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Sea-level studies along the coast of southwestern Norway

With emphasise on three short-lived Holocene marine events

Lisbeth Prøsch-Danielsen

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Cover photo:
Boathouses dated to the Early Iron Age (150-600 AD) at Ferkingstad, Karmøy municipality in Rogaland county. When the boathouses were in use, the sea level was approximately two metres higher.
Photo: Åge Pedersen, Museum of Archaeology, Stavanger.

Abstract

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A detailed study of field-reports, published and unpublished data from archaeological and natural science investigations close to the sea shore in the period from the 1930s to 2005, have been compiled and partly re-interpreted in order to present shore displacement curves. These curves can be used as a tool in location of prehistoric sites in the coastal region of the southwestern part of Norway. This region has experienced a complex shoreline displacement due to pronounced land-sea alteration caused by the interaction of eustacy and isostacy after the deglaciation. The general pattern reveals two distinct transgressions along the coast; one Late Weichselian (Younger Dryas age) and one Holocene transgression (the Tapes transgression, around 6500 yr BP) that intersect close to Reve in Central Jæren. The Tapes level forms the marine limit (ML) southwards in this area. In the northern Boknafjord area an earlier transgression of Bølling age has also been recorded. The shore displacement curves reveal a rapid regression from the Younger Dryas throughout the Preboreal chronozones, putting the brakes on southwards. The regression minimum in the Preboreal chronozone is below the present sea-level south of the Hafrsfjord area. Special attention has been paid to two, possibly three, shortlived marine events. The oldest marine event, dated to ca 9800-9700 yr BP, is only recorded in the Boknafjord area. Sediment studies at the localities Storavatn in Tysvær and the flooded Ahrensburgian site Galta 3 at Rennesøy, point in favour of a local tsunami. Three sites, Hålandsvannet, the Sola airport site and Braastadvann at Lista, show possible indications of the Storegga tsunami dated to 7350-7250 yr BP, but none of these sites record the typical tsunami facies that has been described for the Storegga tsunami layers elsewhere in Norway. The Storegga tsunami in this area is probably lower than the Tapes maximum level giving a possible run-up of 2-3 m. The youngest marine event, dated to ca 4800 yr BP, is recorded from the Karmøy sound and further southwards along the coast to Eigerøy. It levels out eastwards in the Boknafjord area. This event is the result of a small sea-level rise – a transgression – and verifies that the Tapes transgression was double-peaked along this coastal area. The two peaks intersect in the coastal zone at the Randaberg peninsula, the 4800 yr BP event being the highest one southwards.

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Introduction

People that settled along the Norwegian coastal line have always had a strong maritime orientation and adaption. Their settlement patterns were based on a combination of many different factors of which certain landscape characteristics such as sea-level and natural harbours have played a major role as localisation factors. Especially Pre-Neolithic societies, the pioneer population and the mesolithic man, had a maritime adaption (Bjerck 1982, 1995, Bang-Andersen 1995, Fisher 1995, Høgestøl 1995, Nærøy 1999). Flint nodules, the main raw material for tools, were naturally deposited along the elevated Late Weichselian shorelines. Thus vicinity and contact with the seashore was essential for prehistoric man. It also appears that environmental factors such as proximity to good fishing areas and sea mammals were important although hunting in the hinterland also played an essential role (Fisher 1995). The final transition from a primarily hunter-gatherer way of living to a more sedentary way of living when agro-pastoralism gained its final foothold changed the settlement patterns to more focus on inland sites and less on maritime resources. In Rogaland this turnover in subsistence economy occured by the Middle Neolithic II/ Early Late Neolithic transition, approximately 3800 yr BP (Nærøy 1999, Høgestøl & Prøsch-Danielsen 2006). However, proximity to the shoreline has of course also been of importance for the settlers along the coast after this turnover. In Rogaland for instance, the majority of agrarian rock carvings sites face seawards and/or are found in sheltered fjord basins (Bang-Andersen 1999, Prøsch-Danielsen 2002). In the Roman Period and the Migration Period courtsites are often situated near the coast and are accompanied by large boathouses. Some of the prehistoric boathouses may thus be indicators of political communications (Myhre, B. 1985, 1997, Grimm & Stylegar 2004). However, rock art sites and boathouses may be found far distant from the present shoreline (Isachsen 1940, Myhre, A. 1959, Myhre, B. 1973, Rolfsen 1974, Kleppe 1985) and verify that landuplift has occurred.

The earliest attempt to present a shore-displacement curve in Norway and to apply this curve as a tool in localisation of prehistoric sites was provided by Brøgger in 1905 in the Oslofjord area (Brøgger 1905). Due to rapid and continuously postglacial isostatic uplift in this area, the study of sea-level changes seemed to be a tool of major importance for archaeological research, especially by studying Nøstevedt-sites, Middle- and Younger Stone Age sites.

This successful work was carried on in the 1940s by Sulseng (1941, 1942) in the same area, closely accompanied by another geologist in the Østfold area (Undås 1944). Later on, Undås (1955) plotted the location of the Fosna sites in Southern Norway in relation to height above sea-level. In his work, Undås pointed out the "strange and disturbed picture" presented by the shorelines at the south and southwest coast of South Norway.

Due to the dominance of isostatic land rise, the early postglacial coast lines are generally found far above present sea-level in parts of Norway (e.g. the Oslofjord and the Trondheimsfjord area), thus making archaeological location and survey of Late Palaeolithic and Mesolithic coastal settlements quite easy. But, parts of Norway situated near the margin of the Scandinavian Weichselian ice cap, had experienced a more complex shoreline displacement with pronounced land-sea alterations, among others Rogaland in the southwestern part of Norway. In Rogaland down pressure of the ice on land were relatively weak and the following *isostatic* rice relatively small. The fluctuations in the sea-level (*eustasi*) have therefore been of greater importance and, relatively, the sea-level has moved both up and down. Regressions and transgressions have altered (Thomsen 1982). Due to this complicated land-sea alteration, prehistoric sites can be emerged, submerged or transgressed through the Holocene in southwestern Norway.

The data material in this manuscript is based on a detailed study of field-reports, material kept in the topographical archive at the Museum of Archaeology, Stavanger, and publications from 1930s to 2005. Since 1975, archaeologists at the Museum of Archaeology, Stavanger, have collaborated with and included natural scientists as part of the interdisciplinary research team. Special attention has been paid to sea-level studies as the relative sea-level change gives definite limits for where man could settle throughout time. Reconstructions of the sea-level changes also provide environmental backgrounds for the investigated archaeological sites nearby. The knowledge on sea-level changes has partly been initiated by pipeline projects, road constructions and industrial enterprises, but has also been part of research given high priority at the museum. Slowly but steadily, knowledge of the general sea-level displacement curves for Rogaland has been puzzled out. However, the general trends have been disturbed and complicated by some "freaky" or "inexplicable" marine events in the Holocene.

Already, during the World War II, professor Knut Fægri (1940, 1944b) postulated that there had been a double-peaked transgression during the Holocene in the Jæren area as well as in the Bømlo area further north. His observations were based on studies of raised beach ridges and lithostratigraphical studies from basins combined with pollen and diatom analyses. Unfortunately, his study suffered from the lack of absolute dates that did not exist at that time. In the following decades, Fægri's results were criticised and rejected (Thomsen 1982a, 1989, Kaland 1984) stating that only one Holocene transgression could be recognized in western Norway. However, in 1996 Bondevik showed that Fægri's first (oldest) transgression at least north of Rogaland, in Eidestjønn on Bømlo, was in fact the Storegga tsunami dated to approximately 7200 yr BP (Bondevik 1996, Bondevik *et al.* 1997a, 1997b).

By compiling the material from southwestern Norway, three marine episodes have been discovered at some localities in the Boknafjord and Jæren area in the county of Rogaland and at Lista in the county of Vest-Agder. These events dated to ca 9800-9700 yr BP, probably 7200 yr BP and 4800 yr BP do not fit into the generally accepted sea-level displacement curves and models constructed for western Norway (Kaland 1984). These events seem to be concurrent in time in the area representing short-lived events. The time of the second marine event (ca 7200 yr BP) seems to be simultaneously with the Storegga tsunami that are known to have inundated at least south to Bømlo at approximately 7200 yr BP (Bondevik *et al.* 1997a, 1997b, Svendsen & Warren 2001), and the third marine event (ca 4800 yr BP) seems to be simultaneous with one of the tsunami events recorded in Shetland (Bondevik 2002). Due to "the Ormen Lange field development project" offshore the coast of Møre and with the present knowledge about the Storegga submarine slide and tsunami in mind these "inexplicable" data from Rogaland were of current interest. In 2002, the Museum of Archaeology, Stavanger, then got the opportunity to compile published and unpublished results related to raised beach ridges, basin and soil profiles (Prøsch-Danielsen & Bondevik 2003). This manuscript is a revised and extended version of this report and present the updated sea-level displacement curves in southwestern Norway. As concerns the freak marine events dated to 9800-9700 yr BP, possibly 7200 yr BP and 4800 yr BP, three possible scenarios have been tested:

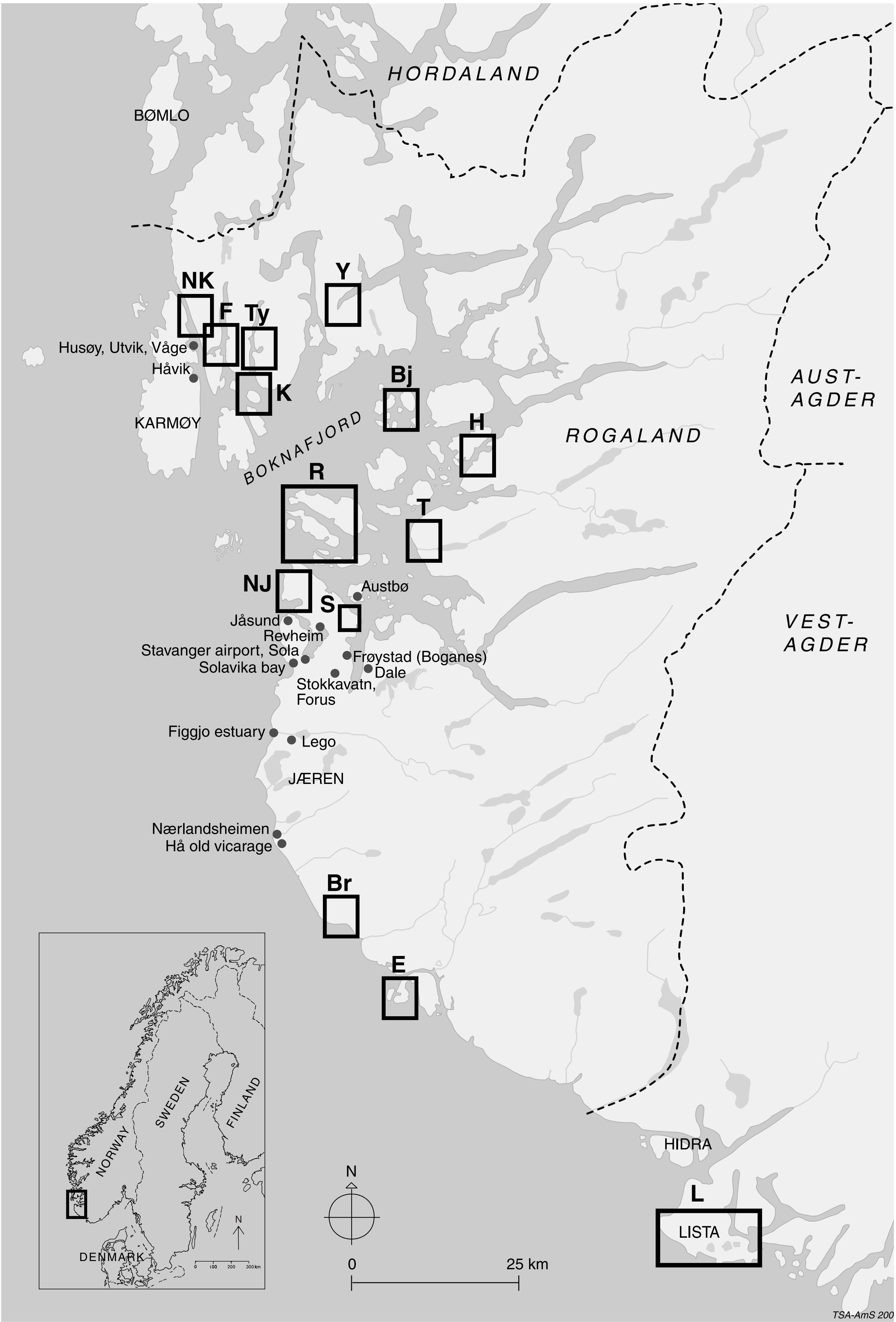
1. Are these marine events tsunamis, and is the youngest one the same as Bondevik found on Shetland?
2. Are these events short-lived sea-level fluctuations, i.e. small transgressions?
3. Are these events the result of heavy storm surges?

In the last few years, special focus has been directed towards the material and immaterial cultural monuments and environments along the coastline (Skar 1995). In Rogaland this resulted in a seminar in October 2004 with the title: "From Galta to Geitungen: coastal culture and archaeology (fjæresteinsarkeologi) close to the transection between the land and sea in Southwest Norway" (Selsing *et al.* 2005). This seminar was made possible due to collaboration between the three institutions responsible for the cultural heritage management in Rogaland; the Museum of Archaeology in Stavanger (AmS), Stavanger Museum and Rogaland County Counsil (RFK). This collaboration underlines the importance of understanding the natural history of the area such as the shore-displacement curves.

This work will hopefully serve as a tool for institutions in charge of cultural heritage management, to predict prehistoric landscape models and to give a better understanding of both rapid and long-term processes within the landscape. Small fluctuations in sea-level may cause dramatic changes in the landscape, particularly in the low-lying parts of Jæren and Lista. It will also serve as a contribution to localise coastal prehistoric sites whether they are emerged, submerged or transgressed, onshore or offshore. In addition, localising submerged sites will increase our knowledge about material culture closely linked to the Norwegian Stone Age, as these sites under normal conditions will be well preserved.

Fig. 1 (right page). Areas in southwestern Norway where sea-level displacement studies have been worked out (squares). Other sites with relevance to this work are plotted (filled circles). For more details, see separate figures.

Y = Yrkje area (Anundsen 1977a, 1978, 1985, Anundsen & Fjeldskaar 1983, Braathen & Hermansen 1985)
NK = Nord-Karmøy (Austad & Erichsen 1987)
Ty = Tysvær (Midtbø 2000)
F = Fosen (Midtbø in work)
K = Kårstø area (Thomsen 1989)
Bj = Bjergøy (Ugland 1984)
H = Hjelmeland (Kaland 1988)
T = Tau (Flatekval 1991)
R = Rennesøy (Prøsch-Danielsen 1993a)
NJ = Nord-Jæren (Thomsen 1982)
S = Stavanger (Simonsen 1971)
Br = Brusand (Bird & Klemsdal 1986)
E = Eigerøya (Simonsen 1982, 2005)
L = Lista (Prøsch-Danielsen 1997)


HORDALAND
BØMLO
NK
F
Ty
Y
Husøy, Utvik, Våge
Håvik
K
Bj
KARMØY
BOKNAFJORD
H
ROGALAND
AUST-
AGDER
R
T
NJ
Austbø
S
Jåsund
Revheim
Stavanger airport, Sola
Solavika bay
Frøystad (Boganes)
Dale
Stokkavatn,
Forus
VEST-
AGDER
Figgjo estuary
Lego
JÆREN
Nærlandsheimen
Hå old vicarage
Br
E
NORWAY
SWEDEN
FINLAND
DENMARK
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N
0
25 km
HIDRA
L
LISTA
TSA-AmS 200

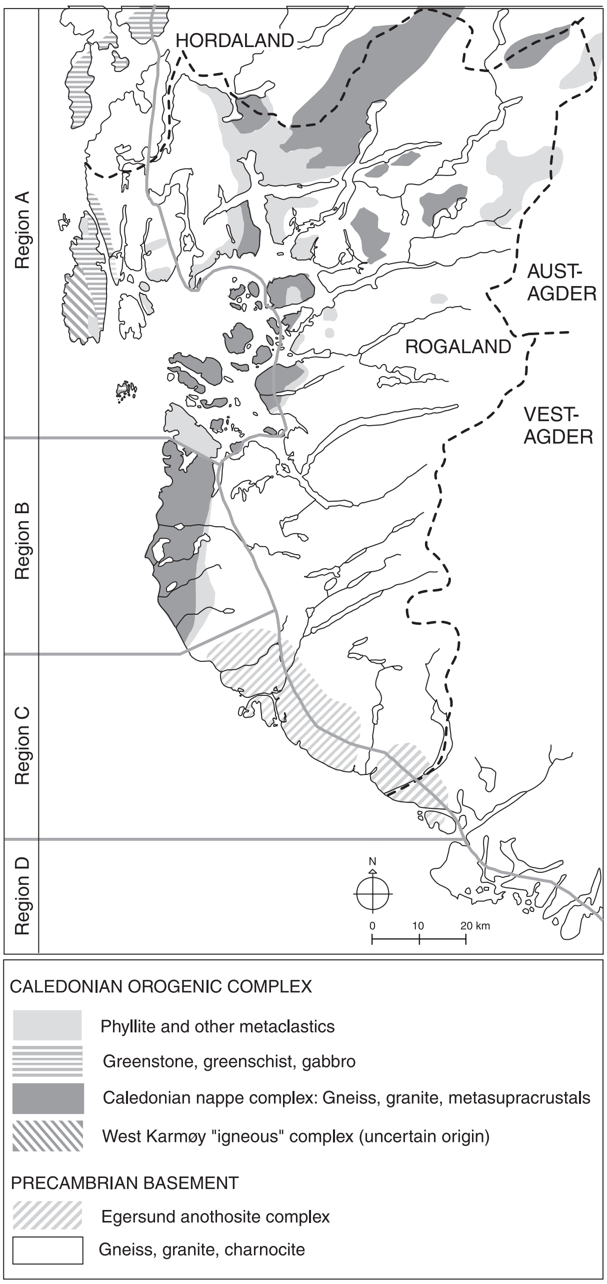
The outer coast of southwestern Norway

Subdivision into four major regions

The shore-bound localities and studied basins described in this paper, all lie within the lowland heath belt of "the coastal section" in southwestern Norway as defined by Dahl *et al.* (1986) and Moen (1999) (Figs. 1 and 2). Recently, three papers have been published dealing with this coastal heath lands (Prøsch-Danielsen & Simonsen 2000a, 2000b, Simonsen & Prøsch-Danielsen 2005). The authors suggested that the coastal section could naturally be divided into four regions (A-D) (Figs. 2a and 2b). These are:

A. The Karmøy, Haugalandet, Boknafjord and North-Jæren, the "Strandflaten" region with upland
B. South-Jæren, low-lying part and coastal upland region
C. The Dalane coastal region
D. The Lista coastal region

The above division is mainly based on local topographical, geological and botanical differences. Leaving out the upland regions, the division is also well suited for this study. The main characterising features include the presence of archipelagos (region A and D), the nature of the bedrock, i.e. Precambrian (region C and D) or Caledonian Orogenic Complex (A and B) and the general presence of thick Quaternary deposits (region B and D).



