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Quaternary marine shell deposits in the region of Uddevalla and Lake Vänern



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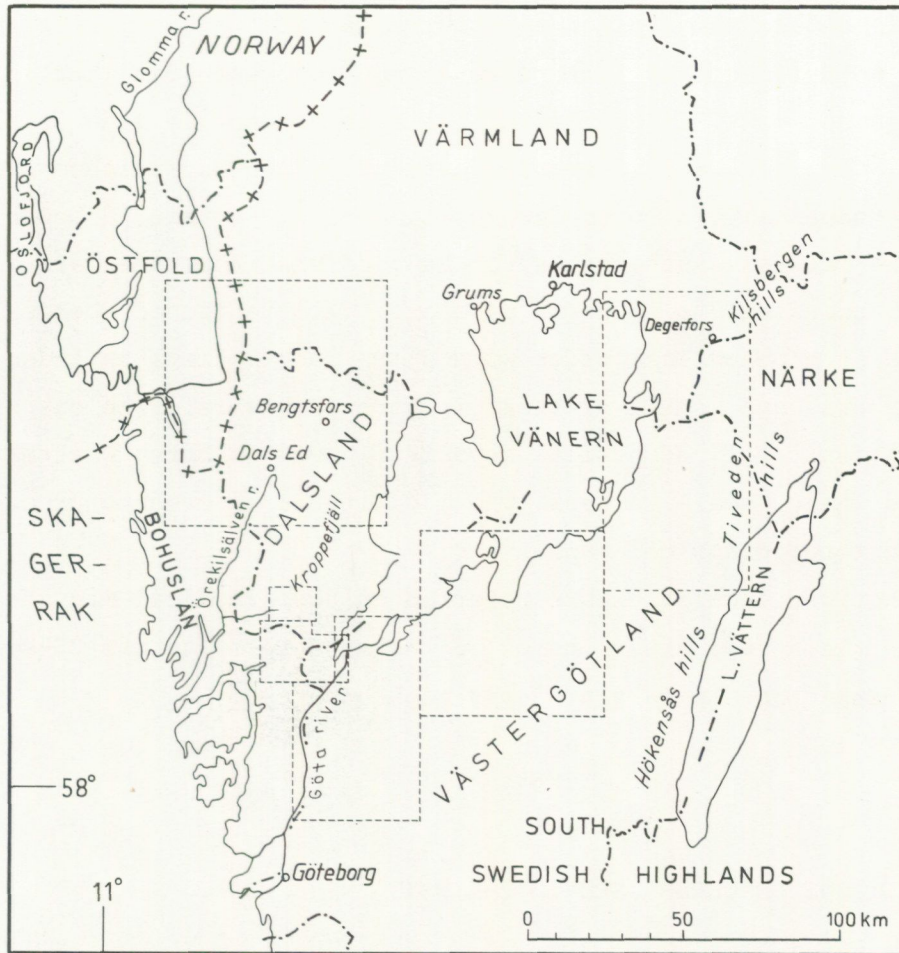


Fig. 1. Key map showing the provinces and localities mentioned in text. Broken lines refer to detailed maps, Figs 5, 29, 32, 38, 39 and 41.

INTRODUCTION

This paper is a compilation of observations from regular geological mapping in western Sweden, literature studies and documentation of known shell deposits in the Vänern region. Today the greater part of the deposits have been tapped and the remains are overgrown. Understandably, only the main features of the deposits can be given.

The shell deposits are divided into four geographical areas besides the Uddevalla deposit, see Fig. 1. These four are described separately with their related discussions and conclusions. It should be noted that this paper deals with the geological importance of the shell deposits; thus, conchological and ecostratigraphical aspects have been left out.

Deglaciation chronology of the Vänern basin is discussed in a special paper.

All mollusc names given in accordance with original sources in order to avoid distortion and so as not to create disorder in the subsequent text. In the faunal lists an attempt is made to eliminate the old Latin names in favor of modern established scientific names. This procedure is somewhat imperfect, as opinions differ between authors. As far as possible, the names are modified according to modern taxonomy. All mentioned species are listed in alphabetical order with short descriptions in index.

Numbers and small letters in parenthesis refer to described localities. All Uddevalla deposits have numbers whereas the others have small letters. The locality names used occur on the relevant topographical maps.

Described localities are referred to topographical map sheets. Codes (1a, 5e) after names of the maps refer to the 25-square grid marked in the margin of the map concerned.

DEFINITIONS OF TERMS USED IN THE TEXT

Due to the present uncertainty of the Late Quaternary development of the Vänern basin, the established terms used have to be defined. Some new terms are introduced.

Geochronological classification

Late Weichselian (Late Glacial) denotes the time from the beginning of the deglaciation up to the Pleistocene/Holocene boundary at roughly 10 200 years B.P.

Younger Dryas Chronozone, about 11 000—10 200 years B.P. ends the Late Weichselian subage.

Preboreal, 10 200—9 000 years B.P. initiates the Holocene age.

Chronostratigraphy

At least in this paper it is convenient to distinguish between clay deposited before and after the ice retreat from the Billingen terminal moraines, Fig. 2, which constitutes the Pleisto-

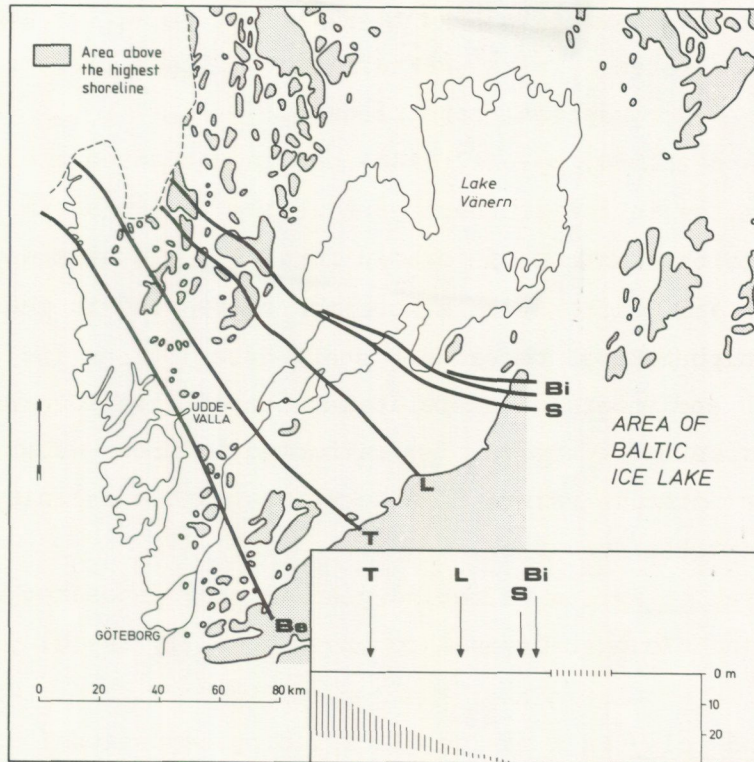


Fig. 2. The main features of the Late Quaternary evolution of the Vänern basin. The letters are abbreviations for the main terminal moraine zones, i.e. Berghem moraine, Trollhättan moraine, Levene moraine, Skövde moraine, and Billingen moraine. The inset profile shows the stratigraphical occurrence of molluscs in the clay sequences of the Vänern basin. From Fredén 1982, Fig. 3:1.

cene/Holocene boundary. During Late Weichselian times the Vänern basin was a bay of the Western ocean and the rate of deglaciation was rather slow. During the Preboreal the deglaciation pattern changed to a fast retreat of the ice front, and due to the deglaciated areas and land uplift the Vänern basin became an inland sea between the Ocean and the Baltic basin.

By tradition, the marine glacial clays in western Sweden have been divided into glacial and late glacial clays — a division which cannot be accepted with reference to the definition of the geochronological terms. In the descriptions of the geological map sheets of Värmland, the terms finiglacial brackish clay, postglacial marine clay, and postglacial brackish clay occur (Magnusson & Sandegren 1933, p. 71).

The designation of the glacial clays used below is chosen among unoccupied names of concept of deglaciation space character. The names are not linked to any reference sequence: they are used more as names for two different types of glacial clays with regional extension. The characteristics are based mainly upon the

occurrence of subfossil and fossil finds of marine vertebrates and invertebrates. To a certain degree these reflect the then prevailing hydrographical conditions.

Dennegård (1984, pp. 147—148) has investigated glacial clays at four sites in the southern part of the Vänern basin i.a. with a view to the content of foraminifers. The presence and absence of micro and macro fossils in clays correspond in character at least in that part of the area.

Glacial sediments are related to deglaciation processes. Usually distinct varved clay is formed in fresh water and non-varved or diffuse varved clay in waters with a salinity of more than 3 per mille (see Stevens 1985, p. 130).

Skagerrak clay is a marine glacial clay deposited up to the end of the Younger Dryas Chronozone. Usually the clay contains shells.

Värmland clay is a marine glacial clay deposited in Preboreal times. It corresponds to the Yoldia clay in the Baltic basin. The Värmland clay is almost devoid of shells and shell fragments.

Postglacial sediments are restricted to processes unrelated to deglaciation, e.g. the Vänern sediments, which consist of silt and silty clay (Lundqvist 1958, p. 93—94).

Bio- and lithostratigraphical terms

Some of the terms are given schematically in Fig. 3. The terminology used by Hessland is described on p. 13.

Subfossil means that the weight of the object when found does not exceed its original weight.

Shells mean shells of sea animals, chiefly of molluscs and barnacles.

Shell layer is a unit of shells or shell fragments mixed with mineralogic particles. In the layer the shells and shell fragments may have an imbricate structure, but more commonly they are irregularly deposited. When shell fragments dominate they have been crushed into sand- or silt-sized pieces.

Shell-bearing sediments are thin shell layers embedded in sand, silt, or clay.

Shell-bed is a formation of stratified shell layers and sand, silt, or clay strata of about the same thickness. The total thickness of the shell-bed unit exceeds 0.5 m.

Shell-bank is a morphological unit covering an area of 500 square metres or more. The shell-bank consists of a shell-bed which is usually discordantly overlain by stratified sand and silt, partly shell-bearing.

Shell deposit is used as a universal term for all kinds of units in which shells or shell fragments are prominent constituents.

Zoogeographical terms

Species are conventionally grouped into three regions with respect to water temperature and salinity.

Arctic is equal to the area north of Spitsbergen and north of the southern part of Greenland's east coast.

Boreal is the region between the British Isles and Spitsbergen.

Lusitanian distribution includes those species which occur in waters south of the British Isles.

METHODS

Drilling techniques

Geotechnical drillings have been carried out east of Uddevalla by Orrje & Co. A piston sampler with a diameter of 12.5 cm was used, and undisturbed samples with a height of about 20 cm were taken from each metre of depth.

The Geological Survey of Sweden later made additional drillings with an auger of 5 cm diameter and 100 cm length. The combined results of these methods suggests a tentative interpretation of the stratigraphy. Since exact definitions of layer boundaries cannot be established, the records show the stratigraphy in general.

Sampling

Shells have been sampled for radiocarbon age determination and for documentation.

Besides the field sampling, available duplicate collections at the Swedish National Museum of Natural History and the Museum of the Geological Survey were searched in order to find suitable shells from tapped deposits for radiocarbon dating. This procedure was carried out very carefully, so that no original reference shells were used and only shells from a large duplicate collection were spoiled.

When collected in situ for radiocarbon measurements, mostly shells and large shell fragments of one species were sampled in undisturbed horizontal layers within a range of about 10 cm in height and, at the most, 100 cm in length and 20 cm in depth.

As to particle size and mode of transportation, the largest shell fragments are assumed to be equal to the unbroken shells, while smaller fragments have been most probably redeposited from assemblages separate in time and space. As the aim was to deliver a sample of at least 100 gr for radiocarbon age determination, most samples collected had a gross weight of slightly more than 200 gr. It is assumed that specimens of a contemporaneous assemblage have been deposited synchronously within the given range. From this follows that only large shell fragments were sampled when necessary. Most datings were carried out on shells of *Hiatella* because the species is common in the deposits and its shell is thick enough for the purpose.

However, shells at some deposits were obviously affected by weathering and contamination, and in some layers it was difficult to find enough material to fulfill the requirements described above. In order to obtain a measureable weight the sampling range was sometimes widened, or else shells of two or three species had to be collected. In some cases the urge to achieve a radiocarbon dating of an interestingly situated locality overcame misgivings about the suitability of the shells.

No restrictions applied when a sample of an embedded shell layer was taken. Mostly these shell layers are thin, only 10—20 cm thick, and have a limited distribution. Independent of size, all shell fragments were assumed to have the same origin as the integrated species.

Shells have been spread by man in large nearby areas, and extra caution was required by this circumstance.

Radiocarbon age determinations

Radiocarbon age determinations of shells from shell deposits are shown in Figs 31, 36 and 49 in connection with the described regions. Almost all determinations were carried out by the Laboratory for Isotope Geology in Stockholm: the $\delta^{13}\text{C}$ -values given for the main part of the samples refer to the PDB standard and are based on measurements made by Dr R. Ryhage at the Karolinska Institutet in Stockholm. Pre-treatment of samples included mechanical cleaning and ultrasonic washing in distilled water. The carbon dioxide was released by treatment with hydrochloric acid. About 10—20 per cent of weight was removed and the innermost parts of the shells were used for dating purposes as far as the samples allowed. Age calculations are based on a contemporary value equal to 0.95 times the activity of the NBS oxalic acid standard and on a half-life for ^{14}C of 5568 ± 30 years. Age expressed in B.P. means radiocarbon years (= years before 1950).

Contamination. Datings from multiple fractions of marine shells are necessary to ensure maximum reliability. Fractionation corrections, $\delta^{13}\text{C}$ normalization and apparent age have been discussed by Olsson & Osadebe (1974).

Shells taken from shell-banks have been exposed to carbonate contamination and leaching over a long time. As appears in Fig. 31, fraction 2 of some samples shows an age difference in comparison with fraction 1 (outer), 3, and 4 (innermost). It follows that the innermost fractions are considered to be the purest, but sometimes fraction 1 or 2 may also be reliable. A small deviation may indicate little or no contamination.

Samples of duplicate shells may have been contaminated during storage. The storing conditions since the field collection of the three museum samples are unknown. According to Olsson (1974, pp. 313—314) stored shells may show an activity corresponding to 1.5 per cent of the activity of the international ^{14}C standard.

Reservoir age of sea water. Exhaustive discussions have been published about the apparent age of sea water in general (Olsson 1974) and of recent marine shells in particular (Mangerud 1972). The complicated problems in determining and interpreting ^{14}C datings of marine shells are only very briefly touched upon in the following treatment of some special aspects.

Atmospheric ^{14}C is transferred at the ocean — atmospheric interface. The ^{14}C activity of oceanic bicarbonate is compared to ^{14}C activity of contemporary terrestrial material. Thus, there is a negative and a positive correction. According to the circulation pattern of water within the oceans, water masses show different ages.

Datings of recent "pre-bomb" marine shells of the Swedish west coast suggest an age of 400 ± 25 years (Håkansson 1975, p. 80). The corresponding correction value has been used in the Figures, though it is doubtful if recent values are applicable on shells of animals which have existed in quite different hydrographical conditions. When corrections are made, the value $\delta^{13}\text{C}$ and the estimated apparent age of sea water are found to be almost equal for marine shells of Late Weichselian times.

SHELL-BANKS AND SHELL-BEARING SEDIMENTS IN GENERAL

Shells and shell fragments are found in shell-banks, in shell-bearing sediments and as individual components in clay.

The described stratigraphy is not unique for the Uddevalla and Vänern shell deposits but is found more or less complete in almost every shell deposit in western Sweden.

Most of the shells found individually in clay are intact and show no traces of erosion. Usually such finds occur in the basal parts of the glacial clay, implying occurrence at an early stage of the clay sedimentation. The species found isolated in clay are consistently the burrowing types of lamellibranches, which could tolerate a low salinity. The most common mollusc in the lower part of the Skagerrak clay is the bivalve *Portlandia arctica*. Observations in a few cuts of basal clays have shown that assemblages of *Mytilus edulis* may be found in horizontal layers at

most one metre long and ca 5 cm thick. The shells are often complete, they lie close to each other, and coarse particles are absent. In contrast with shell-bearing sediments, such a shell layer in clay is considered to be almost autochthonous.

The shell-bearing sediments consist of one or more shell layers in sand or clay. The shell layers are mostly characterized by an abundance of shell fragments mixed with fine and coarse minerologic particles. The thickness of each layer varies between one and ten cm. Signs of a vertical grading may be observed in which the grain size of particles gradually decreases upwards from the basal fraction, which is dominated by sand and gravel. Shell fragments are generally found in the upper part of the layer. Due to the restricted occurrence and the absence of suitable pieces for identification, the number of species identified is usually low.

Shell-bearing sediments may be separated into two groups with different characteristics, shell-bearing clay and shell-bearing sand. Both types originate from littoral processes, but they are deposited at different depths.

Shell layers embedded in clay are usually found in the centre of a valley with no apparent continuity with the valley sides. These shell layers are thus deposited in relatively deep water. When an embedded shell layer in clay is found to be continuous with the valley side, it often constitutes the most distal part of a shell-bed.

Shell layers found in sandy sediments are most often lying close to a valley side. Shell fragments are mostly very small and the number of intact shells is very low. The strong influence of littoral processes suggests a lengthy deposition in shallow water. In comparison with the faunal composition in the shell-bearing clay, the relatively long-time exposure to littoral processes (high energy environment) involves a greater supply of primary and secondary shells for shell-bearing sand. The number of identified species is relatively low.

Shell-banks

There are no longer any good possibilities to observe the stratigraphy and character of the layers from top to bottom in a shell-bank. The following characteristics are built on observations

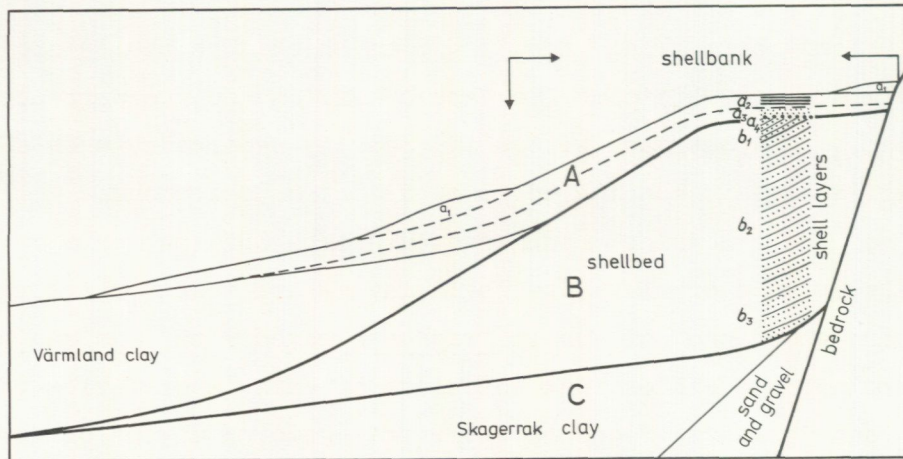


Fig. 3. An outline of an idealized stratigraphy of a shell-bank in the Uddevalla region. Characteristics of strata are given in the text and in Fig. 4.

made during the surveying and on information from literature, primarily from Odhner's works. A rough outline of the location and stratigraphy of a shell-bank is given in Figs 3 and 4. For further stratigraphic information, see Fig. 17.

Usually a shell-bank is related to a more or less steep hillside of bare bedrock, partly at a small fissure valley. The stratigraphy of a shell-bank is divided into three units. The shell-bed, B-unit, is covered by deposits belonging to the A-unit and is underlain by clay, sand, and gravel, or bedrock, the C-unit. These main units are divided into sub-units.

The ideal stratigraphy of a shell-bank is shown in Fig. 3. The stratigraphy of the deposits differs from place to place and usually all sub-units are not present. Shell layers have irregularities caused by primary submarine and secondary terrestrial downslope processes.

At the superficial morphologic foot of the shell-bank, or on top of it at the hillside, a layer of shell-bearing gravelly sand may be found. This a_1 layer is rather insignificant as to distribution and thickness. The shell fragments are often crushed into very small pieces but within the layers less eroded shells of molluscs can also be found. Compared to the B unit and identifiable shells of the other a-layers, the faunal composition is quite different, implying that the unit may have a Holocene origin as a beach deposit, though some shell fragments belong to species with a boreo—arctic character. In the Uddevalla area the

Unit	Assumed max. thickness in m	Minerogenic components in shell layers					Occurrence of		
		pebbles	gravel	sand	silt	clay	shells	shell - fragments	
								large	small
a ₁	0,5	-	+	+	+	-	+	+	(+)
a ₂	1,0	-	(+)	+	+	-	-	-	-
a ₃	1,0	-	(+)	+	+	(+)	-	(+)	+
a ₄	0,2	(+)	+	+	+	-	-	(+)	-
Värmland clay		-	-	(+)	+	(+)	-	(+)	-
b ₁	2,5	-	-	+	+	+	+	+	(+)
b ₂	10,0	-	+	+	-	(+)	+	+	-
b ₃	10,0	+	+	+	-	-	+	+	-
Skagerrak clay		(+)	(+)	+	-	(+)	+	(+)	-
sand and gravel		-	-	-	-	-	-	-	-

Fig. 4. Characteristics of the composition of shell layers in Fig. 3. Occurrence is marked with a plus, rare occasion with a plus within a parenthesis. Asterisk means that complete bivalves are to be found.

a₁ sub-unit is restricted to areas below 55 m above sea level and thus may occur as surficial patches unconnected to shell-banks.

Usually the top unit of a shell-bank consists of a 0.5—1.5 metre thick, horizontally laid and well-defined layer of silt, sand, and gravel. The grain size decreases with the distance from the bedrock. The a₂ sub-unit is free of shells and shell fragments while the a₃ sub-unit is characterized by shell fragments broken into very small pieces, see Fig. 25. The whole A unit is separated discordantly from the shell-bed underneath. The boundary layer, a₄, consists of coarser grain size, and is often sharply marked, see Fig. 14. This layer is almost free of shell fragments. On the frontal slope there is no a₄ sub-unit and the transition between a₃ and b₁ is gradational there.

All substrata in the A unit are deposited close to a beach. The sharply marked boundary surface, a₄, reflects erosion by waves.

Most of the components in the A unit originate from the B unit.

In the distal parts of a shell-bed the shell layers are covered by Värmland clay, which is of maximum thickness in the centre of the valley where it may be overlain by some metres of postglacial clay and alluvial sediments. The Värmland clay is

almost free of shells and shell fragments; cf. the Skagerrak clay, C unit, below. Close to the shell-bank, however, the clay is shell-bearing and a sharp transition between the a_3 or b_1 subunits cannot always be found.

Special erosive features, a grooved boundary surface and two wedged-shaped veins, have been observed in the upper parts of two shell-banks: Kapellbacken (locality 1), 16 m above sea level, and Samneröd (locality 2). As these features have not been investigated satisfactorily, information is given in the locality descriptions.

The shell-bed, B unit, consists of more or less well stratified shell layers, which dip away from the hillside rather uniformly; see Figs 3, 9-10, 14 and 21. The upper proximal part is usually cut off by wave action. The transitions between the three sub-units are gradational.

The b_1 sequence is found in the upper and distal parts of the shell-bed. The sub-unit is characterized by argillaceous shell layers or embedded clay layers up to 10 cm thick. Due to the clay content, the b_1 layers are fairly consolidated, see Fig. 21. The thickness and distribution of the clay layers vary. The thickness of the sub-unit seems to increase with the distance from the bedrock, unlike the b_2 sub-unit which decreases in the same direction. The distal parts of the B unit are usually argillaceous. Shell fragments dominate and observed shells are usually eroded.

Apparently, the b_1 stratum is deposited during moderately quiet conditions in shallow water. Shells and shell fragments have been extensively exposed to erosion before final deposition.

The b_2 sub-unit forms the main part of a shell-bed. Shell layers consist of less eroded shells and, for the most part, the shell fragments are large enough for reliable identification. Particles and layers of sand and gravel are mixed with the shells and the shell fragments, sometimes producing cemented strata. Complete bivalves (united shells) are also found. The grain size and the frequency of non-eroded shells decreases away from the hillside. The largest shell-beds are characterized by this porous type of deposit.

In the basal part of the shell-bed, b_3 , the occurrence of mineralogical particles increases and the grain size becomes

coarser; even pebbles and cobbles are recorded. Comparatively large and thick shells are found.

Layers of b_2 and b_3 sub-units are interpreted as having been deposited in relatively deep water. The shells show notably less evidence of erosion, which implies that vertical movement and burial has taken place in one step without extensive horizontal transport. The compositional variety between minerogenous and biogenous components reflects the supply of material at the time of sedimentation.

The shell deposits are underlain by bedrock, partially cemented sand or gravel, or by Skagerrak clay. The boundary surface between the B and C units is always sharp. In the clay, thin layers of shells or individual shells, even complete bivalves, occur. Apart from some shell fragments in the uppermost part, shells are totally missing in the stratified sand and gravel unit, as might be expected due to its glaciofluvial origin.

Concerning the genesis of shell deposits along the northern coast of Bohuslän, Hessland (1943) divided the shell-banks, which he called aggradation deposits, into progradation deposits and regradation deposits. The former were deposited in the main direction of movement of the transporting medium, while the latter were deposited in the opposite direction. This division is not quite applicable to the Uddevalla area, where, in addition to normal wave and current dynamics along a coast, special hydrographical conditions have had an influence on both faunal inhabitat and deposition of shells, e.g. deposition within a strait perpendicular to the coast. In some cases shells could be deposited in one direction only for morphological reasons.

To avoid misunderstandings Hessland's terminology is not used in this paper. In accordance with the morphology of shell-banks, Hessland (1943) differentiated between terraces, cones and deltas, all formed as progradation deposits. The terraces are found on slopes of fairly flat bedrock surfaces, while cones are mainly associated with accentuated fissures. Deltas occur mostly on the lee side of a local sill. Transitional forms were recorded between all three types of progradation deposits.

Regradation deposits are found only as terraces. A characteristic feature of this type is a high content of minerogenous

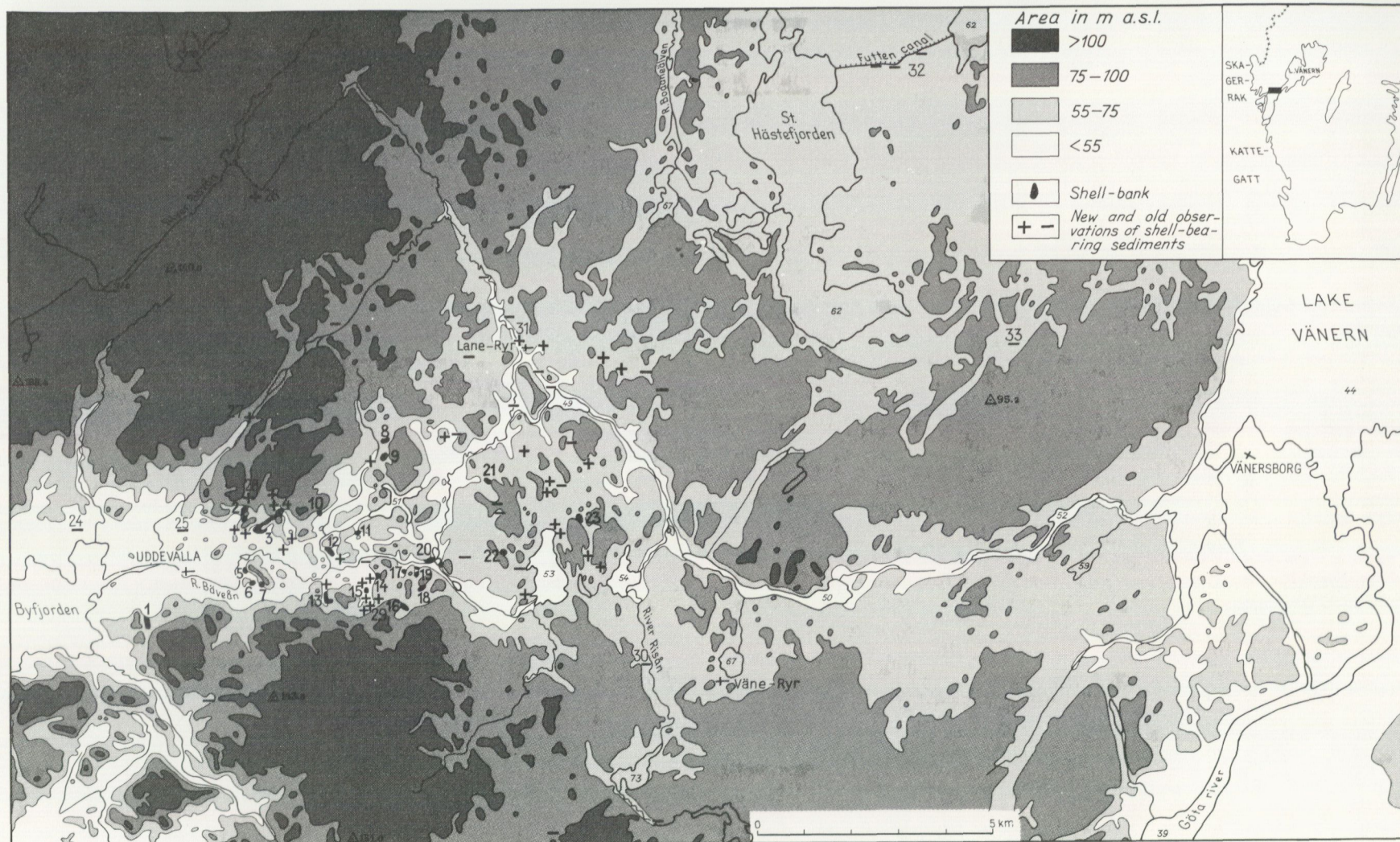


Fig. 5. Essential features of the morphology and location of known shell deposits in the Uddevalla region. The northern continuation of Bodaneälven river is shown in Fig. 29. Numbers according to descriptions in text.

The map is based on the topographical map sheets Vänersborg NV, NO, SV and SO (NW, NE, SW and SE resp.). The intersecting lines are situated 1500 m southeast of Uddevalla church.

particles. The deposit is furthermore recorded below a thick top layer.

If the Uddevalla and Vänern deposits are related to the coastal ones of northern Bohuslän, representatives for each group and transitional form are present.

SHELL DEPOSITS IN THE UDDEVALLA REGION

By the Uddevalla region is meant the northeast quadrant of a circle with a radius of about 30 km from Uddevalla city. Within this area, shell deposits are concentrated within two main valleys of east—west orientation, Figs 5 and 29. The valleys are separated by a flat bedrock plateau between 100 and 125 m above sea level. Hilly areas above the highest shoreline (see below) limit the region to the north and south.

The Quaternary map sheet of Vänernsberg NO (Fredén 1974) covers the main part of the area concerned. The region is characterized by vast areas of exposed bedrock. The sediments in the distinct valleys are dominated by glacial fine clay.

No reliable evidence of the highest shoreline is to be found within the map area. Delta surfaces to the north and south suggest an altitude of 135—140 m above sea level at Uddevalla.

Known shell deposits will be described in two parts. As is shown in Fig. 5, there is such a concentration of shell deposits in the valley east of Uddevalla that there is reason to divide the description into shell-banks and shell-bearing sediments. The part dealing with the shell-banks is relatively extensive, since it forms the central point of this paper.

The valley between Uddevalla and Vänernsberg can be divided into two morphological parts, Fig. 5. The eastern one is moderately flat and broad, running through the elevated Precambrian peneplain, while the western part shows typical features of the Bohuslän fissure landscape — the valley is narrow and the valley floor is hilly. In the border zone between these different types of landscape the valleyline makes a northerly detour. The present watershed is located in the easternmost part, almost 55 m above sea level. It is formed by alluvial sediments and clay with thickness of more than 28 m (Fredén 1974). Between the watershed and Byfjorden certain stretches of the rivers Risån and Bäveån run on bedrock outcrop.



Fig. 6. Section of the former embankment of the state railway northwest of Uddevalla. The present highway and railway are seen in the background. The section shows the technique of railway construction in the Uddevalla area at the turn of the century. On a body of sandy-gravelly material (glacifluvial sediments and till), a 20–30 cm thick shell layer is visible below 30–40 cm of sand at the top. On the slopes there is clay 10–20 cm thick and covered by sand. The white stick where the right-hand rail used to lie is 1 m long. The railway embankment will be pulled down and the shells will be spread over again. — Photo CF 1976-09-01.

Shell-banks

Twentythree shell-banks have been recorded in the Båveån river valley and its vicinity, Fig. 5. Most of them are more or less totally exploited and the remains are covered with vegetation. It follows that reconstructions have been made according to the original extension. When the area was mapped in 1968–1970 sufficient exposure for some reconstruction was available. It may be noted that the occurrence of a shell-bank indicates that distal shell layers embedded in clay are to be expected.

The shell-banks have been exploited for centuries and have had a wide field of application: fertilizing, poultry-fodder and road construction. Large quantities were cut away for the construction of the standard-gauge railway from Uddevalla to Vänersborg (1863–1864) and the narrow-gauge railway from Uddevalla to Bengtsfors, opened in 1895 and closed in 1964 (Brögger 1900–1901, p. 312,

Forsaeus 1985). The old structural engineering of railways is shown in Fig. 6, and at Ryr railway station one can still see fillings of gravel, sand and shells, mainly *Hiatella*, on the platform and on track number one.

When Nordmann (1906, p. 80) visited Uddevalla at the turn of the century, he was, upon arriving, immediately reminded of being in a town of shell-banks. All roads and paths in the residential district were covered with "macadamized" shells.

Hauling plants were later used to extract shells and shell fragments below groundwater level for lime-works, see locality 20. When the Samneröd (locality 2) military rifle-ranges were rebuilt shell layers, due to low specific gravity, were used as insulation material in the unstable clay of the harbour area. Some companies have carried on mining at several localities at different times. At the turn of the century one company started at Ramseröd (locality 13), then it moved to locality 15, operated Bräcke (locality 3) until it became a nature reserve, and ended with the mining at Älje (locality 20). Another company operated the Björbäck (locality 12) deposit when the Kapellbacken (locality 1) deposit 16 m above sea level was emptied.

The shell-banks are divided into three geographical groups. The western shell-banks include localities 1-7, the central shell-banks, localities 8-15, and the eastern ones, locality 16-23.

Western shell-banks, localities 1-7

The best known shell-banks in the region, and in Sweden as well, are situated in the western part of the Uddevalla-Vänernsberg valley, where the land surface lowers to sea level, represented by the Byfjorden.

The classical "shell hills of the Samneröd domains" are known since the beginning of the 1700's. Three of the deposits, Kapellbacken, Bräcke and Kuröd, have been scientifically examined several times before the end of the mining about 40 to 50 years ago. The Samneröd deposit has been investigated recently.

Some faunal notes are made in the following descriptions. All the identified invertebrates and subfossil skeletal parts of marine vertebrates are listed in the chapter Faunal composition. In faunal respects the shell-banks must all be regarded as one

unit. In the early days of investigation no distinction was usually made between them. Finding-places were labelled "Uddeval-la" or "Uddevala shell-banks", and when local names were used they were often inaccurate.

The larger shell-banks, 1—4, are described separately and accompanied by a synopsis while the three smaller ones, 5—7, are treated together.

1. Kapellbacken, Fig. 1. The locality is known to science since the days of Linné and Swedenborg. During the last two centuries many researchers have visited Kapellbacken, chiefly for its palaeozoological interest.

The different deposits are substantiated by De Geer (1910a) with lists of identified species and a map in scale 1:5 000. De Geer's paper largely consists of a rather theoretical discussion about land subsidence "proved by molluscs". His ideas may have influenced the description, because in it there is an annoying lack of stratigraphical information. De Geer (1889, p. 207; 1910a, p. 1152, p. 1177) had visited the Kapellbacken deposits periodically since 1881. The main map work was carried out in 1884.

Valuable information about the Kapellbacken deposits is given in Brögger's (pp. 317—323) comprehensive paper of the mollusc fauna in the Kristiania (Oslo) region. There was not much to see when Nordmann paid a visit in 1906.

Odhner (1927, pp. 81—82), who had been one of De Geer's assistants in the analyses, returned in 1922 to the area accompanied by Caldenius, Munthe, and Sandegren. At this time mining operations were taking place, at least in the deposit 16 m above sea level (op.cit. Fig. 2). Between 1926 and 1928 Ringström (1928) with the assistance of the workers collected the skeletal parts of vertebrates found during the mining (see p. 85). In the beginning of the 1930's industrial mining diminished and ceased. Since the 1940's most of the Kapellbacken sites have been built over. A reconstruction of the deposit locations is shown on Fig. 7.

Apart from De Geer's compilations, identified species have been published by Thudén (1866), Brögger (1900—1901), Lindström (1902) and Odhner (1927). As mentioned in the introduction, De Geer's interpretation of the shell deposits was contradicted by Odhner (1918, 1927).

