill a new stage occurred in the evolution of the Baltic basin – the Yoldia Sea stage. A historical review of the stage was published in 1979 (Fredén). The palaeogeographical conditions of the Väner basin in the Preboreal times are illustrated in Fig. 3:4. The purpose of the inset map is to give the reader an idea of the volumes of meltwater which must have been transferred through the Väner basin during the stage, with the assumption of course, that no other outlet in the Baltic basin was accessible.

The Väner basin is relatively shallow – present maximum depth being 106 m. During the deglaciation large meltwater volumes were discharged into the Skagerrak. In some respects the straits of Uddevalla and the The Göta river valley can be regarded as large river mouths. Saline bottom water was pushed towards the sea by the supply of meltwater. When the Otteid strait was opened westwards, the Väner basin had a connection with saline water which was mixed with the meltwater in the basin. At about the same time the Närke strait was deglaciated. Both straits were approximately equal in dimensions, having a maximum width of *c.* 10 km and a maximum depth of *c.* 60 m.

The highest shore line was metachronic in nature. The straits south of Närke and Otteid straits had relatively small vertical areas and were laid dry

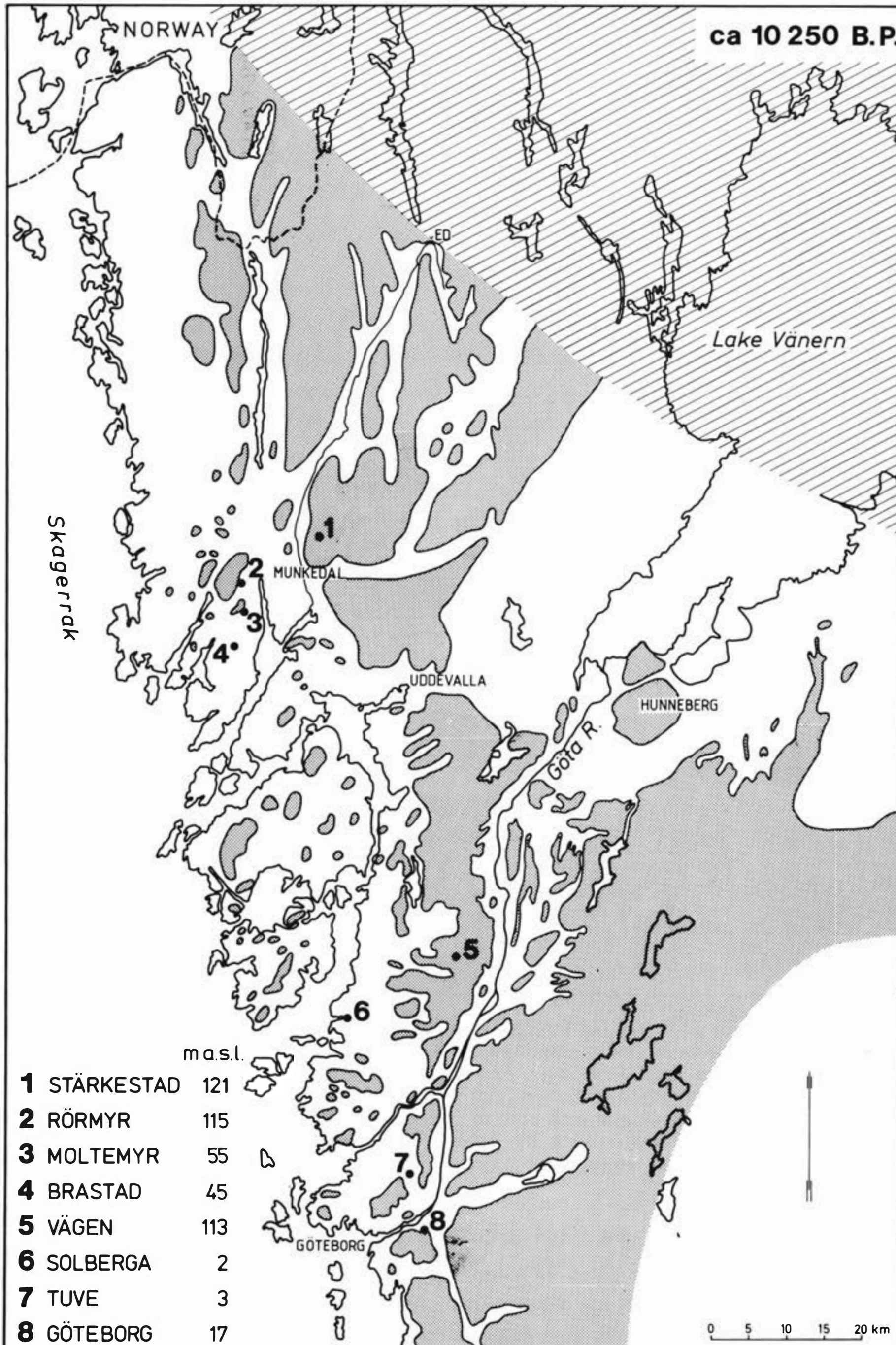


Fig. 3:3. Outline of the palaeogeography at the end of the Younger Dryas stadial. Slanting lines = land ice, grey areas = land.