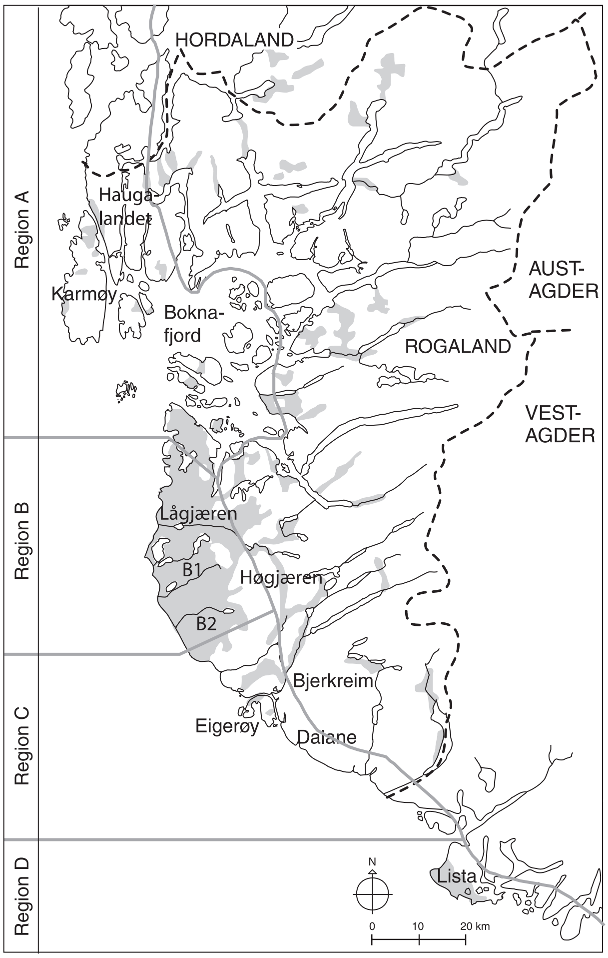
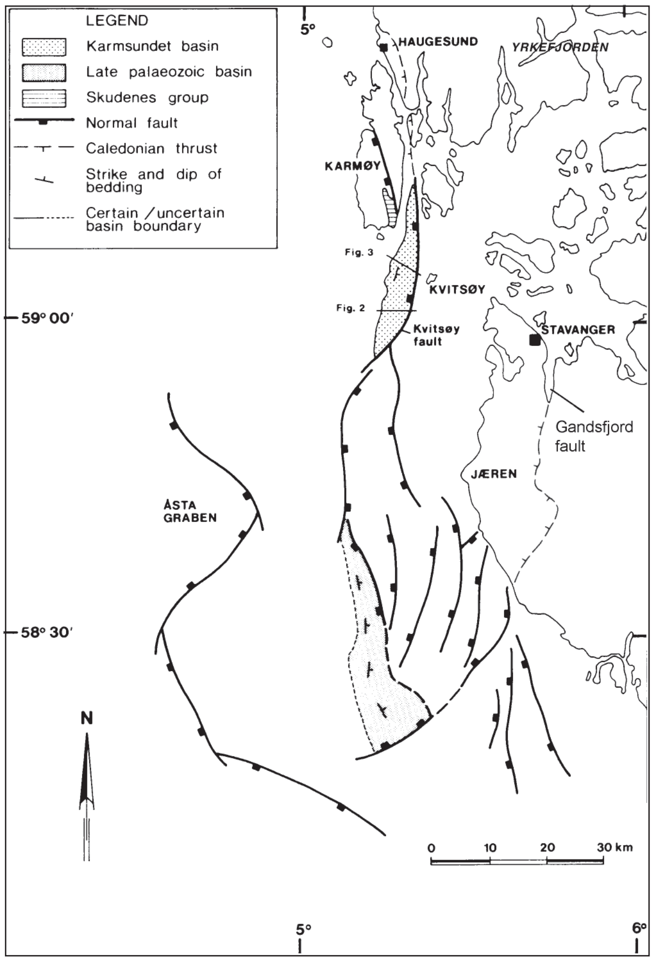


Fig. 2a (left). A simplified bedrock map of Rogaland county and Lista in the county of Vest-Agder, southwestern Norway (Prøsch-Danielsen & Simonsen 2000a).

Fig. 2b (right). Distribution of till and Quaternary deposits (marked grey) in region A-D in southwestern Norway (after Thoresen 1990). The eastern limit of the coastal heath section and the division into four regions are outlined (Prøsch-Danielsen & Simonsen 2000a).



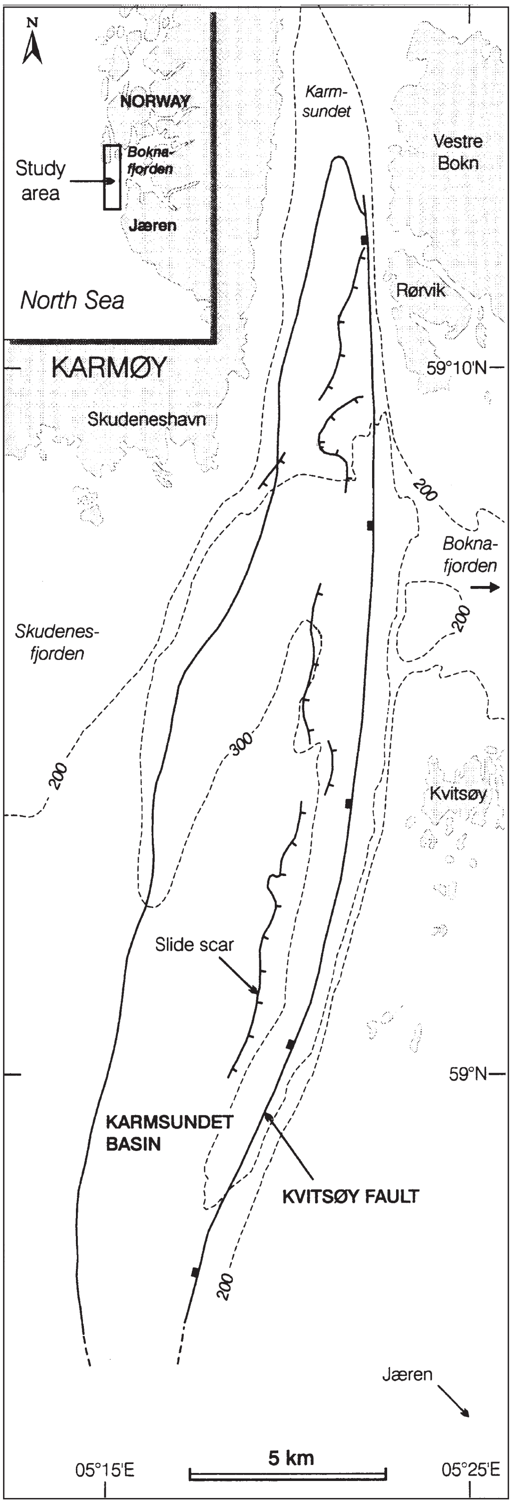


Fig. 3 (left). Geological map showing the location of the Karmsundet Basin and tectonic elements in the northeastern part of the North Sea. The geology south of 58°45' S is based on unpublished data from Elf Aquitaine Norge A/S. The Gandsfjorden lineament is also marked (Bøe et al. 1992).

Fig. 4 (right). Locality map of the Karmøy sound and the Skudesnes fjord area in the Rogaland county, southwestern Norway, showing the outline of the Karmsundet Basin half-graben (solid line) with the trace of the Kvitsøy fault and the headwalls of marine slide-scars (lines with hatches) (Bøe et al. 2000).

Bedrock, fault systems and submarine basins

Region A

The Caledonian bedrock of the island of Karmøy (Figs. 2a and 3) is rather complex, but there is a distinct difference between the northeastern and southwestern parts of the island following the Karmøy-fault. In southwest, bedrocks belonging to the Caledonian West Karmøy Igneous Complex, gives an acid soil of low fertility. This is also reflected in the natural vegetation cover (Lundberg 1998). Metamorphic lavas and phyllite dominate the northeastern part, which produce a very fertile soil (Menuge *et al.* 1989). A thrust of Caledonian age separate these bedrocks from the Precambrian gneiss and granite found on the mainland (Haugalandet) and islands east of Karmøy (Sigmond *et al.* 1984, Bøe *et al.* 1992).

Towards the south the Caledonian thrust runs into the Kvitsøy-fault separating the Caledonian Karmøy bedrocks on the western side from Precambrian and Cambro-Ordovician metamorphic rocks to the east (Bøe *et al.* 1992). The islands between Karmøy and the mainland of North-Jæren consist of soft phyllite, meta-basalt and trusted Precambrian rocks of different composition. At the Stavanger peninsula phyllite bedrock is exposed as rocks or rocky hills. The Caledonian Nappe Complex rests on top of these series, and is best represented on the islands of the Boknafjord.

The Kvitsøy-fault is situated 2 km to the west of the islands of Kvitsøy in the mouth of Boknafjord and follows approximately 11 km offshore the northern and southern part of Jæren. It stretches from Karmsundet in the north turning southwards parallel to the coast (Bøe *et al.* 1992) (Fig. 3). Recently, Bøe *et al.* (2000) discovered an elongated half-graben, the Karmsundet Basin, at the mouth of Boknafjord (Fig. 4), where the eastern boundary of the half-graben equals the major Kvitsøy-fault. The Karmsundet Basin has an extent of approximately 28 x 5 km, broadest just west of Kvitsøy and extending as far south as 58º55'N. It contains tilted sedimentary rocks dipping towards the Kvitsøy-fault covered with up to 250 m thick Quaternary deposits separated into 4 units, A to D. Seismic data reveal a very thin cover of Holocene deposits in the upper part of unit D. Relevant to the present study is the fact that several Late Weichselian and Holocene faults, slide scars and associated mass-movements have been recorded within this basin (unit D) triggered by seismic reactivation by the postglacial regional rebound (Bøe *et al.* 2000). It is also evident from earthquake activity and observed faulting that this part of Norway is still tectonically active (e.g. Anundsen 1988).

There is also evidence of submarine slides in the area between the islands Vestre and Austre Bokn and the island of Rennesøy (Prøsch-Danielsen *et al.* 2005, Bøe *et al.* in prep.).

Region B

The underlying bedrock in South-Jæren belongs to the Caledonian Nappe Complex with trusted gneiss, granite and metasupracrustals with an exposed rim of phyllite to the east along the Jæren escarpment (Birkeland 1981). Except for some localities, e.g. the Tananger peninsula, thick Quaternary sediments in this region usually cover the bedrock.

The morphological boundary between Høgjæren and Lågjæren along the Jæren escarpment follows a north-south trending fault line referred to as the "Gandsfjord-fault" (Fig. 3). The lineament stretches from Gandsfjorden east of Stavanger to Brusand, and borders the Caledonian gneiss/phyllite to the west and Precambrian gneiss to the east. At Høgjæren, marine sediments (dated to ca. 32,000 yr BP) as high as 200 m a.s.l., have been recorded and heavily debated since the beginning of the last century (e.g. Fugelli & Riis 1992, Sejrup *et al.* 1998). Several models have been questioned due to the fact that the postglacial marine limit on Jæren generally is between 20 and 10 m a.s.l. Sejrup *et al.* (1998) concluded that these sediments are the results of glacial isostasy, rather than recent regional tectonic movements as suggested by Fugelli & Riis (1992). They also explain the Jæren escarpment as having been formed by glacial erosion.

However, the Gandsfjord-fault has its continuation or at least its counterpart in the Vindafjord-Yrkjefjord fault system further north, where Karl Anundsen measured recent movements (Fugelli & Riis 1992).

Region C

In the Dalane coastal region the dominating rock is Precambrian anorthosite with narrow bands of more nutrient-rich norite (Michot 1966).

Region D

Lista is a peninsula located on the extreme southern coast of Norway. It is divided into a low-lying outer coastal area and an inner mountainous area with a low relief. The bedrock consists of Precambrian metamorphic rocks belonging to the Egersund complex (Falkum 1982), and consists of acid gneisses and granitic igneous rocks.

Quaternary deposits and coastal classification

In general, the Boknafjord area was already deglaciated at 15,000-14,000 yr BP (Thomsen 1982b, Anundsen 1985, Paus 1988, 1989a, 1990) while the oldest dates for the deglaciation on Jæren are close to 13,000 yr BP (Andersen *et al.* 1987, Paus 1989b) (Fig. 5). The deglaciation in region C has not yet been absolute dated. The deglaciation of Lista took place in the time period between the Lista substage and the Spangereid substage. The assumed age of the Lista substage is controversial, ranging from 13,500-13,000 yr BP (Andersen 1979) to more than 15,000 yr BP (Anundsen 1985). Based on the dating of mollusc shells (Holtedahl 1988), the retreat of the main ice cap in the Lista basin is supposed to have taken place at least 12,500 yr BP, possibly 13,000 yr BP (Holtedahl 1993).

Region A

The islands in the outer part of the Boknafjord area (Karmøy and the islands of Rennesøy municipality) as well as the northern part of Jæren (the Stavanger peninsula) belong to the so-called "Strandflaten", a geomorphologic feature that can be followed along the coast from Troms to Jæren (Larsen & Holtedahl 1985) where sediment cover is discontinuous and bedrock is exposed as rocks or rocky hills. This has resulted in a varied landscape with peninsulas, rocky headlands as well as protected gravel or sand beaches, but where rocky shores dominate. The coast can also be partly classified as a fjord coast according to Klemsdal (1982).

Region B

The southern part of Jæren is almost completely covered by thick Quaternary deposits (Wangen *et al.* 1987, Andersen *et al.* 1987, Janocko 1997) (Fig. 2b) that record at least four glaciations and partly record "ice-free" periods in which glaciomarine clays were deposited by a Norwegian Channel Ice Stream (Sejrup *et al.* 1998, Stalsberg *et al.* 1999). This resulted in huge series (up to 130 m) of tills and glaciofluvial deposits interbedded with marine sediments. Late Weichselian erosion has exposed these series in a mosaic pattern (Grimnes 1910, Wangen *et al.* 1987) resulting in the subsoils of Jæren having very diverse soil fertility (Semb 1962). Traditionally, the area has been morphologically divided into Lågjæren and Høgjæren. Lågjæren forms a rim of coastal lowland close to the Norwegian Channel. Høgjæren is a mountaineous area situated east of the Jæren escarpment. Lågjæren has been further separated into two geomorphologic areas, B1 and B2 (e.g. Sejrup *et al.* 1998, Stalsberg *et al.* 1999, Jónsdottir *et al.* 1999) (see Fig. 2b):

<u>B1. Lågjæren</u> – a hummocky lowland area (north of Nærbø)

This area is relatively flat but with an undulating and hummocky landscape with shallow lakes. It is covered by glaciofluvial deposits and a sandy and gravely till interpreted as having been deposited during the last glaciation, and ridges orientated in an E-W direction as a result of ice lobes from the east.