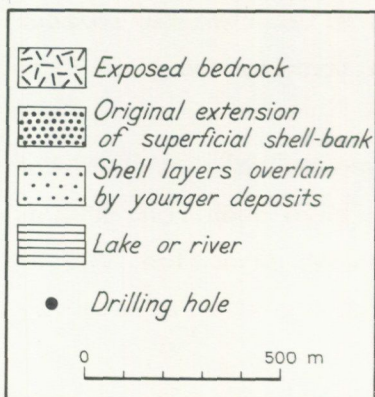
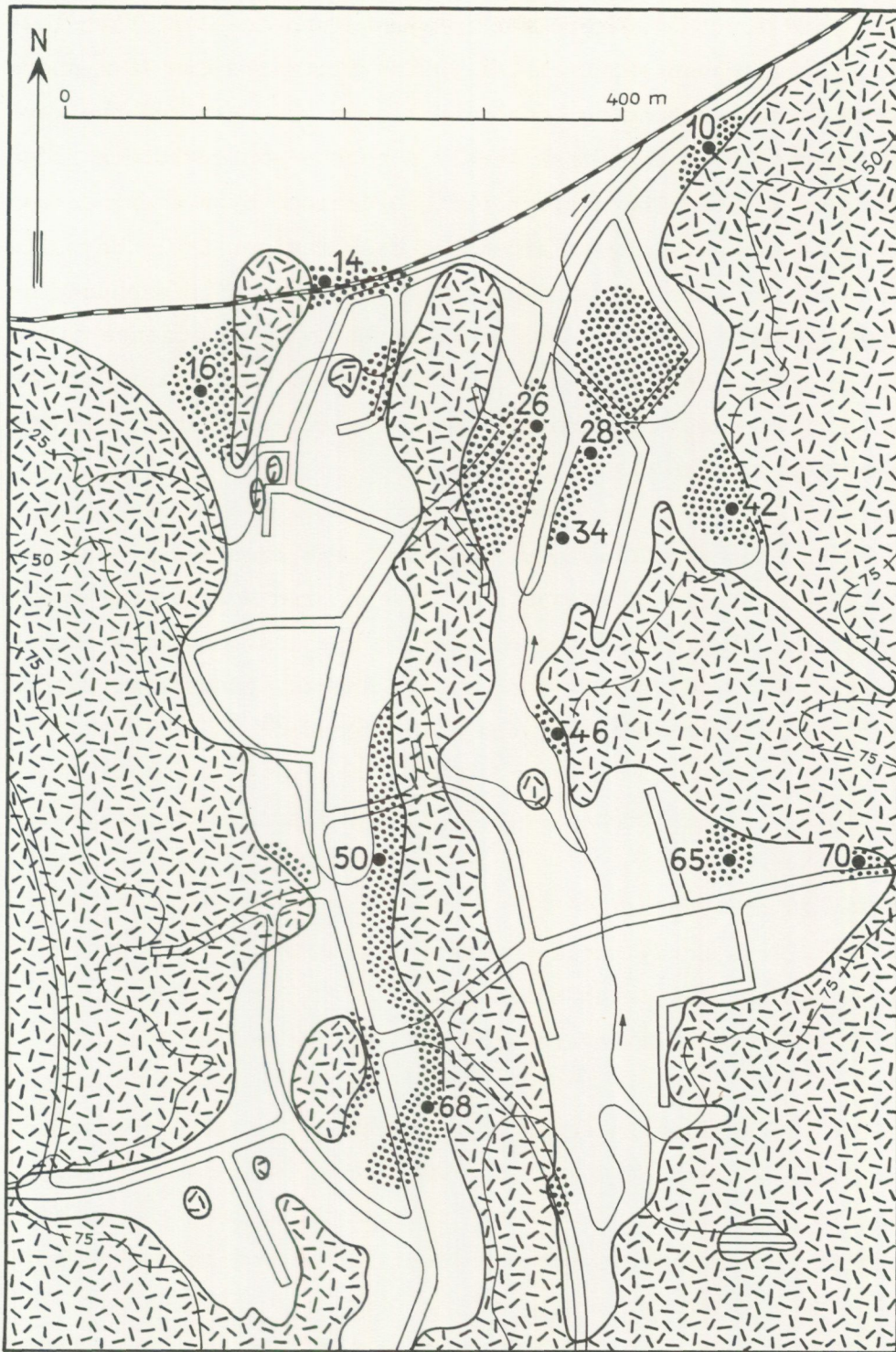


Fig. 7. A reconstructed map of the shell deposits in the Kapellbacken valley, locality 1, southwest of Uddevalla. Contour interval 25 m. Numbers mean m above sea level and refer to locality descriptions. Shell deposits 26 and 28 are embedded shell-beds in clay and their extension to the north and east is uncertain. The outcrop of the central bedrock is generalized. Between the railway and locality 46 the rivulet runs in a gully.

Kapellbacken is a valley of an almost north--south direction, Figs 5 and 7. Its northern portion runs into the Byfjorden lowlands. The highest parts of the valley floor lie 65--70 m above sea level. The surrounding bedrock hills to the east and the west reach above 75 m above sea level. A north--south bedrock ridge divides the valley. The eastern part is drained by a small stream which runs in a fairly enlarged and deep ravine. Shell deposits in the valley are only known in the part, which is exposed towards Byfjorden.

The compilation below is for the most part after De Geer (1910a). Altitudes given for the deposits refer to location numbers in Fig. 7.

From the deposit 70 m above sea level one sample was analysed by De Geer. Shells of barnacles, *Saxicava* and *Mytilus* were common. *Balanus crenatus* was the dominating species among the shells of barnacles. Individual shells of *Anomia ephippium*, *Macoma baltica*, and *Macoma calcarea* were also recorded.

At locality 68 Odhner (1927, p. 83) measured the following stratigraphy:

- 0 — 20 cm Top-soil
- 20 — 32 cm Sandy shell layers
- 32 — 44 cm Clay with no shells
- 44 — 159 cm Shell layers underlain by weathered bedrock.

Lists of identified species are given by De Geer (1910a) and Odhner (1927).

Locality 65. No information or identification list is known.

Concerning the locality 50 m above sea level De Geer stated only that clay about one metre thick covered the shell layers. It seems that the deposit along the west side of the central bedrock ridge has been overlain by 0.5--1.0 m of younger deposits. The shell-bed was probably slightly thicker than one and a half metre. The old main road to Uddevalla passed on this side of the Kapellbacken valley and the shell deposits have been long known. The redrawn extension in Fig. 7 may be somewhat deceptive.

The locality 46 m above sea level was found 1898 by De Geer (1910a, pp. 1159, 1171). At the foot of a rock-face he found a 0.6 m thick shell-bed on clay. In addition to the dominating *Saxicava arctica*, the following species were numerous: *Balanus crenatus*, *Anomia ephippium*, *Mytilus edulis*, *Littorina littorea*, and *Hydrobia ulvae*. These species may be characterized as living in shallow water.

Locality 42 was situated at the mouth of a small tributary valley. According to De Geer (1910a, pp. 1159—1160) the stratigraphy was the following:

- 0 — 0.5 m Clay
- 0.5 — 2.3 m Stratified shell layers dipping eastwards
- 2.3 — 2.8 m Sand
- 2.8 — 3.3 m Clayey sand

In 1973 shells were visible on the surface of the northwest side of the deposit.

A surficial shell-bearing sand, locality 34, has a divergent faunal composition (De Geer 1910a, pp. 1177—1178, Table C). Shells of *Littorina littorea* and *Balanus crenatus* dominate. No less than 24 shells of *Cardium edule*, 4 of *Ostrea edulis*, 10 of *Bittium reticulatum*, and 6 of *Nassa reticulata* were recorded. In this shell-bearing sand, which was underlain by clay, shells belonging to Holocene species dominated.

At localities 26 and 28 a rivulet has cut embedded shell-beds in the valley. Later human activity has enlarged the gully. The stratigraphy is given according to De Geer (1910a, pp. 1157—1158, Fig. 3):

- 0 — 0.4 m Sand
- 0.4 — 1.2 m Sandy clay
- 1.2 — 5.6 m Shell-bed underlain by clay in which shells of *Arca glacialis*, *Macoma calcarea*, *Portlandia arctica*, *Leda pernula*, and *Nucula tenuis expansa* were found. The latter two were identified by Brögger (1900—1901, p. 320).

The extension of the deposits of the east and the north is unknown. On the basis of what was visible on the slopes in 1973,

the thickness increases to the west, i.e. toward the central bedrock ridge. According to Brögger (1900—1901, p. 320) the shell-bed had been sliding on the underlying clay in "recent" times.

Most of the recorded species from the Kapellbacken area come from the deposit 26 m above sea level. Samples for analyses were taken by De Geer at the bottom and at the top. Today the ground on both sides of the gully is developed. Visible shells are not assumed to be *in situ*. The slopes of the gully have been used as refuse dumps.

The best known of all Kapellbacken deposits is the one at 16 m above sea level, also known in literature as Kristineberg. The locality is situated in the central part of a small valley running northwards. The surrounding bedrock terrain reaches slightly more than 24 m to the east and above 75 m above sea level to the southwest. The main part of the shell deposit lies close to the bedrock hill in the east.

De Geer estimated the thickness of the shell-bed to 4—5 m. Due to talus only a couple of metres were visible to him. When Odhner (1927, pp. 81—82, Fig. 2) later visited the area, the cut was close to the bedrock hill and a vertical wall of almost 7 m was accessible (cf Munthe, Johansson & Sandegren 1923, Fig. 72).

A brief but comparatively complete description was given by Carlzon (Caldenius) in 1920. Carlzon (p. 320) had been asked to make a geotechnical assessment of the shell-bank and the distal shell layers in order to find out the stability effects on the adjacent railway between Uddevalla and Göteborg. According to Carlzon, the deposit had a length of about 190 m along the bedrock hill. In the proximal parts, the layers were gravelly, contained large and thick shells, fairly well preserved, whereas in the distal parts the layers were sandy and silty and contained smaller, thinner shells that were often crushed. Longitudinal sections and cross-sections had been made, but unfortunately the report is not to be found in the archives of the state railways (Torsteinsrud, personal communication).

In the beginning of the 1930's the deposit was totally exploited. Nowadays only signs of extensive mining are visible. The western part of the valley, however, is almost untouched signifying negligible shell amounts.

A shell-bearing sand was reported to lie discordantly upon the shell-bed, which had layers showing a regular dip to the west. According to De Geer (1910a, p. 1161, Figs 5 and 6) the boundary surface was grooved due to littoral erosion. Later Halden (1925) discussed cylindrical forms as sand pipes, which he interpreted as a local dissolution of carbonate and subsequent in-filling by the overlying sand. Where these sand pipes are present the boundary surface is grooved. Odhner (1927, p. 91), who had probably seen the feature mentioned by De Geer, attributed the grooved surface to leaching, as suggested by Halden.

The shell-bearing sand had a similar faunal composition to locality 34. The following species were listed by De Geer (1910a, pp. 1160—1161, 1178): *Cardium echinatum*, *Cyprina islandica* (even with both shells united), *Lucina borealis*, *Ostrea edulis*, *Aporrhais pespelecani*, *Hydrobia ulvae*, *Montacuta* sp., and probably *Bittium reticulatum*. Later, when the cut was closer to the bed-rock hill, Odhner (1927) examined the uppermost part of the shell-bed, i.e. just below the shell-bearing sand. He identified shells of the following species: *Astarte costata*, *Cardium fasci-natum*, *Littorina rudis*, *Hydrobia ulvae*, *Rissoa inconspicua*, *Bittium reticulatum* and *Discus (Patula) rotundatus*. However, *Dicus (Patula) rotundatus*, a land snail, is to be regarded as sub-recent.

Almost all known species from the Kapellbacken deposits have been recorded at this locality.

The deposit 14 m above sea level is not commented upon by De Geer.

The list of identified shells in the deposit at 10 m above sea level shows a Late Weichselian fauna. No shells of Holocene origin are recorded.

Summary. The classical locality Kapellbacken was composed of different shell deposits at altitudes between 10 and 70 m above sea level. Almost all of them have been destroyed. The largest shell-banks are found below 30 m above sea level in the northern part of the valley. The well-stratified shell layers were underlain by glacial clay (Skagerrak clay) and overlain by 0.5—1.0 m of younger deposits, clay and sand. In one deposit the boundary

between the A and B units consisted of a grooved surface caused by leaching.

Surficial shell-bearing sands, a₁ sub-unit, showing a distinct faunal composition of Holocene origin were recorded below 40 m above sea level.

Regarding stratigraphy and faunal composition it seems probable that the valley, mainly the central bedrock ridge, has been inhabited more or less continuously by an arctic—boreal fauna, which has obviously moved downwards *parvi passu* with land uplift in order to keep batymetrical and hydrographical conditions as consistent as possible. The most favorable conditions prevailed when the molluscs lived between 20 and 30 m above sea level. The corresponding water depth is unknown. As shells were concentrated at certain levels and not uniformly spread, sea level changes affecting habitat and later sedimentation conditions may have contributed to this heterogeneous pattern.

The highest recorded deposit of Holocene shells is situated at 34 m above sea level.

Calculations of volumes are uncertain, but especially in this case, as most of the signs of shell deposits are eliminated by urbanization. A volume of 10 000 cubic metres is assumed along the upper west side of the bedrock ridge. About 20 000 cubic metres have been cut by man and eroded by the rivulet on the east side of the bedrock ridge. At least 50 000 cubic metres have been mined in the shell-bank at locality 16. Together with the other small deposits and the unknown extension of the 4—5 m thick shell-bed on both sides of the rivulet a rough figure of about 100 000 cubic metres total seems likely.

One radiocarbon determination has been carried out on stored shells. The exact collecting site is unknown. The age of shells of deep water molluscs given tells only when the dated molluscs inhabited the area.

2. Samneröd. The deposit has not been described previously. Its regional position is shown in Fig. 8 and its local position relative to the exposed bedrock in Fig. 9. The shell-bank is situated along the east side of a short north—south-orientated valley. The whole area is used as military rifle-ranges. The shell layers have now and then been cut for road repairs and road

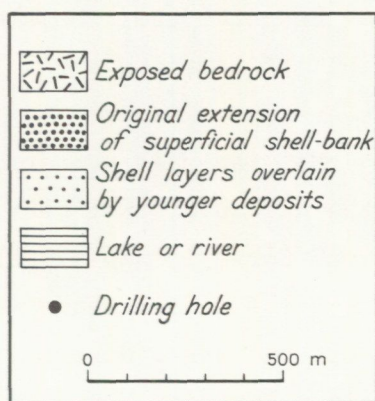
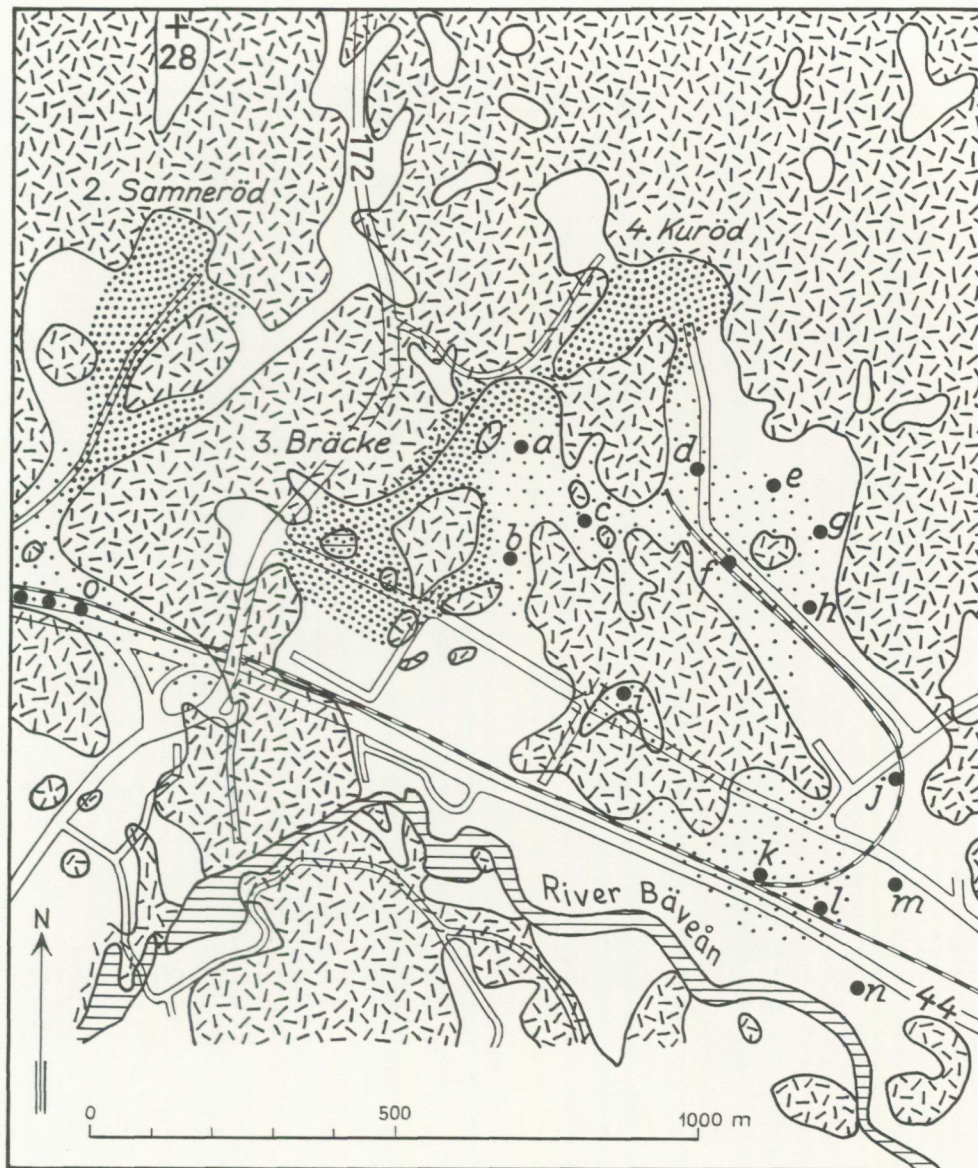


Fig. 8. Map of the western shell-banks and embedded shell deposits north of River Bäveån. The subsurface extensions shown are valid for marked patches only. For stratigraphical information of the drilling holes, see Fig. 17. Drilling hole o is situated south of Samneröd. Shell-banks and bedrock according to the Quaternary map Vänersborg NO (Fredén 1974).



Fig. 9. Northeastern part of the Samneröd shell-bank. The wall on the left is orientated WNW—ESE and the one on the right is almost perpendicular. The scattered trees grow on bedrock. The flat surfaces in front of the trees are safety banks within the rifle-ranges. Figs. 10 and 11 are close-up pictures of the stratified layers to the right; for identification notice the concave moulding (black). In the right-hand margin of the picture a small tributary valley is situated. — Photo CF 1968-09-09.

building within the military area. Vertical walls have been easy accessible for stratigraphical zoological investigations, see Figs 9 and 10. It may be noted that the shell-bank formerly has served as an artificial infiltration area. That process has made the shells ferruginous.

The surveying of the map sheet Vänersborg NO (Fredén 1974) started in 1968. In the autumn of that year the Quaternary geologists of the Geological Survey's map division visited Samneröd. During the winter 1969 the rifle-ranges were rebuilt and large quantities of shells were cut away. No scientific authorities had been notified of this operation, so the last opportunity to document the deposit as well as the fauna in the area was lost. The only finds that were taken care of by the workers were well-preserved skeletal parts, identified as belonging to domestic animals. "Old and ugly" skeletal parts roused no interest. Fortunately, Dr Anders Warén of the Zoological department of Göteborg University had examined the cuts out of personal interest before the devastation. Among the species identified by Warén are some



Fig. 10. Samneröd shell-bank. Well stratified shell layers, b sub-unit, dipping southwards. The shell layers are very porous, and even without human activity talus slopes are rapidly formed. The concave moulding on Fig. 9 is seen to the left of the man. Note the wedge-shaped and silt-filled veins to the left. — Photo J.Lundqvist 1968-10-09.



Fig. 11. Samneröd shell-bank. Close-up picture of shells and shell fragments mixed with particles of gravel, sand, and silt. Porous layers — mainly shells — are intersected by more consolidated layers of shell fragments cemented with sand and silt. The dark-coloured shell layer by the knife is ferruginous. Shells of *Hiatella* and side-plates of *Balanus hammeri* dominate in the picture. — Photo J.Lundqvist 1968-10-09.

previously not known in the area or in all Scandinavia, see Fauna composition.

The Samneröd deposit is composed of at least two accumulations which are continuous with each other. The original topography is unknown.

In the northern part of the valley a shell-bank accumulated at the foot of a bare hill slope rising above 100 m above sea level. On top of the deposit, about 75 m above sea level, there was a layer of sand and gravel, 0.5 m—1.0 m thick, with a horizontal stratification — A unit. The surface close to the hill was flat. The A unit of the shell-bank has not been found unspoiled.

The original surface, the a, sub-unit, sloped gradually downward from about 75 m above sea level to about 50 m above sea level in the south. The original extension of the shell-bank is uncertain west of the minor road.

The shell-bed, B unit, consisted of well stratified shell layers with a uniform dip to the west and the south, see Figs 9—11. About 50 m south of the hill slope the shell-bed was up to 15 m thick in the central part, according to construction drawings.

A residual portion of the shell-bank is found in the small valley orientated perpendicularly to the main valley in its northeastern corner. The flat surface of the deposit lies 68 m above sea level. The slope to the east is fairly steep. This part of the shell-bank has been used for military trenches and the flatness of the surface might be man-made. The only *in situ* shell layer may be found between the traces of the trenches.

During the construction works in the spring of 1969, shells of *Portlandia arctica* were found in the shafts of the underlying dark bluish Skagerrak clay. The clay surface had a low gradient southwards.

In the upper part of the shell-bed two wedge-shaped veins, one deep and one shallow, were noticeable in the autumn of 1968, see Fig. 10. Both were filled with unstratified silty sand. The upward continuation is unknown due to human activity. The deep vein was faulted and had a width of 18 cm on the visible surface. The shallow one was 10 cm wide at the ground surface. The original depths were at least 220 cm and 60 cm respectively. The shell layers were cut very sharp and the transition to the sand was

"razor-sharp". Unfortunately a closer examination in three dimensions was put off until the spring of 1969. However, some impressions will be related.

During the construction works cross-sections of more or less temporary water courses were visible in the south part of the shell deposit. The ditches were V-shaped and half-filled with silty sand, partly mixed with shell fragments. While the old drainage pattern was destroyed during the spring of 1969, the surface water rapidly cut new V-shaped furrows in the easily eroded shell layers. The summarized observations suggest that the origin of the two wedge-shaped veins may be related to water erosion and filling with alluvial sediments. Cylindrical forms caused by leaching are described on p. 23.

East of the minor road a shell-bank existed on the west and south sides of a bedrock hill, which has a peak about 85 meter above sea level. The surface of the shell-bank close to the bedrock is almost 50 m above sea level. In the south, shell layers filled up the lower part of the small valley orientated southwest-northeast. In this valley the thickness of shell layers was 4-5 m. The shell-bed was overlain by about 0.5 m of sandy sediments and underlain by Skagerrak clay. The visible upper part of the B unit consisted of shells mixed with sand and gravel along the west and south side of the hill. In the southeast part of the small valley the shell layers were clayey.

Further southwards shell layers are overlain by a greyish and partly sulphurous clay. In the east-west valley the shell layers are connected with a shell-bed originating in the bedrock hill south of the railway, see Fig. 8. At drilling-hole "o" the following stratigraphy was measured:

- 0 — 5 m Postglacial and Värmland clay
- 5 — 12 m Sandy and gravelly shell layers
- 12 — 16 m Skagerrak clay underlain by sand and gravel

At a distance of 400 m west of drilling-hole "o" the thickness of the post glacial and mainly the Värmland clay increases to about 10 m and the thickness of the shell layers decreases to a few metres.

See also description of locality 25 which is situated about 500 m west of drilling-hole "o".

Summary. Of the original Samneröd deposit, less than 5 per cent are still untouched. The deposit consisted of at least two accumulations. One lay at the foot of the steep-sided bedrock area to the north. At a horizontal distance of about 50 m to the north, the 100 m contour level is crossed. The other accumulation was situated at the bedrock hill which has a peak about 85 m above sea level. South of the Samneröd shell-bank, shell layers embedded within the clay are known.

A rough figure of 100 000 cubic metres is estimated for the north accumulation of the shell-bank, about 50 000 cubic metres for the south part and about 10 000 cubic metres for the embedded shell-beds and shell layers, which gives an approximate figure of 160 000 cubic metres for the total volume of shell deposits of the Samneröd area.

One radiocarbon measurement has been carried out.

3. Bräcke. One of the best-known shell deposits, the Bräcke shell-bank, Fig. 12, is situated in a triangular basin with its apex to the northeast, Fig. 8. From the narrow gorge in the northeastern part there is a continuation of shell deposits to the Kuröd shell-bank, locality 4, Fig. 8.

The shell-bank was described briefly by Brögger (1900—1901, pp. 312—317) and De Geer (1910, pp. 1168—1170). The latter has it confused by name with the Kuröd shell-bank. The thickness of the deposit, the altitude of underlying glacial clay and the proximity to the Uddevalla—Herrljunga railway (op.cit., p. 1192; cf. Nordenskiöld and De Geer 1910, p. 50) confirms that De Geer's "Kuröd" shell-bank corresponds to the Bräcke shell-bank, as described in this paper.

The top layer, A unit, which can still be seen at the gorge, was characterized by De Geer as about one metre of shells, gravel and pebbles unconformably covering the shell-bed, cf. Fig. 14. When Brögger (1900—1901, p. 321) visited the area in the 1890's, he observed a thin layer of shells overlying the *Saxicava* bed at the foot of the shell-bank, about 45 m above sea level. In this layer, a₁ sub-unit, shells of *Littorina littorea* and *Cardium edule* were identified. During the surveying (Fredén 1974) other species of supposed Holocene age were observed in the vicinity, see Faunal composition.



Fig. 12. The nature reserve Bräcke shell-bank. The natural deposit is nowadays limited by modern roads. View towards NNE. In the background, behind the upper part of the junction, the flat original surface, a_2 sub-unit, is seen cf. Odhner 1927, p. 78 Fig. 1. — Photo CF 1976-03-30.

According to De Geer (1910, p. 1168) the shell layers in the shell-bed dipped 20 to 27 degrees away from the bedrock, i.e. southwards. When he visited the shell-bank in 1888 a vertical section of 7 metres existed, ten years later a thickness of 12 m was visible. The known maximum thickness of the shell-bank, about 13 m, was measured by Odhner (1927, p. 78), who also levelled the flat top surface in the northeast part to 57.5 m above sea level (op.cit., p. 88). The shell-bed is underlain by glacial clay of Skagerrak type.

Brögger (1900—1901, pp. 312—313) estimated the length of the cut at 100 m and the width at 120 m. Brögger stated that at least 50 000 cubic metres had been quarried. A panorama of the deposit, obviously after the exploitation had stopped, is given by Ramsay in 1931.

Through resolutions in 1930 and 1947 the remains of the Bräcke shell-bank have become a nature reserve. A small pond with its bottom in clay reminds us of the former enterprise. As no activity has occurred in several decades most of the deposit consist of naturally overgrown slopes. Human activity (moped scrambles, visitors walking in all directions) accounts for the fact that only about ten species can be easily found and identified.



Fig. 13. Eastern part of Kuröd shell-bank during the palmy days. View towards the north. Notice the polished outcrop to the left. — Photo between 1910 and 1914, cf. Odhner, p. 84 Fig. 3. By courtesy of the Uddevalla museum.

Summary. A total volume of the shell-bank of more than 100 000 cubic metres is probable. Less than 25 per cent of that are left.

4. Kuröd. The main part of the shell-bank is located in a narrow valley with bare bedrock on the sides, see Fig. 8. In the southwestern part, the outcrop crosses the valley and the thickness of the shell deposit was a couple of metres at this position. The original flat surface in the southwest was measured by Odhner (1927, p. 84) and found to lie 62.5 m above sea level. Close to the bedrock side the surface rose to 63.2 m. The remains along the south side of the bedrock show that the surface of the shell deposit had a low gradient to the northeast.

After the exploitation ceased in the 1930's parts of the deposit have sometimes been used as a motorcross track. All present slopes are affected by man.

The top unit of horizontal layers of sand and gravel is shown on Fig. 14. The lowermost layers are mixed with small shell



Fig. 14. Kuröd shell-bank. Notice the discordance between the A and B units and the dipping away from the bedrock hill. — Photo between 1910 and 1914. By courtesy of the Uddevalla museum.

fragments, a_3 sub-unit. The shell-bed had a thickness of about 8 m in the southwest part, which is believed to be the maximum thickness. The upper part of the stratified shell-bed had a high clay content due, in part, to thin clay layers of variable extension. In general, the clay layers seem to have been more common in the Kuröd shell-bank than in the shell-bank at Bräcke. Due to talus and overgrown slopes, no dip information is available from the Kuröd deposit. The valley floor consists of a greyish Skagerak fine clay.

As is seen on Fig. 13, extensive mining has taken place in the central parts of the shell-bank. Today parts of the northeastern area consist of artificial fill, cf. Odhner 1927, p. 90, Fig. 5. Brögger (1900—1901, p. 313) estimated the volume of the shell-bank to have been as great as the Bräcke deposit.

The shell-bank lay to leeward of wind and currents. Evidence has been to indicate that some faunal assemblages were non-transported. Complete and non-eroded shells of *Saxicava* and barnacles attached to the bedrock suggested and *in situ* assemblages, i.e. a bicoenose. Needles of *silica algae* have been found in the shell-bed (Odhner 1927, pp. 83—86, stratigraphy is seen on Fig. 4).



Fig. 15. Remains of the northeastern part of the Kuröd shell-bank. The board to the right stands in a fenced round nature reserve, which shows the locality of *silica algae*. — Photo CF 1979.

The patch around the locality is a nature reserve since 1926, Fig. 15. The object of protection is hidden for the visitor today, because the fenced area of the shell-bank is almost overgrown talus. The whole area of the Kuröd shell-bank is a nature reserve since 1983.

In the remains of the shell-bank about 20 species can be easily found in a fairly short time (cf. Bräcke shell-bank). For identifying different species the Kuröd shell-bank is the best locality in the region. Hopefully, with some restrictions the remaining parts will serve as a reference area for the future.

No shells have been collected for absolute dating. An attempt to document an intact sequence from top to bottom may ruin the best part or even most of the remains. As some datings are carried out in the area the scientific purpose does not justify the damage in this case.

Summary. The Kuröd shell-bank has been built up during temporarily calm conditions. A total of about 75 000 cubic metres is estimated. Less than 10 per cent of this amount are still left.



Fig. 16. View of the remains of the Kuröd shell-bank southwest towards Byfjorden. The head of the minor road runs about level with the original surface, which is also seen to the left of the cut, where it has a low gradient. — Photo CF 1976-03-30.

Deposits associated with the Bräcke and Kuröd shellbanks.

Shell-bearing sediments and embedded shell-beds are known in the vicinity of the Bräcke and Kuröd shell-banks, see Fig. 8.

The area southeast of Bräcke and Kuröd shell-banks has been occupied by industries since the 1960's. Before construction, geotechnical investigations were made by Orrje & Co. In order to get a picture of the occurrence of shell layers below surface, additional drillings were carried out during the geological surveying of the map sheet Vänersborg NO (Fredén 1974). Due to the beginning of construction, these latter drillings could not be done at all desirable sites. A summary of the drilling records is shown in Fig. 17. Usually, the bottom layers of sand and gravel were cemented.

It is evident that a shell-bed is located at drilling-hole f, probably with its maximum thickness at or close to the drilling-hole. Note that the distribution of embedded shell-beds and shell layers is quite limited in areas away from the bedrock hills, which are almost surrounded by the two shown railway tracks on Fig. 8.

Older residents of Uddevalla say that in their youth they could walk on shell ground all the way between the Bräcke and Kuröd shell deposits. A connection between the shell-banks was also witnessed by Brögger (1900—1901, p. 313). In patches along

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Grey clay, somewhat muddy	-	-	-	7	-	-	-	4	-	2	4	-	-	-
Grey clay, somewhat silty	-	5	-	-	5	4	6	3	3	3	3	6	5	4
Grey clay, sulphurous	-	-	-	-	6	3	-	-	2	5	-	2	3	4
Clayey shell layers and clay	6	1	4	2	5	2	-	-	-	-	1	3	-	-
Sandy shell layers	2	4	4	-	2	11	-	-	1	-	5	2	-	-
Shell-bearing greyish clay	-	-	-	-	-	-	4	2	-	2	-	-	2	5
Clayey silt	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Sand and gravel	-	1	-	-	6	-	1	1	-	1	5	-	5	12
Total thickness to bedrock	10	11	8	9	24	20	11	10	6	13	18	13	15	25

Fig. 17. Thickness in m of recorded strata in the drilling holes a-n in the Bräcke-Kuröd vicinity, Fig. 8. Figures shown are approximate. Exact limitations of some strata are difficult to establish. The uppermost part of the top clay may be of a postglacial origin, while the main part of the grey clay sequence is assumed as a Värmland clay. The shell-bearing greyish clay is a Skagerrak clay.

the hillsides, signs of shellbeds below a top layer of sandy sediments were still seen in the beginning of the 1970's. The original surface dipped to the south by southeast, i.e. away from the bedrock hill. The ground surface level of these deposits lay slightly above 50 m above sea level. It is not clear what dimensions these deposits had. About half way between the Bräcke and Kuröd deposits there is a valley in the bedrock, orientated northwest-southeast. There may have been a shell-bank around its mouth, and the distal parts of the deposit may have reached the distal parts of the Kuröd shell-bank in the northeast and the Bräcke shell-bank in the southwest.

North and northwest of the Kuröd shell-bank the surface of the small basins consists of sandy, shell-bearing sediments. The stratigraphy of these small deposits is unknown.

Summary. Like the shell-banks, embedded shell-beds in clay occur in patches. A volume of about 10 000 cubic metre is estimated.

Localities 5—7. Äsperöd, 1 km south of Bräcke shell-bank. Three small deposits are recorded on the west side of a fairly large bedrock hill in the centre of the Bäveån valley, Fig. 5.

Locality 5, 1300 m east of Uddevalla church, is an untouched shell deposit between a steep bedrock wall and a small bedrock hill. The surface of the deposit lies 33 m above sea level, which is about 3 m lower than the top of the hill. Below a cover of about 0.5 m of sand, shells and shell fragments have been observed at a minor digging. The thickness and distribution is unknown. The depth of the bedrock is assumed to be a few metres.

Locality 6 is situated 300 m SSE of locality 5 in the innermost part of a narrow valley orientated north-south, which is bordered by a low-lying bedrock area to the west and a major bedrock hill to the east. The deposit is totally exploited and the few remaining signs of it in 1973 will soon be gone since this part of the valley is being used as a garden refuse heap. It seems that the shell layers were argillaceous. The maximum thickness was a few metres. Undoubtedly, the C unit consisted of glacial clay. The original ground surface of the shell deposit lay some 48 m above sea level.

The third deposit, locality 7, is situated 400 m southeast of locality 5 in a small valley orientated north-south. The shell-bank is found in the upper part of the valley 56 m above sea level. It consists of half a metre of silty sand, A unit, covering a shell-bed mainly of shell fragments mixed with pebbles and gravel. The depth to bedrock was at most a few metres. Shells of *Mytilus* and *Hiatella* dominate. Side plates of *Balanus hammeri* occur. Some other shells and shell fragments are identified as

Buccinum sp., *Macoma calcarea*, *Mya truncata*, and *Trophon clathratus*. More than half the deposit has been removed.

Shells of *Hiatella* have been radiocarbon determined.

The volume of the three deposits together is assumed to have been approximately 5 000 cubic metres.

Central shell-banks, localities 8—15

The central shell-banks, localities 8—15, are grouped in and around the north—south orientated Skäleryr valley, which in the south is crossed by the Båveån river with a water surface slightly above 45 m above sea level. To the west the valley is bordered by a bedrock plateau rising above 100 m, and to the east by a hilly area transected by four valleys, of which the southernmost is occupied by the Båveån river. The highest-situated transverse valley is the northernmost one, slightly above than 60 m above sea level about 10 m higher than the two central transverse valleys. The hilly area rises above 75 m but does not exceed 100 m above sea level.

The location of the valley is shown in Fig. 5 and the location of the shell-banks in Fig. 18. The place names used below refer to the geological map Vänersborg NO (Fredén 1974).

Locality 8. About 500 m southeast of Skäleryr, a shell-bank is found 58—63 m above sea level on the south side of a small hill area of bedrock reaching about 70 m above sea level. The maximum thickness of the shell-bank has been about three metres. Close to the bedrock there was about half a metre of wave-washed sand on top of the shell-bed. The shell layers in the shell-bed are mixed with particles and layers of sand and gravel. In the distal part the shell-bed rests upon glacial clay.

The dominating shells are of *Hiatella arctica uddevallensis* and *Mytilus edulis* and side-plates (10 cm in height) of *Balanus hammeri*. Less common are the shells of *Hiatella arctica*. Few shells of *Buccinum undatum*, *Natica clausa*, *Trophon clathratus*, *Astarte borealis*, and *Macoma calcarea* have been observed.

The volume was about 3 000 cubic metres, but less than 10 per cent of this exist today.



Fig. 18. Location of shell deposits in the Skäleryr valley and its surroundings. Bedrock outcrop according to the Quaternary map sheet Vänersborg NO (Fredén 1974). Numbers refer to descriptions in text. Observation of shell-bearing sediment is marked by +.

Locality 9. About 700 m SSE of Skäleryr a minor road crosses a shell deposit. There are no cuts. Judging from what can be seen in the ditches and cultivated fields, the shell layers are mixed with sand and gravel. The deposit is probably underlain by bedrock and the thickness is assumed to be a few metres. The highest ground surface lies almost 60 m above sea level.

In addition to the fauna at locality 8, shells of *Neptunea despecta tornata*, *Trophon truncatus*, *Chlamys islandica* and *Mya truncata* were observed superficially.

The volume is unknown but is estimated not to exceed 5 000 cubic metres.

Thick shells of *Hiatella* were used for radiocarbon age determinations.

Shells from localities 8 and 9 are found at the bottom of the nearby rivulet.

During a weight sounding in the clay fields southwest of locality 9 (between Nöthult and Bitarehagen) an indurated layer was recorded at a depth of 12.5 m. Further down to a depth of 20 m (bedrock), layers of variable resistance were noted. When the sounding poles were drawn up artesian water brought to the surface abundant shell fragments of *Hiatella* and *Balanus*, as well as particles of sand and gravel.

Locality 10. About 400 m southwest of Gräskärr there has been a shell-bank in a narrow valley on the southeast side of the bedrock plateau, which extends to about 90 m above sea level north of the locality. The highest ground surface of the deposit lay 67 m above sea level. The deposit is totally exploited and overgrown. On the sides of the valley silty layers with small shell fragments are visible.

An original volume of about 5000 cubic metres is estimated.

About 150 m ESE of the locality a drilling in the flat valley floor showed following stratigraphy:

- 0 — 2 m Grey clay, somewhat silty
- 2 — 3 m Grey clay, sulphurous
- 3 — 6 m Shell-bearing clay
- 6 — 9 m Clayey shell layers
- 9 — 13 m Shell layers with sand and gravel
- 13 — 24 m Sand and gravel underlain by bedrock.

The drilling and sampling techniques make it difficult to distinguish properly between shell-bearing clay and clayey shell layers.

The volume of the buried shell-bed is estimated to be at least 5 000 cubic metres.

The same stratigraphy should prevail in the clay basin further to the south. In the valley, between localities 10 and 12 about 3 m of clayey shell layers are overlain by 8 m of clay. In the northern part of the clay basin to the east, sandy shell layers are found below 2 m of silty clay.

Locality 11. About one kilometre NNW of Groröd a small shell-bank is located on a flat bedrock ridge across a small valley between an even plateau 55—60 m above sea level to the west and a hilly area in the east, which has a maximum altitude of about 75 m above sea level. The lowest part of the ridge, at 52 m above sea level, serves as watershed boundary between the river of Bäveån in the south and the outlet of Lake St.Köperödssjön in the north. The mineralogical particles within the shell layers were fine grained, silt and clay seem to have been characteristic components. In the shallow and overgrown cuts shells of *Hiatella* and side-plates of *Balanus* can be seen.

The original volume was less than 2 000 cubic metres. Most of the shell-bank has been exploited.

About 100 m southwest of the locality 5 m of sandy shell layers are covered by 2 m of silty clay.

12. Björbäck. Along the bedrock side west of Björbäck the overgrown remains of a shell-bank can be seen, Fig. 19. At the shell-bank there is a crevice, a few metres wide and deep, in the bedrock side. The thickness of the deposit close to the bedrock has been 5—8 m. Judging from what was visible in 1976, shells of *Hiatella* and side-plates of *Balanus hammeri* dominated the deposit.

Southwest of the shell-bank a shell-bed of about 5 m is found below 5 m of clay and alluvial sediments.

At the mouth of the Skäleryr rivulet and eastwards the sequence consists of clay intrabedded silty layers, which are partly shell-bearing.

A total volume of 10 000 cubic metres is estimated. Less than 10 per cent of the shell-bank remain.