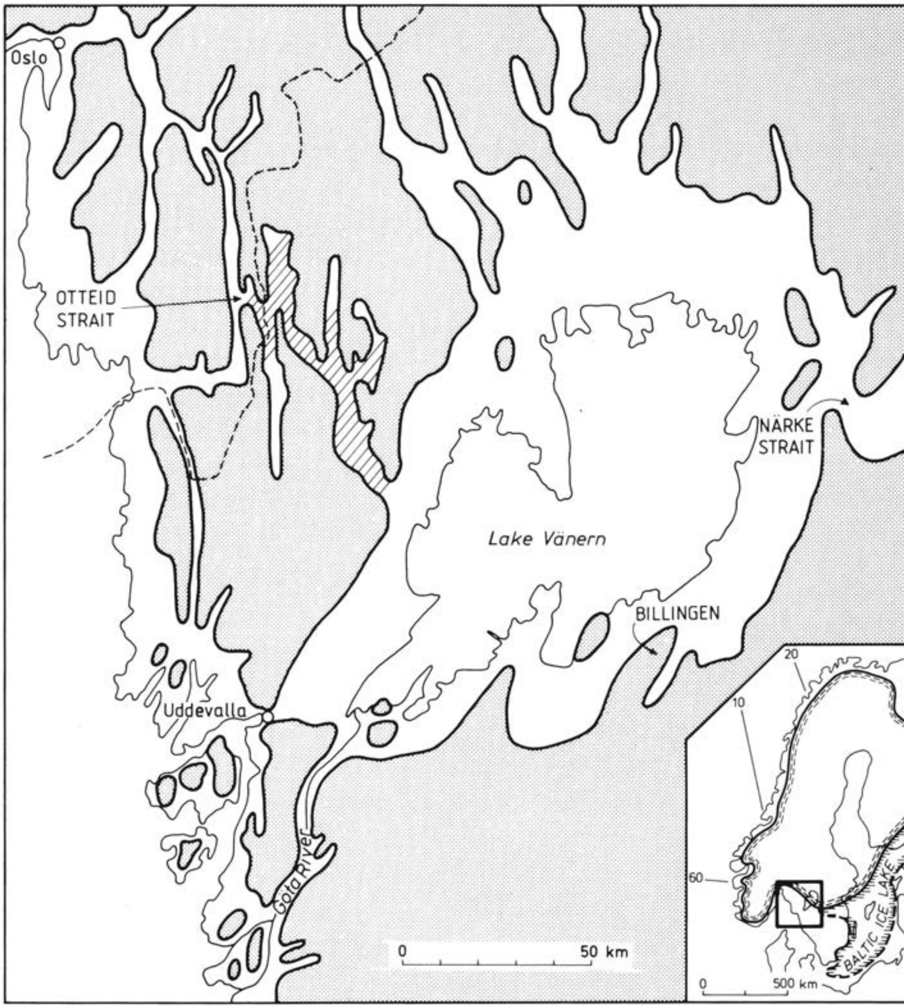


Fig. 3:4. Generalized outline of the land–sea conditions of the Väner basin during approximately the mid-Preboreal times. Slanting lines show the distribution of found mollusc localities within the drainage area. Inset map shows the extension of the Baltic Ice Lake and the Scandinavian ice sheet at the end of the Younger Dryas Stadial. Slightly more than 1 000 years later the land ice had disappeared and all meltwater and freshwater in the Baltic basin is assumed to have been discharged to the Atlantic Ocean via the Väner basin during this time.

fairly soon due to the land uplift. North of the Otteid strait another connection westwards has existed. No macrofossils are known in the valley.

During a time span of about 100 years the bivalve *Portlandia arctica* inhabited areas east of the Närke strait. The shells are found in the lowermost part of the clay sequences. West of the Närke strait the clays are mostly non-varved while east of the strait, *i.e.* within the Baltic basin, they are mostly varved. These circumstances imply different sedimentation conditions – pronounced freshwater conditions in the Baltic basin while the salinity in theVäner basin was sufficient to induce symmict sedimentation. A review of the Närke strait has been published by Fredén (1981). In this review it seems clear that – according to Finnish and Swedish investigations – the Närke strait was opened about 10 000 years ago.

When the clay sedimentation ceased in the archipelago environments of the Otteid strait, Boreal to Arctic-Boreal molluscs inhabited the slopes of the pronounced valleys. The distribution is seen on Fig. 3:4 (cf. inset profile on Fig. 3:1). Apparently there were favourable conditions for the fauna during a few hundred years; most of the radiocarbon dated samples gave ages about 9 800 to 9 700 years B.P., cf. Fig. 3:2 D.

Due to the land uplift the Otteid strait was laid dry at about the same time as the water exchange in the Närke strait ceased. This must have happened a hundred years, or so, before the Närke strait was laid dry, which occurred following calm conditions at least 9 000 years ago (Fredén 1981). Contemporaneously, the Väner basin was isolated from the sea (Fredén, op.cit.).

## A BRIEF AND TENTATIVE OUTLINE FOR THE MAIN EVENTS OF THE MARINE EVOLUTION OF THE VÄNER BASIN DURING THE PREBOREAL TIMES.

The outline is given in chronological order with assumed ages.

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| Ice retreat from the Fennoscandian terminal moraine zone | *c.* 10 250 years B.P. |
| The lowering of the Baltic Ice Lake surface. Beginning of the Yoldia Sea stage | *c.* 10 200 years B.P. |
| Närke and Otteid straits are opened. Saline waters enter the Baltic basin | *c.* 10 000 years B.P. |
| Molluscs inhabit the western part | *c.* 9 800 years B.P. |
| Molluscs fauna extinct | *c.* 9 600 years B.P. |
| Otteid and Uddevalla straits are laid dry | *c.* 9 300 years B.P. |
| The threshold of the Närke strait is laid dry. The Väner basin becomes isolated from the sea | *c.* 9 000 years B.P. |

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