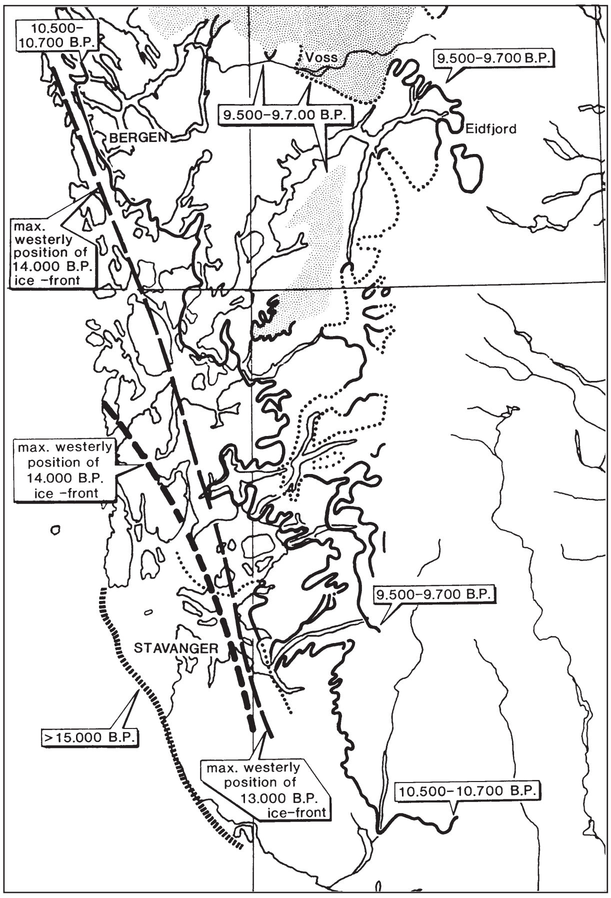


Fig. 5. Approximate ice-front positions in southwestern Norway in Late Weichselian and Preboreal chronozones (Anundsen 1985).

<u>B2. Lågjæren</u> – a smooth lowland area with streamlined morphology (south of Nærbø)

The area has ridges running predominantly NW-SE parallel to the coast, which have been interpreted as drumlins formed by ice flowing along the Norwegian Channel. Superimposed on these is a weaker imprint of later E-W flowing ice. This southern part of Jæren is also covered by sand and gravely till but has pronounced clay till content on the ridges.

The coastal rim belonging to the Jæren lowland is characterised by the absence of protecting skerries and islands. The coastline is exposed to the North Sea and is sensitive to sea-level changes where even small fluctuations in sea-level may cause dramatic changes in the landscape (Bang-Andersen 1986). Here littoral forms developed in sediments dominate. Sequences of rocky shores are interrupted by a stony moraine topography coasts, moraine cliff coasts and sandy beach coasts along the rim of Jæren (Klemsdal (1982), Sjulsen (1982) Bird & Klemsdal (1986) and Janocko (1997)).

At the beaches of Sola and Sele-Bore (B1) old lagoons have been filled with sand washed in across the beaches, and finally covered by eolian material. The site of these lagoons is now a sand-flat with grassland behind the dunes (Bird & Klemsdal 1986).

The north-south drumlinised Lågjæren (B2) suggests that this area was a border zone to the Norwegian Channel Ice Stream. The ridges are restricted to the coastline in the middle and northern part of the area and form the last barrier towards the North Sea. The drumlins are eroded by marine processes, leaving a rocky shore zone. It reveals a mature coastline that reflects a generally smooth coastal morphology (Stalsberg *et al.* 1999). In the southern part of region B2, at Ogna, sandy beach coasts take over. At Brusand there is a good example of a coastal lagoon (Bird & Klemsdal 1986).

Region C

The Dalane coastal region differs strongly from the Jæren region. It is a mountainous area dominated by exposed bedrock and is almost lacking Quaternary deposits. However, unconsolidated sediments are found in the bottoms of valleys. On the island of Eigerøy several drumlins are recorded (Garnes 1976). The coast is characterised as "a cliff abrasion and fjärd coast" by Bird & Klemsdal (1986).

Region D

In the low-lying outer costal area of Lista, thick Quaternary deposits cover the bedrock. It consists mainly of reworked Weichselian till and glaciofluvial deposits (Andersen 1979). The *in situ* till deposits have a varying sand and clay content (Bjørlykke 1929). The low-lying part of Lista has changed its appearance from an archipelago to a lowland peninsula due to the movement of loose deposits and a changing sea-level (Prøsch-Danielsen 1997). The coast has been classified as: "a moraine topography coast, a moraine cliff coast, a sandy beach coast, fjärd- and/or fjord coast" (Klemsdal 1982).

Radiocarbon dates and chronology

The geological chronostratigraphical subdivisions follow Mangerud *et al.* (1974). The archaeological chronological subdivisions of the Mesolithic and the Neolithic follow Nærøy (1987, 1993) (Fig. 6). This chronology of western Norway is based on local artefact assemblages with data compiled primarily from Hordaland County. This is correlated with the south Scandinavian chronology and periodization proposed by Fisher (2002) and for the pioneer periods by (Petersen 1993):

Early Mesolithic: 10,000–9000 yr BP
Middle Mesolithic: 9000–7000 yr BP
Late Mesolithic: 7000–5200/5000 yr BP

The chronological subdivisions of the Bronze Age follow Vandkilde *et al.* (1996) while the traditional Norwegian subdivision of the Iron Age is used (Slomann 1972) (Fig. 6).

The radiocarbon dates are presented as uncalibrated ^{14}C years BP in the text. The Radiological Dating Laboratory in Trondheim, Norway calculated conventional radiocarbon dates and the AMS dates by The Svedberg Laboratory at the University of Uppsala, Sweden and Beta Analytical Inc. Florida, USA. Radiocarbon dating was carried out on the NaOH soluble fraction (A-fraction) and in some instances on the insoluble fraction (B-fraction).

A review of the shore level displacement history of southwestern Norway

Before the radiocarbon method was introduced in the 1950s, shore level studies were mainly based on field observations and on measured altitudes of littorale forms as accumulation terraces, deltas, beach ridges and abrasion terraces, and notches in unconsolidated sediments in addition to information from molluscs, drifts of pumice and bones from marine vertebrates (e.g. Rekstad 1908, Kaldhol 1941). Morphological studies were later carried on by Rønnevik (1971), Bird & Klemsdal (1986) and Prøsch-Danielsen (1993). On Lista, in Vest-Agder, mapping of littorale forms has been compiled by Sørensen (1985), a study that is based on recent field studies and earlier observations by Reusch (1901), Danielsen (1910, 1912, 1929), Øyen (1926), Bjørlykke (1929), Andersen (1960) and Klemsdal (1982).

Later on, shore level displacement curves were also constructed from sediment studies (litho- and biostratigraphy) from basins at different levels (Fægri 1940, 1941). When the radiocarbon method was introduced, a more precise chronostratigraphical subdivision was possible. In addition, environmental changes in the basins were thoroughly checked for algae, pollen and diatoms. Especially diatoms are sensitive to changes in salinity, nutrient content, pH and water depth, and turned up to be the best tool for levelling of isolation or ingression of the various basins (e.g. Thomsen 1982a, 1982b, 1989, Kryzwinski & Stabell 1984, Braathen & Hermansen 1985, Prøsch-Danielsen 1993, 1997, Lohne 2000). By combining these methods isobase directions for desired periods were calculated for parts of Rogaland (Rønnevik 1971, Lorentzen-Styr 1977, Anundsen 1985, Andersen unpublished).

Two distinct transgressions, one in the Late Weichselian and one in the Holocene (the Tapes transgression), were recorded along the entire coastal area of Rogaland (Fig. 7) as well as the coast of Lista. The Late Weichselian transgression, has been known since the early 1940s in Rogaland ("the Alvevatn transgression" cf. Fægri 1940)

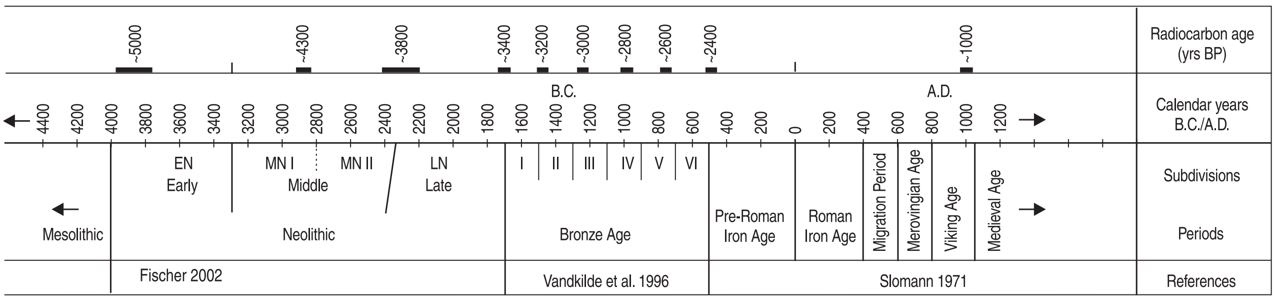


Fig. 6. Overview of the chronology of the Neolithic, the Bronze Age and the Iron Age in southwestern Norway presented in uncalibrated ^{14}C-years BP and calibrated calendar years BC/AD (Prøsch-Danielsen & Sandgren 2003).

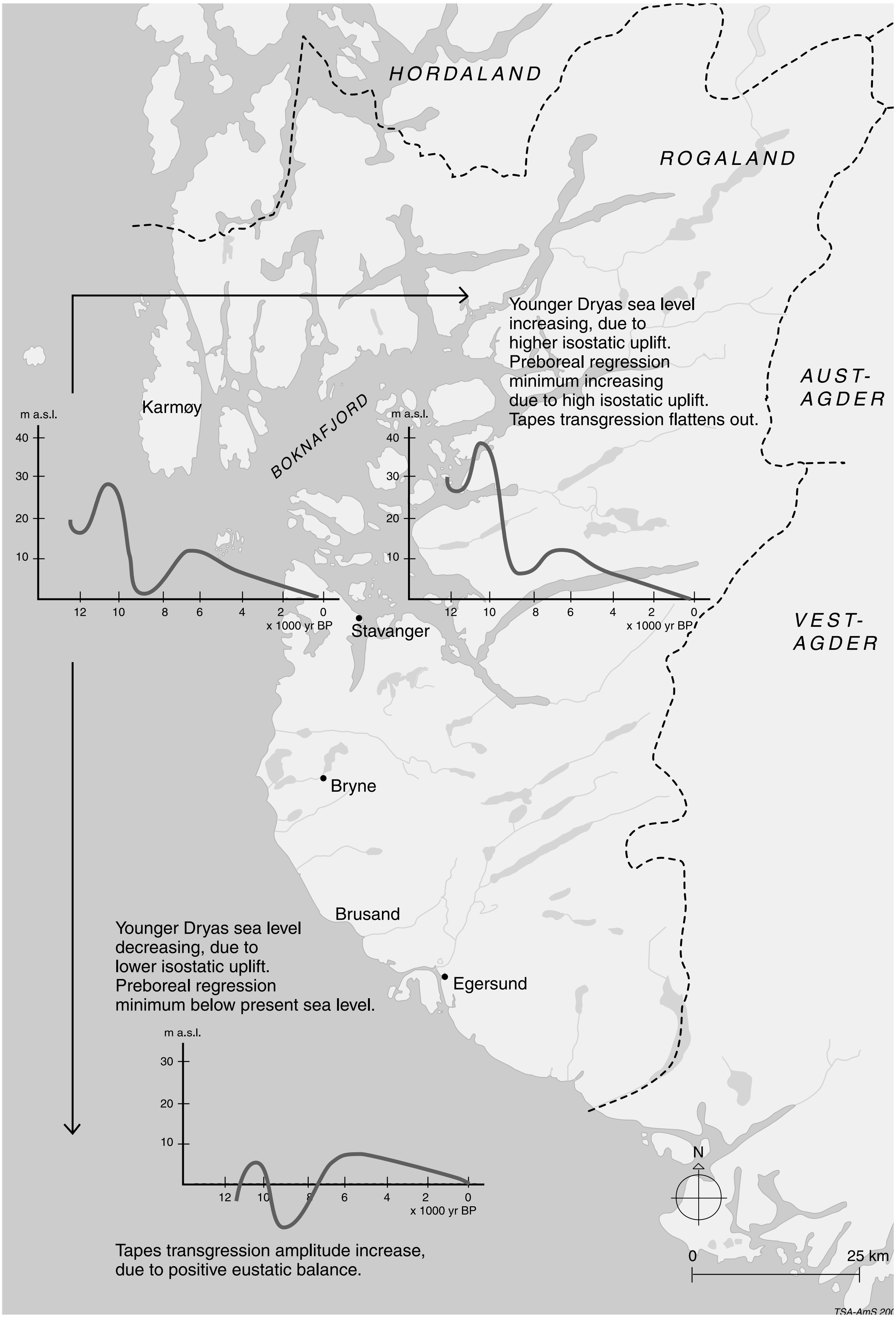


Fig. 7. Map illustrating the general E-W and N-S variations in the shore level displacement curves for Rogaland county, south-western Norway, updated until 2003 (Prøsch-Danielsen & Bondevik 2003).

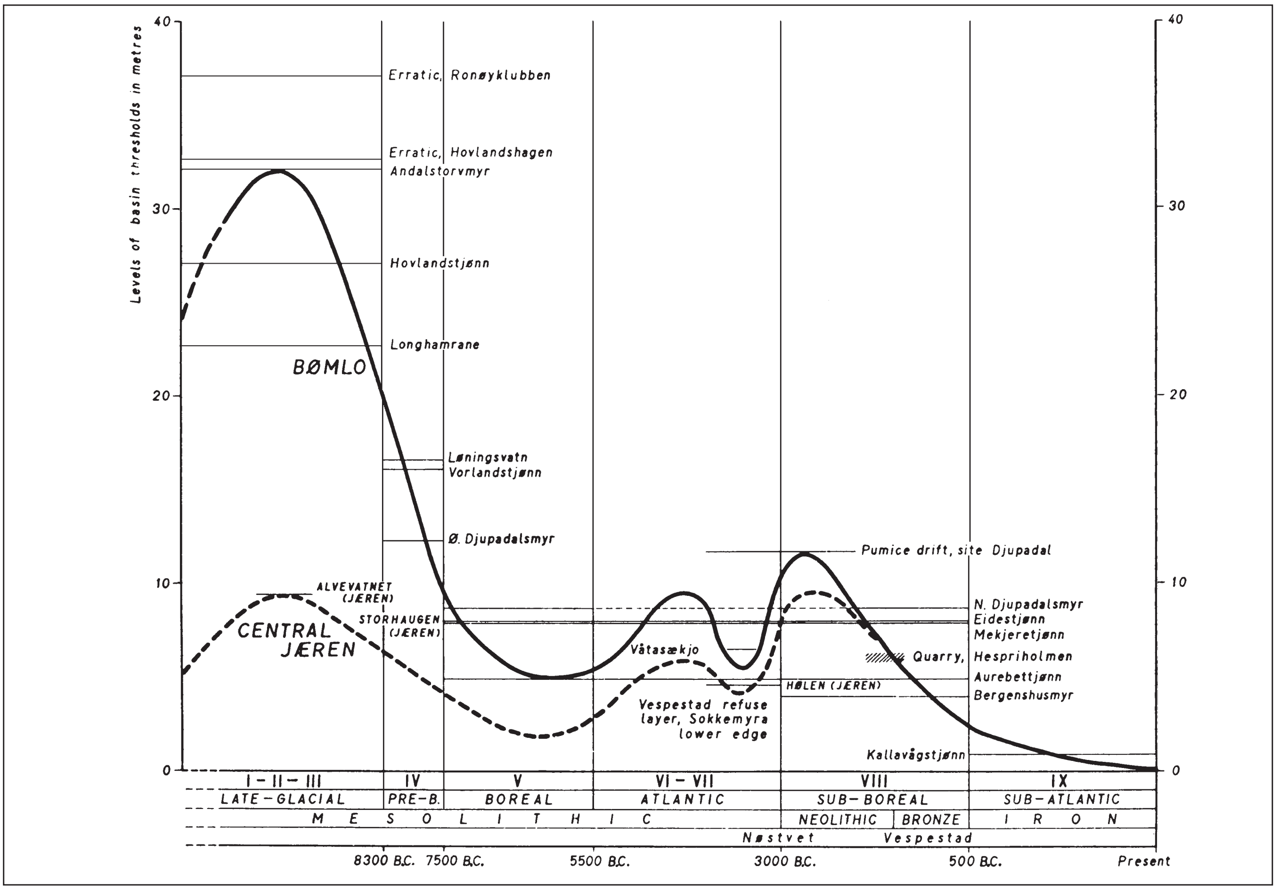


Fig. 8. Late Weichselian and Holocene sea-level displacement curves for Bømlo in Hordaland county and the central part of Jæren in Rogaland county, constructed on the basis of Fægri's results (1940) (In Kaland 1984).