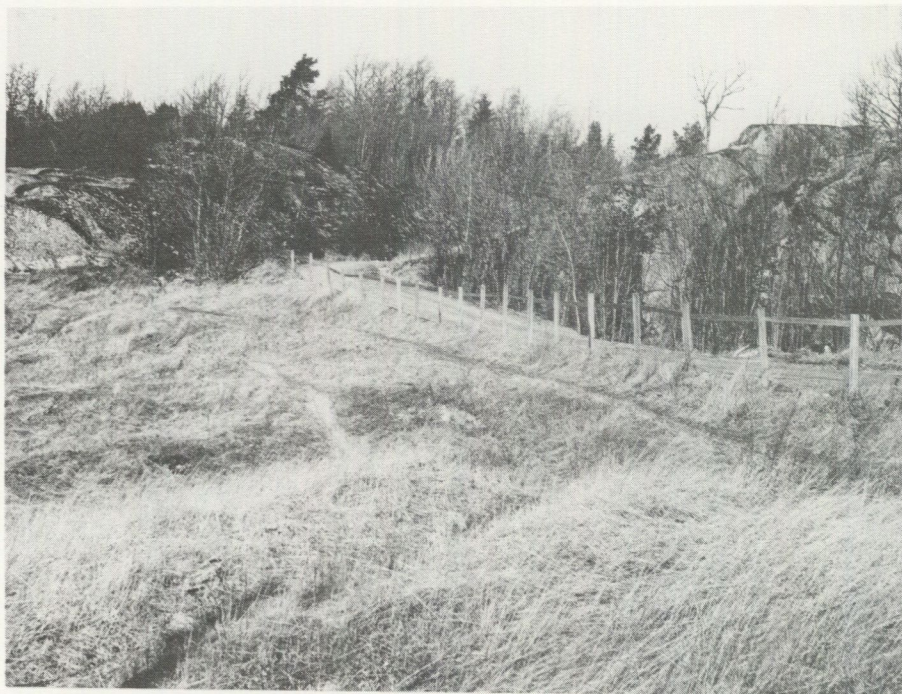


Fig. 19. The proximal part of the Björbäck shell-bank, locality 12. The minor road runs in a small fissure valley, in which the highest-situated part of the shell-bank is found. View towards the north. — Photo CF 1976-03-30.



Fig. 20. View of the Ramseröd shell-bank eastwards, locality 13. A bedrock ridge is visible to the left. A mill used to operate by the trees in the foreground. The section in Fig. 21 is situated behind the tree in the centre of the picture. — Photo CF 1976-03-30.



Fig. 21. The east—west wall in the Ramseröd cut, vies to the north, cf. Fig. 20. The dark-coloured areas to the left reflect clay layers, which consolidate the shell-bed. Clay layers are also found to the right, but to a dry spell they are light in colour. The layers dip away from the bedrock outcrop, which is situated about 20 m to the right of the picture. The sandy top of the right-hand layer is destroyed; to the left the shell-bed is overlain by Värmland clay. Roman numerals show position of shell samples taken for radiocarbon age determinations. The industrial mining has ceased. — Photo CF 1971-10-13.

13. Ramseröd. South of the river Bäveån and opposite the Skäleryr valley two separate shell-banks have been deposited along the east side of a valley orientated north—south, Fig. 18.

Formerly, a mill quarried the deposits. When the northern shell-bank was emptied the mill moved to the southern one.

The northern shell-bank was situated west of the property Ramseröd. Today the area is cultivated. The shell-bed had a thickness of 4—5 m; it was underlain by glaciofluvial sand and gravel and overlain by Skagerrak clay, less than one metre thick. According to local residents, the removed material had a sandy character with high frequency of shells.

In the southern, narrow part of the valley, shells are found in the area where an east—westerly fissure cuts the bedrock slope on the east side.

Originally the shell-bank may have blocked the valley to some extent, Fig. 20. On the end of the bedrock ridge west of the rivulet sandy shell layers are found.

The main part of the shell-bank was situated on the east side, and through the gorge embedded shell layers can be followed around the southern part of the elongated bedrock hill with a peak 66 m above sea level. In the gorge and east of it sandy shell layers are overlain by sand and gravel.

A cut in the remains of the shell-bank, see Fig. 21, shows that the shell-bed is composed by clay layers, 1–20 cm thick, and clayey shell layers dominated by shell fragments. The central and sandy parts of the shell-bed have been removed. The original shell-bank surface lay 57 m above sea level and the maximum thickness is estimated to have been 8 m.

Subfossil parts of a grey seal *Halichoerus grypus*, have been recorded in the deposit (Jägerskiöld 1933, p. 9). A skeletal part of a juvenile specimen was found in the pit in 1978. These finds represent two individuals of grey seal (Lepiksaar, personal communication).

Roughly estimated, 25 000 cubic metres have been exploited. About 2000 cubic metres are supposed to remain.

For radiocarbon measurements shells of *Hiatella* were collected in three limited areas in the vertical cut wall, see Fig. 21.

14. Groröd. At the foot of a sandy slope shells were visible in a small cut. The shell layers were covered by at least 0.5 m of sand and were, in the patch, underlain by bedrock. At the cut, shells of *Hiatella* and side-plates of *Balanus hammeri* dominate.

Extension and volume are unknown; less than 2000 cubic metres is probable. The deposit may be characterized as a transitional form between shell-bank and embedded shell-bed.

Locality 15. About 500 m southwest of Groröd, 2–4 m deep and overgrown pits on the east bank of a stream indicate earlier mining. Sandy shell layers are underlain by silt and sand at the stream. In the upper part of the shell-bed the shell layers are clayey. Eastwards the shell-bed is covered by clay. Probably, the proximal part of the shell-bank was deposited upon the flat bedrock surface 55–60 m above sea level in the north. The level of the buried bedrock southwards is unknown.

As usual, shells of *Hiatella arctica*, especially the variety *uddevallensis*, and side-plates of *Balanus hammeri* dominate. Other species found in the pit are: *Buccinum* sp., *Trophon truncatus*, *Chlamys islandica*, *Mya truncata uddevallensis* and *Mytilus edulis*.

The original volume did not exceed 5 000 cubic metres.

Unfortunately, the deposit is not shown on the Quaternary map Vänersborg NO due to a technical mishap.

Eastern shell-banks, localities 16--23

On the eastern shell-banks, localities 16--23, five are located around the southern part of a relatively wide north-south valley where the river Båveån bends perpendicularly and runs westward through a narrow and steep-sided passage in a hilly area. The three other shell-banks are located in a north-south valley in the bedrock area east of Båveån valley, Fig. 5.

Place-names used refer to the geological map Vänersborg NO (Fredén 1974).

16. Stämnen. 65--70 m above sea level a shell-bank occurs nearly crossing a north--south valley at Stämnen. The shape is like a ridge-formed fan with its tip connected to a glaciofluvial deposit to the east. The western part, i.e. at the rivulet, is underlain by 3--4 m of glacial clay resting upon glaciofluvial sand and gravel.

A small cut in the western part shows an A unit of 0.5--1.0 m of gravelly sand. The shell-bed, B-unit, is composed of 5--10 cm thick layers of shells, sand, gravel, and pebbles. The shells are frequently imbricated. The minerogenic content is high and the grain size comparatively coarse. The maximum thickness in the western part is estimated at about 4 m.

A distinctive trait in the cut is the great number of unbroken shells. Often they are large and thick. Dominating species are, as usual, *Balanus hammeri*, *Hiatella arctica uddevallensis*, and *Mytilus edulis* (large fragments). Fairly common are shells of *Astarte borealis*, *Mya truncata*, and *Trophon truncatus*. Few shells are found of *Buccinum undatum*, *Buccinum groenlandicum*, *Astarte*



Fig. 22. Morphological features of the shell-bank at locality 17. Small bedrock outcrops are seen in the wooded area. No shells were visible in the ditch in front of the small pit, which lies at the apex of the deposit. View towards the east. — Photo CF 1975.

elliptica, *Chlamys islandica* (large fragments, diam. 9—10 cm), *Macoma calcarea*, and *Mya truncata uddevallensis*, as well as side-plates of *Balanus crenatus*.

In the cut, pebbles of flint — ice-dropped from floating sea ice comings from southwest or south — are observed.

Of the original volume of about 2 000 cubic metres less than 25 per cent have been removed.

One sample has been radiocarbon age determined.

Locality 17. In the valley 200 m west of Skäldalen lies a triangular-shaped shell-bank with the base towards the hillside in the east and the apex at a gently rounded ridge in the west, Fig. 22.

The surface of the shell-bank lies almost 52 m above sea level. One small pit occurs. The thickness of the shell-bank is estimated at a few metres in the central area.

The sand cover is moderately thin, 0.2—0.3 m. The shell layers are clayey. A characteristic feature of the fauna is an abundance of large fragments of *Mytilus edulis*.

The original volume is estimated at about 2 000 cubic metres. More than 75 per cent are left.



Fig. 23. Partly overgrown remains of the shell-bank SSE of Skäldalen, locality 18. The original surface is seen in front of the gentle bedrock slope to the right. Bedrock outcrop is also seen in the pit at the talus slope. View towards the north. — Photo CF 1975-02-24.

Locality 18. About 500 m SSE of Skäldalen a shell-bank has been deposited on flat bedrock ground south of a bedrock hill which has its peak about 85 m above sea level, see Fig. 23. The surface of the deposit lies about 67 m above sea level close to the bedrock hill. The mostly overgrown pits suggests that the maximum thickness was a few metres. The shell-bed is overlain by silty sand, and the shell layers in the shell-bed are characterized by shell fragments mixed with sand and silt. North of the deposit glacial clay is found. The peat-covered basin south of the shell-bank is drained into Skäldalen, locality 19.

The faunal composition, as recorded by visible shells in the pits, is somewhat different from the prevalent fauna in other deposits; cf. locality 16, which was deposited at about the same altitude. Shells of *Hiatella arctica* (4–6 cm in height) and side-plates of *Balanus hamneri* (5–7 cm in height, 3–4 cm in width) dominate. Very few shells of *Hiatella arctica uddevallensis* occur. Other identified shells are referable to *Balanus crenatus*, *Buccinum undatum*, *Natica clausa*, *Trophon truncatus*, *Macoma calcarea*, and *Mytilus edulis*.

An original volume of about 5 000 cubic metres is estimated. About 25 per cent are left.

Shells of *Hiatella arctica* were collected for radiocarbon age determination.

19. Skäldalen (translated as "valley of shells"). Two deposits, underlain by glacial clay, have been accumulated in the short and narrow valley running into the transverse Båveån valley. The distance between the two shell-banks is about 200 m.

The southern shell-bank is the main one, and it is almost totally tapped. It had a flat upper surface, 64 m above sea level along the east bedrock side in the southern, precipitous part of the valley. There are no signs of shell layers on the west bedrock valleyside. The shell-bank lies north of a bedrock hill extending above 85 m above sea level on the south side of which locality 18 is situated.

On top there was about 0.5 m of sand at the hillside. Pebbles of flint are observed in the uppermost part. There are no signs of clay or clayey layers. Most of the former extension of the shell-bank is covered by forest and bushes. The total thickness is estimated to have been about 8 m.

Shells of *Hiatella* and side-plates of *Balanus hammeri* seem to have dominated the faunal composition.

At least 30 000 cubic metres have been removed. Only a few per cent of the deposit remain.

A triangular-shaped shell-bank is situated in the northern part of the valley. The base line lies along the east bedrock valleyside. The surface lies about 53 m above sea level and the thickness is estimated to be 2—3 metres. The western part of the flat shell-bank is a smooth rounded ridge which may originally have crossed the valley. A rivulet (draining locality 18) and a minor road from the formerly large shell-bank in the southern part run along the west side of the valley.

In a small pit on top of the ridge a relatively large number of gastropods can be seen in the clayey shell layers. Dominating species are *Buccinum undatum* and *Natica clausa*. Shells of *Trophon truncatus* and of *Nassa reticulata* are also found. Shells of *Hiatella* and *Mytilus* fragments occur abundantly while side-plates of *Balanus* are subordinate (mainly *B. crenatus*).

A volume of about 2 000 cubic metres is estimated.

For radiocarbon measurement shell of *Buccinum undatum* were collected in the pit.



Fig. 24. View towards the northwest of the enormous Älje shell deposit, locality 20. Along the facing bedrock sides of the centre hill there are signs of shell-banks. The two large lakes are water filled mine excavations. The foreground lake is connected with Bäveån river by a canal. At the bend of the minor road ruins of the kiln can be seen. The road runs north where formerly pipes for blown-out waste were situated. — Photo CF 1976-03-30.

20. Älje. Large-scale mining of shells has taken place in the area where the river Bäveån bends from a north--south to an east--west direction, see Fig. 24. Along the bedrock hillsides north and east of the river, shell-banks have been deposited up to about 55 m above sea level judging by the small remains which can still be seen. In the valley itself, shell layers of a thickness of slightly more than 20 m are recorded from drillings. The shell-bed is covered by 5—6 m of alluvial sediments and underlain by glacial clay of Skagerrak type.

The landscape has been influenced by the mining. When the mining started in the 1930's, the shell-banks at the hillsides of Bäveån river and in the inner part of the valley at Skäldalen (locality 19) were quarried. Obviously clay deposits were avoided. After some time the surficial deposits were exhausted and mining below water surface started. The water level of Bäveån was lowered and the shallow lake Svalsjön north of Skäldalen became a fen. As the mining continued a hauling plant and a barge were used. During the hauling the shells were automatically washed.

The two lakes at the river bend commemorate the shell-mining enterprise which ceased finally in 1967.

Two mills and one kiln for lime-works were in operation. One mill was situated on the north side of the northern lake. In literature this locality is called "Porsen" after the property on the bedrock hill 500 m NNW of Älje. In 1973 the ruins of the other mill, the kiln and the barge were still to be seen at the end of the minor road west of the river bend. During mining operation rock fragments accompanied by small shell fragments were blown through pipes to the fen area northwest of the northern lake.

In the "refuse material" around the ruins, the observed shells are very large; for instance, shells of *Chlamys islandica* measure slightly more than 10 cm and *Buccinum undatum* 9—10 cm in height.

A subfossil skeletal part of a grey seal, *Halchoerus grypus* is recorded from Porsen.

With a mean thickness of 10 m of the shell-bed across the valley, approximately 400 000 cubic metres have been quarried below water surface. Considering the large-scale mining this figure seems plausible. Including the remains below surface, which occur in the lowlands west of the southern lake, and an estimation of the removed volumes along the hillsides, a total volume of about 500 000 cubic metres is calculated for the Älje area.

Locality 21. The northernmost known shell-bank in the Uddevalla region lies in the northeast corner of a small transverse valley at Tängelsröd, east of the fairly wide north—south-orientated Båveån river valley. To the east and south the Tängelsröd valley is bordered by bare bedrock hills, about 80 m above sea level.

The stratigraphy and morphology of this former shell-bank are almost unknown. The overgrown remains show that a sandy shell-bed lay in an east—west direction on a flat bedrock surface. The original surface of the shell-bank is estimated to have lain about 60 m above sea level, and the thickness is assumed to have been a few metres. A small pool south of the minor road reminds us of a former subsurface mining. The distal shell layers, visible at low water in the pool, are clayey and overlain by clay. In the shell-bank area shells of *Hiatella* and fragments of *Mytilus edulis* are common.



Fig. 25. Cut in the distal part of the shell-bank at Skogen, locality 23. Laminated silt and sand layers, a sub-unit, and shell-bearing layers, a sub-unit, discordantly covers a sandy shell-bed. Shell fragments dominate this part of the deposit. The spade is one m long. — Photo CF 1971-09-28.

The volume of the deposit was probably less than 5 000 cubic metres.

Locality 22. About 70 m above sea level an almost totally exploited shell-bank exists on and southwest of a flat bedrock hill, about 800 m NNW of Fridhemn. The locality is situated in an about 200 m wide, flat, north-south-orientated valley within a bedrock plateau with peaks at about 90 m above sea level.

Original stratigraphy is unknown. The remains show an abundance of gravel, sand and silt. According to Sidenbladh (1870, pp. 86-87) the maximum thickness was 10 feet. Dominating species among the visible shells are *Balanus hammeri* (10-12 cm in height), *Hiatella arctica uddevallensis*. Shell fragments of *Mytilus edulis* are common. Shells of the following species can also be found: *Littorina saxatilis*, *Natica clausa*, *Trophon truncatus*, *Astarte borealis*, *Astarte elliptica*, *Chlamys islandica*, *Macoma balthica*, and *Mya truncata*.

Small shell deposits also occur in the vicinity.

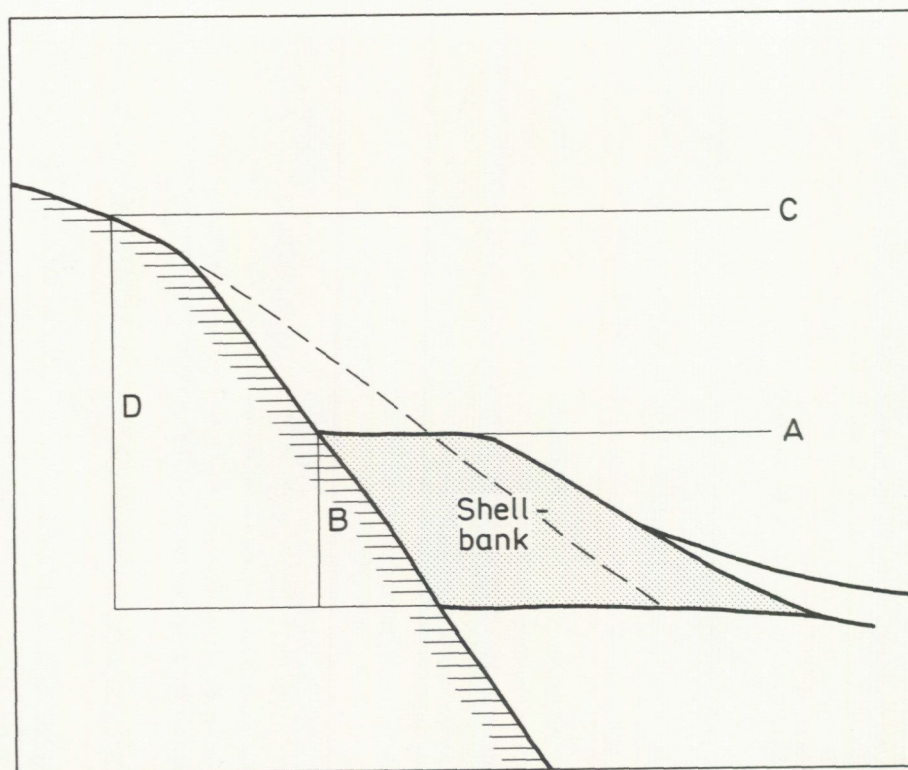


Fig. 26. Schematic explanation of the terms used in Fig. 27. In several cases C is determined by a closely situated peak of a hill or by a flat bedrock surface over a relatively long distance (50 m or more). On slopes, C is calculated according to the gradient of the slope and the assumed original extension (broken line) upwards of the shell layers.

The original volume is estimated to have been 5 000 cubic metres. Only a few per cent are left.

Thick shells of *Hiatella* were collected for radiocarbon age determination.

23. Skogen. Remains of the easternmost known shell-bank are situated about 300 m ESE of Skogen. The shell-bank occupies the southern part of a small north-south valley. In the south the shell-bank is connected to a moderately flat bedrock surface. The original surface, 65 m above sea level has to a great extent been destroyed by many excavation pits. According to Sidenbladh (1870, p. 86) the thickness was at least 10 feet. The stratigraphy of the distal (northern) A unit can be seen in Fig. 25. A characteristic of the visible distal part is the high frequency of small shell fragments. Shells of *Hiatella*, *Macoma calcarea*, *Mya truncata*, *Mytilus edulis*, and side-plates of *Balanus hamneri* occur.

Most of the shell-bank remains are wooded.

Locality	A	B	C	D	E
1. Kapellbacken					100
	16	7	24	15	
	26	5	31	10	
2. Samneröd	75	15	100s	40s	160
3. Bräcke	58	13	70	25	100
4. Kuröd	63	10	80	27	75
Vicinity deposits					
5. Äsperöd	33	3s	36	6s	1
6. Äsperöd	40	3s	50s	13s	2
7. Äsperöd	56	3	75s	22s	2
					<hr/> 450
8. SE Skäleryr	63	3	70	10	3
9. SSE Skäleryr	60	3s	65	8	3s
10. SW Gräskärr	67	5s	85s	23	10s
11. NNW Groröd	54	2	60	8	2
12. Björbäck	45	8	55	18	10
13. Ramseröd	57	8	66	19	27
14. Groröd	52	2s	60	10s	2s
15. SW Groröd	57	3	60	6	5
					<hr/> 62
16. Stämnen	68	4	75s	11s	2
17. W Skäldalen	52	3s	60s	11s	2s
18. SSE Skäldalen	67	3	75s	11s	5
19. Skäldalen	64	8s	85	29s	30
	53	3s	60	11s	2s
20. Älje	55	20	70	35	500
21. Tängelsröd	60s	3s	65	8	2s
22. Fridhem	70s	3	75	8s	5
23. Skogen	65	3	70	8	10
					<hr/> 558
				<hr/> Total	1070

Fig. 27. Data for all the shell-banks in the Uddevalla area.

A = Top surface, m above sea level

B = Maximum known thickness, m

C = Highest approx. habitat level, m above sea level

D = Maximum amplitude, m

For explanation of A,B,C and D, see Fig. 26

E = Estimated volume, 1000 cubic m

s = supposed figure

Less than 10 per cent of an estimated original volume of 10 000 cubic metres remain. Perhaps more can be found along the bedrock ridge under the sand layers to the east.

Summary of shell-banks. The 23 shell-banks described are summarized in Fig. 27. The shell-banks are divided, according to geographical location, into three groups.

Localities 1—7 are found in the western part of Bäveån valley, where the valley widens and runs into Byfjorden. In this area four large shell-banks have been recorded. One of them, Kapellbacken, consists of several deposits and is situated southwest of the Bäveån valley in a tributary valley extending northward to Byfjorden. The other three are situated on the north side of the Bäveån valley. Thus all four are located away from the deepest parts of the Bäveån valley. Furthermore, they are situated where the morphology gradually slopes toward Byfjorden. The shell deposits in the western area are estimated to have had a combined volume of slightly more than 450 000 cubic metres; less than 10 per cent remain.

The second group of shell-banks, localities 8—15, is associated with the north—south Skäleryr valley, perpendicular to Bäveån valley. These deposits too are situated away from the central part of the Bäveån valley. The volume of shell deposits is estimated to have been about 67 000 cubic metres; roughly 25 per cent are left.

The third group of shell-banks, localities 16—23, is situated east of the narrowest part of the Bäveån valley, where the river runs in a gorge through the hilly area which borders the Skäleryr valley. Most of the shell-banks are found close to the Bäveån valley, which has a north—south orientation east of the gorge. Three of the deposits are found at the sides of a north—south valley in a hilly bedrock area east of Bäveån river. This hill area forces the drainage pattern in the east—west-orientated valley between Vänersborg and Uddevalla to make a semicircular detour to the north. The largest shell deposit in the whole area is found east of the gorge of the Bäveån valley. The estimated volume, about 500 000 cubic metres, represents almost half the total volume in the whole area. Of the combined volume of the eastern deposits, almost 560 000 cubic metres, probably less than 10 per cent remain.

As to the distribution pattern, the shells have not been transported or spread over large areas; they are associated locally with the bedrock valley sides where the deposit is found. Most of the shell deposits are located at fissures along bedrock valley sides. The horizontal distance from an assemblage habitat to the most proximal part of a shell deposit seems to be about 50 m at most. In Fig. 26 some terms are schematically indicated; they are used in Fig. 27 for calculations of the data given for all shell-banks. Even if estimations are always awkward, there seems to be a connection between volume and amplitude. Shell deposits of a volume of more than 25 000 cubic metres have an amplitude between finding level and maximum living level of more than 20 m. The greatest amplitude is positively correlated to the largest volume.

The three easternmost shell deposits seem to be almost autochthonous. The morphological relief within relevant areas is less than 8 m.

Most of the deposits are underlain by glacial clay. The mean value of the top surface (except the Kapellbacken deposits) is approximately 60 m above sea level; nine shell-banks are found between 55 and 65 m above sea level.

Mollusc habitats of at least 19 of the shell-banks have existed between 65 and 85 m above sea level.

Judging by stratigraphical features most of the shells had been deposited before the final morphological shape of the shell-banks was created by littoral processes.

Shell-bearing sand and clay

Observations of mollusc shells of special interest are described in this chapter, which is divided into two parts, one for the Uddevalla--Vänernsberg valley and surroundings, Fig. 5, and one for the valley south of Kroppefjäll, Fig. 29.

Observations of shells have been made accidentally in cuts such as cleared-out ditches, foundation-layings, etc. Most of the shell layers are 10--20 cm thick and have a visible extension of a few metres. Usually the shell layers are silty -- sandy and

occur embedded in clay. Shell fragments dominate, and only species with thick shells can be identified properly. Obviously the number of species is underrepresented in these limited exposures.

Uddevalla—Vänernsberg area, localities 24—33

As far as possible old observations are marked on Fig. 5. All deposits shown by Olbers (1862) could not be transferred to the new map due to errors on the old map compared with a modern one. Only a few of the shell-bearing sediments shown on the geological maps concerned (Sidenbladh 1870; Lindström 1887, 1902) are described in the relevant texts. According to the field logbooks of the mapping geologists, the following species have been identified in shell-bearing sand and clay: *Buccinum undatum*, *Fusus turtoni*, *Natica clausa*, *Scalaria* sp., *Astarte sulcata*, *Astarte* sp., *Mya truncata*, *Mytilus edulis*, *Pecten islandicus*, *Saxicava rugosa*, *Tellina calcarea* and *Balanus* sp. This faunal composition shows no features aberrant from the subsequent descriptions.

Locality numbers refer to Fig. 5.

24. Kasen. When Brögger (1900—1901, pp. 323—324) paid a visit to the Uddevalla shell-banks he also examined a small cut west of Uddevalla, close to the clay-pit of the former Kasen brickyard (about 650 m WNW of Uddevalla railway station, map sheet Vänernsberg NV 5e). The locality is situated 5—10 m above sea level in the southern part of a small valley running into Byfjorden.

According to Brögger, the stratigraphy and faunal composition was as follows:

- 0 — 0.5 m Sand
- 0.5 — 2.75 m Greyish clay
- 2.75 — 2.85 m A layer of shells
- 2.85 — 3.35 m Sandy clay with a few shells
- 3.35 — 4.35 m Bluish clay with several sandy shell layers
and individual shells which occurred in the
clay continuing downwards

In the bottom part of the visible clay shells of *Saxicava arctica*, *Saxicava arctica uddevallensis*, *Macoma calcarea* (42 mm), and *Leda pernula* were identified. Shell fragments of *Mytilus edulis* were also common. These species occurred in the shell layers together with shells of:

Mytilus modiolus, fairly common

Pecten islandicus, one valve

Astarte borealis, rare

Astarte elliptica, common, even united shells

Astarte compressa, rare

Anomia ephippium, common

Leptea coeca, some small specimens

Buccinum sp., common, probably a transitional form of *B.groenlandicum* and *B.undatum*.

Natica affinis, fairly common

Brögger characterized the fauna as a typical boreo—arctic one. His remark about *Buccinum* sp. is interesting; see the description of *Buccinum* species.

25. Marieberg (situated 1 km NNW of Uddevalla church, map sheet Vänersborg NV 5e). During the construction of the railway to Vänersborg, the following stratigraphy was recorded north of a bedrock hill (after Erdmann 1868, p. 155):

0	—	0.5 m	Sand
0.5	—	2.15 m	Sandy clay, varved, distinctly laminated
2.15	—	3.80 m	Dark grey clay, (varved).
3.80	—	5.15 m	Black-coloured clay with shells
5.15	—	6.30 m	Shell-bed underlain by bedrock

In the shell-bearing clay shells of *Natica clausa*, *Trophon clathratus major*, *Astarte arctica*, *Leda pernula*, *Tellina proxima*, *Yoldia arctica*, *Yoldia pygmaea gibbosa* and others were identified.

The shell-bed was said to have a composition similar to the Kapellbacken shell-banks.

In the dark-grey clay, subfossil skeletal parts of a red deer, *Cervus elaphus*, a fox, *Vulpes vulpes*, a bottle-nosed whale, *Hyperoodon ampullatus*, were found (op.cit. pp. 156--157).

The stratigraphy is somewhat confusing (cf. Brögger 1900—1901, pp. 320—321, footnote 2). Judging by the faunal composition and the known stratigraphy in the area, there is no doubt that the black-coloured clay is older than the shell-bed. The stated varvity is apparently non-annual. The most probable explanation is that the clay unit has slipped over the shell-bed in a landslide.

26. Hultekärr. In a ditch in the centre of a northeast—southwest-orientated valley, about 650 m NNE of Hultekärr, a 10 cm thick shell layer was observed during the surveying. The valley is situated in a vast and fairly flat bedrock plateau between 100 and 125 m above sea level. The valley floor lies about 110 m above sea level. The shell layer was found in clay at a depth of 0.9 m. The clay was overlain by 20 cm of fen peat.

Besides shells and shell fragments of *Hiatella arctica*, *Hiatella arctica uddevallensis*, and *Mytilus edulis*, some small shells of *Macoma baltica* were recorded. According to the geological map sheet Uddevalla (Lindström 1902), shells have been found at Sägmon, 2.5 km northwest of Hultekärr. The locality lies 125 m above sea level in a relatively flat area of bedrock. In the vicinity of Uddevalla this is the highest-situated locality of shells. No information is given in the map description and check-ups in the area has been unsuccessful.

Locality 27. In a ditch about 650 m southwest of lake Bjursjön a 5 cm thick sandy shell layer was observed in clay at a depth of 0.7 m below the ground surface, which lies about 80 m above sea level. The uppermost 0.4 m consist of fen peat. Shell fragments of *Mytilus edulis* dominate, *Hiatella* shells are common, and a few shells of *Trophon truncatus* and *Macoma calcarea* occur.

The locality is situated in a narrow and moderately steep-sided valley in which ran the former narrow-gauge railway to Bengtsfors. The valley borders on a military area to the east. These two circumstances imply a warning that shells found superficially in the valley may be transported by man.



Fig. 28. Location of the shell deposit south of Råhagen, locality 28. Only about one cubic metre of mostly sand remains on the bedrock. View towards the small tributary valley to the northeast. -
--Photo CF 1975-02-24.

28. Råhagen. At the southern end of a gently sloping bedrock, a small deposit accumulated where a minor valley from the northeast joins the narrow, north--south valley between Råhagen and Samneröd, locality 2. The latter is situated about 500 m southwards. The height is about 95 m above sea level.

In 1968 sandy shell layers, 0.3--0.5 m thick, occurred close to the bedrock. During a visit in 1972 only small remains were visible, Fig. 28. The shell layers had originally been covered by 0.5 m sand and were also underlain by sand. About 30 m southwards, glacial clay is found in the valley.

Shells of *Hiatella* and *Mya truncata* dominated the deposit. Very few fragments of *Mytilus edulis* and *Balanus hammeri* were visible.

Shell samples have been radiocarbon age determined.

Locality 29. About 700 m SSW of Groröd, locality 14, Fig. 18, a 0.5 m thick shell-bed is found below 2.5 m of sand on the east side of a minor road. The locality is situated in the upper part

of a narrow passage in a bedrock ridge. The bedrock ridge about 75 m above sea level separates a sand field in the north about 55 m above sea level and a small sand accumulation 70 m above sea level in the south. The minor road is cut down almost to bedrock. At the foot of the bedrock ridge an overgrown old cut can be seen. There are no signs of shells in this cut. In the northern sand field surficial shells are to be found in patches. They may be underlain by shell-beds.

The shell-bed consists of stratified shell layers composed of sand, silt, and small shell fragments.

A shell sample has been radiocarbon age determined.

30. Risån. Several remarkable finds were made along the west bank of the Risån river during the construction of the railway bridge on the Uddevalla—Vänernsberg line. The original surface was about 65 m above sea level, water level is about 55 m above sea level.

Stratigraphy according to Erdmann (1868, pp. 155—156):

- 0 — 0.3 m Sand
- 0.3 — 1.9 m Yellow sandy, varved clay
- 1.9 — 5.7 m Black clay with an abundance of shells.

The stated varves are to be regarded as non-annual structures.

The faunal composition was like that of locality 25, with the addition of *Leda caudata*, *Leda myalis*, *Natica groenlandica*, *Astarte sulcata*, and *Pecten islandicus*. Sidenbladh (1870, p. 87) claimed that *Ostrea* shells had been found in the clay. This bivalve makes great demands upon clean water, salinity and temperature. When the oyster inhabited the west coast in Holocene times, it is doubtful whether these favourable conditions were prevailing in this locality. As no detailed information is given, human disturbance of the find cannot be ruled out.

Subfossil skeletal parts were recorded at a depth of 6 m below surface. Unfortunately, the greater part of them were destroyed. The remains were determined in the abstract by Kinberg as probably belonging to a bear and a whale (Erdmann 1868, p. 157). However, Holst (1902, p. 9) later claimed that the skeletal parts referable to a bear had been misinterpreted.

31. Lane Ryr. An area of about 40 square metres of shell layers in clay was exposed during a foundation laying in September, 1970, about 100 m northwest of the Lane Ryr church. The locality was situated about 55 m above sea level on the east bank of the Båveån river.

In the cross section towards the river there were no signs of shells or shell fragments. About 50 m east of the foundation bare bedrock is exposed. The church stands about 70 m above sea level.

Stratigraphy, in cm, in the east cross section:

- 0 — 100 Alluvial fine sand
- 100 — 150 Blue-grey Värmland clay
- 150 — 190 Sandy shell layers, 3—5 cm thick, embedded in clay. The exposed length of layers was almost 10 m. The shells were only little eroded
- 190 — 260 Bluish Skagerrak clay continuing downwards
One shell of *Portlandia arctica* was observed

Side-plates of *Balanus hammeri*, shells and large shell fragments of *Hiatella arctica*, and *Mytilus edulis* dominated, but not to the extent that is usually observed in sections of shell layers, which on the other hand has a considerably less exposure. Other identified species were *Buccinum groenlandicum*, *Buccinum undatum*, *Astarte borealis*, *Astarte elliptica*, *Chlamys islandica*, *Hiatella arctica uddevallensis*, *Macoma calcarea*, and *Mya truncata*.

32. Futten canal. Several finds of shells and vertebrate skeletal parts were made in clay during the 1867—68 construction of the Futten canal between the lakes of St.Hästefjorden and Ö.Hästefjorden. The present water level of the canal lies 62 m above sea level.

Shells from this locality of *Buccinum groenlandicum*, *Neptunea despecta*, *Sipho latericus*, *Sipho togathus*, *Trophon clathratus*, and *Cyprina islandica* are kept at the Swedish National Museum of Natural History in Stockholm (Hägg 1947, p. 472 and 1952, p. 133).

According to Sidenbladh (1870, p. 83) the following subfossil finds of marine vertebrates were made in the clay from west to east along the canal:

Skeletal parts of three almost complete harp seals, *Pagophilus groenlandicus*, at a depth of 6.8 m, found in 1867.

A skeleton of a codfish, *Gadus morhua*, at a depth of 4.5 m.

A skeleton of a harp seal, *Pagophilus groenlandicus*, at a depth of 2.4 m found in 1868.

In addition, a vertebra of a bearded seal, *Erignathus barbatus*, is recorded by Kinberg (1869, pp. 15—16).

In the clayey mud at Ö. Hästefjorden, 17 skeletal parts are recorded of a man, a lynx, an elk, and a swan (Sidenbladh 1870, p. 83). The finds are of Neolithic age or later.

Skeletal parts of two of the harp seals have been radiocarbon determined.

33. Mynningsmossen. Shells of *Astarte* sp. are recorded at a depth of about 2.5 m at the east side of the bog Mynningsmossen (Sidenbladh 1870, p. 88). The locality is situated almost 7.5 m above sea level.

According to the field logbook the shell deposit at Millingsmossen (the former name) was dominated by shells of *Astarte*. Shells of *Saxicava* and *Tellina* and shell fragments of *Mytilus* and *Balanus* were also observed. The shells were found in clay below peat.

Area south of Kroppefjäll, localities 34—36

South of Kroppefjäll range of hills a narrow fissure valley runs almost east—west. The morphological features are shown in Fig. 29.

The valley separates a hilly area, which lies above 150 m above sea level to the north, from a moderately flat bedrock plateau, 100--125 m above sea level to the south. The highest part of the valley floor, which also forms the watershed boundary between the Skagerrak Sea and the Vänern basin, lies 85—90 m above sea level in the eastern end of the valley. The highest shoreline has not been determined in the area but is assumed to lie about 150 m above sea level (Fredén 1974, p. 54).

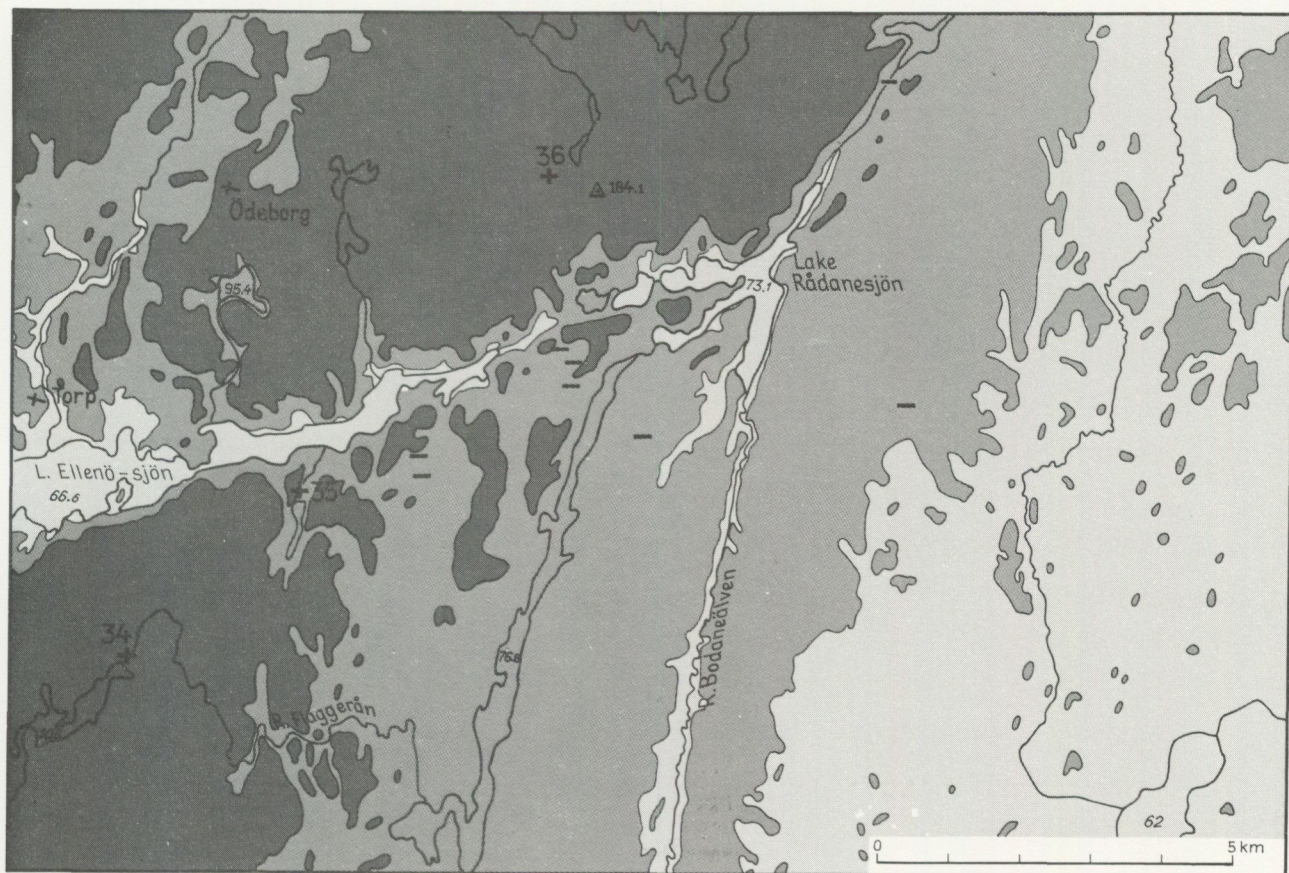


Fig. 29. Main morphological features of the northwestern part of the map sheet Vänersborg NO. The southern end of Kroppefjäll hill is situated north of Lake Rådanesjön. East of the lake, the even lowlands of the Precambrian peneplain can be seen and to the southwest lies a bedrock plateau with a low relief. The southern continuation of the map and an explanation of symbols is shown in Fig. 5. Numbers refer to descriptions in the text.