(Fig. 8). This transgression started in Allerød biozone with a maximum between 10,800 yr BP and 10,200 yr BP (Thomsen 1982b, Anundsen 1985, Braathen & Hermansen 1985, Austad & Erichsen 1987, Kaland 1988, Flatekval 1991) (Figs. 9, 10, 11, 12 and 13). The Late Weichselian (Younger Dryas) and Tapes transgressions intersect at Reve in Central Jæren, where the Tapes level forms the marine limit (ML) southwards (Fægri 1940, Thomsen 1982b). The oldest transgression had an amplitude of minimum 13 m in the northern part of Rogaland (Anundsen & Fjeldskaar 1983), and at least 9 m in the southern part of Rogaland (Fægri 1940). The Younger Dryas isobases increase eastwards in the fjord district due to higher isostatic uplift, and decreases southwards along the coast due to lower isostatic uplift. The isobases during the Younger Dryas followed a NW-SE direction (Figs. 14 and 15).

In 1910 Danielsen postulated that the maximum Late Weichselian and Holocene shore levels almost intersect on Lista, with the highest-lying ridges being the oldest. Hansen (1913), Bjørlykke (1929) and Andersen (1960) came to the opposite conclusion that the marine limit (ML) was reached during the Holocene in this area.

About 20 years ago, Anundsen & Fjeldskaar (1983), Anundsen (1985) and Braaten & Hermansen (1985) pointed out that there had also been an earlier transgression at least in Yrkje, in the northern part of the Boknafjord area. This transgression is the result of glacier oscillations

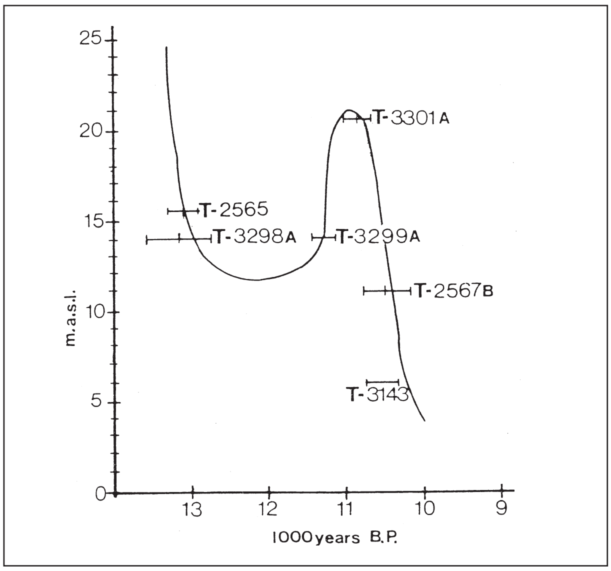


Fig. 9. Late-Weichselian sea-level displacement curve for Nord-Jæren, Rogaland county, southwestern Norway (Thomsen 1982a).

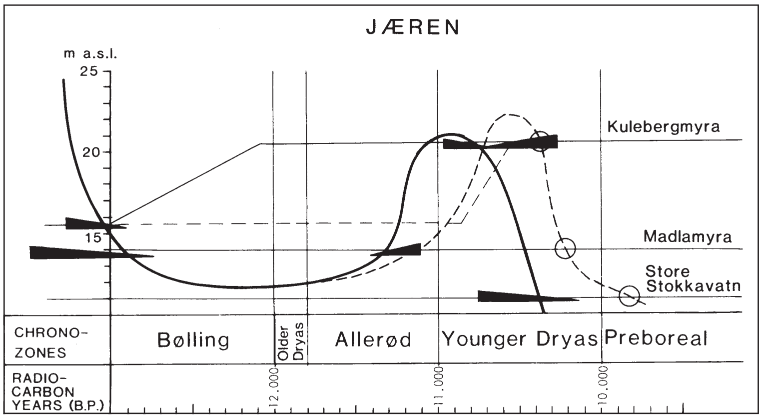


Fig. 10. Late Weichselian sea-level displacement curve for Nord-Jæren, Rogaland county (Thomsen 1982a). Stippled curve is the interpretation made by Anundsen (1985).

Ingression
Isolation
Lacustrine phase

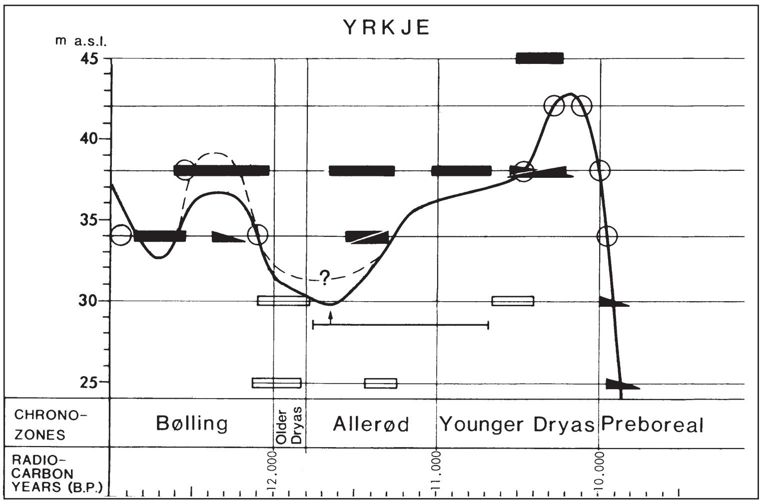


Fig. 11. Sea-level displacement curve for Yrkje, northern Rogaland county, southwestern Norway. ^{14}C-dates are shown with one standard deviation. The time period represented in the different cores are shown as horizontal lines. Pollen-analytical datings of ingressions and isolations are given by circles (Anundsen 1985).

Ingression
Isolation
Marine phase
Lacustrine phase

that occurred during the Bølling Chronozone, with a maximum between 12,600 yr BP and 12,300 yr BP. Isobases during this transgression followed a NNW-SSE direction (Anundsen 1985) (Fig. 16).

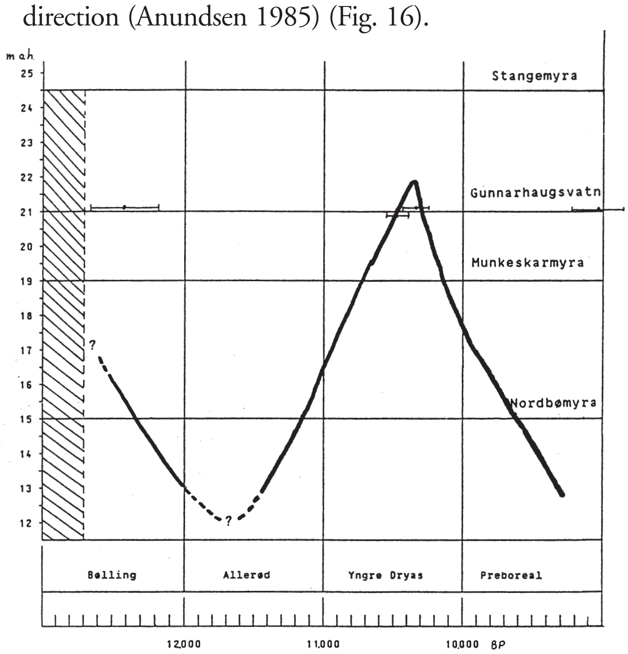


Fig. 12. Sea-level displacement curve for Nord-Karmøy, northern Rogaland county, southwestern Norway (Austad & Erichsen 1987).

In general, the sea-level displacement curves reveal a rapid regression from the Younger Dryas throughout the Preboreal Chronozone. In the Boknafjord area the sea-level dropped from 2 m/100 yrs (western part) (Prøsch-Danielsen 1993a) to 4-5 m/100 yrs (eastern part) in this time interval (Ugland 1984). Southwards this regression was slower due to lower isostatic uplift. In the southern part of Rogaland as well as further southeast along the coast to Lista, the Preboreal regression minimum was

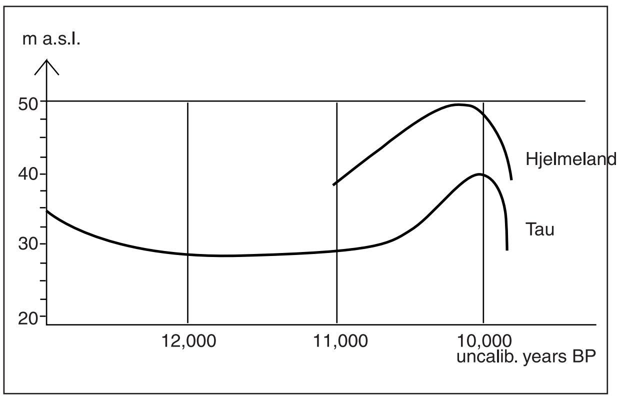


Fig. 13. Sea-level displacement curve for Hjelmeland and Tau, Ryfylke in Rogaland, southwestern Norway (Kaland 1988, Flatekval 1991).

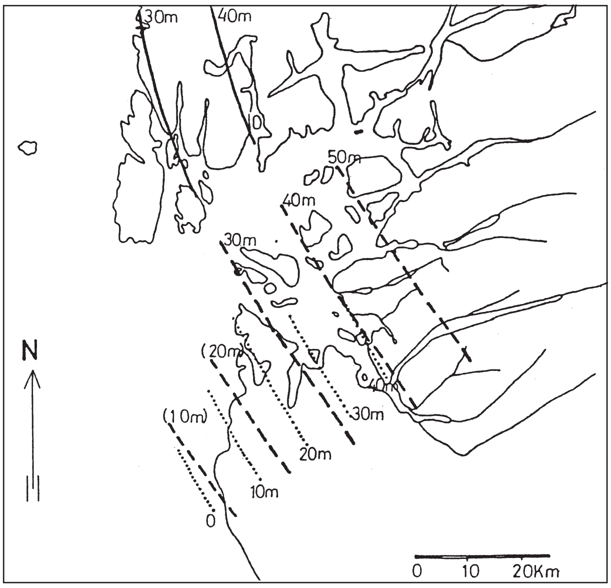


Fig. 14. Different proposals of isobases for Younger Dryas in Rogaland county, southwestern Norway.
—— Isobases constructed by Rønnevik (1971)
······· Isobases constructed by Andersen (unpublished)
- - - Isobases constructed by Lorentzen-Styr (1977)
The 10, 20 amd 30 m isobases are extrapolated (after Lorentzen-Styr 1977)

below the present sea-level. The displacement was the result of interaction between the isostatic rebound and eustatic variations in the Late Weichselian and the Holocene, where the isostatic rebound dominated up to 9000 yr BP, than eustatic movements were more prominent.

The Tapes transgression started ca 8500-8000 yr BP with a maximum approximately 6500-5000 yr BP at least in the northern part of Rogaland. Fægri (1940) postulated that the Tapes transgression had a double peak (Fig. 8). However, only one peak has been recorded by Eide (1982), Thomsen (1982a, 1989) and by Midtbø (2000). In the northern part of Rogaland the Tapes transgression rised up to 12-13 m above present sea-level, in the southern part it is below the 10 m isocountour line. Isobases for 6500 yr BP have been drawn by Sørensen *et al.* (1987) (Fig. 17).

Danielsen (1929) postulated that there had been two transgressions during the Holocene on Lista. He also stated that the last oscillation had been the smallest one. This is in contrast to the investigations made by Andersen (1960), who concluded that the last oscillation that took place in the late Atlantic or Subboreal period was the highest.

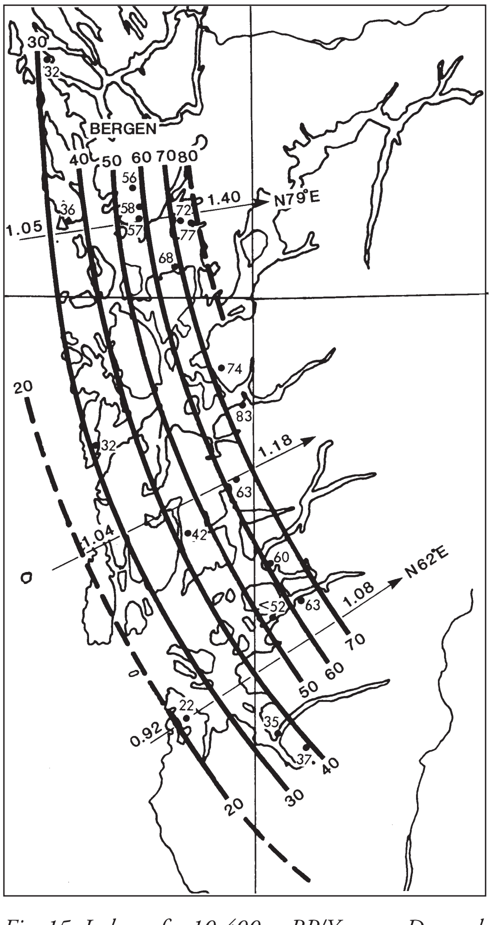


Fig. 15. Isobases for 10,400 yr BP/Younger Dryas glacial advance for southwestern Norway (Anundsen 1985).

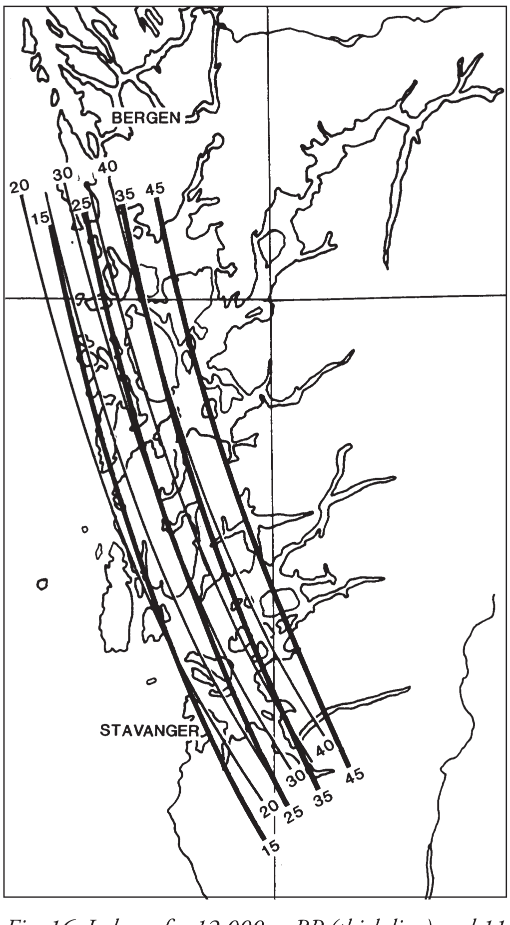


Fig. 16. Isobases for 12,000 yr BP (thick line) and 11,000 yr BP (thin line) for southwestern Norway (Anundsen 1985).

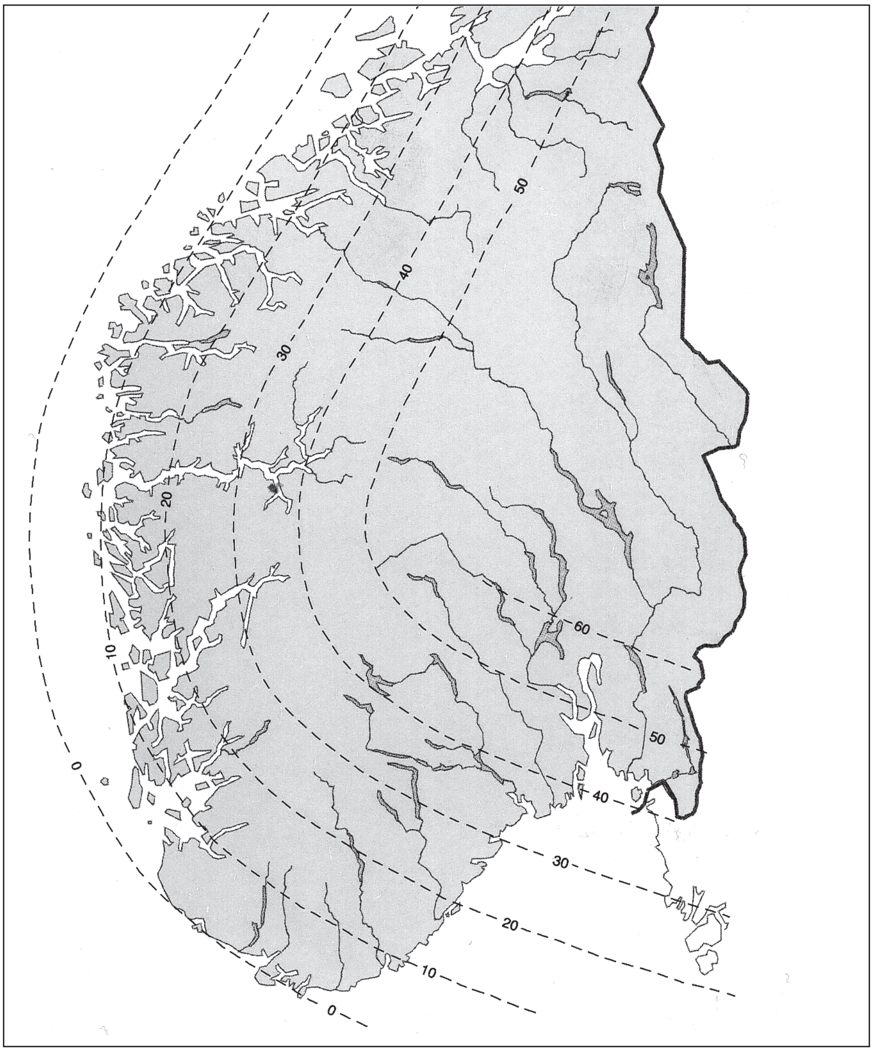


Fig. 17. Isobases 6500 yr BP in Norway (Sørensen et al. 1987).