The fissure valley, occupied by Lake Ellenösjön and other lakes, runs westwards to Munkedal, where it joins the north-south valley of the Örekilsälven river, which debouches into Saltkällefjorden. The western part of the valley lies within the map sheet Vänersborg NV, which has not been surveyed. Shell deposits several metres thick are known in the area northeast of Munkedal (Svedmark 1901, p. 48). They are situated about 65—75 m above sea level. The famous Dals Ed delta, which forms part of the Skövde terminal moraine zone, is located in the north part of the Örekilsälven valley. It seems that the melt-water discharge from Dals Ed created more favourable conditions for the mollusc fauna in the Munkedal vicinity than the restricted water circulation in the east transverse valley. As shell deposits are known from the present shoreline up to about 125 m above sea

level on the map sheet Vänersborg NV, there are reasons to do another special paper when the area is surveyed.

In the area around the southern end of Kroppefjäll range of hills, shell-bearing sediments have been observed on both sides of the fissure valley and along the perpendicular fault scarp to the Precambrian peneplain, see Fig. 29. No shell-banks are known.

On the geological map Rådanefors (Karlsson & Wahlqvist 1870) finds of "North sea and arctic molluscs" are indicated in the vicinity of Lake Rådanesjön. All these localities are situated below 100 m above sea level and were probably accidental observations in ditches, etc. Inquires have been made in the area and then only sporadic finds of shells were known by the residents.

The occurrences of shells described below are of insignificant extension, but interesting from geological and zoological points of view. Two of the localities, nos. 34 and 35, have been known since the surveying in the 1860's.

Place names used refer to the geological map Vänersborg NO (Fredén 1974).

34. Vassalen. A 15 cm thick shell layer in clay is situated on the northern bank of the river Flagerån, about 150 m northeast of Lake Vassalen. The locality lies about 100 m above sea level south of a small bedrock hill. There are no signs of shell layers in the southern riverbank.

The shell layer is silty and dominated by small shell fragments. Shells of *Hiatella arctica*, *Hiatella arctica uddevallensis*, and *Macoma calcarea* were identified. The deposit was spotted with blue and violet from shell fragments of *Mytilus edulis*.

35. Hovsjön. About 100 m north of Lake Hovsjön a similar shell layer in clay was exposed in a ditch. Besides *Mytilus* and *Hiatella*, shells of *Modiola modiolus*, *Mya truncata*, and barnacles were observed, some of which are kept at the Swedish National Museum of Natural History in Stockholm (Hägg 1952, p. 132). The locality is situated almost 100 m above sea level.

36. Stadsängen. The highest-situated locality known of shells in the map area of Vänersborg NO lies east of Stadsängen in the broken bedrock morphology of the southern Kroppefjäll hills. The

highest shoreline in the area is estimated at about 150 m above sea level (Fredén 1974, p. 54). About 125 m above sea level a 10 cm thick and two metres long shell layer was found in glacial clay on the east side of a ditch along the main road to Stigen. The shell layer was situated at the bottom of the ditch, about 1.5 m below surface. The shell layer is underlain by clay, at least one metre thick.

The shell layer was characterized as silty clay with shell fragments, gravel and sand particles. Thick shells of *Hiatella arctica* and *Mya truncata uddevallensis* were recorded, as were shell fragments of *Balanus crenatus* and *Mytilus edulis*.

Shells of *Hiatella* were collected for radiocarbon age determination.

Faunal composition

Knowledge of the faunal composition is based primarily upon investigations of the four great shell-banks east of Uddevalla, localities 1--4. The species described below reflect part of the animal life in the area during the time interval when it served as an important connection between the basins of the Skagerrak Sea and Lake Vänern. Species found in shell deposits of solely Holocene origin in the Uddevalla region are excluded in the list below, as their occurrence is posterior to the development of the Vänern basin.

The faunal list is divided in two chapters, invertebrates and vertebrates.

Invertebrates

The shell deposits at Bräcke, Kuröd and Kapellbacken have been investigated several times. Faunal lists have been published by Jeffreys (1863), Thudén (1866), De Geer (1910a), and Odhner (1927). Before the Samneröd shell-bank was ruined in 1969 Dr Anders Warén had accidentally examined the vertical walls in the deposit (Figs 13--15). Warén's investigation is very important as

it was the last one that could be made in the region. The remains of the great shell-banks do not allow further meaningful examinations. Like the few deposits, still untouched, they are small and reflect only part of the fauna.

The faunal composition differs from one locality to another and from layer to layer. Single species may be represented by a few shells within a limited range. Finds have been made accidentally and species reported from one locality may have been present in others. When Nordmann (1906) visited the Kuröd shell-bank he observed three species not recorded previously or since. Warén's investigation of the Samneröd shell-bank increased the number of identified species by five bivalves and eleven gastropods. Some of the recently recorded species are not hitherto known from any other place in Sweden. When comparisons are made with the former lists, allowances must be made for the extent of the former reference collection and the then established taxonomy. Of course, old works require correction in the light of later advances in knowledge. However, the faunal characteristics of the four great shell-banks (1-4) are more or less identical. Our knowledge of the Late Weichselian marine fauna in Sweden is, to the greater part, based upon the investigations and observations of these four deposits.

In the old days no distinction was usually made between the different shell deposits. Shells were ascribed to the "Uddevalla shell-banks", or the finding-places were mixed-up. During the investigations of the Kapellbacken deposits, De Geer (1910a, p. 1152) called attention to erroneous locality labelling in the Uddevalla museum. At the Swedish National Museum of Natural History in Stockholm several thick shells of *Cyprina islandica*, are labelled Bräcke, Uddevalla. The combination of names is fairly puzzling, since this bivalve has never been listed in any description of the Bräcke shell-bank. Bräcke, however, is not an unusual name.

The frequency of subfossil occurrence is subjective and influenced by the state of the shell-banks during the surveying. These estimates also reflect the frequency figures given by De Geer, Odhner and Warén (the latter by personal communication). As mentioned above, the association of species differs from place to place and from layer to layer.

All specimens found in the Samneröd deposit were identified by Anders Warén. The information about the species from deposits at Kapellbacken, Bräcke and Kuröd is from De Geer (1910) and Odhner (1927) if not otherwise stated. It should be noted that De Geer's list of identified species from the stated "Kuröd shell-bank" has been corrected to refer to the Bräcke shell-bank, see above. During the geological surveying additional species were found in the distal parts of the shell-banks and in shell-bearing sediments in the Bäve valley.

In addition to the listed species, *Spirorbis* sp. (*Polychaeta*) and *Hornera* sp. (*Bryozoa*) have been reported by Odhner (1930, p. 503). The land slug *Patula rotundata* (renamed *Discus rotundatus*) found in the Kapellbacken deposit (Odhner 1927, p. 83) is most probably recent or sub-recent. In all probability, shells of the bivalve *Astarte montagui* may be added as the species is fairly common in the shell deposits around upper Göta River.

E c h i n o d e r m a t a

Strongylocentrotus droebachensis

Echinus droebachensis

Numerous spines have been found in the deposits at Bräcke, Kapellbacken and Kuröd. Ringström (1928, p. 8) reports an abundance of shells of *Echinus* at a depth of 8.2 m in the Kuröd shell-bank.

B r a c h i o p o d a

Dallina septigera

Waldheimia septigera

One shell has been found by Odhner (1927) in the Kuröd deposit.

Terebratella spitsbergensis DAVIDSON

One shell recorded by Thudén (1866) from a deposit at Kapellbacken.

Polyplocophora

Amphineura

Ischnochiton albus LINNÉ

Lophyrus albus

Trachydermon albus

Valves have been found in the Kuröd and Samneröd deposits.

Tonicella marmorea FABRICIUS

Boreochiton marmoreus

One valve found in the Samneröd deposit.

Gastropoda

Acirsa eschrichti MÖLLER

Acirsa borealis BECK

Scala borealis

Scalaria borealis

Scalaria eschrichti

Two shells in the Kuröd deposit were identified by Odhner (1927).

Acmaea rubella FABRICIUS

Tectura rubella

A few shells were recorded in the Kuröd and Samneröd deposits.

Acmaea virginea MÜLLER

Tectura virginea

This gastropod has been found in the Kapellbacken deposit, 46 m above sea level.

Alvania mighelsi STIMPSON

Alvania arenaria MIGHELS & ADAMS

Cingula castanea

Onoba castanea

This gastropod is known from the deposits at Kapellbacken, Kuröd and Samneröd.

Amauropsis islandica GMELIN

The species is fairly rare as a subfossil. It is found in the Bräcke (Brögger 1900—1901, p. 315), Kuröd and Samneröd deposits.

Aporrhais pespelecani LINNÉ

During the surveying one specimen was found in a ditch in the southern part of the Samneröd deposits. It is known from the Kapellbacken deposit at 16 m above sea level (Brögger 1900—1901, p. 322). The gastropod is frequently found in deposits of Holocene times.

Astyris rosacea GOULD

It is rare and only found in the Samneröd deposit.

Bela kobelti VERKRÜZEN

Bela viridula SARS

One shell is recorded from the Kapellbacken deposits (Hägg 1950, p. 358).

Bela rugulata TROSCHEL

This gastropod is identified only in the Kuröd and Samneröd deposits.

Beringius turtoni BEAN

Chrysodomus turtoni

Fusus turtoni

Jumala turtoni

A few shells of this gastropod were found by Odhner in the Kapellbacken and Kuröd deposits and by Brögger (p. 315) in the Bräcke deposit.

Bittium reticulatum DA COSTA

Shells were common in the Kapellbacken deposits at 34 m above sea level (De Geer 1910a) and 16 m above sea level (Odhner 1927). The species is common in Holocene shell deposits.

Buccinum canaliculatum HISINGER

One complete shell was found in 1889 in one of the Kapellbacken deposits. An incomplete specimen was recorded by Hisinger (Hägg 1925) at locality n Tusendalersbacken in Dalsland, west of lake Vänern.

Buccinum glaciale LINNÉ

One shell found in the Bräcke deposit (Brögger 1900—1901, p. 314). The identification is questioned by Warén.

Buccinum groenlandicum CHEMNITZ

Before 1930 this species was the only one listed of *Buccinum*, De Geer (1910a, pp. 1166—1167) stated, however, that varieties of *B. undatum* were included. Brögger (1900—1901, p. 314) claimed that the dominating *Buccinum* species in the Bräcke shell-bank was not *B. groenlandicum*, but a related species.

Buccinum hydrophanum HANCOCK

Two shells from Kuröd and one from Kapellbacken are known (Hägg 1950, p. 357).

Buccinum hydrophanum elata

One shell recorded from Kuröd and one from Risån (Hägg 1950, p. 357).

Buccinum labradorensis REEVE

Three shells, recorded from the Kapellbacken deposits, have been identified by Hägg (1950, p. 357). The identification is questioned by Warén.

Buccinum meridionale HARMER

Several shells have been identified in the Samneröd shell-bank.

Buccinum terraenovae BECK

It is only identified in the Samneröd deposit.

Buccinum undatum LINNÉ

This is the most common gastropod in the area. The species is not listed until 1930 when Odhner (p. 502) points out that it occurs abundantly (cf. *B. groenlandicum*). Shells have been radiocarbon dated.

Buccinum undatum conoidum SARS

One shell is recorded from the Kapellbacken deposits (Hägg 1950, p. 35).

Capulacmaea radiata SARS *glacialis* ODHNER

Capulacmaea glacialis

Several subfossil finds have been made in the deposits at Kapellbacken and at Kuröd.

Colus islandicus CHEMNITZ

Sipho islandicus

This gastropod is only known from the Samneröd deposit.

Colus togatus MÖLLER

Sipho togatus)

One specimen is identified in the Samneröd deposit and one among the shells from the Futton canal (locality 32).

"*Cyclostrema*" sp.

Subfossil shells are known from the Kapellbacken deposit 16 m above sea level.

Homalogyra atomus PHILIPPI

Omalogyra atomus

This has only been found in the Samneröd deposit. Its supposed rarity may be due to its small size, 0.5—1.0 mm.

Lacuna divaricata FABRICIUS

Lacuna vineta MONTAGU

Some shells have been found in the deposits at Kapellbacken and at Kuröd.

Lepeta caeca MÜLLER

Lepeta coeca

Shells of this relatively deep-water gastropod have been found in the deposits at Kuröd and at Kapellbacken, especially at 46 m above sea level.

Littorina littorea LINNÉ

In the Kapellbacken deposits at 34 m and 46 m above sea level, shells are very common. Specimens are also reported from the distal part of the Bräcke shell-bank (Brögger p. 321). This gastropod invaded the coast in Holocene times.

Littorina obtusata LINNÉ

Subfossil shells are only found in the Kapellbacken deposits at 26 m and 68 m above sea level. This gastropod usually occurs in Holocene deposits.

Littorina obtusata palliata SAY

Littorina palliata

The *palliata* form is low-arctic with its southern limit at northern Norway. It is very rare in Late Weichselian deposits.

Littorina saxatilis rudis MATON

Littorina rudis

One shell has been found at Fridhem (locality 22) during the geological surveying and some shells are recorded from the Kapellbacken deposits at 16 m above sea level. The gastropod is common in Holocene deposits.

Lunatia pallida BRODERIP & SOWERBY

Lunatia groenlandica BECK

A few shells were found in the deposits at Kapellbacken, Kuröd and Samneröd.

Margarites argentata GOULD

Margarites olivacea BROWN

Very rare as subfossil. The species was found and identified by Nordmann (1906, p. 83) during a short visit at the Bräcke shellbank.

Margarites helicina FABRICIUS

It is moderately common in the Kapellbacken deposit below 26 m above sea level and rare at higher levels. Nordmann (1906, p. 83) has identified the species in the Kuröd deposit.

Margarites undulata SOWERBY

Margarites groenlandica GMELIN

Very rare as a subfossil. It is identified in the deposits at Samneröd and at Kapellbacken, below 42 m above sea level.

Moelleria costulata MÖLLER

Shells of the gastropod are moderately common in the deposits at Kapellbacken, Kuröd and Samneröd.

Nassa reticulata LINNÉ

Nassarius reticulatus

One shell was found during the geological surveying in the north deposit at Skäldalen (locality 18) at about 50 m above sea level, and 6 specimens are recorded from the Kapellbacken deposit at 34 m above sea level. This gastropod is common in the deposits of Holocene times.

Natica affinis GMELIN

Natica clausa BRODERIP & SOWERBY

The species is moderately common in most of the shell deposits.

Natica bathybi FRIELE

The find in the Samneröd deposit is the only subfossil of *N. bathybi* recorded in Scandinavia (Warén, personal communication).

Neptunea antiqua LINNÉ

Neptunea despecta LINNÉ

Fusus despectus

Subfossil shells are not very common. A few specimens were found at Kuröd (Nordmann 1906; Odhner 1927) and in the Kapellbacken deposit at 16 m above sea level (De Geer 1910). This gastropod is also recorded from the Futton canal (locality 32). During the surveying of the geological map sheet one shell was found at Älje (locality 20).

Neptunea despecta tornata GOULD

During the surveying one shell, identified by Warén, was found in the deposit SSE of Skäleryr (locality 9).

Onoba aculea GOULD

Onoba arctica LOVÉN

Onoba saxatilis MÖLLER

The species is only recorded from the shell deposits at Kuröd and at Samneröd.

Peringia ulvae PENNANT

Hydrobia ulvae

Subfossil shells were common in the Kapellbacken deposits below 50 m above sea level. The species may have inhabited the coastal areas already in Late Weichselian times.

Plicifusus kröyeri MÖLLER

Sipho kröyeri

One shell is known from the Kuröd shellbank (Hägg 1950, p. 357).

Plicifusus latericus MÖLLER

Sipho latericus

This gastropod is rare as a subfossil and is found in the deposits at Kuröd and at Samneröd. The species is also recorded from the Futton canal (locality 32).

Ptsianula limnoides

Shells of this gastropod have been found in the deposits at Kapellbacken and Kuröd.

Puncturella noachina LINNÉ

Shells have been found commonly in the deposits at Kapellbacken, Kuröd and Samneröd.

Rissoa inconspiqua ALDER

This small gastropod, 3 mm, is only recorded from the Kapellbacken deposit, at 16 m above sea level.

Rissoa membranacea ADAMS

Six shells are found in the Kapellbacken deposit 34 m above sea level.

Rissoella opalina JEFFREYS

Jeffreysina opalina

One specimen in the Kapellbacken deposit at 28 m above sea level was identified by Odhner (De Geer 1910, p. 1165).

Solariella obscura bella FRIELE

Solariella obscura COUTHOUY *bella* SARS

One shell has been recorded from the Kapellbacken deposits (Hägg 1950, p. 35) and one, from the Samneröd deposit.

Trophon clathratus LINNÉ

Trophonopsis clathratus

The species is common in the Kuröd deposit. In the whole area it is less common than *T. truncatus*.

Trophon truncatus STRÖM

Trophonopsis truncatus

This species and *Buccinum undatum* are the most common gastropods in the shell deposits. Large shells, about 35 mm high, are observed in the dredged material at Älje (locality 20).

Turitella communis RISSO

Turitella terebra

The gastropod was found in the Bräcke deposit during surveying. It usually occurs in Holocene deposits.

Velutina velutina MÜLLER

Velutina laevigata PENNANT

Shells are recorded from the Kapellbacken and Kuröd deposits.

Lamelibranchia

Acanthocardia echinata LINNÉ

Cardium echinatum

During the surveying one shell was found in a thin layer of shell-bearing sand north of the Ramseröd shell-bank (locality 13) at a level of 40 m above sea level (Brögger, p. 322).

This mollusc is common in Holocene shell deposits.

Anomia ephippium

Subfossil finds of *Anomia ephippium* recorded from the Kapellbacken deposits above 46 m above sea level should be changed to *Anomia patelliformis* (Warén, personal communication).

Of 16 shells of *Anomia ephippium* identified by Nordmann (1906, p. 83) in the Bräcke shell-bank, at least 7 specimens belong to *Heteroanomia squamula aculeata* (Kaj Strand-Petersen, personal communication).

Arctica islandica LINNÉ

Cyprina islandica

Shells were found in 1868—1869 during the construction of the Futtan canal (locality 29) (Hägg 1947, p. 472; 1952, p. 133). Shells are known from the Kapellbacken deposit at 16 m above sea level (Brögger 1900—1901, p. 323). The mollusc is very common in Holocene shell deposits.

Astarte borealis CHEMNITZ

Tridonta borealis SARS

Astarte arctica GRAY

Astarte corrugata BROWN

Astarte semisulcata LEACH

Shells of this bivalve are fairly common in the whole region.

Astarte crenata GRAY

Astarte costata

One shell was identified by Odhner in the upper part of the Kapellbacken deposit at 16 m above sea level.

Astarte elliptica BROWN

Astarte compressa LINNÉ

Astarte banksii LEACH

The species is less common than *A. borealis* but is to be found throughout the whole region.

Astarte sulcata DA COSTA

The species is recorded from Risån (locality 30).

Bathyarca glacialis GRAY

Arca glacialis

Two shells from the Kapellbacken deposit at 16 m above sea level are known.

Cerastoderma edule LINNÉ

Cardium edule

Shells have been found at the Kapellbacken deposits at 46 m and 34 m above sea level; in the distal part of the Bräcke shell-bank (Brögger 1900--1901, p. 321); and, during the surveying, in shell-bearing sand layers situated below 50 m above sea level in the Bäveån valley.

The species is very common in Holocene shell deposits.

Chlamys islandicus MÜLLER

Pecten islandicus

Shell fragments of this bivalve are moderately common throughout the whole area. Large shells, about 10 cm in diameter have been observed at Älje (locality 20). The diameter generally varies between 5 and 7 cm.

Ensis ensis LINNÉ

During the surveying shell fragments were found superficially in the south part of the Bräcke deposit. This mollusc occurs usually in Holocene deposits.

Heteroanomia squamula aculeata LINNÉ

Anomia aculeata

Anomia squamula

A few shells have been found in the shell-banks at Kapellbacken, Bräcke and Samneröd. See also *Anomia ephippium*.

Hiatella arctica LINNÉ

Saxicava arctica

Saxicava rugosa

Elongated and rather regular shells are very common in almost every shell deposit. Usually the shells are thick, but below about 70 m above sea level many of the shells are notably thinner.

Hiatella arctica uddevallensis JEFFREYS

Saxicava arctica uddevallensis

Shells of *Hiatella arctica uddevallensis* are characterized as short and thick to very thick, usually irregularly developed shells. This shell form is very common in the shell deposits, especially in those which are situated above 70 m above sea level, where the shells often represent more than 75 per cent of the total number of shells.

Lucina borealis LINNÉ

Lucinoma borealis

The species is reported by De Geer (1910, p. 1178) and Brögger (p. 322). It was found superficially at the Kapellbacken deposit 16 m above sea level. The bivalve is known from Holocene deposits.

Macoma balthica LINNÉ

Tellina balthica

Tellina proxima

The species is found in the Kapellbacken deposit at 70 m above sea level, at Marieberg (locality 25) and at Risån (locality 30).

Macoma calcarea GMELIN

Tellina clacarea

Tellina sabulosa

Shells of *Macoma calcarea* are moderately common in the whole area.

Modiolus modiolus LINNÉ

Mytilus modilus

The species is known from Kasen (locality 24) and Hovsjön (locality 35). The horse-mussel has a shell similar to *Mytilus edulis*, except that the shell is usually more reddish and the surface structure differs slightly. It can only be properly identified if the umbo is found in good condition. Consequently, shell fragments of *Modiola modiolus* can hardly be distinguished from those of *Mytilus edulis*. The presence of the horse-mussel is probably underestimated in the shell deposits.

Montacuta sp.

Subfossil fragments are reported by De Geer (1910, p. 1178) from the Kapellbacken deposit at 16 m above sea level. The find was superficial and made together with other Holocene molluscs.

Musculus discors LINNÉ

Modiolaria discors

Shells are common in the Bräcke, Kuröd and Samneröd deposits. According to Odhner (1927) shells are common in the Kapellbacken deposits though the species is not listed by De Geer (cf. *Musculus laevigata*).

Musculus laevigata substriata GRAY

Crenella laevigata striata

Modiolaria discors laevigata

According to De Geer's list, shells of *Crenella* are moderately common in the Bräcke and Kapellbacken deposits. The species is not listed elsewhere. On the other hand, *Modiolaria discors* (see *Musculus discors*) is reported from the Kapellbacken deposits by Odhner. In older literature these two names seem to be synonymous. In the Samneröd shell-bank, however, Warén has identified shells of both species

Mya truncata LINNÉ

Subfossil shells of *Mya truncata* are common in most deposits.

Mya truncata LINNÉ *uddevallensis* HANCOCK

Subfossil shells are moderately common in the whole area but to a lesser extent than *Mya truncata*.

Mytilus edulis LINNÉ

Shell fragments are more or less common in all deposits. Intact shells are very rare in shell deposits but they are accidentally found in glacial clay. As the species is found in clay about 25 m below the highest shoreline, it is obvious that it invaded the area close to the retreating ice (cf. Hjort & Funder 1974).

Nuculana minuta MÜLLER

Leda minuta

Leda caudata

It is recorded only from Risån (locality 30).

Nuculana pernula MÜLLER

Nuculana pernula costigera LECHE

Leda pernula

Shells of *Nuculana pernula* have been found in several deposits.

Nuculana tenuis expansa REEVE

Nuculana tenuis Mont. *expansa* HANCOCK

The species is only found at Samneröd.

Ostrea edulis LINNÉ

Four shells have been recorded in the Kapellbacken deposit at 34 m above sea level. A doubtful find (Neolithic?) is reported from Risån (locality 30). Oyster shells are common in Holocene deposits.

Parvicardium ovale SOWERBY

Cardium fasciatum

Two shells are recorded from the upper part of the Kapellbacken deposit at 16 m above sea level (Odhner 1927). The species is moderately common in Holocene deposits.

Portlandia arctica GRAY

Yoldia arctica

A few shells have been found in the deposits at Kapellbacken, Kuröd and Samneröd. Individual shells are fairly common in glacial clay.

Thracia papyracea POLI

Thracia phaseolina LAMARCK

A few shells are recorded from the Kapellbacken deposit at 16 m above sea level (De Geer 1910a). Shells of this bivalve occur in Holocene deposits along the west coast.

Thyasira flexuosa MONTAGU

Axinus flexuosus

Shells reported as *T. flexuosa* have been found at the Kapellbacken deposit at 46 m above sea level. Until a closer examination of the shells is made the occurrence of the species in the shell deposits is uncertain.

Thyasira gouldi PHILIPPI

Shells have been identified in the Samneröd deposit.

Voldia hyperborea TORELL

Leda myalis

The species is recorded from Risån (locality 30).

Voldiella fraterna VERRIL & BUSCH *nana* M. SARS

Voldia nana

The species is only found in the Samneröd deposit.

Voldiella frigida TORELL

Portlandia frigida

Voldia frigida

The species only found in the Samneröd deposit.

Voldiella lenticula MÖLLER

Portlandia lenticula

Voldia pygmaea gibbosa

Shells are only found at Kuröd and Samneröd. The limited observation of this mollusc in the shell-banks is due not only to its

small size, as it is also rare in observed cuts in the Skagerrak clay.

Zirphaea crispata LINNÉ

Subfossil shells of *Zirphaea crispata* are rare in the region. A few have been found in the deposits at Kuröd and Kapellbacken (16, 42 and 68 m above sea level). Though the species is of a non-arctic character it existed along the coasts of north Jutland about 14 000 years ago (KROG and TAUBER 1974).

C r u s t a c e a

Balanus balanus LINNÉ

Balanus porcatus

Parts of shells are not very common in the area.

Balanus crenatus BRUGUIERE

Almost complete individuals and side-plates are moderate common in the whole area.

Balanus hammeri LINNÉ

Finds of side-plates are very common in the area, especially below 100 m above sea level. Large plates, 10-12 cm high, have been found at localities 8, 16, 20 and 22.

Coronula diadema LINNÉ

The species has been found in the Bräcke shell deposit (Odhner 1930, p. 505).

Verruca stroemia MÜLLER

The species is common from the deposits at Bräcke, Kapellbacken and Kuröd.

Spongiae

Suberites montalbidus

The species has been found in the deposits at Kuröd and Samneröd.

Thetya cranium

Finds have been made in the deposits at Kapellbacken (Odhner 1930), Kuröd and Samneröd. At Gunnarsberg, southeast of the Futton canal (locality 32), needles have been found in clay at a depth of 0.6—0.9 m. They were, with some hesitation, identified as *Thetya cranium* (Fristedt 1884).

Vertebrates

In the Uddevalla region a great number of subfossil skeletal parts have been found. Except for archaeological sites no other locality in Sweden can stand comparison with the subfossil finds in the Uddevalla area. Listed below are not only finds from the shell deposits but also individual finds made in clay. All vertebrates have existed more or less contemporaneously with the invertebrate fauna. In addition to the listed species it should be noted that several unidentified subfossil skeletal parts from the Uddevalla shell-banks are registered at the Museum of Natural History in Göteborg. Hopes are entertained about the presence of at least two more species of *Cetacea*, see below. Excluded from the list are subfossil finds of vertebrates of Holocene age (cf localities 25 and 32).

Reviews of all finds in Sweden of seals and tooth whales were published by Lepiksaar in 1964 and 1966 respectively. A review of subfossil finds of arctic whales and seals in Sweden was published by Fredén in 1975. In the latter review a series of radiocarbon age determinations is included.

During the mining of the shell-banks at Bräcke, Kuröd and Kapellbacken, several skeletal parts were said to have been observed, but they were spoiled. Ringström (1928) made an attempt to register all subfossil finds made during the 1926—1928 quarrying of the deposits at Kapellbacken and Kuröd. A presentation,

including comments regarding the *in situ* conditions, would increase the value of this project. When it was closed about 40 finds had been recorded. Ringström had found four of them.

To encourage the workers' interest, finds were rewarded according to their scientific importance (Lepiksaar, personal communication). From this follows that information about finding-places of most of the finds were built on details given by "financially motivated" workers. Ringström described finds of cod, ling, white whale, killer whale, harp seal, grey seal, and land vertebrates such as sheep, cow, horse, elk, and reindeer.

As mentioned in the faunal list below, skeletal parts of a haddock were mistaken for the teeth of a killer whale. Only a few of Ringström's 12 finds of harp seals are acceptable without question.

It is, however, the finds of the domestic animals that are sensational. If authentic, they would be of an age before man is known to have inhabited the coast and from a time when the region was an inhospitable archipelago. Zoologists question the purity of the finds. The Swedish problem may be characterized as a Piltdown mystery in miniature.

Ringström (op. cit. p. 9) was sceptical about the skeletal part of a sheep. He points out that in the Kuröd shell-bank, as in most of the other shell-banks, old holes have been filled in through the years; and at this site even a small watercourse is known to have been filled in.

The find belonging to an elk skeleton was found through a screening procedure at Kuröd. The original finding-place is, thus, unknown. The skeletal find of a cow was made at the bottom of the pit at Kapellbacken. Ringström described both finds as unusually well kept, with no signs of wave-washing.

In the summer 1927 three vertebrae from a horse were found by workers at Kuröd. Ringström examined the stated finding-place and declared that the indicated layer was primary (in modern language, one might say bingo for the discoverer). On the other hand, Ringström described the vertebrae as conspicuously non-eroded.

The finds of the domestic animals were, with some difficulty, confirmed. Unfortunately, the finds were treated for preservation with an organic liquid and are thus unsuitable for radiocarbon age determination.

When the Samneröd rifle ranges were rebuilt in 1969 skeletal parts of domestic animals only were delivered to the Museum of Natural History in Göteborg via the Uddevalla museum. Some of these zoologically worthless finds were radiocarbon dated. A skeletal part of a cow (St 4240) and a skeletal part of a goat (St 4241) both yielded ages younger than 250 years.

This result was not surprising. Apart from relying upon the workers, who must have seen a chance of additional income, it is difficult to distinguish between primary and secondary layers when only small vertical parts of a shellbank are visible. There are no zoological or geological doubts that these finds of land vertebrates are secondary, and they are therefore omitted.

The species listed below give an idea of the Late Quaternary vertebrates in the Uddevalla region and a subsequent reconstruction of their evolution. Characteristics of the vertebrates are given in the Index.

T e l e o s t e i, bone fishes

Gadus morhua, cod

Two vertebrae of different specimens have been found in the Kuröd deposit (Ringström 1928, p. 5). One of them was found at a depth of 8.2 m in the lower part of the shell-bank. Skeletal parts of cod have also been found in the Bräcke shell-bank Jägerskiöld 1941, p. 10). During the construction of the Futton canal (locality 32) a skeleton was found in clay at a depth of 4.5 m.

Melanogrammus aeglefinus, haddock

Gadus aeglefinus

From the Kuröd shell-bank two finds have been described by Ringström as teeth of a killer whale, *Orcinus orca*. Later these finds were checked by Dr Henrici at the Museum of Natural History in Göteborg and identified as the lower, thickened parts of the *cleithrum* of a haddock (Nybelin 1941, p. 10 and Fig. 2).

Molva molva, ling

Three connecting vertebrae were found in the Kuröd shell-bank at the same place, 8.2 m below the ground surface, as was one of the cod vertebrae found by Ringström (1928, p. 5).

Pinnipedia, seals

Erignathus barbatus, bearded seal

Two finds of the bearded seal are recorded in the area. One, *astragalus*, is labelled "the shellbanks of Uddevalla", and the other, a vertebra, was found at the Futton canal (locality 32).

Halichoerus grypus, grey seal

Skeletal parts are known from the Bräcke, Kuröd and Ramseröd (locality 13) shell-banks. One find labelled "Porsen" originates from the Älje (locality 20) area. The recorded subfossils have been eroded by wave-washing, implying that the skeletal parts have been in a beach position and are thus younger than the concerned shell-banks.

One skeletal part is radiocarbon dated.

Pagophilus groenlandicus, Greenland seal, harp seal

Several finds have been made in the shell-banks at Bräcke and Kuröd. At least three of them have been identified without question (Lepiksaar 1964), p. 262).

At the Futton canal (locality 32) four almost complete skeletons have been found in clay at various depths. Parts of two of the skeletons have been radiocarbon dated.

Pusa hispida, ringed seal

This species is the most common of all subfossil finds of seals in Sweden. In the Uddevalla shell-banks no less than 57 finds of at least 21 individuals are recorded (Lepiksaar 1964, p. 264). Skeletal parts of the ringed seal have also been found in clay at Frändefors (Fredén 1975, p. 47).

C e t a c e a, whales

At the Museum of Natural History in Göteborg there are several finds of unspecified whales from the Uddevalla area. Although the Greenland right whale, *Balaena mysticetus*, has not been identified in the region, one can assume that the species was present, as it is the most common subfossil find of arctic vertebrates in western Sweden. Finds of the barnacle *Coronula diadema* indicate that even the humpback whale, *Megaptera nodosa*, occurred in the area (Odhner 1930, p. 505).

Delphinapterus leucas, white whale

Skeletal parts of different individuals have been found in the deposits at Bräcke and Kuröd (see Fredén 1975, p. 28). One vertebra has been radiocarbon dated.

Eubalaena swedenborgii, the Swedenborg whale

A find of *bullæ ossea*, earlier identified as referable to a Greenland right whale, was found in 1932 in the Bräcke shell-bank (Nybelin 1946).

Lagenorhynchus albirostris, white-beaked dolphin

One vertebra found in the Kuröd shell-bank (Nybelin 1953, p. 3; Lepiksaar 1966, p. 16). Skeletal parts of this species have also been made in Holocene shell deposits along the west coast.

Phocaena phocaena, common porpoise

One find from the "Uddevalla shell-banks" is recorded (Nybelin 1938).

Carnivora, beasts of prey

Thalassarctos maritimus, polar bear

Ursus maritimus

From the Bräcke shell-bank, part of an upper left arm bone is recorded (Jägerskiöld 1933, p. 91) and also a tooth (Jägerskiöld 1937, pp. 9—10). From the Kuröd shell-bank part of a right shoulder blade (Jägerskiöld, 1933, p. 91) and of three rib fragments (Nybelin 1953, p. 2) are known. The recorded find at Risån is questionable, see description of locality 30.

Artiodactyla, hoofed animals

Rangifer tarandus, reindeer

Finds are recorded from the Kuröd shell-bank (Ringström 1928, p. 10; Jägerskiöld 1933, p. 92; Nybelin 1941, pp. 9—10). The reindeer is known to have lived in ice-free areas in Denmark during Late Weichselian times (Degerböl and Krog, 1959).

Aves, birds

Somateria mollissima, common eider

Skeletal parts have been found in clay underlying the shell-bank at Samneröd (Hansson 1970, p. 14). The find is the oldest one of a bird from the Weichsel deglaciation. The presence of eider is not surprising, considering the then rocky archipelago and good supply of food (mainly *Mytilus edulis*), which would have suited the species very well.

Summary of fauna

In Fig. 30 a brief outline of the number of species and their present zoogeographical distribution is given. As most shells are found in secondarily position it is wise to limit far-reaching ecological conclusions.

Even if the bedrock today is bare, one can assume that when it was sea bottom there were patches, hollows, and fissures with clay and sand, thus providing different kinds of soft and hard substrata for the molluscs. Due to the hilly landscape, favourable hydrographical conditions for faunas requiring different kinds of salinity, nature of bottom, batymetrical conditions, etc., may have existed synchronously in a limited area. On the other hand, it is obvious that certain patches have been favourable for assemblages during several hundreds of years; though, at least, the batymetrical conditions changed gradually with the land uplift.

In the zoogeographical characteristics in Fig. 30, it is clear that an arctic to arctic-boreal fauna dominates the faunal composition of the shell deposits. Most of the recorded species today prefer a water depth of 30—50 m.

Despite the fact that the gastropods are the most numerous in species, no gastropods are known higher than 75 m above sea level or in the Skagerrak clay. Shells of *Hiatella arctica*, *Mya truncata* and of their varieties *uddevallensis*, shell fragments of *Mytilus edulis*, and side-plates of one or two barnacle species are found up to about 25 m below the level of the highest shoreline. Valves and complete shells of *Portlandia arctica* and of *Mytilus edulis* have been recorded in Skagerrak clay. The species mentioned above are supposed to be the first shell-bearing inhabitants of the area after deglaciation.

With the exception of *Lirphaea crispata*, all recorded species with a present boreal to lusitanian distribution are found less than 55 m above sea level, and they are abundant at less than 45 m above sea level.

	a	ab	abl	b	bl	total
INVERTEBRATES						
<i>Echinodermata</i>	-	-	-	-	1	1
<i>Brachiopoda</i>	2	-	-	-	-	2
<i>Polyplacophora</i>	-	2	-	-	-	2
<i>Gastropoda</i>	21	16	1	8	7	53
<i>Lamellibranchia</i>	13	7	5	4	9	38
<i>Crustacea</i>	-	1	3	1	-	5
<i>Spongiae</i>	1	1	-	-	-	2
	37	27	9	13	17	103
VERTEBRATES						
<i>Teleostei</i>	-	2	-	1	-	3
<i>Pinnipedia</i>	3	-	-	1	-	4
<i>Cetacea</i>	2	-	-	1	1	4
<i>Carnivora</i>	1	-	-	-	-	1
<i>Artiodactyla</i>	-	1	-	-	-	1
<i>Aves</i>	-	1	-	-	-	1
	6	4	-	3	1	14
Total	43	31	9	16	18	117

Fig. 30. Present distribution of the species recorded in the Uddevalla region. a = arctic, ab = arctic-boreal, abl = arctic-lusitanian, b = boreal, bl = boreal-lusitanian.