Sørensen (1985) postulated the existence of no less than three transgression phases in the Holocene, while Hafsten (1979, 1983a, 1983b) was content with no more than one. By sediment studies in a serie of basins, Prøsch-Danielsen (1997) showed that the number of marine events recorded depended on location, exposure and coastal type. She recorded one transgression at exposed localities, and no less than three marine events at sheltered localities.

Region A

The Northern Boknafjord area

Since the early 1970s extensive archaeological registrations and excavations as well as studies on the natural history have been carried out in the Karmøy sound area and the northern part of the Boknafjord area, provoked by the establishment of major industrial enterprises and other construction works such as gas pipelines and road constructions in the municipalities of Karmøy, Bokn and Tysvær:

- Statoils plans for a gas terminal at Kårstø (Eide & Paus 1982, Paus 1988).
- Statkrafts plans for a new gas power plant connected to the existing gas terminal at Kårstø (Thomsen 1989, Gjerland 1990).
- Europipe II, plans for a new gas pipeline on Vestre Bokn (Museum of Archaeology, Stavanger, topographical archive).
- New road alignment from Årsvågen, Vestre Bokn to Aksdal, connecting the northern islands in the Boknafjord to the mainland further north (Museum of Archaeology, Stavanger, topographical archives).
- Åsgard transport, a new gas pipeline stretching from Karmøy in the west, passing Fosen to the Kårstø gas

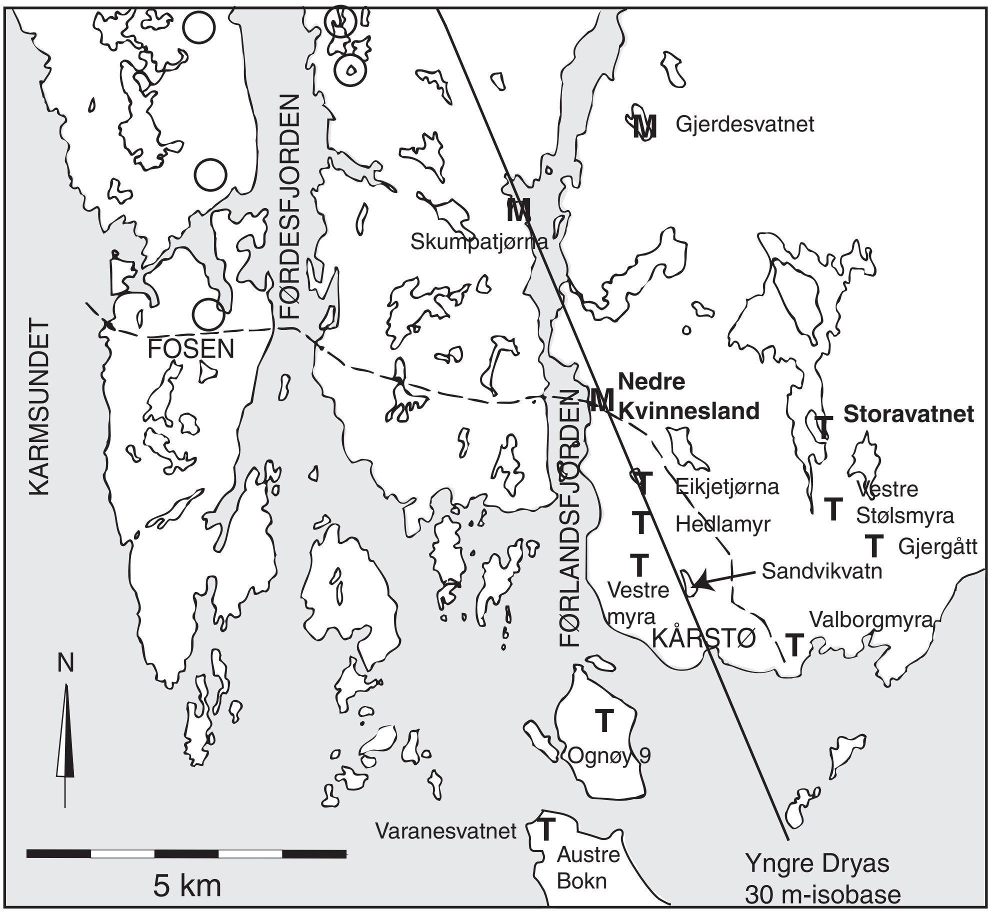


Fig. 18. Map showing localities investigated by Thomsen (T) (1989) and by Midtbø (M) (2000) in the northern Boknafjord area, Rogaland county, southwestern Norway. The Åsgard transport gas pipeline is stippled and the Younger Dryas 30 m isobase line is marked. Open circles = work in progress (T-forbindelsen, a new road network) (Skjelstad 2004, Bruen Olsen et al. *2005).*

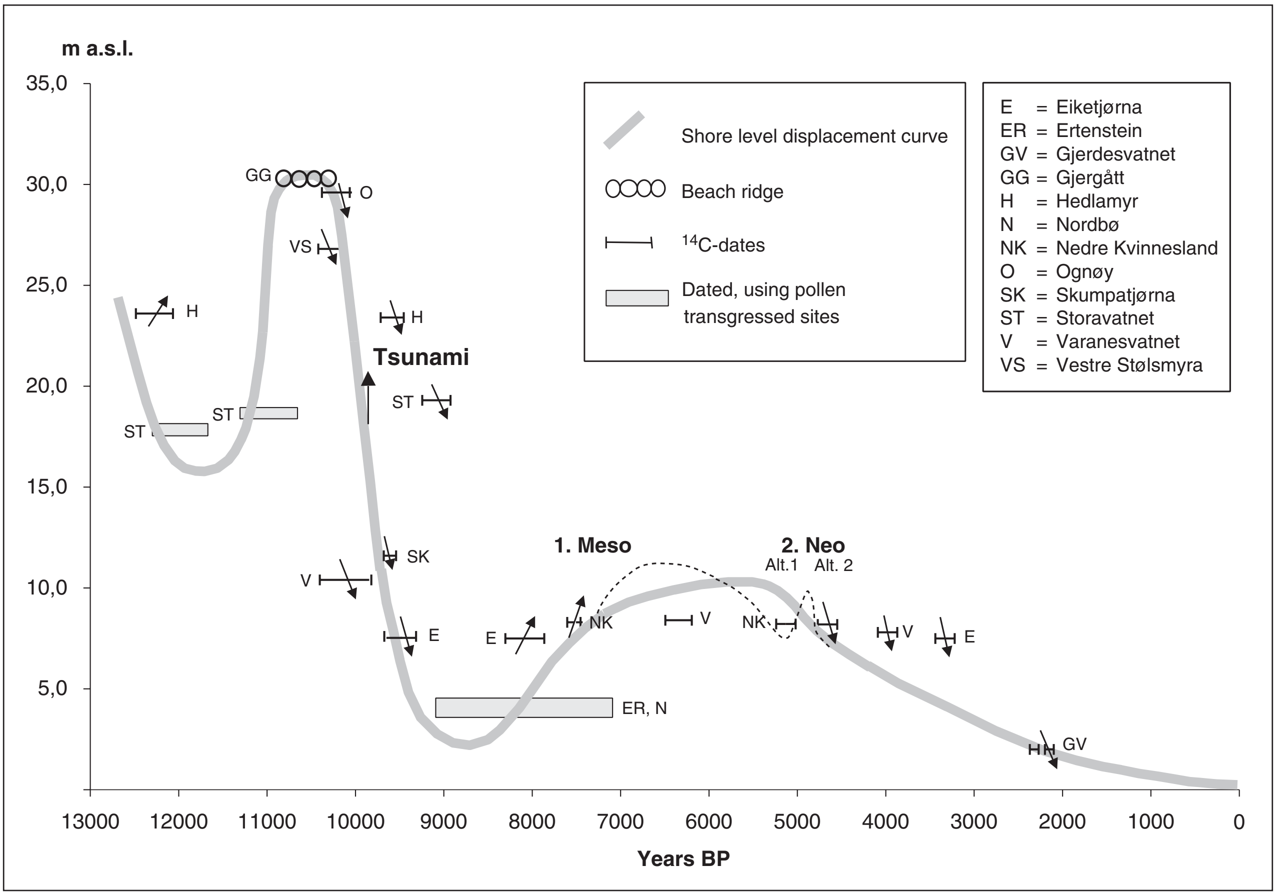


Fig. 19. The constructed sea-level displacement curve for Tysvær municipality, Rogaland county, southwestern Norway, including Thomsen's (1989) and Midtbø's localities (Midtbø 2000) – adjusted for the Younger Dryas 30 m isobase line. Suggested displacement curve is dotted.

terminal at the Tysvær peninsula (Løken 2000).

- Work in progress: "T-forbindelsen", a new road network in the municipalities of Karmøy and Tysvær, financed by The Norwegian Public Roads Administration (Statens Vegvesen) (Skjelstad 2004, Bruen Olsen *et al.* 2005).

Sea-level studies

In the period from 1977 to 1988, Thomsen (1989) constructed three separate shore displacement curves for the Austre Bokn, Ognøy and Tysvær peninsula, based on the investigation of seven lakes and infill-basins ranging from 31.5 m down to 5.0 m above sea-level; Vestre Myra (31.5 m a.s.l.), Vestre Stølsmyra (28.5 m a.s.l.), Ognøy (28 m a.s.l.), Hedlamyr (23 m a.s.l.), Storavatnet (20.5 m a.s.l.), Varanesvatnet (7.5 m a.s.l.) and Eikjestjørna (5 m a.s.l.) (Fig. 18). The Younger Dryas transgression maximum was put to the 32 m contour line in the eastern part of the area due to the find of a raised beach ridge at Gjergått.

The constructed shore displacement curve (Fig. 19) follow the main course described from Rennesøy (Fig. 27). However, Thomsen was not able to find more than one Tapes transgression phase although she was aware that a double-peaked transgression had been postulated earlier (Fægri 1940). However, new investigations of basins between the 20.5 m and the 7.5 m levels could perhaps have picked up the problem.

This approach was actualised in 1998 due to the Åsgård transport project, which included an 18 km gas pipeline from Kalstø at Karmøy in west to Kårstø at the Tysvær peninsula (Løken 2000). The investigations involved studies of three basins localised on both sides of the Younger Dryas 30 m-isobase line, following NNW-SSE along the Førlandsfjorden area (Midtbø 2000). Special emphasise was put to find basins at levels near the estimated regression minimum and Tapes transgression maximum in the Holocene. Three basins were chosen; Skumpatjørna (11.6 m a.s.l.), Nedre Kvinnesland (8.3 m a.s.l.) and Gjerdesvatnet (2 m a.s.l.) (Figs. 18 and 19). Skumpatjørna (11.6 m a.s.l.) was isolated from the sea 9610±70 yr BP (β-126390) and was not affected by the later Tapes transgression or any other marine events. This gives the upper limit for the Tapes transgression in this particular area. A transgression has been recorded in the soil section at Nedre Kvinnesland. Here, two peat layers (layer 6 and 8) were separated by a sandy to gravelly layer containing plant remains (layer 7). The upper part of layer 6 is dated to 7445±55 yr BP (T-13779A) and the lower part of layer 8 to 4965±115 yr BP (T-13778B) and 4630±95 yr BP (T-13778A) respectively. This implies that the infill basin was transgressed in a time interval between ca 7400 yr BP and 4600 yr BP.

Lake Storavatnet – a gravel bed in marine gyttja

A complete Late Weichselian sediment sequence (Fig. 20) was recorded in one basin, lake Storavatnet, situated 20.5 m a.s.l. The stratigraphy is as follows (cm below surface):

200 - 235 cm	brown algae gyttja
235 - 256 cm	clay gyttja. Gravel and clasts of gyttja at 247 - 250 cm
256 - 287 cm	greygreen silty clay gyttja
287 - 294 cm	sand
294 - 333 cm	grey clay gyttja
333 - 334 cm	sand
334 - 337 cm	grey clay gyttja
337 - 355 cm	sand
355 - 360 cm	silt

The sediment sequence was analysed for diatoms by Thomsen in 1983 (Thomsen 1989). Unfortunately the sediments has not been quantitatively analysed for pollen. A brackish to marine assemblage probably of Bølling age characterizes the samples from the bottom layers up to 334 cm. Then follows a regression as seen by the lacustrine sequence from 334 cm to ca 294 cm and a brackish to lacustrine sequence from 294 cm to 287 cm (sand layer). The sand layer represents the transition from a lacustrine to a marine environment e.g. probably the start of the Younger Dryas transgression. The next layer (256-287 cm) comprises a greygreen silty clay gyttja where the diatom samples solely contain marine taxa. However, *there is a hiatus in the marine gyttja layer recognised as a gravely layer containing clasts of gyttja at level 247-250 cm. The marine diatoms found just below and above this gravely layer is ruptured and some appear as chains (Melosira sulcata) that must have been washed into the basin during a storm or possibly a tsunami.* This event happened some time before 9060±160 yr BP (T-8351A) (Fig. 20). Thomsen (1989) assumed that this date is too young and that the basin had a high marine diatom content in a time interval after the basin was isolated from the sea. This is explained as due to the large size of the basin.

To sum up: During the Younger Dryas regression phase a layer of gravel with clasts of gyttja and long chains of *Melosira sulcata* was present within the marine gyttja. This sequence is not in accordance with the general shoreline displacement curve and has probably been deposited either during a storm or a tsunami. This event is older than 9060±160 yr BP (T-8351A). Neither Thomsen's (1989) nor Midtbø's (2000) investigations revealed a double-peaked Tapes transgression or other unsystematic marine events during the Tapes transgression.

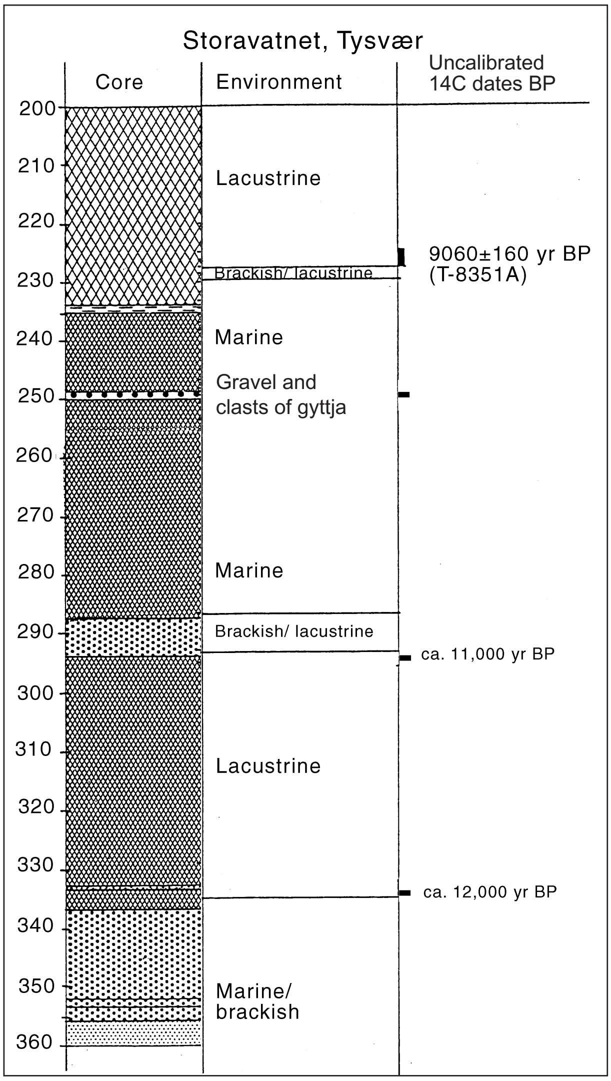


Fig. 20. The Late Weichselian – Early Holocene sediment sequence from lake Storavatnet (20.5 m a.s.l.) in Tysvær municipality, Rogaland county, southwestern Norway. Notice the gravely layer containing clasts of gyttja at 247-250 cm below surface (modified after Thomsen 1989).

Nedre Kvinnesland – two separate beach sequences containing artefacts

At Nedre Kvinnesland (Figs. 18 and 21), one Mesolithic and one Neolithic site have been sealed and preserved by (a) marine event(s). These sites were excavated in 1998 (Jaksland 2000). The sites are today situated between 7.5

m and 8.5 m a.s.l. The artefact bearing layers could be separated into two distinct stratigraphic layers (Fig. 22). The lowermost layer, a heterogeneous mixture of clay/silt, sand, gravel and pebbles, have been interpreted as representing “an old beach sequence” (Jaksland 2000). The layer contained exclusively Mesolithic artefacts that were dated to the Middle Mesolithic period (in between 8000-7500 yr BP). This date has been verified by charcoal samples in-context from the site; 7780±50 yr BP (bð-119500) (wooden material) and 7570±50 yr BP (bð-122522) (burnt hazelnut shells). The material is partly water-rolled and partly redistributed. The situation is explained by the shore displacement curve for the area (Fig. 19), where the Tapes transgression maximum, app. 6500 yr BP, is lower than and do not exceed the 11.6 m contour line (Skumpatjørn).

The uppermost layer called “the new beach sequence” by Jaksland (2000), consisted of well sorted sand and gravel, and contained Mesolithic (partly water-rolled) as well as Neolithic (not water-rolled) artefacts. The Neolithic artefact inventory is rather sparse, probably reflecting a short occupation. Jaksland suggested that Mesolithic artefacts were mixed into ”the new beach sequence” under the influence of the proceeding transgression/regression which according to Midtbø (2000) lasted from app. 7500 to 4900/4600 yr BP. Jaksland (2000) concluded that the Neolithic man stayed on the freshly emerged beach (4600 yr BP). He placed the maximum date for the Neolithic occupation to 4600 yr BP (Middle Neolithic), mostly based on the constructed shore level curve for the area where only one transgression phase has been recorded 7.5 m a.s.l. (Midtbø 2000). None of the Neolithic arte-

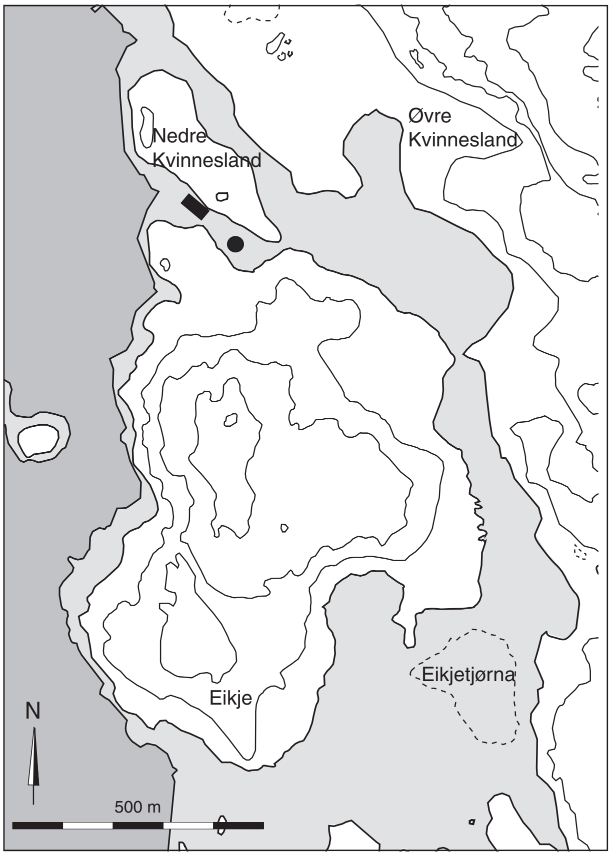


Fig. 21. Map showing the archaeological excavated area at Nedre Kvinnesland in Tysvær municipality, Rogaland county, southwestern Norway (filled square) and the location of the investigated basin nearby (filled circle). Present sea-level is dark shaded, while the situation with a sea level 10 m above the present sea-level is slightly shaded (Midtbø 2000).

Fig. 22. Photo showing the two separate beach gravel deposits containing artefacts at Nedre Kvinnesland in Tysvær municipality (photo: Lasse Jaksland in Løken 2000).

facts found in "the new beach sequence" are diagnostic for either the Early- or the Middle Neolithic periods. They may have been used in both periods.

An alternative explanation is that the two beach gravel deposits represent two separate marine events, i.e. two transgressions were the youngest one, of short duration, requires a second transgression at least 7.5 m a.s.l. (probably 2-3 m below the first one). Then the Neolithic man occupied the area before a second marine event some time before 4900/4600 yr BP. This alternative can also explain the mixture of Mesolithic and Neolithic artefacts in "the upper new beach sequence" (see Fig. 19).

At Ogn in the outer part of Boknafjorden, a Late Mesolithic site situated 13-14 m a.s.l. has been transgressed (Gjerland 1990) (Fig. 18). However, at Breiviksklubben, Bratt-Helgaland in the Karmøy sound, one of the most find-bearing Early Mesolithic sites from the Preboreal in western Norway and a Middle Mesolithic site have not been transgressed (Kutschera & Waraas 2000:92). These sites are situated 12-15 m a.s.l.

The Karmøy sound

The island of Husøy (highest point is 22.5 m a.s.l.) situated in the Karmøy sound near Haugesund (Fig. 23), was investigated for prehistoric cultural remains in the period from 1974 to 1982 (Lindblom *et al.* 1997). Husøy belongs to a group of islands called Veldeøyene, including Stutøy, Midtøy as well as Håvøy. These investigations, which also involved studies on the natural history, were made possible due to announced plans of an industrial development. The 8 m contour line was chosen as the lower limit of the investigation, due to the preconception that the shoreline above this level was of special importance to Stone Age man. The constructed shore level displacement curve for the area (Fig. 24) was based on Kaland´s (1984) investigations from Bømlo 30 km north of Husøy, supported by two pollen diagrams from Håvik, 2 km south of Husøy (Hafsten unpublished; one of these diagrams was published later in Prøsch-Danielsen & Simonsen 2000a). This puts the Tapes transgression at the 10 m contour line in this area.

The investigations resulted in the finds of 10 archaeological sites that could be divided into two groups based on topographic location and size; Group A sites were situated below 13 m a.s.l. (site X, 6-8 m a.s.l.), while group B sites are located above 13 m a.s.l., on saddles not directly adjacent to the shoreline. The group A sites were obviously disarranged, without clear outer limits/boundaries. The stratigraphy was complicated. Datable finds were normally scattered throughout the soil profile, and did not belong to any particular layer or feature. Hearths and other structures were missing at these sites. The artefact distribution patterns or say lack of pattern caused a great deal of confusion in analysing the material. In 1979 the authors (Lindblom *et al.* 1997) questioned if these features were due to a wide spread activity and/or if the artefacts had moved vertically throughout the soil profile. At the final stage the authors concluded that this puzzling stratigraphy most reasonably could be explained if the sites had been exposed to wave erosion. They also added that *this erosion must have taken place over a short period of time, as practically none of the artefacts found were water-rolled (Lindblom et al. 1997).* Site IV appeared to lie in and beneath beach sediments, and here some water-rolled flint flakes appeared. All over, the datable artefact types from the type A sites were commonly found in Late Mesolithic. However, not all the artefact types can be precisely dated, and some are definitely also associated with Neolithic people (see Fig. 25). At site II, no Nøstvedt axes (preferably associated with the Mesolithic) were found, which may indicate that the site is older than the Neolithic. However, the authors argue in favour of a continuous occupation for short periods of time dated to the latest part of the Mesolithic. *All in all, this implies that*

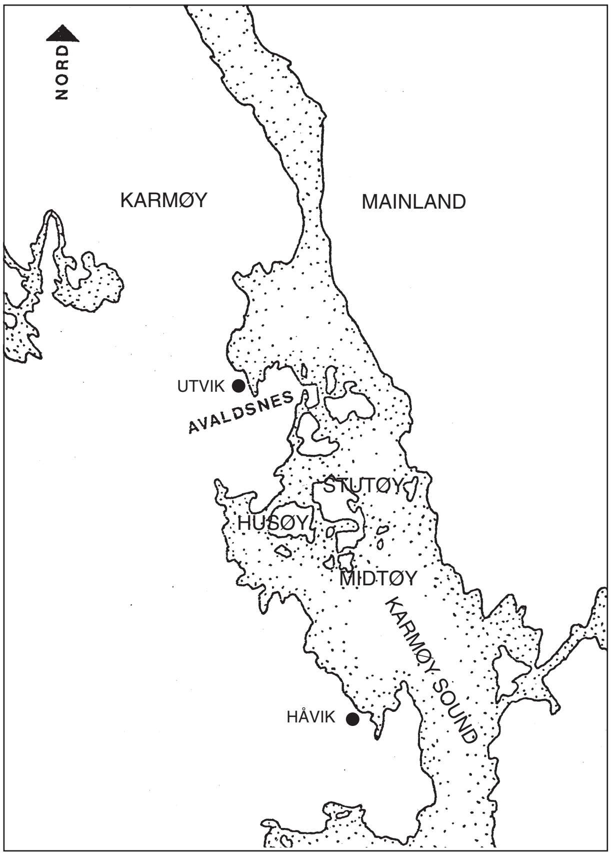


Fig. 23. Map showing the localisation of Utvik, Håvik, and the islands of Husøy, Stutøy and Midtøy in the Karmøy sound, northern part of Rogaland county, southwestern Norway (Lindblom et al. 1997).

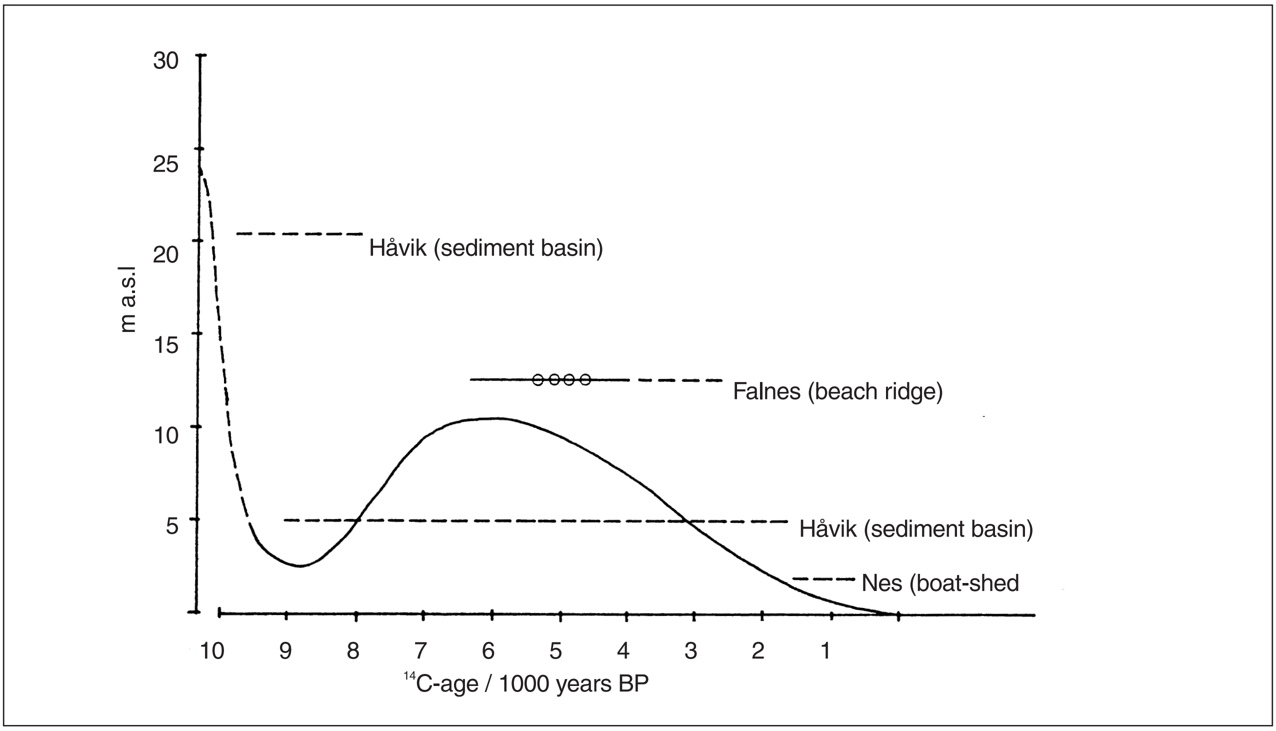


Fig. 24. Sea-level displacement curve from northern Karmøy, northern part of Rogaland county (Lindblom et al. 1997).

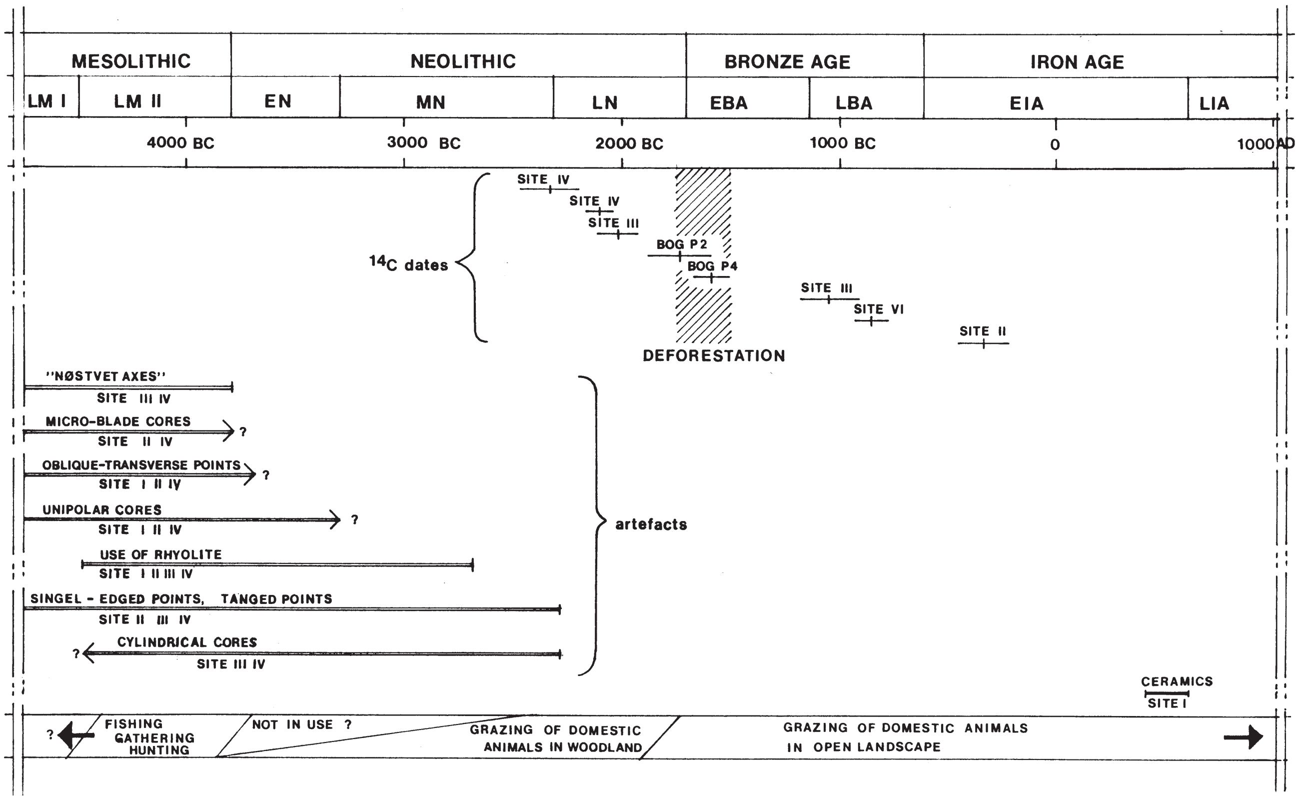


Fig. 25. Composite diagram showing the relation between 1) the archaeological periods for parts of western Norway, 2) the ^{14}C-dates from Husøy, in the Karmøy sound, northern part of Rogaland county, southwestern Norway 3) age of deforestation, and 4) the most important artefacts of the western Norway and their general occurrences in time. At the bottom the prehistoric peoples different use of the island are indicated (Lindblom et al. 1979).

the sites were exposed to wave erosion after the transition to the Early Neolithic (5000 yr BP).

The artefacts from the group B sites were too meagre to support any definite conclusion based on function or date.