Radiocarbon measurements

Thirtynine radiocarbon determinations have been carried out, mostly on shells of *Hiatella*, see Fig. 31. It must be pointed out that the datings only reflect when the particular animal lived in the concerned area. As most of the shell deposits have been exploited, it is difficult to collect *in situ* shells from a complete stratigraphy for radiocarbon measurements. Excellent possibilities were at hand in the lower part of the Samneröd

Lab. no. St	LOCALITY	Lat. N	Long. E	SPECIES	Frac- tion	Age in years B.P. ± stat. err.	δ C ¹³ ‰ PDB	Apparent age of sea water	Total corr. in years	Corrected ages	
										B. P.	B. C.
5013	1. KAPPELLBACKEN	58° 20'	11° 51'	<i>Chlamys islandica</i>	2	10 855 ± 235			+ 10	10 865 ± 235	8 915 ± 235
5014					3	10 915 ± 220	- 0.4	- 400	0	10 915 ± 220	8 965 ± 220
4753	2. SAMNERÖD	58° 21'	11° 58'	<i>Buccinum</i> <i>Hiatella</i>	1	10 575 ± 200	- 4.0	- 400	- 65	10 510 ± 200	8 560 ± 200
4749	7. ÄSPERÖD	58° 20'	11° 58'	<i>Hiatella</i>	1	10 195 ± 130			- 45	10 150 ± 130	8 200 ± 130
4750					2	10 180 ± 130	- 4.0	- 400	- 60	10 120 ± 130	8 170 ± 130
5224	8. SE SKÄLERYR	58° 23'	12° 0'	<i>Hiatella</i>	1	10 545 ± 135			+ 35	10 580 ± 135	8 630 ± 135
5225					2	10 060 ± 155			+ 40	10 100 ± 155	8 150 ± 155
5226					3	10 680 ± 130	+ 1.7	- 400	+ 45	10 725 ± 130	8 775 ± 130
5227	9. SSE SKÄLERYR	58° 23'	12° 0'	<i>Hiatella</i>	1	10 355 ± 140			+ 55	10 410 ± 140	8 460 ± 140
5228					2	10 515 ± 150			+ 60	10 575 ± 150	8 625 ± 150
5229					3	10 365 ± 125	+ 2.6	- 400	+ 55	10 420 ± 125	8 470 ± 125
4449	13. RAMSERÖD I layer II II layer III III	58° 21'	12° 0'	<i>Hiatella</i>	1	10 125 ± 180					
4443					1	10 625 ± 170					
4444					2	10 625 ± 210					
4447					1	10 235 ± 165					
4448					2	10 195 ± 220					
5230	16. STÄMMEN	58° 21'	12° 2'	<i>Hiatella</i>	1	10 835 ± 135			+ 45	10 880 ± 135	8 930 ± 135
5231					2	10 730 ± 215			+ 45	10 775 ± 215	8 825 ± 215
5232					3	10 995 ± 140	+ 1.9	- 400	+ 5	11 000 ± 140	9 050 ± 140
5221	18. SSE SKÄLDALEN	58° 21'	12° 2'	<i>Hiatella</i>	1	9 860 ± 125			+ 55	9 915 ± 125	7 965 ± 125
5222					2	10 035 ± 110			+ 55	10 090 ± 110	8 140 ± 110
5223					3	10 230 ± 125	+ 2.6	- 400	+ 55	10 285 ± 125	8 335 ± 125
4754	19. SKÄLDALEN	58° 21'	12° 2'	<i>Buccinum undatum</i>	1	9 340 ± 135	- 4.9	- 400	- 70	9 270 ± 135	7 320 ± 135
5233	22. FRIDHEM	58° 21'	12° 4'	<i>Hiatella</i>	1	10 425 ± 145			0	10 425 ± 145	8 475 ± 145
5234					2	10 150 ± 155			0	10 150 ± 155	8 200 ± 155
5235					3	10 540 ± 120	- 0.7	- 400	0	10 540 ± 120	8 590 ± 120
4751	28. S RÅHAGEN	58° 22'	11° 58'	<i>Mya truncata</i> & <i>Hiatella</i>	1	10 995 ± 200	- 3.4	- 400	- 30	10 965 ± 200	9 015 ± 200
4752					2	11 480 ± 200			- 75	11 405 ± 200	9 455 ± 200
3963					1	11 395 ± 175			- 25	11 370 ± 175	9 420 ± 175
3964					2	11 200 ± 170			- 70	11 130 ± 170	9 180 ± 170
3965					3	11 170 ± 175			- 80	11 095 ± 175	9 145 ± 175
3966	4	11 080 ± 170	- 5.1	- 400	- 85	10 995 ± 170	9 045 ± 170				
4450	29. S GRÖRÖD	58° 21'	12° 0'	<i>Hiatella, Trophon,</i> <i>Balanus</i>	1	10 790 ± 185					
4445	36. STADSÄNGEN	58° 33'	12° 5'	<i>Hiatella</i>	1	11 450 ± 210					
4446					2	11 240 ± 400					
6654					1	11 565 ± 320	+ 0.7	- 400	+ 25	11 590 ± 320	9 640 ± 320
6655					2	11 090 ± 175	+ 0.5	- 400	+ 20	11 110 ± 175	9 160 ± 175
6656					3	11 400 ± 115	+ 0.6	- 400	+ 25	11 425 ± 115	9 575 ± 115
6657	4	10 830 ± 130	+ 1.2	- 400	+ 30	10 860 ± 130	8 910 ± 130				

Fig. 31. Radiocarbon age determinations of shells in the Uddevalla area.

deposit (locality 2), but, unfortunately, the intact remains were ruined before anything definite was done.

For the purpose of an easy-to-grasp comparison, the localities below are described and annotated in four age groups.

Shells older than 11 000 years

28. South of Råhagen. The shells were collected in 1970 and 1972. On the first occasion only thick shells of *Mya truncata uddevalensis* were sampled. During the second visit a limited amount of thick shells and shell fragments were available. It was impossible to assign the collected shells to a specific shell layer.

The dated samples are attributed to the deposit as a whole, which is itself considered restricted in time.

36. Stadsängen. The locality is situated about 25 m below the highest shoreline. When the shell layer was deposited, the bathymetrical conditions were such that later more than one metre of glacial fine clay could accumulate. The Trollhättan terminal moraine zone lies about 5 km west of Stadsängen and at a distance of 10 km northeastwards the Levene terminal moraine traverses the landscape.

Samples were collected on two occasions. As the locality is situated at a relatively high level between two ice marginal deposits, the result of the dating is very important. Apparently the first sample, collected in 1973, was too poor to give a good result. Not until the summer of 1978 were there good opportunities for an additional sampling — the ditch had then been cleared and the water level was low. Because of the importance of the dating a careful sampling was made. Only relatively large and thick shell fragments of *Balanus* sp., *Hiatella*, *Mya* and *Mytilus* were collected. Though four fractions were dated, it is obvious that the whole shells were contaminated. The mean value of all six radiocarbon determinations give an uncorrected age of 11 200 years B.P.

Shells between 10 600 and 11 000 years

The dated shell samples overlap in a time span of 10 600-10 800 years B.P.

1. Kapellbacken. From a storage box labelled "Pecten islandicus, Kapellbacken" at the Swedish National Museum of Natural History in Stockholm, seven shells, relatively thin and 8-9 cm high, were used for radiocarbon age determination. No correction for the storage effect has been made. No information about stratigraphy or exact finding-place is available. This bivalve is recorded from almost all of the Kapellbacken deposits.

13. Ramseröd. Shells and shell fragments of *Hiatella* were sampled in layer II as marked on Fig. 21. It should be noted that the

central part of the Ramseröd shell-bank is withdrawn, which means that the dated sample had a moderately distal position. In contrast with the Skäleryr deposit (locality 8) layer II is characterized by numerous small shell fragments and in contrast with the shell deposit south of Groröd (locality 29), layer II is clayey. All three faunas seem to have been more or less contemporaneous; the conditions of sedimentation are different.

16. Stämmen. In this shell-bank there were no problems in sampling, *in situ*, thick shells of *Hiatella* at a depth of one metre below surface. The altitude of the locality is similar to SSE Skäldalen (locality 18), see below. It is interesting that the two shell-banks, which have different stratigraphy and faunal composition, also show a marked difference in age.

29. South of Groröd (locality 29). One sample for radiocarbon age determination was taken 700 m south of Groröd in a sandy shell-bed below 2.5 m of sand. All dug-out shells (few) and shell fragments of *Trophon*, *Hiatella* and side plates of *Balanus hammeri* were used.

Shells between 10 300 and 10 600 years

Datings from four localities are found in this time span. One is from the easternmost shellbank, locality 22, and one from the westernmost, locality 2, but one. The distance between these localities is almost 6 km.

2. Samneröd. The sample was collected in small remains of undisturbed layers very close to the southwest end of the bedrock hill. At a depth of slightly more than one metre below the original surface, 46 m above sea level, mainly large shell fragments and some shells of *Hiatella* and *Buccinum* were chosen.

8. Skäleryr. Thick shells of *Hiatella* were collected at a depth of about 1.5 m below the supposed original surface (63 m above sea level) of the shell-bank.

9. SSE Skäleryr. Thick shells of *Hiatella* were collected surficially (60 m above sea level) in one 10 m long furrow of the cultivated field. The radiocarbon-dated sample from the other Skäleryr shell-bank, locality 8, see above, was taken at a depth of 1.5 m. The datings of the two nearby localities do not overlap.

22. Fridhem. In the remains of the shell-bank thick shells of *Hiatella* were collected by digging at the bottom of the pit about 1.5 m below the supposed original surface 70 m above sea level.

Shells between 10 000 and 10 300 years

Samples from three localities. The placing of locality 13 in this group of datings is somewhat uncertain.

7. Äsperöd. Due to a sparse occurrence of thick shells and large shell fragments of *Hiatella* the collecting range was wider than usual. The samples were taken in the north (proximal) wall of the bank with a collecting area of 3 m in length, 0.2 m in height and depth.

13. Ramseröd. The samples of *Hiatella* shells and shell fragments in layer I and III were collected in areas as is shown on Fig. 21. The horizontal sampling depth was about 0.2 m. The two samples are regarded as being of about the same age, as supported by stratigraphy.

18. SSE Skäldalen. The radiocarbon dated, moderately thick, shells of *Hiatella*, were collected in a vertical wall in a small pit, where the shell-bank thickness was slightly more than one metre, Fig. 24. The samples shells were taken close to the underlying bedrock. Compared to the fauna of the contemporaneous datings this shell-bank has a high frequency of gastropods.

Shells between 9 000 and 10 000 years

A vertebra of a white whale and one of a grey seal, both found in the Bräcke and Kuröd deposits, have been previously dated (Fredén

1975, p. 14, p. 28, pp. 57-60). No information about the finding circumstances is at hand. The vertebrae showed distinct erosion marks from beach processes. The obtained ages, $10\ 160\pm 380$ and $10\ 170\pm 215$ resp., are almost identical. However, the statistical error amplitude is quite high, and the finds only reflect the presence of each species some time between 9 600 and 10 200 years ago (a correction of -250 years included).

19. Skäldalen. The youngest radiocarbon age determination derives from shells of the gastropod *Buccinum undatum* collected in the small pit of the shell-bank near the river Bäveån. The age shown is for fraction 1. By comparison with deviations for fractions 2 and 3 of other samples, an addition of a few hundred years is probably called for.

Among the gastropods in the pit several shells of *Nassa reticulata* were observed. This species requires higher water temperature than the fauna of the Uddevalla shell-banks and is generally found in shell deposits of Holocene times. Obviously, this part of the Bäveån valley was a marine creek at the time and the mouth of Bäveån river was situated some km further north.

Summary of shell deposits in the Uddevalla region.

Shell deposits with a total volume of more than one million cubic metres have existed in the Uddevalla region. Most of them are situated in the valley between Uddevalla and lake Vänern, especially in the hilly area of the valley between two bedrock ridges which are perpendicular to the valley. All shell deposits are found away from the central and deepest parts of the valley. The shell-banks are located at crevices in the bedrock. Most of the large shell deposits are found between 55 and 65 m above sea level. The molluscs have had a living space between 60 and 85 m above sea level.

In hydrographical terms, the main part of the shell deposits are found in an area which has served as a water passage between fairly narrow straits westwards to marine conditions and eastwards to shallow and brackish waters. These conditions were favourable to an abundant fauna flourishing during slightly more

than 1000 years in Late Pleistocene and very early Holocene times. Subfossil finds include more than 100 species of invertebrates and more than 15 species of vertebrates.

The oldest dated shells, slightly more than 11 000 years, were collected in small deposits at relatively high levels, 90--125 m above sea level. As the deposits were small the molluscs habitat is limited in time and space. This means that the radiocarbon age determination is representative for the habitat as a whole.

Within a radius of 400 m at least three mollusc habitats have existed at different times during a time span of about 1500 years. The composition of the shell deposit at Stämmen, locality 16, indicates sedimentation in deep water and burial of shells of molluscs which lived almost 11 000 years ago. Sampled shells from the deposit at SSE Skäldalen, locality 18, 67 m above sea level—about the same level as the Stämmen locality—were about 800 years younger. The shell deposit of Skäldalen, locality 19, 53 m above sea level, had a pronounced boreal-lusitanian faunal composition and sampled shells yielded a radiocarbon age of Late Preboreal times.

Radiocarbon datings of different samples from one shell-bank, locality 13, proves that good ecological conditions for a mollusc fauna have existed in this area for at least 200—500 years. The same circumstances are valid for the other shell-banks.

Considering the margin of error the radiocarbon age determinations carried out on shells of arctic—boreal molluscs in the Uddevalla area overlap from about 11 500 to 10 000 years ago. Optimal conditions for the fauna prevailed for some hundreds of years about 10 500 years ago.

Most of the radiocarbon dated samples were collected in the remains of the upper part of the shell deposits, which means that they belong to the youngest part of the sequence.

SHELL DEPOSITS SOUTH OF LAKE VÄNERN

During deglaciation the southern part of the Vänern basin was connected with Skagerrak by several straits of different importance for palaeohydrography, see Fig. 32. Cross-sections of the connections are shown in Fig. 33.

The easternmost connection—the valley of the Sävån river—was insignificant, as the valley floor lies close to the level of the highest shoreline. The other deglaciated connections were very wide and deep in the then existing archipelago between the inland ice and the Skagerrak basin. The easternmost strait of any importance was the valley of the Mellbyån river. North of Lake Mjörn the valley is steep-sided and very narrow. The two Cambro-Ordovician table hills Halleberg and Hunneberg have been pronounced steep-sided islands during the marine stage of the Vänern basin. The westernmost connection was provided by the present-day lake Vänern outlet, the fault valley of the Göta älv.

The landscape is characterized by large areas of exposed bedrock and vast clay fields in the east part and in the main valleys, in which considerable sediment thickness, 30–100 m, is recorded.

The highest shoreline lies almost 135 m above sea level on Hunneberg hill (Digerfeldt 1979) and about 110 m above sea level at the northeastern part of Lake Mjörn (Hillefors 1969, p. 259 Jutås delta). The Late Weichselian shore displacement curve at Hunneberg hill has been calculated to be about one metre per century; between 11 000 and 10 300 B.P. it is calculated to 3.3 m per century. A rapid increase of the gradient started in the beginning of Preboreal times, see Fig. 34.

According to von Post (1928, pp. 54–57) the Vänern basin was isolated some time before the beginning of the *Alnus* pollen-grain curve.

Preliminary results of a new investigation supports von Post's statement; this means that the isolation occurred about 9 000 years ago. The determination of the rational *Alnus* pollen grain limit is questionable—should it be set at the first appearance of a continuous pollen grain curve or at the steep rise of the curve? Consequently the absolute age determination of the colonization and development of alder is awkward, furthermore there is a discrepancy in ages carried out on gyttja samples and on peat samples (cf. Olsson & Florin 1980). One may summarize the present discussion as that the Vänern basin was isolated some time between 9 000 and 8 600 years ago. The gradient of the shore displacement curve on Fig. 34 may thus be corrected later. The altitude of Lake Vänern is about 45 m above sea level.



Fig. 32. Orographic map of the area south of Lake Vänern, see Fig. 5 for explanation. Small letters as in descriptions in the text.

Surveys of the Quaternary deposits of the map sheets Vänersborg SO (Fredén 1984), Göteborg NO (Fredén 1986) and Göteborg SO (Magnusson 1978), which areas are located west of Hunneberg—Mjörn, have recently been published. So far one shell-bank similar to those at Uddevalla has been found, locality j. Hålan. It may be noted that observations of shell-bearing clays in the vicinity of the upper Göta älv valley and south of Hunneberg are found to be moderately common. The statement includes local residents' oral reports of shells found in clay during digging of different kinds.

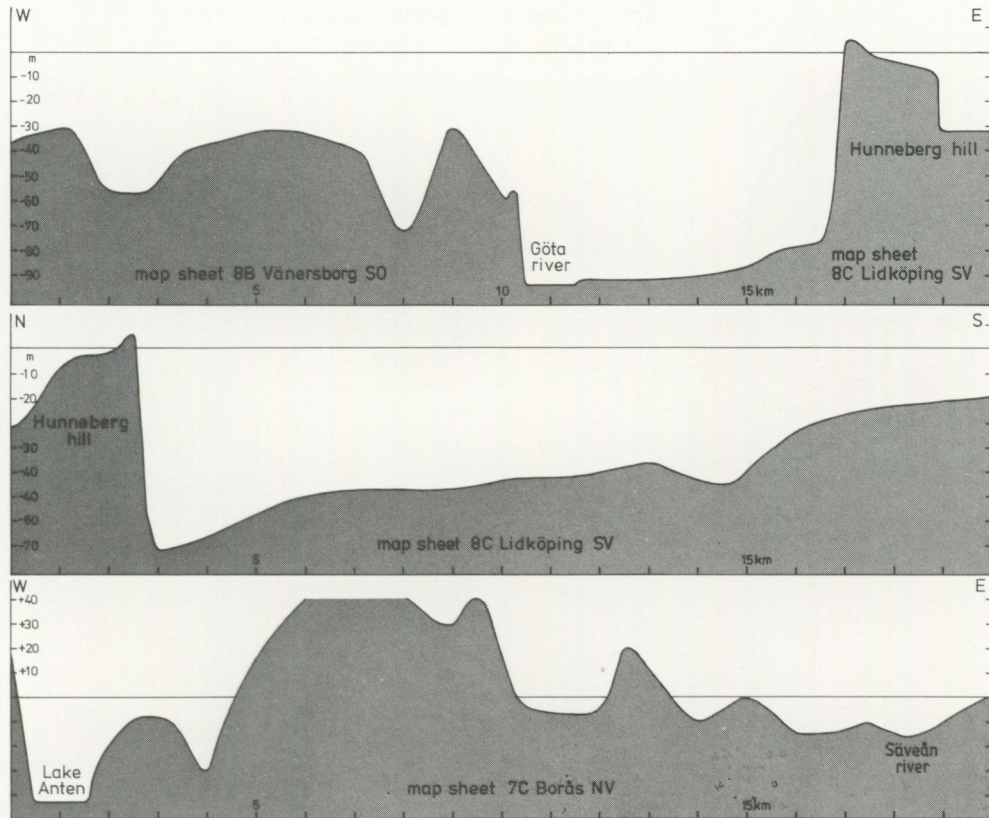


Fig. 33. Transverse sections of the former straits south of Lake Vänern at their maximum dimensions.

Descriptions of localities

With one exception the localities shown on Fig. 32 have at least two recorded species. The exception is St.Lärsbovattnet, locality b, as it is the highest situated locality.

At sites south and east of Hunneberg, individual shells have been found in clay at depths of several metres, mainly in connection with well diggings (Mohrén & Larsson 1974, pp. 72--76). Shells have also been found with subfossil skeletal parts of arctic whales and seals, see radiocarbon measurements. An essential feature in the distribution pattern is that most localities are situated west of the watershed between Göta River and Nossan River, the latter debouches into Lake Vänern.

Recorded molluscs and cirripeds are shown in Fig. 35.

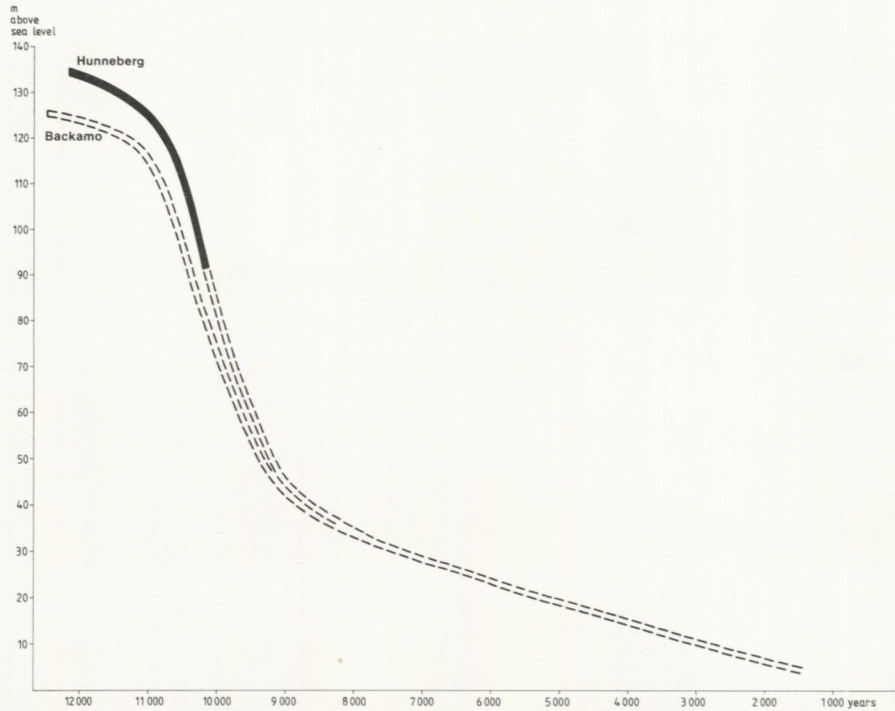


Fig. 34. Generalized shore displacement curves for Hunneberg and for Backamo, situated 30 km WSW of Hunneberg. The unbroken line is based on analyses of diatoms and radiocarbon determinations (Björck & Digerfeldt 1982b). From Fredén (1984, Fig. 29).

Hunneberg

8 C Lidköping SV 4a

Shells of *Mytilus* have long been known in the area; see locality e, Eldmörjan. Recently Björck and Digerfeldt (1982a) have recorded finds of *Mytilus* in silty sand in two lake basins on the table hill Hunneberg. The recorded finds at Kroppsjön and Ekelunds Gransjö, 122 and 119 m above sea level respectively, attract special attention by their stratigraphic position. The shells were found in a sequence of layers of silty sand, clayey silt, and silty clay, which was overlain by glacial clay. The finding depths were 6.8 and 4.2 m respectively. The described part of the clay sequence has been deposited close to the ice front, thus proving that *Mytilus* has inhabited the area in the very beginning of deglaciation.

The shells have been radiocarbon dated.

a. Funneshult

8 B Vänersborg SO 3f

In a narrow east-west-orientated valley shell-bearing sand is found about 90 m above sea level, some 600 m east to ESE of Funneshult. Small, shallow, and totally overgrown pits in the wood speak of diggings in the old days. The remains consist mainly of small shell fragments, which occur in some tens of cm at a depth 50-60 cm below surface. The sand is about one metre thick and is underlain by glacial clay. Shells have been radiocarbon determined.

b. St. Lärsebovattnet

8 B Vänersborg SO 3g

In the vicinity of Lake St. Lärsebovattnet, sandy and clayey shell layers dominated by *Mytilus* fragments have been recorded (Sidenbladh 1870, p. 88). The finding-places are situated about 110 m above sea level. According to Sidenbladh's field logbook of the geological map sheet, the pulverized, violet-coloured layer contained no perceivable species.

c. Smedstakan

8 B Vänersborg SO 3h

On the gentle slope southeast of Smedstakan a shell layer dominated by *Mya* has been recorded (Sidenbladh 1870, p. 88; Hägg 1952, p. 144). According to the field logbook of the geological map sheet, shells of *Mya truncata* dominated, fragments of *Mytilus* and *Balanus* were also common. Individual shells of *Saxicava* and *Buccinum undatum* were observed.

During the mapping of the geological map sheet Vänersborg SO (Fredén 1984, Fig. 27), the following stratigraphy was recorded:

- 0 — 60 cm Gravelly sand.
- 60 — 90 cm Shell-bearing sand.
- 90 — 120 cm Sand underlain by glacial clay.

The locality is situated about 105 m above sea level in a small valley (crevasse) close to the eastern slope of a bedrock hill reaching almost 120 m above sea level.

In small basins 1400 and 1550 m respectively ESE of Smedstakan (north of Garnviken), 5–10 cm thick shell lenses have been observed at a depth of 50 cm in glacial clay. Both localities are situated at about 110 m above sea level close to bedrock hills.

The faunal composition of all three localities are shown in Fig. 35. Radiocarbon determination has been carried out.

d. Hjärtum

8 B Vänersborg SO 1g

The small village of Hjärtum is situated at the north end of an about 60 m high and 1500 m long northeast–southwesterly moraine ridge on the west side of the Göta River valley. The direction of the ridge is the same as the main ice direction. The distal part of the ridge is connected with bedrock slightly more than 100 m above sea level. In the former large exposure on the slope west of the church, shells were observed in a 4–5 m thick glacial clay layer (Hillefors 1969, p. 169) overlain by two metres of wave-washed sand. According to Hillefors (op.cit.) the clay had a poorly-defined varve structure, a phenomenon which is common in the lowermost glacial clays of western Sweden. The ground surface of the ridge at the finding-place lies at about 85 m above sea level which is 40–50 m below the highest shoreline. The shells have been radiocarbon age determined.

e. Eldmörjan

8 C Lidköping SV 4a

At the outlet of Lake Eldmörjan, 96 m above sea level, a minor shell layer in clay (according to notification by Fries) was observed during the construction work involved in lowering the lake surface (Sidenbladh 1870, p. 88; Hägg 1928, pp. 3–5; 1952, p. 135). The locality is situated on the northwest edge of the table hill Hunneberg at the mouth of a depression running into the pronounced valley between Halleberg and Hunneberg. According to Hägg no other locality is known in the interior with such a great number of species; cf. locality k. Ålanda below. Shells are common in the clayey substratum of the lake. Shells of *Mytilus* are recorded in nearby lake basins, see description to Hunneberg above.

f. Åker

8 B Vänersborg SO 3i

During the construction of Trollhätte canal shells were collected by Hisinger west of the old, lowermost lock (Sidenbladh 1870, p. 84, 88). The shell collection of Hisinger has been reviewed by Hägg (1925).

The landscape is dominated by the steep-sided valley of the Göta River. The surface of the finding-place lies about 15 m above sea level.

g. Heden

8 B Vänersborg SO 2h

The locality, previously called Torpa, is situated about 500 m NNE of Heden (Lindström 1887, p. 58; Hägg 1952, p. 145). Today shell-bearing sandy layers about 50 cm thick are found at a depth of ca 2 m in a sandy-silty cliff along the rivulet southeast of the Kullhagen property. The surface level of the present finding-place is about 50 m above sea level. The shell-bearing layers are dominated by small shell fragments.

On the east clay slope of the Göta river, about 1 km WSW of Heden (Kalvhålan), a sandy shell-bearing layer, 2--5 cm thick, was exposed through a small landslide in December 1977. The layer, in which even gravelly particles were observed, was situated in clay about 2 m below surface, some 20 m above sea level. The thickness of the clay is estimated at slightly more than 5 m.

The faunal composition of both localities is listed in Fig. 35. Shells from the exposed layer at Göta river have been radio-carbon determined.

h. Ramsebacken

8 C Lidköping 1a

In 1972, when the Vislaån river was cleaned out and deepened, a large number of molluscs and barnacles were found about 600 m southwest of Ramsebacken. The finds were made in clay about 75 cm below the bottom of the river, which corresponds to some 5 m below the surrounding surface 75 m above sea level. The clayey shell layers are assumed to have been some tens of centimetres thick. The thickness and frequency of shells diminished from a

small bedrock hill northwards along a distance of about 100 m. The locality is situated at the northern end of a quite narrow part of the Vislaån river. The landscape has a low relief.

The shells were collected by Mr Olle Ludvigsson at Sjuntorp. Shells have been radiocarbon determined.

i. Kullen

8 B Vänersborg SO 0j

In the narrowest part of the small east—westerly valley 450 m ENE of Kullen, two 10—30 cm thick clayey shell layers were found in a cleaned-out ditch during the geological surveying (Fredén 1984). The surface of the valley lies about 70 m above sea level and is bordered to the north and south by 10—15 m higher, bedrock hills, The ditch runs in the centre of the valley.

Both shell layers were embedded in glacial clay at a depth of slightly more than one metre. The sequence along the ditch was moderately disturbed by human activity, which means that no exact information of the distribution pattern can be given. The shell layers may be characterized as limited zones of shell-bearing clay within the clay. Most of the shells were found individually, some complete bivalves occurred, and the strain of sand and gravel particles was very low. There was a horizontal interval of about 10 m, and there seemed to be a vertical difference of some tens of centimetres between the shell layers. The faunal composition of the shell layers differed.

The western shell layer was situated in the narrowest part of the valley (unconnected with firm ground) where the clay sequence gradually decreases to about one metre. The visible horizontal distribution was 7 m and the shell layer was dominated by thick shells of *Hiatella arctica uddevallensis*. Transitional forms to the less common, thinner and more elongated shells of *Hiatella arctica* occurred.

The eastern shell layer, which had a horizontal length of about 10 m, was dominated by large, 3.0—3.6 cm, and thick shells of *Astarte borealis*. Even complete specimens occurred. Shells of *Astarte elliptica* were moderately common. In general, shells of *Astarte* are quite common in the area northwest of Lake Vanderyds-vattnet (west of Lagmansered, Fig. 32). In addition to the *Astarte* species, a few shells of *Mya truncata*, a few fragments of

Mytilus edulis, some 7 cm high side-plates of *Balanus hammeri*, and fragments of side-plates of *Balanus crenatus* were recorded.

Two samples were radiocarbon dated, see Fig. 36.

j. Hålan

7 B Göteborg NO 9h

During the surveying of the Quaternary map Göteborg NO (Fredén 1986) one shell-bank and small remains of another were found in the vicinity of Hålan (Brännefjäll). Both localities are situated about 50 m above sea level.

The shell-bank was deposited 350 m NNW of Hålan on the east side of a narrow valley running almost north-south. The water divide between two minor drainage systems lies just north of the shell-bank. The valley is surrounded by a bare bedrock topography, which reaches 75 m above sea level a short distance east of the shell deposit.

The shell-bank has an estimated thickness of a couple of metres and forms a topographical feature of its own. As the deposit has not been used for some years no vertical walls are accessible, thus the stratigraphy is unknown. The shells are mixed with a large amount of pebbles and particles of sand and gravel. The original volume is estimated at about 2 000 cubic metres, of which about one-half still exists.

Small remains of the other deposit are found about 500 m ESE Hålan at the southern slope of a minor valley occupied by a small stream. The original volume of the deposit was smaller than that of the shell-bank described above.

In the visible parts of the shell-bank the fauna was dominated by *Hiatella arctica*. Side-plates of *Balanus hammeri* up to 8.5 cm high were common, as were shells of *Astarte borealis*, *Astarte elliptica*, *Hiatella arctica uddevallensis*, *Mya truncata*, and *Mya truncata uddevallensis*. One shell of *Macoma calcarea*, fragmented shells of *Mytilus edulis*, and side-plates of *Balanus crenatus* were observed. No gastropods were seen.

Samples of four species were radiocarbon dated.

k. Ålanda

7 C Borås NV 6a

Along the east side of the partly narrow and steep-sided valley between the lakes of Anten (66 m above sea level) and Mjörn (58 m above sea level), three localities of shell layers in sand and clay were recorded during the geological surveying in the 1880's (Lindström 1883, pp. 53—54). From north to south they are:

Ålanda, north of Åsjön (Hägg 1952, p. 145).

Brobacka, three observations (Ibid., pp. 134—135).

Näset, close to Mjörn (Ibid., pp. 143—144).

During the zoological investigations of Lake Anten in 1911, shells of 13 species were found in bottom layers at a water depth of one metre (Odhner 1927, p. 96).

The number of recorded species in the area is not as great as in locality e, but the distance to the present sea shore is longer.

l. Torp

7 C Borås NV 6b

Hoberg

7 C Borås NV 7e

S.Härene

7 C Borås NV 8e

According to the field log of the map sheet Vårgårda (Fries 1866), shells of *Mytilus edulis* and *Yoldia arctica* were found in clay at the former Torp brickyard in the Säreån valley. The surface of the valley floor at Torp is about 70 m above sea level.

Shells of *Yoldia* are also recorded at Hoberg (Hogberg), 2 km west of Vårgårda. The finding-place is situated about 90 m above sea level where the river Säreån makes a "U-turn", see Fig. 32.

According to field notes by Fries, a small lense of shell fragments was observed in an esker close to the S. Härene (Härene) church, 7 km north of Vårgårda. Only fragments of *Mytilus edulis* were identified. The finding-place was probably within the glaciofluvial deposit at 105—110 m above sea level, 5 km north of Vårgårda in a tributary valley to the Nossan river valley. Obviously the find was made in clay on the slope of the deposit.

m. Borydsjön

8 B Vänersborg Oh

In the small north-south valley occupied by the lake Borydsjön, 56.5 m above sea level, shells have been collected in 1979 in the cleared-out clays from a recently made deepening of the outlet. The valley is narrow and pronounced in a hilly area.

Shells have also been observed about 1500 m further north in the same valley.

For radiocarbon age determination, see Fig. 36.

Faunal composition

The faunal composition of the described localities, are shown in Fig. 35. In addition to the listed species, individual shells of *Portlandia lenticula* are known in glacial clay (Mohrén & Larsson 1974, pp. 72—74). Except for *Astarte montagui* and *Lora pyramidalis* all the species in Fig. 35 are known in the Uddevalla region. The recorded find in Lake Anten (locality k) of *Lora pyramidalis* is listed as *Bela pyramidalis*. Recent finds of *Hiatella* are included in the older designation *Saxicava*.

Of the 35 species and varieties listed, two thirds have an arctic--boreal distribution. None of these molluscs have a preference for boreal--lusitanian conditions.

Radiocarbon measurements

In addition to the radiocarbon age determinations listed on Fig. 36, comparisons are made to completed radiocarbon measurements (corrected by -250 years) of finds of marine vertebrates within the area. Location of the concerned finding-places are shown on Fig. 32.

SPECIES	LOCALITIES												
	a	b	c	d	e	f	g	h	i	j	k	l	m
Gastropoda													
<i>Amauropsis islandica</i>						x							
<i>Beringius turtoni</i>						x							
<i>Buccinum groenlandicum</i>			x			x					x		
<i>Buccinum undatum</i>			x		x	x	x				x		
<i>Fusus despectus</i>							x				x		
<i>Littorina littorea</i>											x		
<i>Littorina rudis</i>											x		
<i>Lora pyramidalis</i>											x		
<i>Lunatia groenlandica</i>											x		
<i>Natica clausa</i>	x					x	x				x		
<i>Neptunea antiqua</i>						x							
<i>Puncturella noachina</i>							x				x		
<i>Sipho islandica</i>						x							
<i>Sipho togatus</i>						x							
<i>Trophon clathratus</i>						x	x						
<i>Trophon clathratus major</i>					x						x		
<i>Velutina velutina</i>							x						
Lamellibranchia													
<i>Astarte borealis</i>			x		x		x	x	x	x	x		
<i>Astarte borealis withami</i>					x						x		
<i>Astarte elliptica</i>			x		x	x	x		x	x	x		x
<i>Astarte montagui</i>			x		x	x	x				x		
<i>Astarte montagui striata</i>					x						x		
<i>Astarte sulcata</i>						x							
<i>Leda minuta</i>				x									
<i>Leda pernula costigera</i>						x							
<i>Macoma calcarea</i>			x		x		x			x			x
<i>Mya truncata</i>	x		x	x	x	x	x	x	x	x			x
<i>Mytilus edulis</i>	x	x	x	x	x	x	x		x	x	x	x	
<i>Pecten islandicus</i>					x	x							
<i>Portlandia arctica</i>						x						x	
<i>Saxicava arctica</i>			x	x	x	x	x	x	x	x	x		x
<i>Saxicava arctica uddevallensis</i>	x		x			x		x	x	x	x		x
Crustacea													
<i>Balanus</i> sp.												x	
<i>Balanus balanus</i>					x	x	x				x		
<i>Balanus crenatus</i>			x				x		x	x	x		
<i>Balanus hammeri</i>					x	x	x		x	x	x		x

Fig. 35. Invertebrates recorded at described shell localities south of Lake Vänern.

Shells older than 11 000 years

Hunneberg. Björck & Digerfeldt (1982a) have sampled shells of *Mytilus* in lake basins about 120 m above sea level south of Eldmörjan, locality e. The obtained radiocarbon ages were 11 700–11 500 years (Lu 1903–04, 1906–08) with a correction for the reservoir effect of -400 years. The shells of *Mytilus* are thus the

Lab. no. St	LOCALITY	Lat. N	Long. E	SPECIES	Frac- tion	Age in years B.P. ± stat. err.	δ C ¹³ ‰ PDB	Apparent age of sea water	Total corr. in years	Corrected ages	
										B.P.	B.C.
5636	ELDMORJAN	58° 21'	12° 26'	<i>Hiatella</i>	1	11 145 ± 260	+0.2	-400	+10	11 155 ± 260	9 205 ± 260
4900	N. HÅLAN	58° 6'	12° 13'	<i>Hiatella arctica</i>	1	9 935 ± 150			-25	9 910 ± 150	7 960 ± 150
4901					2	10 125 ± 150	-0.7	-400	-5	10 120 ± 150	8 170 ± 150
4904					1	9 970 ± 125		0	9 970 ± 125	8 020 ± 125	
4905				2	9 940 ± 150		-30	9 910 ± 150	7 960 ± 150		
4906				3	10 230 ± 135	-0.7	-400	-20	10 210 ± 135	8 260 ± 135	
4902				<i>Balanus hammeri</i>	1	10 015 ± 160		-15	10 000 ± 160	8 050 ± 160	
4903					2	10 200 ± 230	-2.7	-400	0	10 150 ± 230	8 200 ± 230
4907				<i>Mya truncata</i>	1	10 570 ± 150		+5	10 575 ± 150	8 625 ± 150	
4908	2	10 815 ± 140	-1.3		-400	-45	10 770 ± 140	8 820 ± 140			
4909	E. HÅLAN	58° 6'	12° 13'	<i>Hiatella</i>	1	10 100 ± 155			-5	10 095 ± 155	8 145 ± 155
4910					2	10 070 ± 150	-1.3	-400	-10	10 060 ± 150	8 110 ± 150
5369	KULLEN	58° 10'	12° 21'	<i>Hiatella</i>	2	10 620 ± 150			0	10 620 ± 150	8 670 ± 150
5370					3	10 810 ± 140	-0.9	-400	0	10 810 ± 140	8 860 ± 140
5371					<i>Astarte</i>	1	10 605 ± 160		+15	10 620 ± 160	8 670 ± 160
5372				2		10 345 ± 115		+20	10 365 ± 115	8 415 ± 115	
5373				3		10 310 ± 110	+0.3	-400	+15	10 325 ± 110	8 375 ± 110
7266	SMEDSTAKAN	58° 17'	12° 9'	<i>Molluscs</i>	1	10 960 ± 125	0.0	-400	+15	10 975 ± 125	9 025 ± 125
7267					2	11 095 ± 180	+0.1	-400	+15	11 110 ± 180	9 160 ± 180
7268					3	11 210 ± 130	+0.1	-400	+15	11 225 ± 130	9 275 ± 130
7316	SE SMEDSTAKAN	58° 17'	12° 9'	<i>Molluscs</i>	1	10 715 ± 125	-0.4	-400	+10	10 725 ± 125	8 775 ± 125
7317					2	11 405 ± 130	-0.7	-400	0	11 405 ± 130	9 455 ± 130
7237	FUNNESHULT	58° 15'	12° 0'	<i>Molluscs</i>	1	11 270 ± 135	-1.7	-400	-20	11 250 ± 135	9 300 ± 135
7238					2	11 320 ± 185	-1.2	-400	-10	11 310 ± 185	9 360 ± 185
7239					3	11 445 ± 135	-0.9	-400	-5	11 440 ± 135	9 490 ± 135
7240					4	11 515 ± 140	-0.2	-400	+10	11 525 ± 140	9 575 ± 140
7241					5	11 750 ± 330	-16.3	-400	-260	11 490 ± 330	9 540 ± 330
6875	RAMSEBACKEN	58° 12'	12° 26'	<i>Mya truncata</i>	1	9 970 ± 125	+0.7	-400	+25	9 995 ± 125	8 045 ± 125
6876					2	10 485 ± 125	+1.5	-400	+35	10 520 ± 125	8 570 ± 125
7036				<i>Astarte</i>	1	10 180 ± 200	+0.7	-400	+25	10 205 ± 200	8 255 ± 200
7037					2	10 540 ± 120	+1.2	-400	+30	10 570 ± 120	8 620 ± 120
7040					<i>Hiatella</i>	1	10 845 ± 125	+1.1	-400	+35	10 880 ± 125
7041				2		11 070 ± 125	+2.0	-400	+45	11 115 ± 125	9 165 ± 125
7042				3		11 075 ± 230	-3.2	-400	-45	11 030 ± 230	9 080 ± 230
6820	HEDEN	58° 12'	12° 10'	<i>Molluscs</i>	1	10 155 ± 170	+1.0	-400	+30	10 185 ± 170	8 235 ± 170
6821					2	9 955 ± 120	+5.2	-400	+100	10 055 ± 120	8 105 ± 120
7121	BORYSSJÖN	58° 08'	12° 11'	<i>Molluscs</i>	1	10 675 ± 125	+0.6	-400	+30	10 700 ± 125	8 850 ± 125
7122					2	10 535 ± 120	+0.7	-400	+25	10 560 ± 120	8 610 ± 120
7123					3	10 835 ± 105	+0.7	-400	+25	10 860 ± 105	8 910 ± 105
7124					4	10 785 ± 210	+1.0	-400	+30	10 815 ± 210	8 865 ± 210

Fig. 36. Radiocarbon age determinations of shells sampled south of Lake Vänern.

oldest known finds of marine animals in the southern part of the Vänern basin.

a. Funneshult. Shell-fragments of *Mytilus edulis*, *Hiatella arctica*, *Mya truncata* and *Natica clausa* were dated. A mean value of the determinations carried out gives an age of about 11 400±185 years.