The distribution of dwelling site areas was compared with the general distribution of charcoal in the soil all over the island Husøy, but no correlation was shown. In addition, none of the radiocarbon dates from charcoal sampled within the sites (e.g. site II, III, IV, VI) agree with the artefact inventory at these sites. The radiocarbon dates range from the Middle Neolithic/Late Neolithic transition to the middle of the Early Iron Age, and the authors therefore suggest that the charcoal mainly can be attributed to the forest clearance of the island starting around 3300 yr BP (Lindblom *et al.* 1997). This implies that there is a discrepancy of roughly 1800 radiocarbon years between the occupation of the Late Mesolithic people and the next group at the Middle Neolithic/Late Neolithic transition as illustrated in Fig. 25.

However, in the late 1980s and further in the middle 1990s work on the Velde islands (including Stutøy and Midtøy) was resumed and several new sites could be added (Hatleskog 1999). Two Early and Middle Neolithic sites were excavated; one 9 m a.s.l. at Husøy (loc. G) and one site (loc. 8) 8.5 m a.s.l. at Stutøy (Moseng 1995). The date of the Neolithic sites has been estimated somewhere between 5200 and 4000 yr BP based on artefact inventory, and confirms that the islands have been in use since the Mesolithic. However, also Hatleskog (1999) pointed to the fact that the number of Neolithic sites are heavily reduced compared to the Mesolithic ones at these islands, and that this is in contrast to the continuity and increase in Neolithic sites elsewhere in western Norway (Kristoffersen 1990). This problem raised many questions. Did the Early Neolithic population leave the area and if so why did they leave?

At the two localities Utvik and Våge in the Karmøy sound both a Mesolithic and an early Neolithic phase are encountered in the same beach gravel sequence (Hernæs 1979, 2000, Hatleskog 1999). The site at Utvik is situated between 11.2 m and 12.3 m a.s.l. The artefacts belonging to the oldest Mesolithic phase are heavily waterrolled, while this is not the case for the Neolithic artefacts although both phases are found in the same beach sediment sequence. The date of the Neolithic phase is estimated to shortly before 3200 BC (ca 4700 yr BP). In 1979, *Hernæs suggested that there had been a double peak in the course of the Tapes transgression* and he refers to Hafstens (1971, unpublished) shore level studies at Håvik.

The Boknafjord area

The RennFast project

The municipality of Rennesøy is situated in the outer part of the Boknafjord area, facing the North Sea towards the west (Fig. 1 and 26). The municipality consists of eight inhabited islands. Four of them were affected by a new road alignment, named the RennFast project, connecting the municipality to the adjacent mainland. As a part of this project the Museum of Archaeology, Stavanger, investigated the new road alignment, 19 km altogether, in the period from 1988 to 1992. 104 ancient monuments and/or sites were surveyed and excavated, and a total of 100 of these contained artefacts, often from several prehistoric periods (Høgestøl 1995, Høgestøl *et al.* 1995, Prøsch-Danielsen & Høgestøl 1995). In addition to the archaeological investigations, studies on vegetation history and sea-level displacements were made due to the fact that knowledge of vegetation and local topography is important in the process of understanding the way of living of prehistoric man (Prøsch-Danielsen 1993a).

Sea-level studies

Before starting fieldwork a theoretical sea-level displacement curve for Rennesøy was constructed based on data from the baseline (as defined by Anundsen 1985) (Fig. 26, the Younger Dryas isobase 32.5 m a.s.l.) and the shoreline gradients following Anundsen (1985) and Kaland (1984). To verify this curve, six lakes within Rennesøy and the adjacent Finnøy were investigated including radiocarbon dates, studies of loss-on-ignition, litho-, pollen- and diatom stratigraphy. The localities were; Kådastemmen (Mosterøy), Torvmyra (Fjøløy), Søre-Reianes (Rennesøy), Brimse (Brimse), Jubemyr (Sør-Talgje) and Tjødnå (Kyrkjøy). In addition information from two transgressed Mesolithic sites and a find of a Greenland right whale skeleton have been of importance for the construction of this curve.

The sea-level displacement curve (Fig. 27) will be discussed thoroughly as this curve among others provides the basis for constructing sea-level displacement curves for adjacent areas e.g. the Stavanger peninsula.

The Younger Dryas transgression maximum at Rennesøy, is dated by the sediments and diatom flora at Kådastemmen (29.2 m a.s.l. and 5.7 km west of the baseline) (Prøsch-Danielsen 1993a). Diatom analysis has been carried out throughout the Late Weichselian and the early Preboreal sequence. In the last half of Allerød Chronozone the diatom flora became brackish. From the transition between Allerød Chronozone and the Younger Dryas Chronozone (dated by pollen analysis) there is a marked

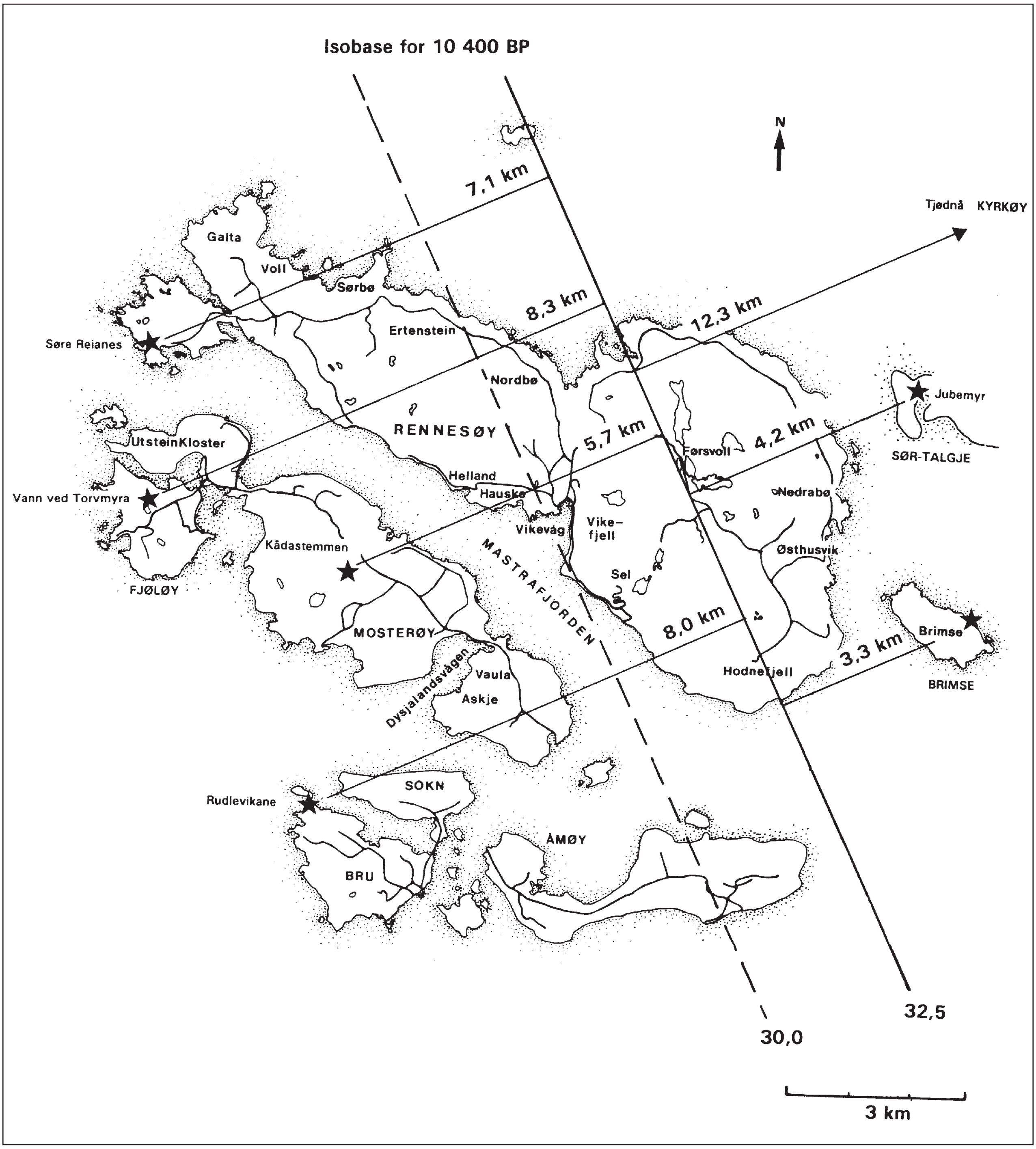


Fig. 26. Isobases for the Younger Dryas (10,400 yr BP) glacial advance at Rennesøy, the Boknafjord area in Rogaland county, southwestern Norway. The distance from each investigated locality to a baseline (32.5 m line) is plotted on the map (Prøsch-Danielsen 1993a).

shift in the sediments from a fine gyttja to a laminated gyttja, usually encountered during brackish conditions. The diatom flora was still brackish. The upper limit of this brackish laminated sediment was dated to 10,420±110 yr BP (T-9131A) and 10,235±140 yr BP (T-9131B). The sea-level has nearly been tangent to the basin at a period between 11,000 yr BP and 10,400 yr BP, probably lying 1-2 m below the 29 m level. The overlying sediments, from younger periods, contain a lacustrine flora.

At Fjøløy, a beach ridge damming up a small basin at 24.0 m a.s.l., gives the Younger Dryas maximum level at this locality. The oldest sediments in the basin are pollen-analytically dated to 10,400-10,300 yr BP, giving the date of the Younger Dryas transgression maximum.

We have not succeeded in finding basins at suitable

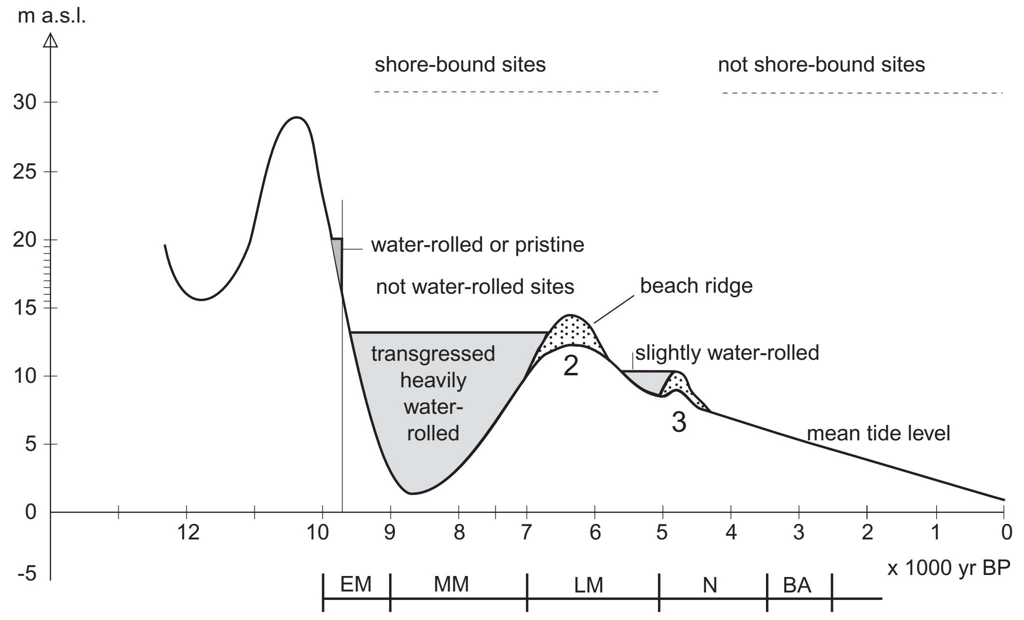


Fig. 27. The relation between the shore level displacement curve and the shore-bound sites along the northern border of Rennesøy and the Galta peninsula in Rogaland county. Early Mesolithic sites = 10,000-9000 yr BP, Middle Mesolithic sites = 9000-7000 yr BP and Late Mesolithic sites = 7000-5200/5000 yr BP (outlined by L. Prøsch-Danielsen 2003).

altitudes for verifying the Late Weichselian regression minimum (in Allerød Chronozone) at Rennesøy. This level is stipulated based on data from Thomsen (1982b, 1989), Anundsen (1985), Braathen & Hermansen (1985) and Austad & Erichsen (1987). The vertical amplitude of the Younger Dryas transgression is probably at least 12 m at Rennesøy. This gives an upper maximum level 20.5 m a.s.l. for the Late Weichselian regression minimum.

In 1983 skeleton bones from a Greenland right whale (*Balaena mysticetus*) were found in a fill-in basin with a threshold 17 m a.s.l. at Galta (Blystad 1983). The bones were dated to 12,420±160 yr BP (T-5120). For this huge whale to be able to enter the basin, sea-level had to be at least 2-3 m above the threshold, i.e. 20 m at that time. Owing to this, the Bølling regression reached the 20 m level at Galta approximately 12,400 yr BP.

From 10,400 yr BP there is an abrupt drop in the sea-level during Younger Dryas and Preboreal Chronozones recorded on several localities; e.g. Brimse (13.8 m a.s.l.) and Jubemyr (6.7 m a.s.l.).

In the fill-in basin at Brimse, 3.3 km east of the baseline, the marine/lacustrine transition is based on the first appearance of freshwater aquatic plant pollen indicating lacustrine conditions (transition layer A/B). However, in layer B there is still a component of a brackish flora and a supply of sand particles. The locality was finally (layer B) isolated from the sea shortly after the regional immigration of hazel (*Corylus avellana*), an event dated to 9595±360 yr BP (T-9181B) at Rennesøy (Prøsch-Danielsen 1993a).

The locality, Jubemyr, indicates a rapid regression through Younger Dryas and Preboreal Chronozones, and is situated 4.2 km east of the baseline. Jubemyr was first isolated from the sea 9170±100 yr BP (T-9750A). After a short lacustrine phase, the basin was ingressed by the sea. The ingression is dated to 8050±100 yr BP (T-9751A) and 7825±85 yr BP (T-9751B). The second and final isolation of the basin is dated to 4120±165 yr BP (T-9752A) and 4030±80 yr BP (T-9752B). The observed data put the Preboreal regression minimum at least 2 m below the theoretically constructed sea-level curve.

Two transgressed Mesolithic sites at Rennesøy also verify this minimum regression level, Ertenstein (loc. 40) and Nordbø (loc. 16) situated between 3.5 and 7.0 m a.s.l. These sites can be typologically dated between 9000 and 8600 yr BP. However, the precise date for the regression minimum has not yet been established, but can probably be put somewhere between 9000 yr BP and 8500 yr BP (according to the results from Jubemyr).

A rise in sea-level, the Tapes transgression, started in the last half of the Boreal Chronozone. However, the basin at Brimse (13.8 m a.s.l.) is not affected by this transgression or any other late Holocene marine events. At this locality the Tapes transgression maximum thus is below

13.8 m. The theoretically calculated maximum was 12.7 m a.s.l. at this site. This shows a good agreement between the theoretical and the observed shore level displacement curves in the last part of Holocene as recorded in Jubemyr and Tjødnå.

One has to be aware that to be able to pick up oscillations within the Tapes transgression, this study suffers from the lack of basins between the 7 m and the 14 m contour lines. Knowledge as concerns the distribution patterns of Mesolithic and Neolithic archaeological sites (see below) will bring us a step further.