A similar radiocarbon age, 11 590±180, was obtained from a skeletal part of a bearded seal, found at Lagmansered east of the Göta river valley, see Fig. 32 (Fredén 1975, pp. 14, 39). Shells of *Mya truncata* and *Balanus hammeri* were recorded at the same locality.

d. Hjärtum. In the clay at the Hjärtum deposit thick shells of *Mya truncata* were collected by Hillefors (1969, p. 271) for measurement at the radiocarbon laboratory of Lund University. The mean value of two fractions (Lu 199, 200) is 11 165±108 years (Håkansson 1975).

About 7.5 km southwest of Hjärtum at Lake Rishagerödvatten (97.3 m above sea level) a skeletal part of a Greenland right whale yielded a ^{14}C age of 11 200±155 years (Fredén 1975, pp. 14, 21--22). The find was made in clay at a depth of two metres. A skeletal part of the same species found at Essunga showed just about the same radiocarbon age, 11 245±100 years (op.cit., pp. 14, 22). Shells of *Astarte corrugata*, *Mya truncata*, *Saxicava arctica* and *Tellina lata* were found together with the skeletal parts.

e. Eldmörjan. Accessible duplicate shells of *Hiatella* (labelled *Saxicava rugosa*) were radiocarbon-dated. The shells, which were fairly thin, had been kept at the Museum of the Geological Survey. Only one fraction was carried out due to the limited amount of usable material. The age shown is not corrected with respect to storage effect.

c. Smedstakan. Shell fragments of *Hiatella*, *Mya* and *Mytilus* were sampled for radiocarbon dating.

At the locality southeast of Smedstakan, called Garnviken, shells and large shell fragments of *Hiatella arctica*, *Mya truncata*, and *Balanus crenatus* have been dated. Apparently the shells were contaminated. The two dated fractions do not overlap. The expected age would be about the same as for Smedstakan.

h. Ramsebacken. An assemblage of *Hiatella* (*Saxicava*) inhabited a small bedrock hill about 11 000 years ago. Obviously the place had good requirements for molluscs as it was later inhabited by other species, see below.

Shells between 11 000 and 10 500 years

i. Kullen. Mostly thick shells of *Hiatella* collected in the western shell layer. Additional dating below.

j. Hålan. Moderately thick shells of *Mya truncata*, collected superficially on the shell-bank; further radiocarbon determinations below.

m. Borydsjön. Thick shells of *Hiatella arctica uddevallensis* and *Mya truncata* were sampled for radiocarbon age determination. The mean value of the carried out datings is 10 735±140 years.

Shells between 10 500 and 10 000 years

i. Kullen. Relatively thick, even complete, shells of *Astarte borealis* and *Astarte elliptica* were collected in the eastern shell layer, which was vertically (vaguely) separated from the western shell layer by some tens of centimetres of clay. The difference in age between the shell layers, which also differed in the faunal composition, speaks for a low rate of sedimentation of clay particles in the valley during the span of about 500 years.

h. Ramsebacken. Shells of *Astarte* and *Mya* are about 800 years younger than shells of *Hiatella* (*Saxicava*), see above. Obviously the place has been inhabited at different times. It is, however, risky to draw any far-reaching conclusions as the dated shells have been collected in secondary position.

g. Heden. Shells of *Astarte elliptica*, *Hiatella arctica* (small ones) and shell fragments of *Mytilus edulis* were sampled for radiocarbon determination.

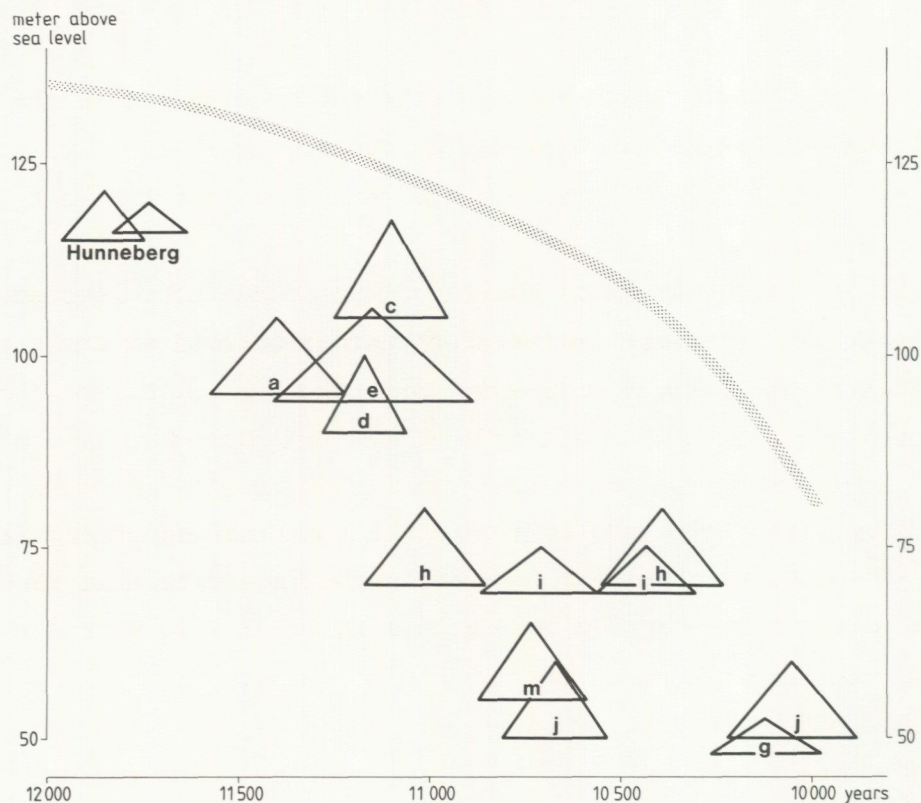


Fig. 37. Late Weichselian shore displacement at Hunneberg (Björck & Digerfeldt 1982b). The triangles represent radiocarbon age determined samples from described localities south of Lake Vänern. The base of the triangle is equal to the age determination, including margin of error. The height of the triangle represents the maximum vertical living space of the dated molluscs and barnacles.

j. Hålan. Shells of three species were collected surficially on the shell-bank. Each species was taken in a limited area of about one square metre and with a sampling depth of less than 20 cm. The obtained ages, and the age determination of *Hiatella* shells and shell fragments east of Hålan, were almost identical, slightly more than 10 000 years B.P.

Since it was possible, efforts were made to sample typical shells of *Hiatella arctica* and *Hiatella arctica uddevallensis* separately. The expected difference in age failed to appear.

The obtained age of the barnacle side-plates is interesting. The maximum water depth was about 70 m when the area was deglaciated more than one thousand years earlier. Thus, when *Balanus hammeri* inhabited the area, the water depth was much less than the species requires today.

Summary of shell deposits south of Lake Vänern

Of the 12 localities with an arctic to arctic-boreal fauna composition of more than two recorded species, six are located between 70 and 110 m, five between 50 and 70 m and one less than 50 m above sea level.

All deposits with a faunal composition of more than five species are situated in the area east of Göta River but west of the watershed between Göta River and Lake Vänern. Except for the occurrences along the east side of the pronounced valley between the lakes of Anten and Mjörn, the shell deposits are thus found in the area of fairly level landscape southwest of Hunneberg, where the ground surface has a low gradient towards the Göta River. At the deglaciation the maximum water depth in the Göta River valley has been about 200 m.

Palaeohydrographically speaking, the deposits are found in the neighbourhood of the fjord-like bay of Göta River valley, which was occupied by a water body with relatively high salinity. It must be noted that the main deposits are found away — east — from the central valley. Thus, the ecological conditions for the mollusc fauna were most favourable on the inclined "sea side" of the former Vänern bay area.

The first mollusc inhabitants were *Portlandia arctica* and *Mytilus edulis*. Individual shells of both species are recorded from the southernmost area about 10 m below the highest shoreline. Shells of *Mytilus* have also been found in the lowest part of glacial clay sequences.

Radiocarbon age determinations imply that molluscs and barnacles existed continuously or on and off after deglaciation up to about 10 000 years ago, see Fig. 37. The oldest age determination of shells in the area has been obtained on shells from Hunneberg sampled by Björck & Digerfeldt. The age of about 11 800 years is an important contribution to deglaciation chronology of the Trollhättan terminal moraine.

At three localities hydrographical conditions have been temporarily favourable to different faunas (localities h, i and j). Up to slightly more than 10 000 years ago a fauna existed which produced shells abundant enough for the development of a shell-bank, the most interior one (locality j) in western Sweden.

The arctic--boreal fauna disappeared from the area about 10 000 years ago.

SHELL DEPOSITIS IN THE SOUTHEASTERN PART OF THE VÄNERN BASIN

West of the Cambro--Silurian flat-topped Billingen hill there is an extensive flatland, the Västgöta plains, dominated by sand and clay. The major part of the area lies less than 100 m above sea level, Fig. 38. The highest shoreline lies about 120 m above sea level in the southern part and ca 130 m above sea level in the north (Strömberg 1974, 1977).

To the north the plains are bordered by pronounced moraine ridges formed during the last portion of the Younger Dryas Chronozone. The Levene terminal deposits in the southwest are less pronounced and in places concealed by glacial clay. Almost perpendicular to these Quaternary formations, exposed Archaean bedrock runs straight through the plains separating them into two parts. Both of them are marked by gullies and landslides along almost every watercourse. Clay thickness of 20--30 m is recorded along fault zones.

Saline ground water is not uncommon in the area (Carlsson 1974).

Description of localities

Fig. 38 shows all known localities of molluscs and barnacles, mostly occasional shells or shell fragments (Hägg 1928; Mohrén & Larsson 1974; Munthe 1901, 1903; Nordwall 1924). In the Lidan valley the finds have been recorded in the lowest part of the glacial clay during well diggings and drillings, and through erosional processes such as landslides. Generally the shells are found in clay at depths between 10 and 20 m.

Two localities command special attention. In a gravel pit at Bromaden several species were recorded in a clay sequence about 4 m thick, overlain by 2 m of clayey gravel with shell fragments and 5 m of sand and gravel with shell fragments and 5 m of sand

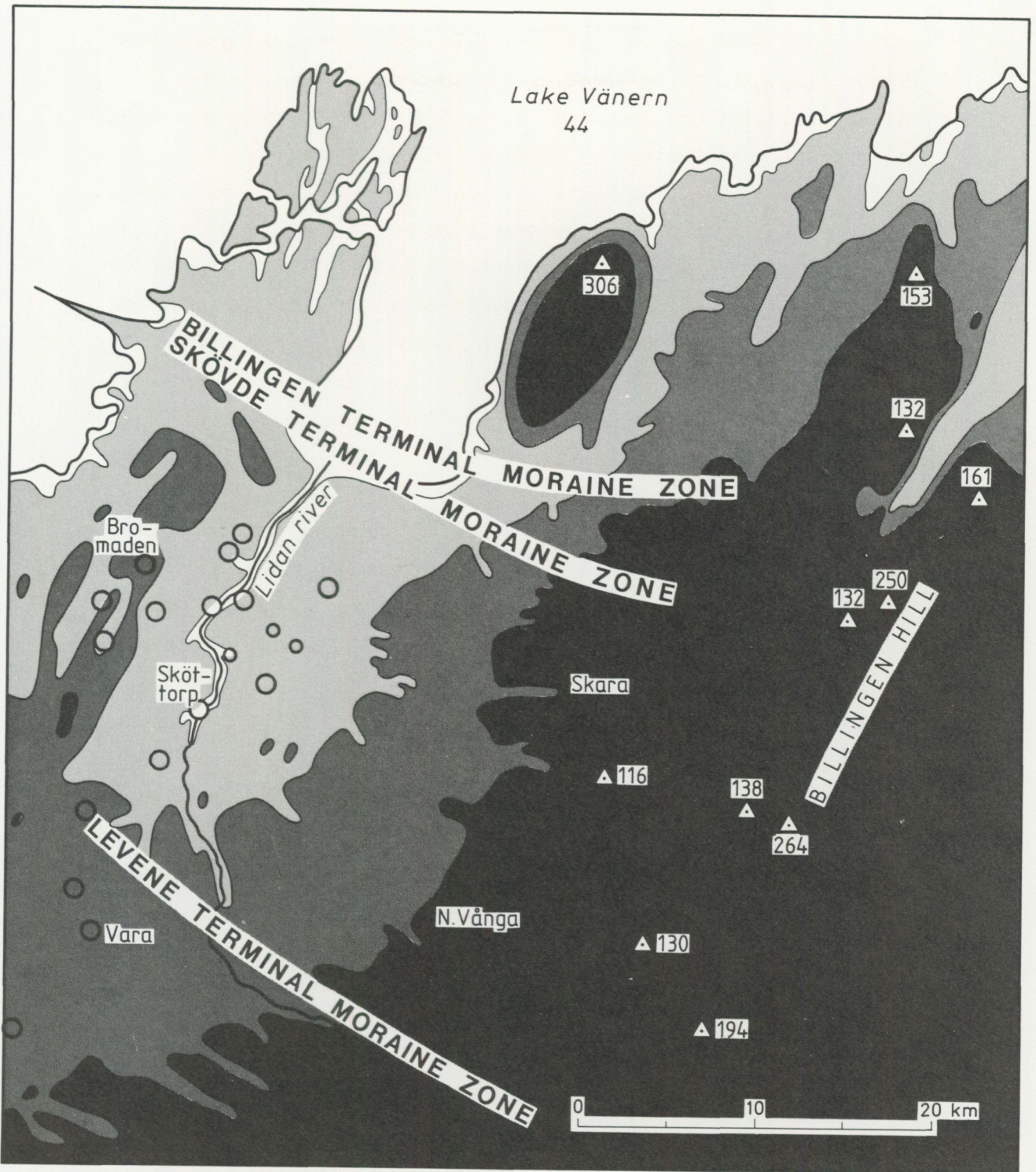


Fig. 38. Orographic map of the southeastern part of the Vänern basin. Circles indicate finding localities of mollusc shells. Small circle for one species, big circle for more than one species.

The map is based on the topographical map sheets Lidköping NO, SO, Skara NV, SV.

and gravel (Mohrén & Larsson 1974, pp. 63—64). According to Mohrén (op.cit.) the stratigraphy suggests an oscillatory phase during deglaciation. Bromaden is located 80—85 m above sea level in an area characterized by exposed Archaean bedrock.

During culvert work in 1977 in the rivulet Dybäcken, about 1500 m southwest of Vara railway station, a shell-bearing layer in clay was observed at a depth of 4 m below surface, which lies ca 75 m above sea level. The thickness of the lense is unknown, as is the thickness of the clay.

Faunal composition

Complete bivalves, shells or shell fragments of *Portlandia arctica* are found in all known localities. In the Lidan valley occasional shells of *Astarte borealis withami*, *Astarte banksii*, *Tellina calcarea*, and fragments of *Portlandia lenticula* have been recorded (Munthe 1901).

Among the abundant shells at the Vara locality, Mr Lars Hasselgren collected lots of specimens of *Astarte borealis*, which was apparently the dominating species. Shells of *Hiatella arctica* were relatively thin. Side plates of *Balanus hammeri* had a maximum height of 55 mm.

At Kocklanda, 7 km WSW of Vara church, many shells of *Astarte borealis* have been found in clay masses from a 5 m deep excavation. Periostracum was almost intact. Individual shells of *Astarte montagui* and *Macoma calcarea* showed traces of erosion.

In the clay at Bromaden several species were observed in the fresh clay. Exposed to the air, the shell fragments dried and became powdery. In addition to the above mentioned species Mohrén & Larsson (p. 64) noticed shells or shell fragments of *Natica* cfr *clausa*, *Neptunea* (?), *Trophon* sp., *Anomia squamula*, *Cyprina islandica*, *Mya truncata*, *Mytilus*, *Saxicava*, and *Balanus* cfr *hammeri*. Most common were shells of *Mya* and *Saxicava*. The presence of *Cyprina islandica* is somewhat remarkable, as the species is a representative of relatively milder conditions than those expected relatively close to an icefront.

It may be noted that in the lowest part of the clay in the Lidan Valley, nodules are common, and occasionally the very

variable shapes may be confusing. Very likely this is the explanation of the observed lobster claw in the landslide at Sköttorp (Fredén 1975, pp. 43—44). Of the collected shells from the landslide, a complete bivalve of *Portlandia arctica* found in marl can be seen in the Järpås Old Homestead Museum.

At a small pond construction 700 m ESE Kinneved, about 5 km NNW of Skara cathedral, an individual shell of *Astarte borealis* has been sampled by Dr Sven Kilander, Skara. The property of Kinneved is situated about 3 km north of the pronounced moraine at Skaraberg, which forms a part of the Skövde terminal moraine.

At drillings 500 m NNE of Skara cathedral shell fragments of *Hiatella arctica* were recorded in clay of a depth of 8—9 m, which is about 1 m above the underlying till (Magnusson 1986).

Radiocarbon measurements

Shells of *Astarte borealis* from Vara have been radiocarbon age determined.

St 7682 fraction 1 10 500±90

St 7683 fraction 2 10 540±230

After corrections for $\delta^{13}\text{C}$ (+0.8 and +0.1 resp.) and the apparent age of sea water (-400 years):

St 7682 10 525±90 B.P. 8 575±90 B.C.

St 7683 10 535±230 B.P. 8 585±230 B.C.

Shell fragments of *Hiatella* from a drilling in the valley 500 m NNE of Skara cathedral are slightly older (Magnusson 1984).

St 9524 10 675±105 $\delta^{13}\text{C}$ +2.0

corrected age (reservoir effect -400 years)

St 9524 10 720±105 B.P. 8 770±105 B.C.

Due to the sporadic occurrence of shells, sufficient material for radiometric datings has not been available from other localities. Most finds are made in the lower portion of the glacial clay sequence. At the Sköttorp landslide site skeletal parts

of a harp seal were uncovered at a depth of about 20 m (Fredén 1975, pp. 43—44). The radiocarbon age of the seal is approximately 11 000 years (op.cit p. 14), which is an interesting age considering the established deglaciation pattern. Shells of *Portlandia arctica* were recorded at the same depth. A radiocarbon dating of a skeletal part of a Swedenborg whale found at N.Vånga showed an age about 1 000 years younger. However, the margin of error is quite high due to contamination (Fredén 1975, pp. 13—14, pp. 25—27).

Summary of shell deposits in the southern part of the Vänern basin

The frequency of specimens and species decreases gradually towards the Skövde terminal moraine. Most of all known shells and shell fragments are recorded in the lowest part of the clay sequence. One radiocarbon age determination of a harp seal at Sköttorp indicates that — at least — *Portlandia arctica* lived close to the ice front, as shells of the bivalve were found together with the skeletal parts. At some distance to the land ice habitats of mainly *Astarte borealis* and *Hiatella arctica* existed during fairly stable hydrographical conditions in Mid Younger Dryas times.

As human activity mainly deals with the upper 4—5 m and no finds are reported from e.g. clay pits of numerous old brickyards, it is obvious that the upper part of the clay lacks macro fossils. In the province of Skaraborg no less than 120 brickyards are known (Julihn 1976), of which 70 have operated in areas with marine clays.

SUBFOSSIL MARINE ANIMALS IN THE NORTHEASTERN PART OF THE VÄNERN BASIN

In this region of the Vänern basin, see Fig. 39, no finds of shells are yet known.

The deglaciation pattern of the region is very important for the understanding of the evolution of not only the Vänern basin but particularly the Baltic basin. When the ice-front finally left the northern end of Billingen hill, the Vänern basin changed from a bay of Skagerrak Sea to an inland sea between the Skagerrak and the Baltic basin. The latter was occupied by melt water from the retreating ice. The conditions must be looked upon from a hydrographical point of view.

To the east there are two broad valleys, see Fig. 39. The south one runs between the relatively flat Tidån river valley and Lake Vättern. West of Karlsborg a bedrock hill area divides the valley into two parts. The highest shoreline of the marine stage is found at Karlsborg at an altitude of 126 m above sea level (Norrman 1964, p. 31). Karlsborg is located at the shore of Lake Vättern, which with its length of 130 km, its average width of 15 km and depths between 67 and 119 m (op.cit. PL.1) has often been taken as a typical example of a rift valley or graben. As to the palaeohydrographical conditions, the location of this deep basin east of the Atlantic-Baltic water divide is very important. When the Karlsborg area was deglaciated, a connection, here called the Vättern strait (Fig. 40), was established between the Skagerrak and the Baltic basins. Almost perpendicular to the strait, the deep Vättern valley served as a trap for inflowing saline water from the west. The glacial marine clays east of Lake Vättern are varved (see concerned geological maps with descriptions), which means that the salinity has not been high enough to cause a sym-mict sedimentation.

The northeastern part of the Vänern basin is bordered to the east by the Tiveden and Kilsbergen hills, see Fig. 39. Between these two massifs of Archaen bedrock there is a relatively wide valley, see Fig. 40. The lowest spot of the Atlantic-Baltic watershed lies 105 m above sea level at Degerfors. The highest shoreline at Degerfors is about 160 m above sea level, (Fredén 1967, p. 243).

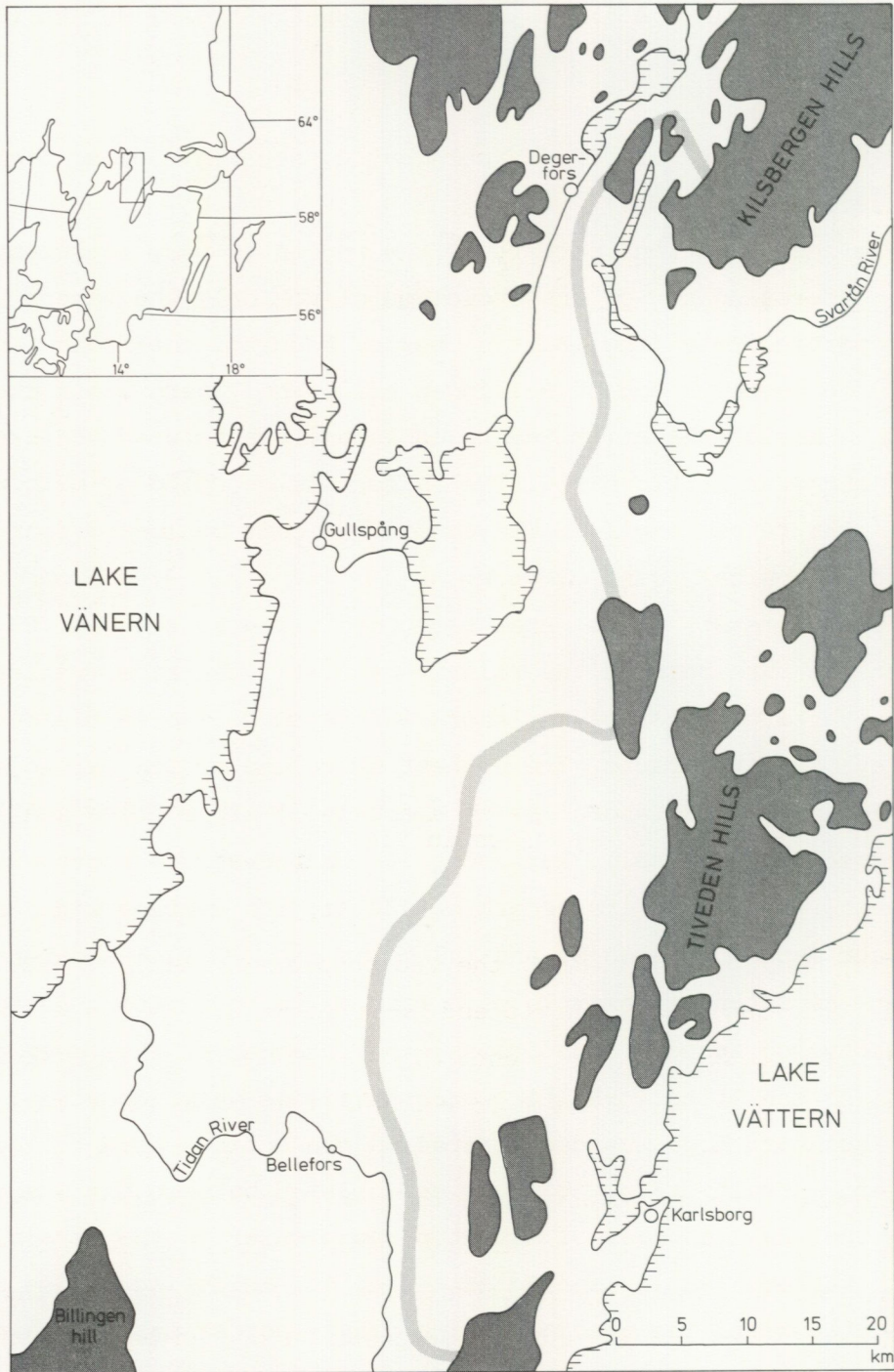


Fig. 39. Map of areas situated above the highest shoreline (dark) and of the Atlantic/Baltic watershed (light grey) in the north-eastern part of the Vänern basin.

When the area was deglaciated the lowland served as the main connection between the Baltic and Skagerrak basins. East of the water divide, diatoms with relatively great demands on brackish water have been recorded in isolation sequences from the Kilsbergen hills (M-B Florin 1977).

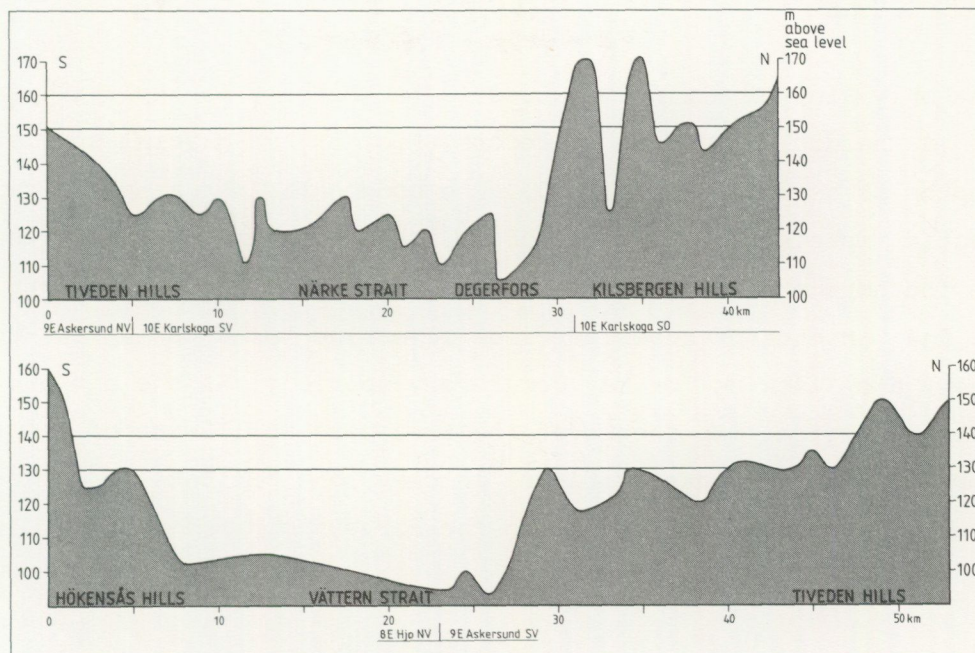


Fig. 40. Cross sections of the strait areas along the Atlantic/Baltic watershed, see Fig. 39. The two lines indicate the level of the highest shoreline in the southern (the lower line) and northern part of the section. The position of Hökensås, Tiveden and Kilsbergen hills are shown in Fig. 1.

The vast clay fields, the Vadsbo plains, north of Billingen hill, consist of non-varved and very heavy clay with a clay content of about 70 per cent. In the lowlands at Degerfors and northwards the glacial clay is reddish, otherwise it is dark grey or brownish. East of the water divide the clay is usually varved.

Through pollen analysis and radiocarbon determinations the lowest parts of the watershed area is found to have been dry about 9 000 years ago (Olsson & Fredén 1969). Through the land uplift, the bottom currents of brackish water had been obstructed by the bedrock thresholds at least a couple of hundred years earlier. As there are no erosion marks in the area corresponding to the tremendous fresh-water discharge of the Baltic basin, one may assume that the water exchange through the Närke strait had stopped some hundred years before it was laid dry. The circumstances of this event have been described by Fredén (1979, 1981, 1982) and Ericsson et al.(1982).

Faunal notes

The only find of marine megafossils in the clay is skeletal parts of a haddock, found at Bellefors (Fig. 39) in glacial clay at a depth of 5—6 m (Munthe 1910). The haddock is not a specifically arctic species. Subspecies of relict salmon has long been known in the northern and northeastern part of Lake Vänern (Ros 1966).

The absence of recorded finds of marine molluscs implies that they are lacking or may occur very sparsely. As the authors of the geological map sheets of the area were well aware of the importance of subfossil finds in clay, one can take for granted that inquiries were made during the surveying.

SHELL DEPOSITS IN THE WESTERN PART OF THE VÄNERN BASIN

Several shell deposits are known around the drainage system of Lake Stora Le, Fig. 41. Knowledge of these deposits comes almost exclusively from literature (De Geer 1902; Hägg 1923, 1947, 1952; Larsson & Sandgren 1956; Lundqvist 1958; Malmberg-Larsson 1960; Rekstad 1922 and Törnebohm 1870). The majority of localities described were known as early as in the 1890's.

Two shell deposits at Sandviken, locality e, may be characterized as shell-banks, while the other localities are fairly insignificant deposits as to their vertical and horizontal dimensions. Most of the latter occurrences are lenses of shells and shell fragments in sandy deposits. Whether some of the discontinuous shell layers are remains of leaching is not clear.

The watershed boundary between Skagerrak and Vänern runs along the Norwegian frontier to the Skövde terminal moraines where it turns eastwards to the Kroppefjäll hills, Fig. 41 and cross sections Fig. 42. The lowest part is situated at Otteid (Norway), about 115 m above sea level, which is approximately 65 m below the supposed highest shoreline. South of Otteid the lowest level of the watershed boundary varies between 140 and 160 m above sea level, which means that the maximum local water depth was about 35 m in that area. In the area of Lake Ulevattnet the lowest part of the watershed boundary lies about 140 m above sea level, which corresponds to a maximum water depth of about 20 m.

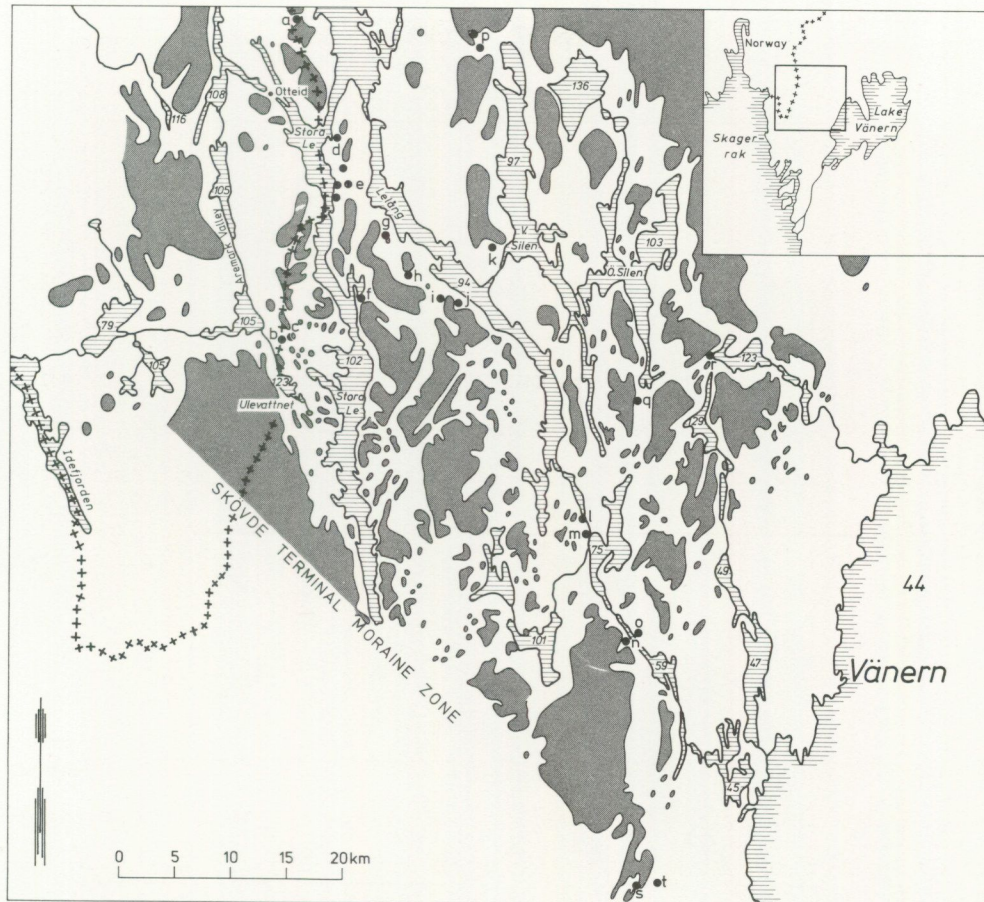


Fig. 41. Generalized map of areas situated above the highest shoreline (dark) west of Lake Vänern. Small letters according to descriptions in text. The map is based on the topographical map sheets Dals Ed NV, NO, Mellerud NV, Årjäng SV, SO, NV, NO, Åmål SV, NV, and the Norwegian map sheets 1913:II Halden, 2013:III Aspern, IV Öymark. Contour interval of the Norwegian maps is 20 m, of the Swedish maps 5 m. This means that marked areas in Norway are very generalized and that error occur. The northern part of Kroppefjäll hills, Fig. 1, lies west of localities s and t.

North of the map area in Fig. 41 there have been other connections between valleys in Norway running into Skagerrak and valleys in Sweden which are drained into the Vänern lake. These palaeohydrographical connections are of no interest for this paper, as they served as straits for a short time only and then consisted entirely of melt water.

The landscape is characterized by a great number of fissure valleys and large areas of exposed bedrock. Except in the broad and pronounced valleys, till and sediment cover is thin. Generally speaking, the morphology and distribution of Quaternary deposits resembles the conditions in the Uddevalla region.

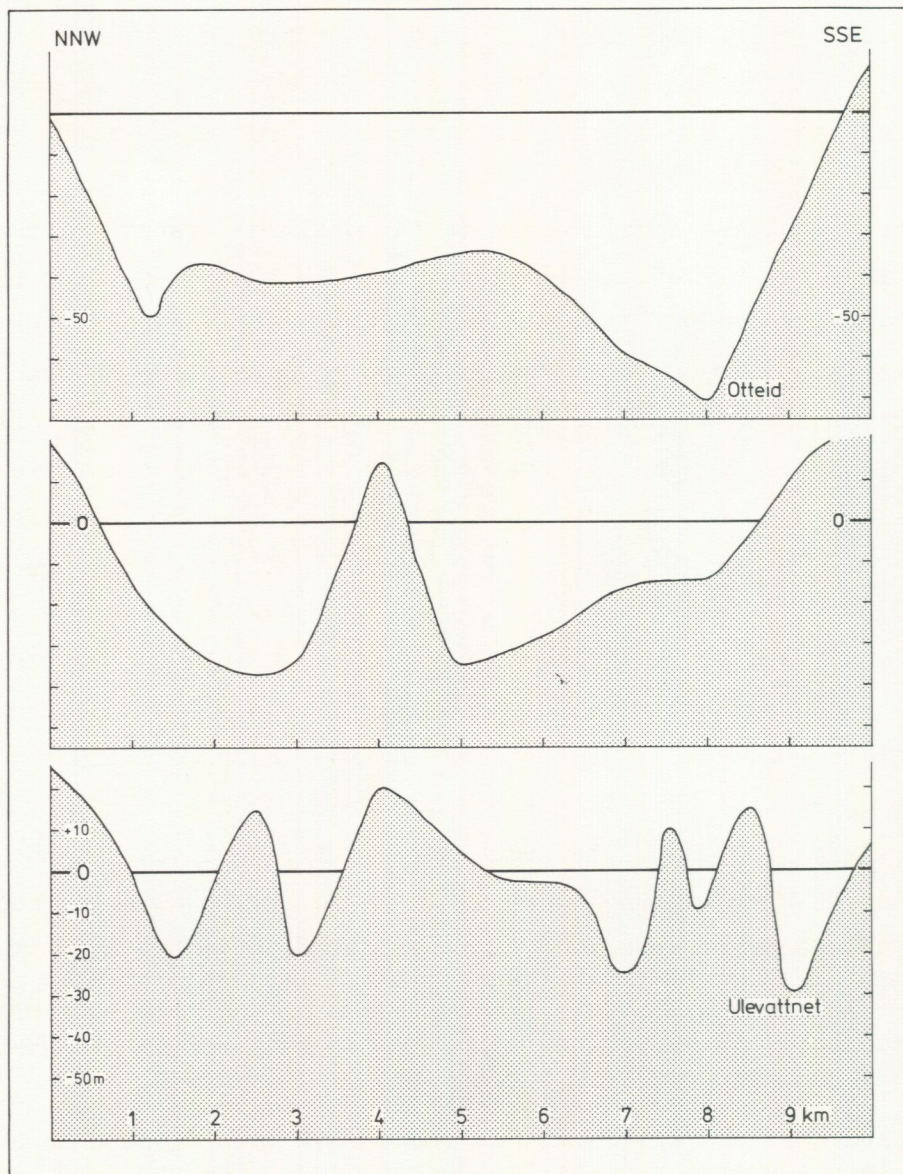


Fig. 42. Transverse sections of three parts of the watershed between Skagerrak and Lake Vänern. The middle section is situated south of the Otteid strait. The horizontal line denotes the highest shoreline, i.e., the profiles show maximum water depths.

The determination of the highest shoreline is fairly well-known in the southern part of the area (Lind 1983) but insufficiently documented in the northern part. A large number of observations have been shown in diagrams by Gillberg (1952). However, no description or detailed information is given for the stated localities. The map in Fig. 42 is based on accessible information; see locality descriptions below. As the purpose of the map is to show the palaeogeographical conditions governing the marine life, anticipated locality additions in the future

will not influence the general picture. A map of the highest shoreline in southeastern Norway was published in 1953 by Høltedahl. Small scale palaeogeographical maps of the deglaciation of southeastern Norway have been drawn by Stabell & Thiede (1985, Fig. 1).

The shoreline displacement in the drainage system of Stora Le and Aremark valley has not yet been investigated. A shoreline displacement curve for South Östfold has been constructed by Danielsen (1970). The graph was based on pollen-analysed isolation sequences from localities situated in the Ra area north of the Idefjorden bend — the southernmost part of the Norwegian/Swedish boundary. The only pollen-analysed sequence outside that area has a very particular interest for this paper. The small lake basin Mymosetjern 112 m above sea level in the Aremark valley was assumed by Danielsen (1970, p. 39, cf. p. 128) to have been isolated about 9 500 years ago. In the pollen diagram this event is recorded well before the appearance of alder pollen grains. Before the isolation occurred, fresh or nearly fresh water with a depth of about 8 m prevailed (op.cit.). The conditions at Mymosetjern are supposed to be synchronous to those at Otteid.

On the Swedish side of the watershed, one peat bog at Blomma, 6 km east of Sandviken, locality e, has been pollen-analysed (Lundqvist 1858, p. 136). Unfortunately, the peat bog, at the suitable altitude of 110 m above sea level was found to be caused by paludification, which according to the pollen diagram took place after the beginning of the rational *Alnus* pollen-grain curve.

Descriptions of localities

Most of the shell deposits are located in the pronounced valleys of the Stora Le drainage area, see Fig. 41. In order to make it easier for the reader, the localities are divided into four separate regions.



Fig. 43. View eastwards of the small valley south of Hulabäcksröset, locality a. The valley is bordered by bare bedrock. — Photo CF 1979-05-28.

Valley of Stora Le

a. Hulabäcksröset

10 B Årjäng NV 8e

The northernmost and highest-situated known shell deposit in the Vänerbassin is found in a small valley, Fig. 43, about 200 m east of the border and 500 m south of border cairn 28, Hulabäcksröset. The valley is orientated SW-NE and drains a peatland which crosses the road to Norway 750 m east of the border. In the rivulet, shells can be observed along 100 m. In patches along the rivulet shell-bearing sand, 20–30 cm thick, on glacial fluvial sand is found below a vegetation cover of 10 cm. Close to the eastern bedrock slope there are small and overgrown cuts. The maximum thickness of these tapped shell deposits has been about half a metre.

The highest shoreline in the area is supposed to lie 180–185 m above sea level (Lundqvist 1958, p. 118). The finding-place, as stated by Rekstad (1922, p. 22), lies 171 m above sea level. However, shells are found at a vertical range of about 5 m along the course of the rivulet.

One sample has been used for radiocarbon age determination.

b. Border cairn 9, Wallen

10 B Årjäng SV 2d

According to Hägg (1947, p. 472) shells are reported in the surveying logbook of the map sheet Strömstad (De Geer 1902, p. 55). The locality is not mentioned in the map description. 400 m further northeast another shell deposit is reported, see locality c.

The lowest points of the Skagerrak—Vänern watershed boundary lie at border cairn 9, at about 160 m above sea level and 5 km southeastwards at about 140 m.

c. Solum

10 B Årjäng SV 2e

According to De Geer (1902, map) shells have been found on the west side of a bedrock hillock which has a peak about 180 m above sea level. The valley floor has a lower level of 30—40 m. At Nössemark, 2.5 km westwards, De Geer (1902, p. 51) assumed the highest shoreline at 171 m above sea level.

d. Border cairn 22

10 B Årjäng NV 6e

Shells have been collected in sand at the former Käppehagen, Björkviken, about 1800 m east of border cairn 22. According to Hägg (1947, p. 473) the finding-place is situated at 156 m above sea level.

A locality called "north of Trollstevägen" probably means the road to the island of Trollön, south of border cairn 22. The locality may be identical with a minor shell deposit about 300 m northeast of Styggemyr, which is found 2 500 m southeast of border cairn 22. The finding-place lies 152 m above sea level (Malmberg-Larsson 1960).

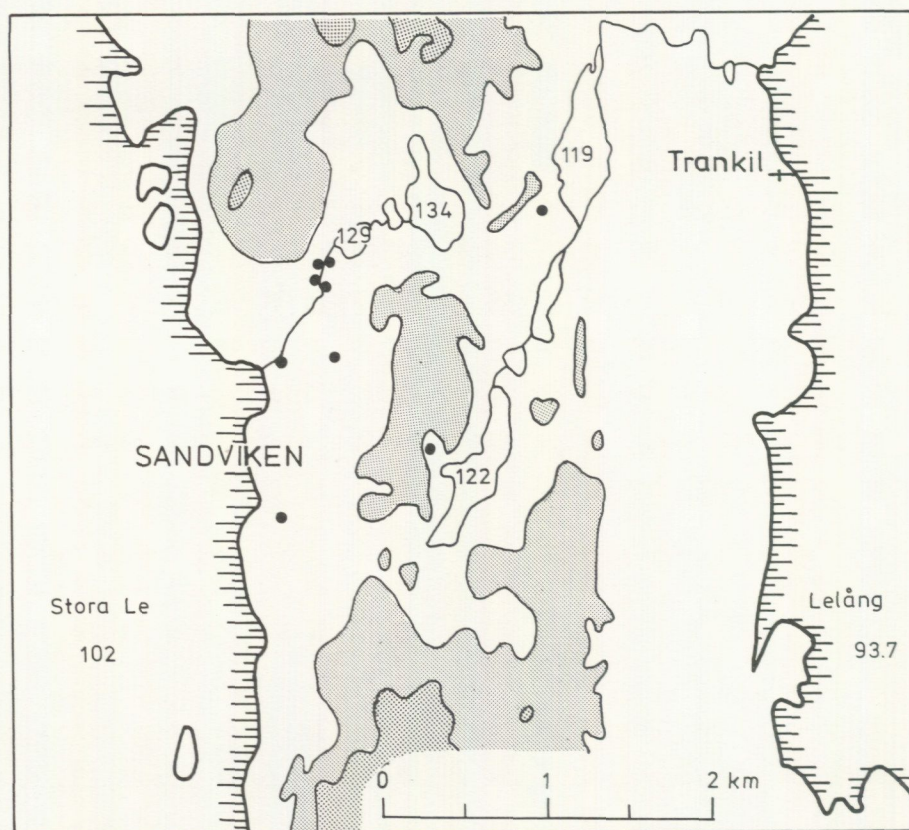


Fig. 44. Shell deposits (black dots) in the Sandviken area, locality e. Dark grey areas lie more than 175 m above sea level, grey areas 150—175 m above sea level. The map is generalized from the topographical map sheets Årjäng NV, NO.

e. Sandviken

10 B Årjäng NO 5f

In the vicinity of Sandviken, Fig. 44, several shell deposits are known (De Geer 1902, p. 55; Hägg 1947, pp. 473—474; 1952, p. 1952, p. 131; Lundqvist 1958, pp. 117—118; Malmberg-Larsson 1960).

In the upper part of the rivulet from V. Kvarntjärn, 129 m above sea level, (almost 1500 m NNE of Sandviken) shells in sand are common on both sides between 120 and 125 m above sea level. The two shell-banks of Sandviken are located on the west side; the southern one is also known as Gullingehålan. On the east side the localities are called Kvarntjärn and Kvarntjärnsbacken. The original proportions of the Sandviken shell-banks are not known.

Other Sandviken deposits are reported 500 m to the north, 500 m to the NNE, 2 000 m to the northeast (southwest of lake Holmtjärn), 800 m to the east (west of lake Hällstjärnet), and the

valley (Stenbocksdalen) about 300 m to the southwest. These localities are situated between 120 and 130 m above sea level and can be characterized as shell-bearing sands. Some observations have been made by chance; e.g. Malmberg-Larsson (1960, p. 19) found a shell-bearing sand (with ten species) at Holmtjärn thanks to the burrowing of a badger. The thickness of the shell-layer was estimated at about one metre. It seems that shells and shell-fragments are common in the area, but usually overlain by a metre or more of sand and silt.

In the peninsula between the lakes Stora Le and Lelången the lowest parts of the watershed are found about 135 m above sea level. As is seen on Fig. 44 most of the finding-places are exposed to the deep basin of Stora Le (maximum water depth 139 m). The highest shoreline is assumed to lie about 175 m above sea level.

The majority of the species in Fig. 48 come from the collection of C.G.Silfversvärd. The shells are kept at the Swedish National Museum of Natural History in Stockholm and have been checked by Hägg. The other species were recorded by De Geer (1902) during the surveying of the map sheet Strömstad, and by Malmberg-Larsson (1960).

Shells of *Mya truncata* and of *Pecten islandicus* have been radiocarbon determined as well as one sample of shell fragments, which was collected about 80 m SSW of western lake Kvarntjärn.

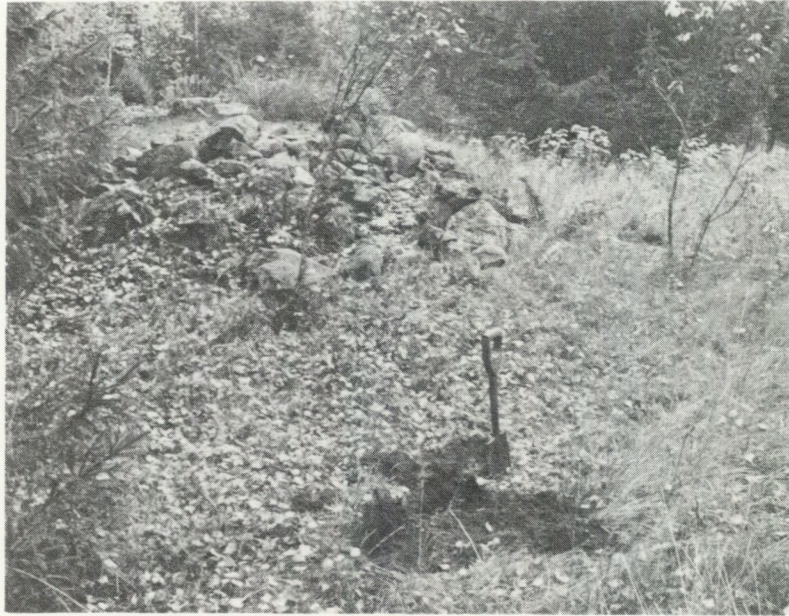
f. Kölviken

10 B Årjäng SO 3f

The locality, formerly called S.Kölviken, is situated close to Ödegårdstjärnet (De Geer 1902, p. 55). On the topographical map it appears as "Högen", close to Kölvikstjärn.

According to Hägg (1947, p. 472) the shell deposit was found 133 m above sea level.

The species in Fig. 48 are quoted by Hägg (op.cit) from a survey logbook of the map sheet Strömstad (De Geer 1902).



A



B

Fig. 45. A. Sampling spot at the Bråtnäs shell deposit, locality g. The boulders in the background are lying on bedrock surface. View towards NNE.
B. The shell-bearing sand is covered by 30 cm thick soil.
Photo CF 1978-10-10.

Valley of Lelång

g. Bråtnäs

10 B Årjäng SO 4g

The locality is identical with the former small farm area of Skäret (De Geer 1902, pp. 55), 2 200 m WNW of Bråtenäs (Bråtnäs), which agrees with the stated altitude 156 m above sea level (Hägg 1947, p. 473). The shell deposit is situated at the southwestern part of the bare bedrock hill Storstensåsen reaching about 165 m above sea level. The highest shoreline is believed to lie about slightly 170 m above sea level (see locality k).

At a horizontal distance of three metres from the outcrop a digging was made in the smooth slope, see Fig. 45. Below 20 cm thick soil there was silty sand with a thickness of more than one metre. The top 15 cm of the sand were shell-bearing with numerous of small fragments of *Balanus crenatus* (dominating), *Macoma calcarea* (few small and whole shells) and *Mytilus edulis*.

Two samples have been radiocarbon determined.

h. Dammtjärn Alsbyn

10 B Årjäng SO 3g, 4g

The locality is situated 1 600 m southwest of Alsbyn, about 125 m above sea level. The listed species are according to De Geer's (1902) survey logbook (Hägg 1947, p. 473).

i. Kesnacken

10 B Årjäng SO 3g

The property of Kesnacken is situated at about 110 m above sea level. Shells collected before 1850 and labelled Remacken were in all probability, found at Kesnacken (Hägg 1947, p. 471). Three small shells of *Cyprina islandica*, 46--57 mm, are identified by Hägg, (op.cit.) and one of them is depicted.

j. Bäcketjärn, Torrskog

10 B Årjäng SO 3h

The locality was described by Sandegren (Larsson & Sandegren 1956, p. 144).

On the northernmost slope of Bäcketjärn the following stratigraphy was given:

- 0 — 20 cm sandy gravel
- 20 — 40 cm shell layer underlain by till

The altitude of the locality is stated to be 154 m above sea level. About 2 km to the SSE the highest shoreline lies 167 m above sea level (op.cit., pp. 139—141).

The recorded shells have been identified by Hägg (1947, p. 473; 1952, p. 131).

k. Gustavsfors

10 B Årjäng SO 3h

At the former small farm of Kockerud in the valley of Bryngelsdalen, 2 300 m NNW Gustavsfors, the following stratigraphy was recorded in 1937 by Sandegren (Larsson & Sandegren 1956, pp. 144—145):

- 30 cm weathered sand
- 5 cm thick shell layer
- 25 cm fine sand
- 8 — 10 cm shell layer
- 7 cm silt
- 3 — 5 cm shell layer, underlain by fine sand

In 1867 Fries (unpublished) described the deposit as a one foot thick shell-bed of exceedingly fragmented shells.

The locality is situated 150 m above sea level along the west side of a bedrock ridge, Fig. 46. About 25 m north of the ruined farm house small shell fragments can be found in 10—20 cm thick lenses in sand within the top metre.

The highest shoreline is determined by Sandegren (op.cit., pp. 139—141) at 172.7 m above sea level about 2 500 m to the NNE of Kockerud.



Fig. 46. View towards the east of locality g. Remnants of the Kockerud farm house can be seen to the right. The property is situated on the south side of Bryngelsdalen valley, about 100 m northeast of the main road. Shell fragments can be seen in the wheel ruts. Close to the outcrop, sandy sediments are thin and the underlying brownish clay is visible.— Photo CF 1978-10-10.

The listed shells have been identified by Hägg (1947, p. 473).

Two separate samples were collected in the same layer for radiocarbon measurements.

1. Dammen

9 B Dals Ed NO 9j

On the gentle slope by Lake Bengtsbrohöljen, Fig. 47, west of the former farm of Dammen almost 2 km NNW of the Billingsfors church, the following stratigraphy has been reported (Hummel & Erdmann 1870, pp. 104—105):

30—60 cm gravelly sand, underlain by 100—120 cm greyish-brownish clay till.

In the basal parts of the sand discontinuous shell layers were found. The listed shells have been checked by Hägg (1947, p. 472; 1952, pp. 131—132).

When a bathing-place was constructed shell layers and lenses 1—3 cm thick became visible at a depth of about 1 m, Fig. 47. The shell layers consisted mainly of shell fragments of *Balanus*



Fig. 47. View of the gentle slope at the southern end of Lake Bengtsbrohöljen, locality 1 Dammen. The uncultivated area consists of till. In the foreground, wave-washed sand covers silty clay. Shell fragments were visible in the pit by the spade to the left of the bog house. View towards east. — Photo CF 1983-09-16.

balanus, *Hiatella arctica*, even juvenile ones, dominated among the bivalves.

The shell layers were embedded in the lower part of the sand and in the uppermost part of a bluish silty clay.

Lake Bengtsbrohöjden is situated 90.1 m above sea level; the finding place of the shell layers lies about 5 m higher.

m. Billingsfors

9 B Dals Ed NO 9j

At the abandoned property Kasen, about 600 m NNW of Billingsfors church, two insignificant sandy shell layers underlain by clay and overlain by two metres of sand and gravel are recorded (Hummel & Erdmann 1870, pp. 105—106; unpublished notifications by Fries). The altitude of the locality is stated by Hägg (1947, p. 472) as 95 m above sea level.

n. Dals Långed, Tusendalersbacken 9 B Dals Ed NO 7j

In the literature the locality is called Tusendalersbacken or Fläskbacken, and it is known since the beginning of the nineteenth century. When the area was surveyed in the 1860's large quantities were said to have been previously removed (Hummel & Erdmann 1870, pp. 103—104). The reported estimates of the volume are exaggerated. There are no indications of a large volume in the small valley.

The locality is situated 81 m above sea level (Hägg 1947, p. 472) in the lower part of a small valley, 1 400 m south of Dals Långed railway station. The highest shoreline is supposed to lie about 160 m above sea level in this area. A stream has cut a gully almost 5 m deep in the valley. When the area was surveyed a 30—35 cm thick shell layer in gravelly sand was observed at a depth of about 0.5 m (Hummel & Erdmann 1870, pp. 103—104). Hägg (1947, p. 472; 1952, p. 133) states that the shells were found in clay, which forms the substratum.

Recently Lind (1983, p. 137) has rediscovered the locality. At a depth of 1.5 m a 10—20 cm thick shell layer is visible in the gully about 90 m above sea level. The shell layer consists mainly of shell fragments. It is overlain by sand and underlain by clay.

Samples have been radiocarbon dated.

o. Glumserud Kasen 9 B Dals Ed NO 7j

On the east slope of Lake Råvarp a shell deposit of about the same faunal composition as that at Tusendalersbacken, locality n, is recorded (Hummel & Erdmann 1870, pp. 103—104). The finding-place was probably located about 1 600 m SSE of Dals Långed railway station, just about where the later-constructed railway is running. The shell deposit was situated somewhat less than 75 m above sea level.

The listed shells have been checked by Hägg (1947, p. 472; 1952, p. 132).

Valleys of the Silen lakes

p. Haltetjärn

10 B Årjäng NO 8i

Today the locality is called Mossbrotjärn, and it is situated about 4 200 m west of the Årjäng church.

Stratigraphy according to Hägg (1923, p. 436):

- 0 — 15 cm humus
- 15 — 35 cm red sand
- 35 — 55 cm sandy shell layer underlain by grey sandy clay

The shell deposit was observed at the foot of a sand terrace situated 167.3 m above sea level. It was examined in 1905 by Hägg (op.cit.), who used the level of the water surface of the Lake Stora Le as a reference mark. The highest shoreline is estimated to be just above 180 m above sea level (Lundqvist 1958, p. 118).

During the road construction to Gerrud (1 500 m southeast of Mossbrotjärn) shells were observed by the workers. When Lundqvist (op.cit.) arrived at the excavation nothing was visible. The faunal composition is assumed to have been the same as at Mossbrotjärn.

q. Solvik

10 C Åmål SV 1a

On the slope of a glaciofluvial deposit at Solvik, a thin shell-bearing clay layer was recorded in 1936 by Sandegren (Larsson & Sandegren 1956, p. 145). According to local residents shells had previously been found in several patches in the gravel-pit and large quantities had been used as poultry fodder. Usually lenses of shell in clay or sand are thin when situated on the sides of glaciofluvial deposits. The number of identified species supports the idea that the stated proportions are exaggerated.

The level of the shell deposit is stated as 135 m above sea level (op.cit.).

r. Hollsten

10 C Åmål SV 2b

In 1917 a lense of shells 10 cm thick and 25 cm long below 80 cm of fine sand was recorded on the west side of a glaciofluvial deposit (Larsson & Sandegren 1956, p. 145). According to the information received, comparatively larger quantities had probably been removed for poultry fodder (op.cit.), cf. locality q.

The locality is situated 125 m above sea level. About 2 km to the northeast the highest shoreline, as stated by Sandegren (op.cit. pp. 139—141), lies almost 165 m above sea level.

Area of Dals Rostock

s. Långetjärn

9 B Dals Ed SO 3j

In 1866 shells were found in clay at a depth of about 2 m in the Långetjärn Valley (Törnebohm 1870, p. 69). The locality is situated at about 130 m above sea level and located 100 m south of a lake which lies 1 500 m west of Dals Rostock. The highest shoreline in the area is estimated at about 150 m above sea level.

t. Hällan

9 C Mellerud SV 3a

On the property of Hällan, 1 km southwest of the Gunnarsnäs church, shells have been found in clay (Hägg 1952, pp. 132—133).

The finding-place lies 60—75 m above sea level.

Faunal composition

The faunal composition of the shell deposit is listed in Fig. 48. Most of the information is based on Hägg's (1925, 1947, 1950, 1952) check-ups of collections kept at the Swedish National Museum of Natural History in Stockholm and at the Museum of the Swedish Geological Survey, also in Stockholm at that time. The

SPECIES	LOCALITIES																			
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
Echinodermata																				
Echinus dröbackensis					x	x														
Gastropoda																				
Buccinum canaliculatum															x					
Buccinum groenlandicum					x	x						x			x	x				
Buccinum undatum					x										x					
Buccinum undatum caerulea					x										x					
Lacuna divaricata						x														
Lepeta caeca					x	x										x	x			
Littorina rudis																x				
Natica clausa					x						x	x			x					
Natica groenlandica					x															
Neptunea sp.					x										x					
Neptunea despecta carinata																x	x			
Puncturella noachina																x	x			
Trophon clathratus major					x							x			x	x				
Trophon clathratus gunneri					x										x	x				
Velutina laevigata					x											x				
Lamellibranchia																				
Anomia squamula					x															
Arca glacialis					x										x	x				
(Astarte arctica)																				x
(Astarte banksii)															x					
Astarte borealis																x				
Astarte elliptica										x						x				
Astarte montagui												x				x				
Astarte sulcata																				x
Axinus flexuosus																x				
Cyprina islandica					x				x											
Leda pernula					x															
Macoma sp.							x													
Macoma balthica	x			x	x	x		x	x	x	x				x	x		x		
Macoma balthica astartoides																				x
Macoma calcarea			x	x	x	x		x	x	x	x	x			x	x	x			
Modiola modiolus					x															
Mya sp.							x													
Mya truncata	x	x		x	x	x		x	x	x	x	x			x	x				x
Mya truncata uddevallensis					x															x
Mytilus edulis	x	x	x		x	x		x	x	x	x	x	x		x	x			x	x
Pecten islandicus	x	x		x	x				x											
Portlandia arctica											x					x				
Portlandia arctica siliqua																				
Saxicava arctica		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x
Saxicava arctica uddevallensis					x					x										
(Saxicava pholadis)	x																			
Thracia truncata															x	x				
Zirphaea crispata					x															
Crustacea																				
Balanus sp.	x			x	x							x	x		x					x
Balanus balanus					x		x		x	x					x					
Balanus crenatus			x		x	x	x		x	x	x				x	x	x	x	x	

Fig. 48. Invertebrates recorded at described shell localities west of Lake Vänern.

composition of locality e includes species from all shell deposits in the Sandviken area. *Balanus hammeri* has been reported by Malmberg-Larsson (1960). Side plates of the barnacle have not been found later in the Sandviken deposits. The species is not known so far inland, not even in Norway (Sörensen personal communication). As Malmberg-Larsson made no comment about the remarkable presence of the deep-water barnacle, and as no signs of it are found today, it has not been listed in Fig. 48.

Lab no St	LOCALITY	Lat N	Long E	SPECIES	Frac- tion	Age in years B.P. ± stat err	δ C ¹³ ‰ PDB	Apparent age of sed water	Total corr- in years	Corrected ages	
										B.P.	B.C.
7113	HULABÄCKSRÖSET	59° 25'	11° 47'	<i>Molluscs</i>	1	9 535 ± 110	-2.4	-400	+25	9 560 ± 110	7 610 ± 110
7114					2	9 760 ± 115	-1.5	-400	-15	9 745 ± 115	7 795 ± 115
7115					3	10 000 ± 120	-1.4	-400	-35	9 965 ± 120	8 015 ± 120
7116					4	9 765 ± 115	-1.3	-400	-10	9 755 ± 115	7 805 ± 115
5016	SANDVIKEN	59° 16'	11° 51'	<i>Chlamys islandica</i>	2	9 520 ± 335			+20	9 540 ± 335	7 590 ± 335
5017					3	9 835 ± 170	-0.7	-400	0	9 835 ± 170	7 885 ± 170
5018				<i>Mya truncata</i>	2	9 795 ± 370			-25	9 770 ± 370	7 820 ± 370
5019					3	9 755 ± 200	-2.3	-400	-30	9 725 ± 200	7 725 ± 200
7117				<i>Molluscs</i>	1	9 470 ± 110	2.0	-400	-20	9 450 ± 110	7 500 ± 110
7118					2	9 740 ± 115	-1.8	-400	-20	9 720 ± 115	7 790 ± 115
5020	DALS LÅNGED	53° 55'	12° 19'	<i>Hiatella arctica</i>	2	9 770 ± 165			-30	9 740 ± 165	7 790 ± 165
5021					3	9 615 ± 125			-15	9 600 ± 125	7 650 ± 125
5022					4	9 925 ± 250	-1.9	-400	-15	9 910 ± 250	7 960 ± 250
6816	BRÅTNÄS	59° 14'	11° 58'	<i>Balanus crenatus</i>	1	9 985 ± 100	-0.9	-400	-5	9 980 ± 100	8 030 ± 100
6817					2	9 840 ± 155	-0.4	-400	-5	9 845 ± 155	7 955 ± 155
6818				<i>Mytilus edulis</i>	1	10 050 ± 105	+0.0	-400	+10	10 060 ± 105	8 110 ± 105
6819					2	9 895 ± 115	-0.3	-400	+15	9 910 ± 115	7 960 ± 115
6812					1	9 525 ± 115	-1.3	-400	-10	9 515 ± 115	7 565 ± 115
6813	<i>Mytilus edulis</i>	2	10 335 ± 95	-1.2	-400	-5	10 330 ± 95	8 380 ± 95			
6814		1	9 200 ± 105	-1.8	-400	-20	9 180 ± 105	7 230 ± 105			
6815		2	9 900 ± 115	-1.1	-400	-5	9 895 ± 115	7 945 ± 115			

Fig. 49. Radiocarbon age determinations of shells sampled west of Lake Vänern.

Including subspecies, the total number of recorded invertebrates is 41. When divided into geographical regions, 10 species are found today in arctic areas, 18 in arctic — boreal, 4 in arctic — boreal — lusitanian, 7 in boreal, and 2 in boreal — lusitanian seas.

Radiocarbon measurements

Shells and shell fragments from five localities have been radiocarbon dated, see Fig. 49. Samples of shell fragments were taken from four localities. Furthermore, accessible duplicate shells of three species of the C.G.Silversvärd collection were chosen.

The radiocarbon age determinations are shown in Fig. 49. Below the localities concerned are listed in the order in which they appear in the description. Only the datings from the Bråtnäs locality differ from the other four.

a. Hulabäcksröset.

Two kilos of shell-bearing sand were delivered for radiocarbon age determination. The mean age of the dated four fractions is $9\ 755 \pm 115$ years.

e. Sandviken.

From the Sandviken deposits shells of *Mya truncata*, 2—5 cm in length, and fairly thin shells of *Pecten islandicus*, 6—7 cm in length, were obtained from the Swedish National Museum of Natural History for radiocarbon measurements. Two labels accompanied each storage box. One stated the northern shell-bank while the other label stated the southern shell-bank as the finding-place. It is probable that numerous shells of one species from both sites were assembled in the same box. Fortunately, one may assume that specimens existed at about the same time.

Dug-out shell fragments of molluscs and side plates of barnacles showed about the same age as the stored shells.

g. Bråtnäs.

Four kilos of shell-bearing sand were collected in two samples, which have been treated separately.

The four measurements carried out overlap, and the average age is 9 950 years. With due regard to corrections and the margin of statistical errors, the age of the sampled shell fragments can hardly be younger than about 9 800 years; these fragments are the oldest found in the area.

The radiocarbon measurements of the shells are in fair accordance with a dating of a subfossil skeletal part of a bearded seal at Grums (Fredén 1975, p. 14, p. 37). An assumed age correction of 200—300 years gave an age of $9\ 900$ — $9\ 800 \pm 180$ years B.P. The location of Grums is shown on Fig. 1.

k. Gustavsfors.

About four kilos of shell-bearing sand were collected in two samples. The age determinations show a fairly large deviation between the dated fractions. Ergo, the collected samples were affected by contamination. The average value of the four determinations is 9 730 years. The datings of fraction 2 of samples from the localities g and k give the same age.

n. Tusendalersbacken.

In the Swedish National Museum of Natural History shells of *Hiatella arctica*, 2-3 cm in length, were accessible for radiocarbon determination. It was noted that the shells showed no resemblance to the form *uddevallensis*. Conflicting information about the parish (Steneby) and finding-place is given on the label; cf. Steneby below. The nearby shell deposit at Glumserud Kasen, locality o, is supposed to be situated in the parish of Steneby. The stated finding-place is probably correct. On the other hand, the two shell deposits concerned are assumed to be of about the same age. On Fig. 49 the regional name Dals Långed, is chosen as the finding-place, although this is somewhat uncertain; cf. descriptions to localities n and o.

The average age of the radiocarbon dated fractions is 9 750 years.

Lind (1983, p. 136-137) has collected a sample for radiocarbon dating. The mean value of the two dated fractions is 9820±140 years (St 7246, 7247).

Lind (op.cit.) has also sampled shell fragments of barnacles in wave-washed sand on slopes of large glaciofluvial deposits, 4 and 7 km northwest of Dals Långed railway station. The localities are situated 1 500 m northeast of Dingelvik, "Snickarekullen", and 1 800 m NNW of Steneby church, "Havdekullen". Only one fraction of each sample has been measured. It is common that the outer fraction is 200-300 years younger than the inner fraction due to leaching. The obtained ages of these samples are contemporaneous with those mentioned above.

Summary of shell deposits in the western part of the Vänern basin

As appears of Fig. 42 the most favourable bathymetric conditions along the Skagerrak — Vänern watershed were present in the Otteid area. Inflow of saline water could take place immediately or shortly after the strait was deglaciated. The meltwater discharge of the Aremark valley north of Otteid has been relatively small as the drainage area is limited. At that time the western part of the Vänern basin was an archipelago, see Fig. 41.

The sedimentation of glacial clay was finished when molluscs inhabited the water of the then existing archipelago. Except for individual shells in the coastland of Lake Vänern no shells are covered by clay.

The majority of the recorded shells and shell fragments are found in the lower part of sand on the slopes of the pronounced valleys of Stora Le and Lelången, which served as the main connection between Skagerrak and the Vänern basin. One-half of the 20 recorded localities are situated 10—30 m below the highest shoreline. They are all minor deposits. Together they comprise 10 of the total 40 species recorded.

The shell-banks at Sandviken are situated about 50 m below the highest shoreline, and the rich fauna deposits at Tusendalersbacken and Glumserud Kasen about 80—90 m below the highest shoreline. No less than 37 species of the total number of 40 are recorded at these three localities.

The faunal composition has a more boreal character compared to the deposits in the Uddevalla strait.

The radiocarbon determinations agree relatively well with each other. However, they only reflect the time when the environmental conditions were congenial to the fauna concerned. Unfortunately, no absolute datings of isolation sequences are available. According to a pollenanalytical investigation by Danielsen (1970), a nearby basin at a corresponding level to Otteid is supposed to have been isolated at about 9 500 years B.P., an estimated figure which is more or less consistent with the radiocarbon determinations. The marine fauna seem to have disappeared from the region about 9 500 years ago.

The clay thickness at most of the finding-places of the shells is estimated at a couple of metres, which with regard to the rate of sedimentation of clay particles, should correspond to a few

hundred years. By comparison to the radiocarbon determinations, this means that the Otteid area was deglaciaded more than 10 000 years ago. Due to changing hydrographical and batymetrical circumstances, primarily caused by land uplift, relatively optimal edaphic conditions for a marine fauna only prevailed for 300—400 years in this region.

When reliable determinations of the highest shoreline are at hand one can discuss the rate of land uplift in areas where molluscs have existed at water depths less than 10—30 m.

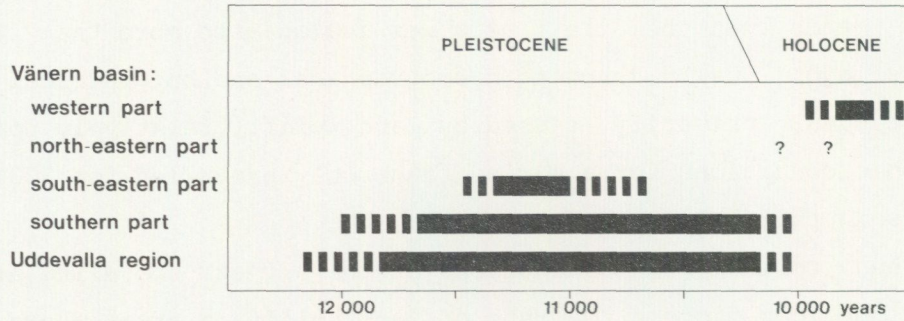


Fig. 50. Marine animals in the region of Uddevalla and Lake Väner. The occurrence is based on radiocarbon age determinations and biostratigraphic information.

SUMMARY

Shell deposits of arctic and arctic/boreal molluscan assemblages have been investigated in the region of Uddevalla and the lake Väner basin. Subfossil finds of more than 100 species of invertebrates and more than 15 species of vertebrates are known. In the Uddevalla region mass accumulation of molluscs and barnacles has resulted in 23 shell-banks with a volume of about one million cubic metres of shells and shell fragments.

Radiocarbon age determinations have been carried out on 43 samples from 28 localities. Mollusc assemblages of arctic and arctic/boreal character have existed in the Uddevalla area and in the southern part of the Väner basin 11 800—10 000 years B.P., and in the western part of the Väner basin 9 900—9 600 years B.P., see Fig. 50.

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SGU = Sveriges Geologiska Undersökning

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INDEX OF INVERTEBRATES AND VERTEBRATES

Short descriptions are given of all mentioned species. It is important to emphasise the fact that this paper does not deal with taxonomical problems. Consequently, the species are listed in alphabetical order.

Invertebrates

Each species is given a brief characterization concerning its present habitat and distribution. Primarily the references by Lindner, Ockelmann, Odhner, and Tebble are used. Most of the molluscs are also described by Nordsieck. However, his works are not fully reliable concerning the distribution characteristics. Some species are not referred by Nordsieck to arctic waters as they are by Odhner, Tebble and others.

References are also made to lists of gastropods along the Swedish west coast published by Hubendick & Warén (1969—1976). For some of the molluscs the recent distribution in general and the subfossil occurrence in Sweden has been closely described by Hägg (1924, 1952).

Some of the species were present already in Miocene times (Sorgenfrei 1958).

As it is awkward to particularize all synonyms, cross-references are given only for names mentioned in the descriptions of finding localities.

Acanthocardia echinata LINNÉ 1758

Cardium echinatum LINNÉ 1758

Mandahl-Barth 1971, p. 98; Tebble 1966, p. 99.

A boreal—lusitanian species living on sandy, gravelly or muddy bottoms from about 4 m to considerable depths. The prickly cockle is living along the Swedish west coast and occurs below a depth of 10 m.

Acirsa eschrichti MÖLLER 1842

Acirsa borealis BECK 1851

Scala borealis

Scalaria borealis LYELL 1842

Scalaria eschrichti MÖLLER 1842

Characteristics, see Nordsieck 1968, p. 74.

Distribution: Greenland--northeast North America (Hubendick & Warén 1973).

Acmaea rubella FABRICIUS 1780

Tectura rubella FABRICIUS 1780

Odhner 1912, pp. 10--11; 1915, pp. 139--140; Warén, personal communication.

An arctic gastropod living on stones and rocks below about 10 m.

Acmaea virginea MÜLLER 1776

Tectura virginea MÜLLER 1776

Nordsieck 1968, p. 16.

A boreal--lusitanian species with a vertical range of 0--120 m.

It is common along the west coast on hard bottoms between 10 and 40 m (Hubendick & Warén 1975, p.36).

Alvania arenaria MIGHELS & ADAMS 1843

Alvania mighelsi STIMPSON 1851

Cingula castanea non MÖLLER 1841

Onoba castanea

Nordsieck 1968, p. 46; Odhner 1915, p. 169.

A mainly arctic gastropod living on muddy substrata at depths below 10 m.

The taxonomy is not clear (see Hubendick & Warén 1969; 1979; 1971 and 1975).

Alvania mighelsi, see *Alvania arenaria*

Amauropsis islandica GMELIN 1791

Hubendick & Warén 1974; Nordsieck 1968, p. 104; Odhner 1915, p. 161.

An arctic—boreal gastropod living on muddy or sandy bottoms. In Skagerrak and Kattegatt it is known at depths between 20 and 60 m.

Anomia aculeata, see *Heteroanomia squamula aculeata*

Anomia patelliformis LINNÉ 1761

Monia patelliformis

Hägg 1924, pp. 456—457; Tebble 1966, pp. 35—36.

A boreal—lusitanian bivalve living on hard substrates and on empty shells down to considerable depths.

Anomia squamula, see *Heteroanomia squamula*

Aporrhais pespelecani LINNÉ 1758

Nordsieck 1968, p. 96.

A boreal—lusitanien gastropod living on bottoms of sand and mud at depths from about 10 to 130 m. It is recent along the west coast.

Arca glacialis, see *Bathyarca glacialis*

Arctica islandica LINNÉ 1767

Cyprina islandica

Tebble 1966, pp. 92—93.

A mainly boreal species living on firm bottoms of sand and muddy sand at depths from about 5 m to several hundred metres. The

Iceland-cyprina is common at depths of 8--50 m along the Swedish west coast and also in the southwestern part of the Baltic.

Astarte arctica GRAY 1824

Hägg 1904, p. 33; Odhner 1915, p. 90.

See *Astarte borealis*.

Astarte banksii, see *Astarte elliptica*

Astarte borealis CHEMNITZ 1788

Tridonta borealis SCHUMACHER 1817

Astarte corrugata BROWN 1827

Astarte semisulcata LEACH 1819

Ockelmann 1958, pp. 74--79.

This bivalve is a circumpolar, coastal form, which usually lives at depths of less than 30 m in arctic (mainly) boreal seas. It inhabits soft bottoms of sandy clay or clay.

Literature also includes some descriptions of varieties, e.g. *arctica* and *withami*. According to Ockelmann (op.cit.) and Odhner (1915, p. 90) the shell proportions of *Astarte borealis* vary from one individual to another. Until more is known a subspecific rank to any of the forms is not appropriate (Ockelmann op.cit.).

The *Astarte borealis* mussel is relict in Kattegatt and in the southern part of the Baltic and lives at depths below 10 m (Mandahl-Barth 1971, p. 96).

Astarte compressa, see *Astarte elliptica*

Astarte corrugata, see *Astarte borealis*

Astarte costata, see *Astarte crenata*

Astarte crenata GRAY 1824

Astarte costata

Nordsieck 1969, p. 69; Ockelmann 1958, pp. 89—92.

Astarte crenata has been divided into two species: *Astarte crebricostata* FORBES 1847 (= *Astarte crenata*) and *Tridonta acuticostata* JEFFREYS & FRIELE 1897 = *Astarte crenata acuticostata*. Ockelmann claims that transitional forms occur between the two species. Both are sublittoral forms with a mainly arctic distribution.

Astarte elliptica BROWN 1827

Astarte compressa LINNÉ

Astarte banksii LEACH 1819

Hägg 1924, PP. 465—466; Ockelmann 1958, pp. 86—89.

The species has an arctic—boreal distribution and lives in clay, mud or sand at depths between 2 and more than 400 m. The preferred depth varies between localities. The species lives along the Swedish west coast.

Astarte montagui DILLWYN 1817

Hägg 1924, pp. 463—465; Ockelmann 1958, pp. 80—85; Tebble 1966, p. 71.

A circumpolar, arctic—boreal bivalve living on sandy or gravelly bottoms to depths of about 75 m. At West Greenland it is known to a depth of 445 m.

Astarte montagui striata LEACH 1819

The proportions of the *Astarte montagui* shells are exceedingly variable. Forma *striata* has about the same latitudinal and bathymetric distribution as forma *typica*.

Astarte semisulcata, see *Astarte borealis*

Astarte striata, see *Astarte montagui striata*

Astarte sulcata DA COSTA 1778

Mandahl-Barth 1971, p. 96; Tebble 1966, p. 70.

A mainly boreal bivalve which burrow into mud, muddy gravel, sandy gravel or shingle from about 5 m to considerable depth. The species lives along the west coast at relatively great depths.

Astyris rosacea GOULD 1840

Nordsieck 1968, pp. 124—125.

A mainly boreal gastropod living at depths below 10 m. Characteristic of areas with strong currents (Warén, personal communication).

Axinus flexuosus, see *Thyasira flexuosa*

Balanus balanus LINNÉ

Balanus porcatus DA COSTA 1778

Stephensen 1933, pp. 119.

An arctic—boreal cirriped attached to rocks to a depth of 300 m. It is common along the west coast to depths of 20--30 m, often attached to molluscs, e.g. *Modiola modiolus* (Ursing 1971b, p. 318).

Balanus crenatus BRUGUIÈRE

Stephensen 1933, p. 124.

This barnacle is distributed from arctic to lusitanian waters and occurs in the Pacific. It is attached to rocks at depths between 0 and 100 m and is common along the west coast (Ursing 1971b, p.318).

Balanus hammeri LINNÉ

Odhner 1930, pp. 499—500; Stephensen 1933, pp. 120—121.

A boreal, deep-water crustacean which is common along the Norwegian west coast at depths of 150—300 m. The species is not known at depth less than 40—50 m. It requires clean sea water. The species occurs in the Skagerrak.

Balanus porcatus, see *Balanus balanus*

Bathyarca glacialis GRAY 1824

Arca glacialis LEACHE 1878

Ockelmann 1958, pp. 44—48.

The species usually lives in soft substratum with gravel and cobbles. Depths ranges from 5 m to nearly 500 m, most commonly below 40 m. Its distribution is arctic—boreal.

Bela kobelti VERKRÜZEN 1875

Bela viridula SARS 1878

This gastropod has an arctic distribution (Hägg 1950, p. 358).

Bela pyramidalis, see *Lora pyramidalis*

Bela rugulata TROSCHERL

Odhner 1915, p. 211.

Odhner distinguishes between v. *spitzbergensis* FRIELE and v. *scalaroides* SARS. Both of these gastropods can be characterized

as mainly arctic species living on muddy bottoms from about 10 m to considerable depths.

Bela viridula, see *Bela kobelti*

Beringius turtoni BEAN 1834

Crysodomus turtoni

Fusus turtoni BEAN 1834

Jumala turtoni

Nordsieck 1968, p. 125.

This gastropod has a boreal distribution and occurs to a depth of more than 1000 m.

Bittium reticulatum DA COSTA 1778

Nordsieck 1968, p.68.

A boreal—lusitanian gastropod. It lives in the littoral algae belt along the Swedish west coast.

Boreochiton marmoreus, see *Toniciella marmorea*

Buccinum canaliculatum HISINGER

Characteristics by Hägg 1925, p. 11 and Fig. 1. The species is deformed type of *Buccinum groenlandicum* (Warén, personal communication).

Buccinum glaciale LINNÉ 1758

Nordsieck 1968, p. 133; Odhner 1915, pp. 185—188.

A circumpolar, arctic gastropod living mainly on bottoms of sand and gravel with algae.

Buccinum groenlandicum CHEMNITZ 1788

Odhner 1915, pp. 192—194.

This gastropod lives mainly in arctic seas, mostly at depths to 75 m. It is a carnivorous mollusc and it occurs on various bottoms.

Buccinum hydrophanum HANOCK 1846

Nordsieck 1968, p. 134.

An arctic species. This gastropod is recorded from muddy and clayey bottoms to considerable depth (Hägg 1905, pp. 63—67).

Buccinum labradorensis REEVE 1855

An arctic species (Hägg 1950, p. 357).

Buccinum meridionale HARMER 1913

Harmer, 1914—1919, pp. 111—112.

The gastropod is known from Newfoundland and as a fossil from Pre-Weichselian Pleistocene layers (Waltonian and Butleyan) in Great Britain.

Buccinum terraenovae MÖRCH 1869

Odhner 1915, pp. 184—185.

An arctic gastropod living on muddy bottoms at depths between 10 and 110 m.

Buccinum undatum LINNÉ 1758

Nordsieck 1968, p. 133; Odhner 1915, pp. 180—182. An arctic—

boreal gastropod found on soft bottoms, mostly muddy, from shallow water to considerable depths. It is recent along the Swedish west coast.

Several varieties are known (see Hägg 1924, pp. 452—454). Usually it is difficult to establish a subspecific rank for subfossil specimens.

Buccinum undatum LINNÉ 1758 *coerulea* SARS 1878

Brögger 1900—1901, Pl. XII:4; Hägg 1924, p. 453; 1952, p. 158.

This variety has a mainly boreal distribution.

Buccinum undatum LINNÉ 1758 *conoideum* SARS 1878

Hägg 1952, p. 163; Nordsieck 1968, p. 133.

This variety has a mainly boreal distribution.

Capulacmaea glacialis, see *Capulacmaea radiata*

Capulacmaea radiata SARS 1878 *glacialis* ODHNER 1913

Capulacmaea glacialis ODHNER 1913

The taxonomy of this gastropod is discussed by Odhner (1927, p. 11). Its distribution is uncertain. Nordsieck (1968, p. 99) claims that it is circumpolar and exists along the Norwegian coast. The species is here regarded as arctic—boreal.

Cardium echinatum, see *Acanthocardia echinata*

Cardium edule, see *Cerastoderma edule*

Cardium fascinatium, see *Parvicardium ovale*

Cerastoderma edule LINNÉ 1767

Cardium edule LINNÉ 1767

Hägg 1924, p. 469; Teblle 1966, pp. 104—105.

This edible cockle has a boreal—lusitanian distribution and lives in sand, mud, and sandy mud in shallow water, 0—10 m. The species can tolerate a low salinity. It is one of the most common molluscs along the west coast and it also occurs in the southwestern Baltic.

Chlamys islandicus MÜLLER 1776

Pecten islandicus MÜLLER 1776

Hägg 1924, pp. 461—463; Nordsieck 1969, p. 50.

A circumpolar, arctic—boreal species found in the algae zone and on clay bottoms (depth range 7—100 m). The species is not present in high-arctic seas (Ockelmann 1958, p. 65). Its occurrence along the east Greenland coast is discussed by Hjorth & Funder (1974).

Chrysodomus turtoni, see *Beringius turtoni*

Cingula castanea, see *Alvania mighelsi*

Cingula striata, see *Onoba aculea*

Colus islandicus GMELIN 1791

Sipho islandicus

Nordsieck 1968, p. 126.

An arctic—boreal gastropod living on clay bottoms between depths of 7 and 1200 m.

Colus togatus MÖRCH 1869

Sipho togatus

Odhner 1915, pp. 201—203.

A mainly arctic species living on muddy bottoms from about 10 m to considerable depths.

Coronula diadema LINNÉ

Stephensen 1933, pp. 126—127.

This barnacle is attached to humpback whales (Odhner 1930, p. 505), which live in the north Atlantic and Pacific waters during the summer and in tropical waters during the winter (Siivonen 1968, p. 132).

Crenella laevigata striata, see *Musculus laevigata substriatus*

Cyprina islandica, see *Arctica islandica*

Dallina septigera LOVÉN 1846

Waldheimia septigera

Sars 1878, pp. 11—13.

This brachiopod is mainly distributed in arctic waters at depths below 10 m.

Echinus droenbachensis, see *Strongylocentrotus droenbachensis*

Ensis ensis LINNÉ 1758

Mandahl-Barth 1971, p. 101; Nordsieck 1969, p. 146; Tebble 1966, pp. 161—162.

A bivalve with a boreal distribution, burrowing into sandy sediments at depths as great as 80 m. Common along the Swedish west coast to a depth of 30 m.

Fusus despecta, see *Neptunea despecta*

Fusus turtoni, see *Beringius turtoni*

Heteroanomia squamula aculeata LINNÉ 1758

Anomia aculeata MÜLLER 1776

Anomia squamula LINNÉ 1758

Hägg 1924, pp. 457—458; Sorgenfrei 1958, pp. 80—82; Tebble 1966, p. 37.

This bivalve has a mainly boreal distribution, from the White Sea to the Bay of Biscay, and is attached to shells, stones, and seaweed. It is moderately common along the Swedish west coast.

Hiatella arctica LINNÉ 1767

Saxicava arctica LINNÉ 1767

Saxicava rugosa PENNANT 1777

The taxonomy of *Hiatella* species is not sufficiently known. In North Atlantic waters at least two species are said to occur, namely *Hiatella arctica* and *Hiatella gallicana* LAMARCK 1818 (*Saxicava rugosa*), and also a number of varieties which are considered intermediate (see Hägg 1924, pp. 471—473; Nordsieck 1969, p. 147). A third form, *Hiatella pholadis* LINNÉ 1771, is regarded by Ockelmann (1958, p. 140) as a doubtful species.

Neither Ockelmann (*op.cit.* pp. 139—142) nor Tebble (1966, p. 173) separate shells of *Hiatella* into distinct species. Two different forms of *Hiatella* larvae are known. The question is whether the adult shells can be distinguished from each other. Shell forms of recent *Hiatella* specimens show an extreme variation. Ockelmann (1958, p. 141) states that hardly two adult specimens of exactly the same appearance seem to be present in material deriving from east Greenland.

Characteristics intended to apply to all species of the genus (Ockelmann 1958, pp. 135—142); Tebble 1966, pp. 172—173; cf. Sorgenfrei 1958, pp. 125—128). The species has a wide geographical distribution in the northern hemisphere, from Arctic seas to the Mediterranean and in corresponding regions in the Pacific. Mostly it is found from the shoreline to depths of several hundred metres. In shallow water the species may be attached to algae, in deeper water, to stones, and specimens are even attached to each other. *Hiatella* forms are common along the Swedish west coast.

Hiatella arctica uddevallensis JEFFREYS 1859

Saxicava arctica uddevallensis

The taxonomy of *Hiatella* species is not clear, cf. *Hiatella arctica* above. From Jan Mayen and East Greenland Ockelmann (1958, p. 141) reports shell forms of *Hiatella arctica* and *Hiatella gallicana* together with a number of intermediate specimens and irregularly developed shells.

In this paper subfossil shells of *Hiatella arctica uddevallensis* are characterized as short and thick to very thick, usually irregularly developed shells. It must be stressed that the classification of the subfossil *Hiatella* shells, other than the typical forms, is very subjective. The question here is whether a future distinction between recent *Hiatella* forms can be valid for the more or less eroded subfossil shells.

Hiatella gallicana, see *Hiatella arctica*

Hiatella pholadis, see *Hiatella arctica*

Homalogyra atomus PHILIPPI 1841

Omalogyra atomus PHILIPPI 1841

Hubendick & Warén 1971.

The species has a wide distribution from the Arctic to the Mediterranean. This small gastropod, 0.5—1.0 mm, is attached to algae and moderately common along the northernmost part of the Swedish west coast.

Hydrobia ulvae, see *Peringia ulvae*

Ischnaction albus LINNÉ

Lophyrus albus

Trachydermon albus

Odhner 1915, pp. 49—50.

An arctic—boreal species living on rocky bottoms at depths between 10 and 600 m. Recent along the Swedish west coast to Öresund.

Jeffreysina opalina, see *Rissoella opalina*

Jumala turtoni, see *Beringius turtoni*

Lacuna divaricata FABRICIUS 1780

Lacuna vineta MONTAGU 1803

Hubendick & Waren 1974; Nordsieck 1968, p. 39.

A mainly boreal gastropod associated with seaweed in shallow water. Recent along the west coast.

Lacuna vincta, see *Lacuna divaricata*

Leda caudata, see *Nuculana minuta*

Leda minuta, see *Nuculana minuta*

Leda myalis, see *Voldia hyperborea*

Leda pernula, see *Nuculana pernula*

Lepeta caeca MÜLLER 1776

Hubendick & Warén 1975, p. 38; Hägg 1924, pp. 445—446; Odhner 1915, pp. 140—142.

A circumpolar, arctic--boreal gastropod which lives mostly on muddy bottoms at depths between 100 and 400 m. Along the coast of Bohuslän it is known on hard bottoms at depths between 40 and 100 m.

Littorina littorea LINNÉ 1758

Hubendick & Warén 1975, p. 40; Hägg 1924, pp. 446—447; Nord sieck 1968, p. 40.

A boreal gastropod attached to rocky substrata at depths of 0—15 m. It is very common along the Swedish west coast.

Littorina obtusata LINNÉ 1758

Littorina palliata SAY 1822

Hägg 1924, pp. 448--450; Nord sieck 1968, p. 40.

A boreal species generally attached to the seaweed *Fucus*, 0—3 m. This gastropod species is common along the Swedish west coast.

Littorina obtusata palliata SAY 1822

Littorina palliata SAY 1822

The *palliata* form is low-arctic with its southern limit off northern Norway (Hubendick & Warén 1975, p. 40).

Littorina palliata, see *Littorina obtusata*

Littorina rudis, see *Littorina saxatilis*

Littorina saxatilis rudis MATON 1797

Littorina rudis MATON 1797

Hubendick & Warén 1975, p. 40; Nordsieck 1968, p. 40.

A mainly boreal species attached to rocky bottoms to a depth of a few metres. This gastropod species is common along the Swedish west coast.

Lophyrus albus, see *Ischnaction albus*

Lora pyramidalis STRÖM 1768

Bela pyramidalis STRÖM 1768

Hubendick & Warén 1974, p. 31; Odhner 1915, pp. 219—220.

A mainly arctic species living on soft and gravelly bottoms.

Lucina borealis LINNÉ 1767

Lucinoma borealis LINNÉ 1767

Tebble 1966, pp. 76—77; Ursing 1971b, p. 252.

A boreal—lusitanian bivalve, which burrows into sandy mud or gravel. It occurs from a couple of metres to considerable depths.

It exists along the Swedish west coast at depths between 20 and 50 m.

Lunatia groenlandica, see *Lunatia pallida*

Lunatia pallida BRODERIP & SOWERBY 1829

Lunatia groenlandica BECK 1851

Natica pallida groenlandica MÖLLER 1842

Hubendick & Warén 1974; Nordsieck 1968, p. 103; Odhner 1915, pp. 157—160.

A circumpolar, mainly arctic gastropod species with a wide vertical range, 2—2300 m. It lives on muddy bottoms in Kattegatt at depths between 10 and 50 m.

Macoma balthica LINNÉ 1758

Tellina baltica LINNÉ 1758

Tellina proxima

Hägg 1924, pp. 466—467; Tebble 1966, pp. 149—150.

An arctic—boreal bivalve living in mud, muddy sand, and muddy gravel in shallow water. The mollusc tolerates a low salinity and is common in the Baltic sea.

Macoma balthica astartoides

This form is characterized by Hägg (1923, p. 438). No information about distribution pattern.

Macoma calcarea GMELIN 1790

Tellina calcarea CHEMNITZ 1788

Tellina sabulosa

Hägg 1924, pp. 468—469; Ockelmann 1958, pp. 125—128.

A circumpolar, arctic—boreal species generally living in shallow water on a clayey or muddy bottom. This species is present along the Swedish west coast and in the Baltic west of Bornholm.

Margarites argentata GOULD 1840

Margarites olivacea BROWN 1828

Nordsieck 1968, p. 18; Odhner 1915, p. 146.

An arctic (mainly)—boreal gastropod living on muddy bottom at a depth from 3 to about 100 m.

Margarites groenlandica, see *Margarites undulata*

Margarites helicina FABRICIUS 1780

Hubendick & Warén 1975, p. 40; Nordsieck 1968, p. 17; Odhner 1915, pp. 143—146.

An arctic—boreal species with a vertical range from 0 to 400 m. It is most common on bottoms consisting of gravel and cobbles with *Laminaria* seaweed. This gastropod species occurs along the coast of Bohuslän at depths between one and 40 metres.

Margarites olivacea, see *Margarites argentata*

Margarites undulata SOWERBY 1813

Margarites groenlandica GMELIN 1790

Nordsieck 1968, p. 17; Odhner 1915, pp. 147—149.

An arctic—boreal (mainly) species living on various types of bottoms at depths between 2 and 300 m.

Modiolaria discors see *Musculus discors*

Modiolus modiolus LINNÉ 1758

Mytilus modiolus LINNÉ 1758

Nordsieck 1969, p. 31; Tebble 1966, p. 43.

The horse-mussel has a wide, circumpolar distribution. It lives generally on sandy and gravelly bottoms at depths to about 150 m. It is also found attached to rocks and *Laminaria* within the littoral zone. It is common along the Swedish west coast.

Moelleria costulata MÖLLER 1842

Nordsieck 1968, p. 33; Odhner 1915, p. 152.

A mainly arctic gastropod species living on muddy bottoms at depths between 14 and 300 m.

Monia patelliformis, see *Anomia patelliformis*

Montacuta sp. MONTAGU 1803

Tebble 1966, pp. 89—91.

Small bivalves with boreal—lusitanian distributions.

Musculus discors LINNÉ 1758

Modiolaria discors LINNÉ 1758

Tebble 1966, p. 46.

This bivalve is found in the littoral—sublittoral zone from the Arctic to Maderia and has a corresponding distribution in the Pacific. It lives under rocks and among small algae, primarily *Corallina officinalis*.

Musculus laevigata substriatus GRAY 1824

Crenella laevigata striata GRAY 1824

Modiolaria discors laevigata GRAY 1824

Nordsieck 1969, pp. 35—36.

A circumpolar, arctic bivalve living on rocky bottoms at depths to 80 m.

The problem of identifying *Modiolaria discors* and *M. laevigata* is discussed by Ockelmann (1958, pp. 56—57).

Mya truncata LINNÉ 1758

Hägg 1924, pp. 470—471; Mandahl-Barth 1971, p. 101; Odhner 1915, pp. 120—123; Tebble 1966, p. 167.

A circumpolar, arctic—boreal bivalve living in sand, sandy mud, or clay at a depth from about 2 m to at least 623 m. It seems to be most common at depths less than 50 m. This blunt gaper occurs along the west coast below a depth of 6—7 m.

Mya truncata LINNÉ *uddevallensis* FORBES 1846

Hägg 1924, pp. 470—471; Hessland 1943, p. 274 footnotes; Ockelmann 1958, p. 148; Odhner 1915, pp. 124—126.

A mainly arctic species living on muddy, sandy, and gravelly bottoms. This distribution is based on finds of empty shells only, most of them at a depth less than 50 m. According to Ockelmann it is an arctic fenotype.

Mytilus edulis LINNÉ 1758

Hägg 1924, pp. 458—460; Tebble 1966, pp. 40—43.

The common mussel is cosmopolitan with a mainly boreal distribution and very common in shallow waters (0—10 m). Requirements as to attachment surfaces and water salinity differs.

Mytilus modiolus, see *Modiolus modiolus*

Nassa reticulata LINNÉ 1758

Nassarius reticulatus

Hubendick & Warén 1971.

A boreal—lusitanian gastropod usually living on bottoms of sand and mud at depths as great as 15 m. It is one of the most common gastropods along the west coast.

Natica affinis GMELIN 1790

Natica clausa BRODERIP & SOWERBY 1829

Hubendick & Warén 1974; Nordsieck 1968, p. 106; Odhner 1915, pp. 153—156; see also Sorgenfrei, pp. 193—194.

An arctic—boreal gastropod living on muddy bottoms at depths from 2—3 m to more than 2000 m. It is recorded from deep water west of Portugal. Off the coast of Bohuslän the gastropod lives in sandy and muddy bottoms between 50 and 200 m.

Natica bathybi FRIELE 1879

Hubendick & Warén 1974.

An arctic species. One specimen known from the Norwegian Sea.

Natica clausa, see *Natica affinis*

Natica groenlandica, see *Lunatia pallida*

Natica pallida, see *Lunatia pallida*

Natica pallida groenlandica, see *Lunatia pallida*

Neptunea antiqua LINNÉ 1758

Neptunea despecta LINNÉ

Fusus despectus

Hägg 1924, pp. 454—456; Nordsieck 1968, p. 130; Odhner 1915, pp. 198—199.

An arctic (mainly)—boreal gastropod living on muddy bottoms from about 20 m to considerable depths. The species is the biggest gastropod, up to 20 cm high, in the North Sea (Warén, personal communication). It is rare along the west coast.

In the species *Neptunea despecta* Odhner includes *Neptunea antiqua* as a variety (cf. Hägg). Nordsieck distinguishes between them and considers *Neptunea despecta* to appear in deeper and more arctic waters than *Neptuna antiqua*.

Neptunea despecta, see *Neptunea antiqua*

Neptunea despecta carinata LAMARCK 1822

The species is known mainly from arctic waters (Hägg 1924, p. 455). It has been illustrated by Brögger (1900—1901, p. 265, Pl. IV:1, Pl. VI:21).

Neptunea despecta tornata GOULD 1841

This gastropod species is found living around Iceland (Nordsieck 1968, p. 130) and Spitsbergen (Hägg 1924, p. 455).

Nuculana minuta MÜLLER 1776

Leda minuta MÜLLER 1776

Leda caudata DONOVAN 1800

Ockelmann 1958, pp. 19—20.

A discontinuously circumpolar, low-arctic—boreal bivalve living on various types of bottoms from 4 m to considerable depths.

Nuculana pernula MÜLLER 1776

Nuculana pernula costigera LECHE 1883

Leda pernula MÜLLER 1776

Ockelmann 1958, pp. 15—18.

The species has a mainly circumpolar, arctic distribution, but is also known around the coasts of the North Sea. It is common in clayey or muddy bottoms at depths from 2 to 210 m, but is found near Jan Mayen at a depth of 1275 m.

Nuculana tenuis expansa REEVE 1855

Nuculana tenuis MONTAGU 1803 *expansa* HANCOCK 1846

Ockelmann 1958, pp. 13—15.

This bivalve has a mainly circumpolar, arctic distribution, but it is also known from the western coast of Europe. It inhabits bottoms of mud, clay, sand, or gravel at depths from 0—13 m to usually 100 m and is rare at greater depths. The species is referred by Nordsieck (1969, p. 3) under the name of *Lionucula*.

Omalogyra atomus, see *Homalogyra atomus*

Onoba aculea GOULD 1841

Onoba arctica LOVÉN 1846

Onoba saxatilis MÖLLER 1842

Hubendick & Warén 1970.

A boreal gastropod species, which prefers brackish water. The taxonomy of *Cingula* and *Onoba* is not clear (cf. *Alvania*). The gastropod is known along the Swedish west coast.

Onoba arctica, see *Onoba aculea*

Onoba castanea, see *Alvania*

Onoba saxatilis, see *Onoba aculea*

Ostrea edulis LINNÉ 1758

Mandahl-Barth 1971, p. 96; Tebble 1966, p. 53.

A boreal-lusitanian bivalve species which lives at depths between 5 and 85 m on various types of bottoms. This common oyster requires a salinity of at least 25 per mille and a summer temperature of about 20°C. It is rare along the west coast.

Parvicardium ovale SOWERBY 1841

Cardium fascinatum MONTAGU 1803

Nordsieck 1969, p. 99; Tebble 1966, p. 102.

This bivalve has a wide distribution, from the White Sea to the Canary Isles. It inhabits bottoms of muddy sand and gravel at depths between 3 and 110 m. The species is common along the west coast.

Pecten islandicus, see *Chlamys islandica*

Peringia ulvae PENNANT 1777

Hydrobia ulvae PENNANT 1777

Mandahl-Barth 1971, p. 90; Nordsieck 1968, p. 42.

A boreal gastropod abundant on muddy bottoms with algae in shallow water. It lives along the Swedish coast as far north as the Gulf of Bothnia.

Plicifusus krøyeri MÖLLER 1842

Sipho krøyeri

Hägg 1905, p. 48; Nordsieck 1968, p. 130.

A circumpolar, arctic gastropod. The species is recorded along eastern Greenland at depths between 3 and 122 m.

Plicifusus latericus MÖLLER 1842

Sipho latericus

Nordsieck 1968, p. 130; Odhner 1915, pp. 204—205.

A deep-water gastropod which lives on muddy bottoms in arctic water. Vertical range: 14—1200 m. The species is rare at depths less than 100 m.

Portlandia arctica GRAY 1824

Yoldia arctica GRAY 1824

Ockelmann 1958, pp. 23—26.

This bivalve burrows in muddy or clayey bottoms in high-arctic seas. Its distribution is circumpolar. The vertical range is from 2—3 m to more than 300 m. It is most common at depths between 10 and 50 m.

This mollusc is used as a character fossil of glacial non-varved clays in western Sweden and the Vänern basin.

Portlandia arctica siliqua REEVE 1855

When *Portlandia arctica* is further classified by the proportions of the shells, forma *siliqua* is of medium size (Ockelmann 1958, pp. 25—26).

Portlandia frigida, see *Yoldiella frigida*

Portlandia lenticula, see *Yoldiella lenticula*

Pseudamussim septemradiata, see *Chlamys septemradiata*

Ptsianula limnoides

According to Odhner (1927, p. 105, foot note 2; 1930, p. 503) the species belongs to the genus of *Toledonia*, which is known from Antarctic and Subantarctic regions.

Puncturella noachina LINNÉ 1771

Hägg 1924, pp. 444—445; Nordsieck 1968, p. 12; Odhner 1915, pp. 142—143.

A circumpolar, arctic—boreal gastropod which lives on various bottoms mostly between 10 and 200 m. Along the Portugal coast it is recorded at a depth of 2000 m. It is not common along the west coast.

Rissoa inconspiqua ALDER 1844

Hubendick & Warén 1970.

A boreal—lusitanian gastropod, smaller than three mm, common on algae at a depth between 3 and 25 m. Recent along the coast to Öresund.

Rissoa membranacea J. ADAMS 1800

Hubendick & Warén 1970.

A small 6—9 mm long gastropod species associated with *Zostera* and *Chorda filum*. Usually occurs at depths less than 10 m in arctic—boreal waters. The species is recent along the Swedish west coast.

Rissoella opalina JEFFREYS 1883

Jeffreysina opalina JEFFREYS 1883

Nordsieck 1968, p. 61.

A 2 mm-sized gastropod associated with algae zone in shallow water. The species is known from European coasts.

Saxicava arctica, see *Hiatella arctica*

Saxicava arctica uddevallensis, see *Hiatella arctica uddevallensis*

Saxicava rugosa, see *Hiatella arctica*

Scala borealis, see *Acirsa borealis*

Scalaria borealis, see *Acirsa borealis*

Scalaria eschrihti, see *Acirsa borealis*

Sipho islandicus, see *Colus islandicus*

Sipho kröyeri, see *Plicifusus kröyeri*

Sipho latericus, see *Plicifusus latericus*

Sipho togatus, see *Colus togatus*

Solariella obscura bella COUTHOUY 1838

Solariella obscura COUTHOUY 1838 *bella* SARS 1878

Hubendick & Warén 1975, p. 40; Nordsieck 1968, p. 19.

A mainly arctic gastropod.

Strongylocentrotus droebachensis MÜLLER 1776

Echinus droebachensis MÜLLER 1776

A boreal—lusitanian species which is common along the west coast at depths between 5 and 20 m (Warén, personal communication).

Suberites montalbidus

Odhner 1930, pp. 503—504.

This sponge has a mainly arctic distribution. It is recorded as a rare occurrence in the fiord of Gullmaren, northwest of Uddeval-la.

Tectura rubella, see *Acmaea rubella*

Tectura virginea, see *Acmaea virginea*

Tellina balthica, see *Macoma balthica*

Tellina calcarea, see *Macoma calcarea*

Tellina proxima, see *Macoma balthica*

Terebratella spitsbergensis DAVIDSON

Brögger 1900—1901, p. 577.

An arctic brachiopod.

Thetya cranium

Odhner 1930, p. 504.

An arctic—boreal sponge common along the Norwegian coasts.

Thracia myopsis MÖLLER 1892

Thracia truncata BROWN 1827

The bivalve *Thracia truncata*, has been renamed *Thracia myopsis* by Hägg. It is an circumpolar, arctic bivalve living on muddy and clayey bottoms between 12 and 350 m.

It may be noted (Warén, personal communication) that *Thracia truncata* MIGHELLS & ADAMS non BROWN 1827 is synonymous with *Thracia septentrionalis* JEFFREYS 1872 (for description, see Nordsieck 1969, p. 161).

Thracia papyracea POLI 1795

Thracia phaseolina LAMARCK 1801

Mandahl-Barth 1971, p. 100; Nordsieck 1969, p. 160; Tebble 1966, p. 195.

A boreal—lusitanian bivalve living in sand, muddy sand, and sandy gravel at depths between 1 and 50 metres. It is moderately common along the Swedish west coast.

Thyasira flexuosa MONTAGU 1803

Axinus flexuosus JEFFREYS 1869

This bivalve is a deep-water species with a boreal—lusitanian distribution. According to Ockelmann (1958, p. 100) some *Thyasira* species, such as *Thyasira gouldi*, have formerly been included in *T. flexuosa* by several authors, for instance Hägg and Odhner (see also Sorgenfrei 1958, pp. 89—90).

Thyasira gouldi PHILIPPI 1845

Ockelmann 1958, pp. 100—104.

A mainly circumpolar, arctic bivalve which inhabits various types of bottoms, mostly at depths between 2 and 50 m.

Toledonia, see *Ptsianula limnoides*

Tonicella marmorea FABRICIUS 1780

Boreochiton marmoreus FABRICIUS 1780

Odhner 1915, pp. 47—49.

An arctic—boreal species living on rocky bottoms at depths between 10 and 40 m. Recent along the Swedish west coast.

Trachydermon albus, see *Ischnaction albus*

Tridonta borealis, see *astarte borealis*

Trophon clathratus LINNÉ 1767

Hubendick & Warén 1972; Hägg 1924, pp. 450—451.

A mainly arctic gastropod which lives on soft bottoms. It is recent in Skagerrak and Kattegatt below a depth of about 30 m.

Trophon clathratus gunneri LOVÉN 1846

The species has an arctic—boreal distribution (Hägg 1952, p. 158). It is placed by Nordsieck (1968, p. 116) in the subgenus *Trophonopsis* (*Boreotrophon*).

Trophon clathratus major LOVÉN 1846

The forma *major* signifies a comparatively large form (Hägg 1925, p. 16).

Trophon truncatus STRÖM 1767

Hubendick & Warén 1972; Hägg 1924, pp. 451—452.

A mainly arctic species. It is recent on soft bottoms below a depth of 30 m in Skagerrak and Kattegatt.

Turitella communis RISSO 1826

Turitella terebra LINNÉ

Hubendick & Warén 197, p. 41; Nordsieck 1968, p. 62.

A boreal—lusitanian gastropod which lives on sand or mud bottoms at depths between 6 and 200 m. In Skagerrak and Kattegatt it is common at depths between 10 and 100 m.

Turitella terebra, see *Turitella communis*

Waldheimia septigera, see *Dalina septigera*

Velutina laevigata, see *Velutina velutina*

Velutina velutina MÜLLER 1776

Velutina laevigata PENNANT 1777

Mandahl-Barth 1971, p. 93; Nordsieck 1968, p. 98; Odhner 1915, pp. 161—162.

A mainly boreal gastropod species attached to ascidians at depths between 2 and about 200 m. It occurs in Kattegatt and Skagerrak at a depth of about 20 m.

Verruca stroemia MÜLLER 1776

Stephensen 1933, p. 115.

This cirriped is distributed from arctic to lusitanian waters. It is attached to sea shells or to firm bottoms to a depth of 200 m. The species is recent in Skagerrak and Kattegatt where it is found to a depth of 30 m (Ursing 1971b, p. 318).

Yoldia arctica, see *Portlandia arctica*

Yoldia frigida, see *Yoldiella frigida*

Yoldia hyperborea TORELL 1859

Leda myalis

Ockelmann 1958, pp. 21—22.

A discontinuously circumpolar, arctic bivalve living in clay or clayey bottoms from 4 m to considerable depths.

Yoldia nana, see *Yoldiella fraterna nana*

Yoldia pygmaea gibbosa, see *Yoldiella lenticula*

Yoldiella fraterna VERRIL & BUSCH 1898 *nana* JENSEN 1905

Yoldia nana M.SARS 1865

Nordsieck 1969, pp. 11—12.

A mainly arctic bivalve living along the coasts of Greenland at depths between 20 and 310 m. The position of *Y.nana* is discussed by Ockelmann (1958, pp. 36—38).

Yoldia frigida TORELL 1859

Portlandia frigida TORELL 1859

Yoldia frigida TORELL 1859

Ockelmann 1958, pp. 34—37.

The species is found in high-arctic seas living on bottoms of clay, mud, or clay mixed with particles of sand and gravel. It is recorded from depths between 5 and 300 m and seems to be most common between 30 and 150 m. Sometimes a transitional form, *v. siliqua*, is described. However, it is always found together with *f.typica* (Odhner 1915, p. 60).

Yoldiella lenticula MÖLLER 1842
Portlandia lenticula SARS 1878
Yoldia pygmaea LOVÉN 1846 *gibbosa*
Ockelmann 1958, pp. 30—32.

This bivalve lives on bottoms of clay and mud in mainly arctic seas and is most common at depths between 20 and 200 m in the vertical range of 0—1400 m. The species is also known as far south as the Shetlands and the Faroes.

Zirphaea crispata LINNÉ 1758
Tebble 1966, pp. 182—183.

The oval piddock has a boreal—lusitanian distribution and also lives in the north Pacific. It bores into peat, clay, and soft rocks in shallow waters. The species is moderately common along the Swedish west coast.

V e r t e b r a t e s

Characteristics after Hvass (1970); Muus & Dahlström (1969); Siivonen (1968) and Ursing (1971a).

Balaena mysticetus LINNÉ

The Greenland right whale is an arctic, species living in the drift-ice area. It feeds mainly on plankton.

Delphinapterus leucas PALLAS 1776

The white whale occurs mainly in coastal areas of arctic seas. It feeds on fish, cephalopods and crabs.

Erignathus barbatus FABRICIUS

The bearded seal lives in coastal areas of the Arctic drift-ice region. It feeds on a bottom fauna consistin of crustaceans, molluscs, fish, etc., at depths less than 50 m.

Eubalaena swedenborgii LILJEBORG 1862

The Swedenborg whale has not been fully proved to be recent. Subfossil finds of the species have been made only in Sweden (see Fredén 1975, pp. 25—27). Zoologists are uncertain whether the Swedenborg whale is an extinct species of its own or a subspecies of the Greenland right whale or more probably of the Biscayan right whale (North Atlantic right whale), *Eubalaena glacialis*.

Gadus morhua LINNÉ 1758

Formerly synonymous with *Gadus callarias*.

The codfish has a southern arctic—boreal distribution. It lives to depths of about 600 m and requires a temperature of 2—10°C.

Haliochoerus grypus FABRICIUS

The grey seal is distributed from the Murmansk area to the British Isles. An isolated population occurs in the northern Baltic. The species is rare along the Swedish west coast. The grey seal can dive to a depth of 100 m and feeds mainly on fish.

Lagenorhynchus albirostris GRAY 1846

The white-beaked dolphin is a boreal—lusitanian species feeding on fish and crustaceans. It is recent along the west coast.

Megaptera nodosa BONN

The humpback whale lives in the north Atlantic and Pacific waters during the summer and in tropical waters during the winter. It lives in herds and feeds on plankton and fish.

Melanogrammus aeglefinus LINNÉ

Gadus aeglefinus

The haddock lives in arctic—boreal waters close to the bottom at depths between 10 and 200 m. It prefers a temperature of 4—10°C. The haddock is common in Skagerrak and Kattegatt.

Molva molva LINNÉ 1758

The ling has a mainly boreal distribution and lives at depths between 100 and 600 m. It occurs along the northern west coast.

Pagophilus groenlandicus ERXLEBEN

The harp seal usually occurs in herds on ice floes in the open sea. It can dive to a depth of almost 300 m. Its diet consists of crustaceans and fish. The species inhabited Swedish coasts for a time in Holocene times (see Fredén 1975, p. 40).

Phocaena phocaena LINNÉ 1758

The common porpoise occurs in the north Atlantic and is recent along the west coast and in the Baltic. It feeds mostly on fish.

Pusa hispida SCHREB.

The ringed seal lives in arctic seas and feeds on fish. A variety of the ringed seal is relict in the Bothnian Bay. Like the harp

seal, it returned for a time to Swedish coasts during the Holocene epoch.

Rangifer tarandus LINNÉ

The wild reindeer lives in the mountains of southern Norway above the timber line.

Somateria mollissima LINNÉ

The common eider has an arctic—boreal distribution and feeds entirely on mussels and crustaceans. The bird can dive 20—30 m and prefers a rough and rocky coastline. It breeds along the Swedish coasts.

Thalassarctos maritimus

Ursus maritimus PHIPPS

The polar bear inhabits the region of Arctic drift-ice and feeds mainly on seals.

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