Søre-Reianes – minerogenic layer with marine diatoms

Søre-Reianes (Figs. 26, 28a and 28b) is situated 7.1 km west of the baseline. The locality is a filled-in basin with a sheltered position. Mollusc shells and diatoms in this filled-in basin reflect one marine phase from the bottom of the basin to ca. 9800 yr BP (layers B, C and D) (pollen analytically dated). Then followed a brackish phase (layers E and F) until the final isolation of the basin took place dated to 9665±135 yr BP (T-8817A) and 9605±105 yr BP (T-8817B) (Fig. 29). Layer D consists of a brown to

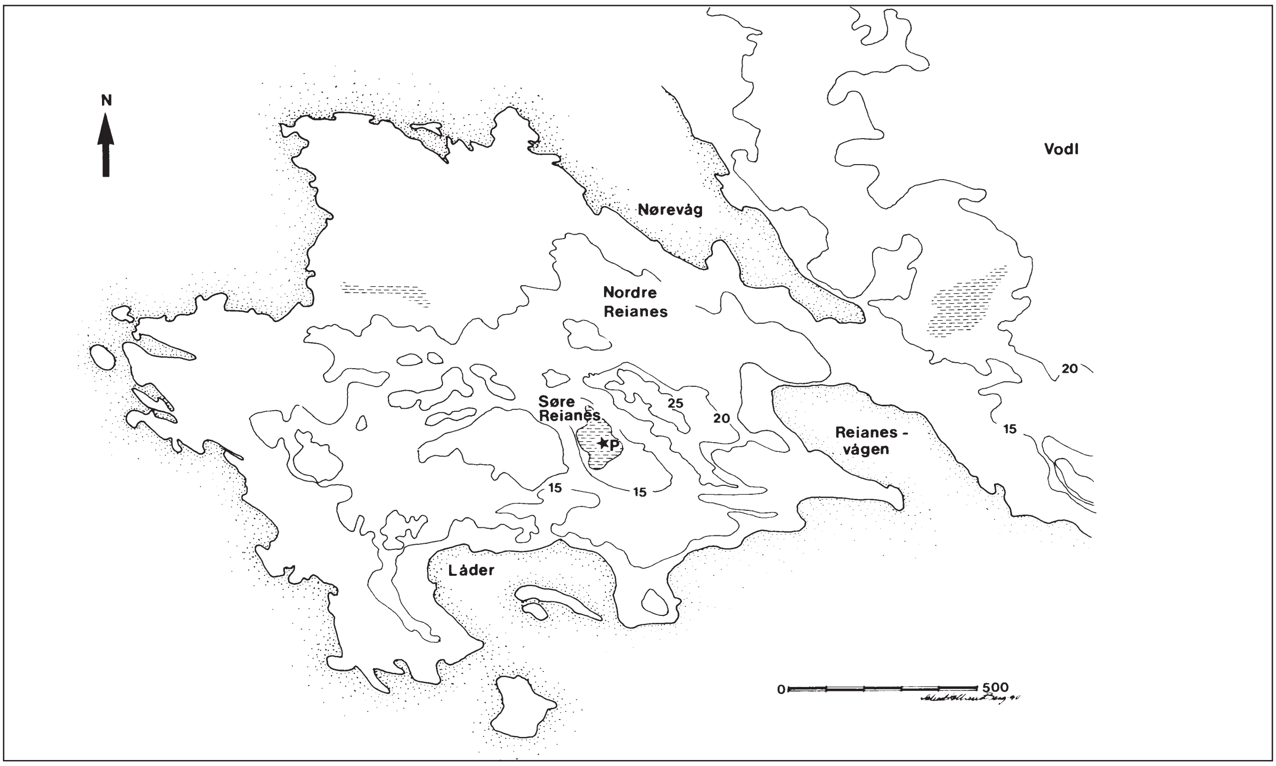


Fig. 28a. The locality, Søre-Reianes at the Galta peninsula on Rennesøy in Rogaland county, southwestern Norway, has a sheltered position from wind and waves coming from south, west and north (Prøsch-Danielsen 1993a).

Fig. 28b. Today the basin at Søre-Reianes, Rennesøy municipality, is undergoing in-filling (photo: Prøsch-Danielsen 1993a).

green fine detritus gyttja with a marine diatom flora. In the next layer E, the marine diatoms are broken to pieces and there are a pronounced component of mica schist particles. It also shows a high content of chains of *Melosira sulcata* that may indicate a stormy episode (Bjørg Stabell pers. com.). The sediments are described in Table 1.

At present, *it is suggested that layer E represents a tsunami event*: However, it does not have the typical tsunami facies that has been described for the Storegga tsunami layer in similar settings (Bondevik *et al.* 1997a). Layer E is also found in a marine sequence and is deposited when the basin was below sea-level and is thus not a

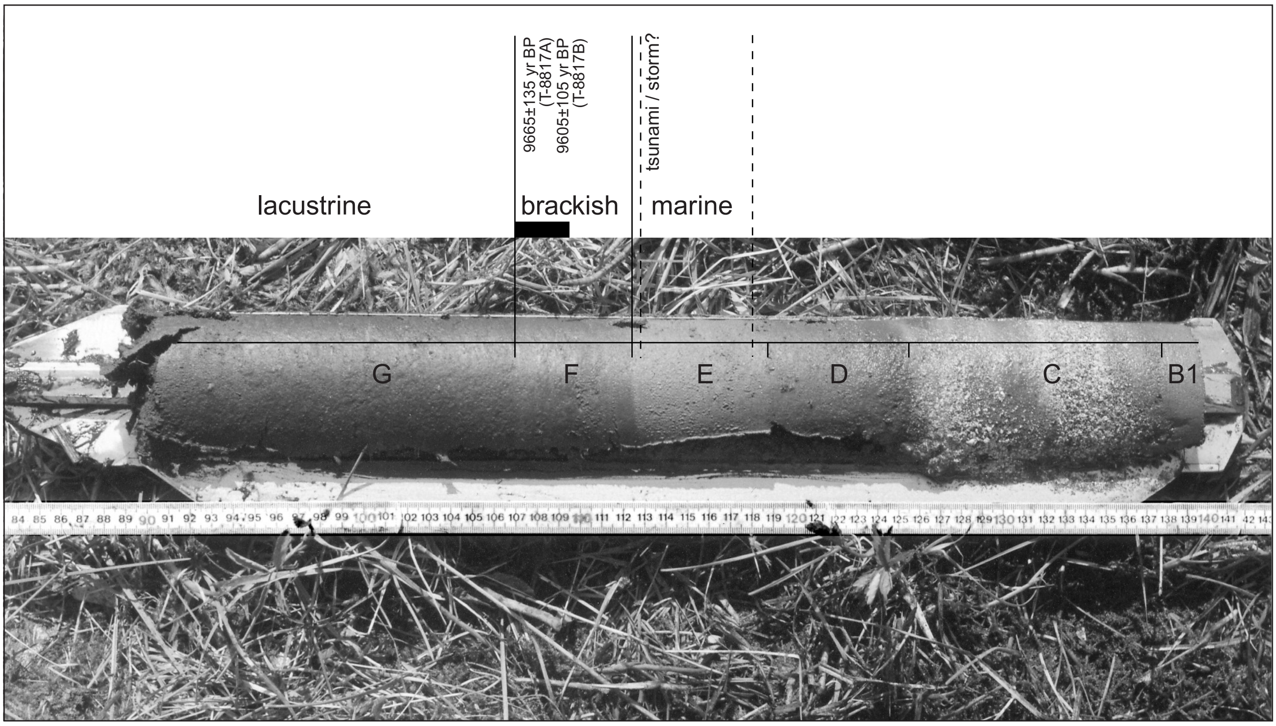
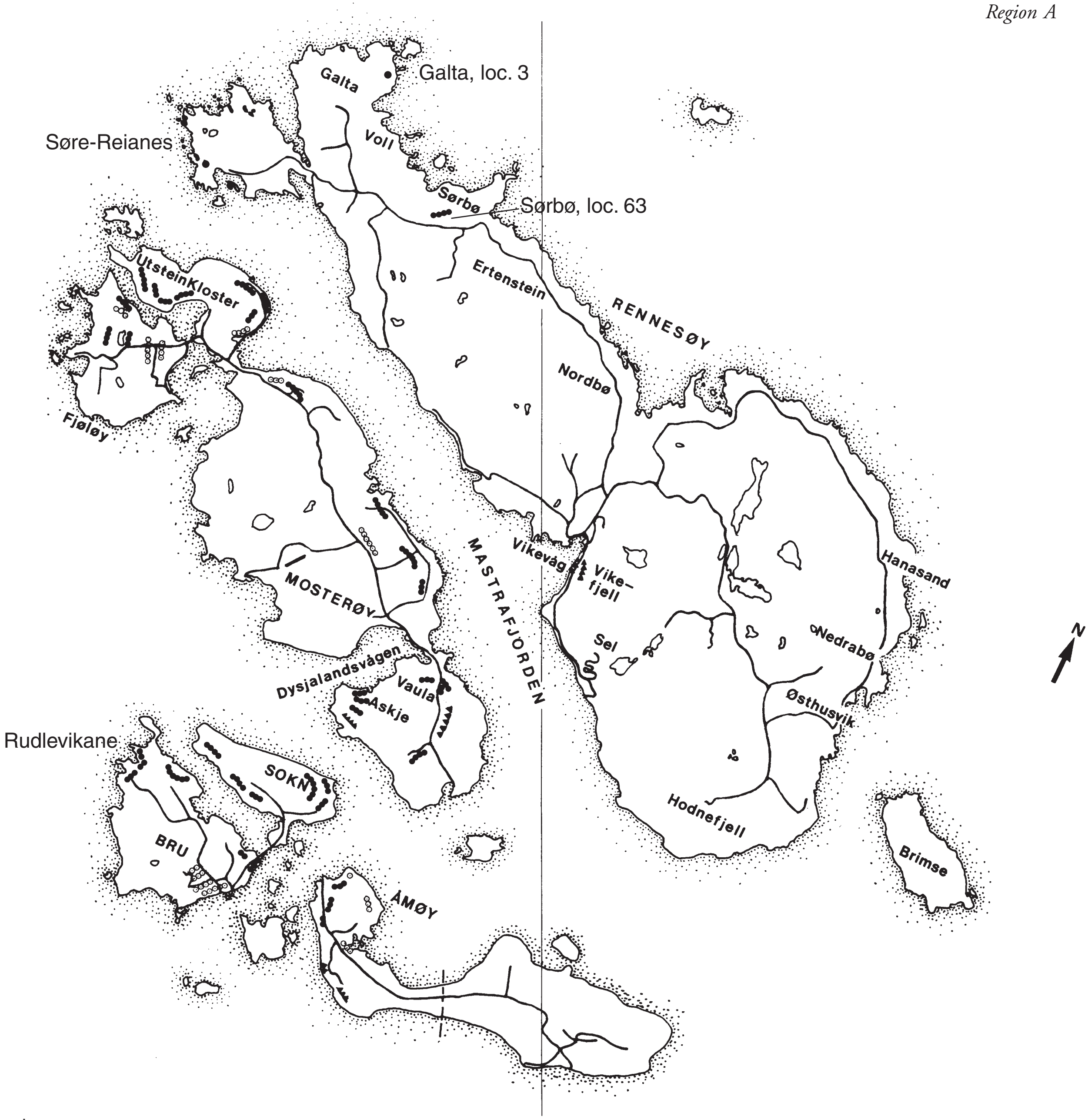


Fig. 29. The Late Weichselian – Early Holocene sediment sequence in the filled-in basin at Søre-Reianes, Rennesøy municipality. Notice the minerogenic component in layer E (photo: Lisbeth Prøsch-Danielsen 1993a).

Table 1. The sediment analyses of cores from the filled-in basin at Søre-Reianes. Description according to Troels-Smith (1955) and colour according to Munsell (1973).

Layer	Type	Colour	Constituents	Physical characteristics
G	Gyttja	5Y 2/2	Ld^{1}2, Dg1, Dh1	Lim.s.0, Nig.3^{+}, Sicc.2-3, Strf. 1, Elas.2
F	Gyttja	5Y 2/2	Ld^{0}3, Th1,Dg^{+}, As^{+}	Lim.s.0, Nig.2^{+}, Sicc.2, Strf. 0, Elas.2
E	Gyttja w. mica schist particles	5Y 3/1	Ld^{0}2, As1, Ga1, Gs^{+}	Lim.s.0, Nig.2, Sicc.2, Strf. 0, Elas.2
D	Fine detritus gyttja	5Y 2/2	Ld^{0}3, Dg1, Th^{+}	Lim.s.0, Nig.3^{-}, Sicc.2, Strf. 0, Elas.1
C	Sand w. molluscs	5Y 2/1	Ga2, Gs1, Ag1, As$^{+,}$ Gg (maj)$^{+}$ [test.(moll.)]	Lim.s.0, Nig.1-2, Sicc.2, Strf. 0, Elas.0
B1	Sand w. clay content	5Y 3/1	Ga2, As1, Gs1, Ld^{0+} [part.test.(moll.)]	Lim.s.0, Nig.1-2, Sicc.2, Strf. 0, Elas.0
B	As above w. molluscs	5Y 3/1	As2, Gs1, Ga1, Ag^{+} [part.test.(moll.)]	Lim.s.0, Nig.1, Sicc.2, Strf. 0, Elas.0
A	Clay	5Y 4/2	As3,Ag1, (Ga^{+}, Dg^{++})	Lim.s.0, Nig.1, Sicc.2, Strf. 0, Elas.0

Fig. 30 (right page). Beach ridges, notches and terraces in unconsolidated sediments within Rennesøy municipality, Rogaland county. Notice that the littoral forms are separated into three distinct groups (Prøsch-Danielsen 1993a).


Galta, loc. 3
Galta
Voll
Søre-Reianes
Sørbø
Sørbø, loc. 63
Ertenstein
RENNESØY
Utstein Kloster
Nordbø
Fjøløy
MASTRAFJORDEN
Vikevåg
Vike-fjell
Hanasand
MOSTERØY
Sel
Nedrabø
Dysjalandsvågen
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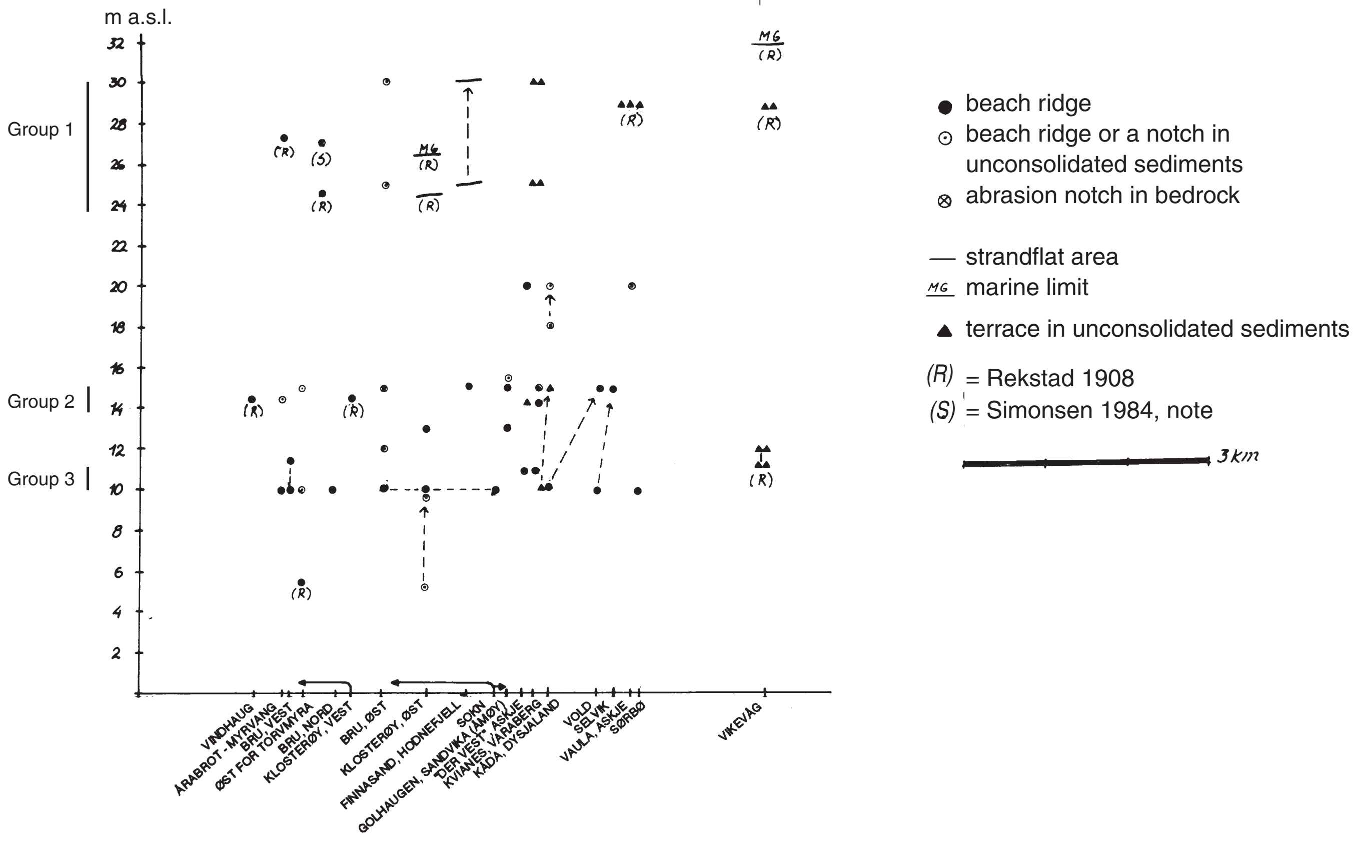

m a.s.l.
Group 1
Group 2
Group 3
MG
(R)
(S)
VINDHAUG
ÅRABROT - MYRVANG
BRU, VEST
ØST FOR TORVMYRA
BRU, NORD
KLOSTERØY, VEST
BRU, ØST
KLOSTERØY, ØST
FINNASAND, HODNEFJELL
GOLHAUGEN, SANDVIKA (ÅMØY)
SOKN
DER VEST, ASKJE
KVIANES, VARABERG
KÅDA, DYSJALAND
VOLD
SELVIK
VAULA, ASKJE
SØRBØ
VIKEVÅG
beach ridge
beach ridge or a notch in unconsolidated sediments
abrasion notch in bedrock
strandflat area
marine limit
terrace in unconsolidated sediments
(R) = Rekstad 1908
(S) = Simonsen 1984, note
3 km

proof of a tsunami event. More fieldwork is needed to map the distribution of layer E across the basin and especially towards the threshold area where one should expect the deposits to show a more chaotic and violent nature with erosion, rip-up clasts and sand and gravel (Bondevik *et al.* 1997a). At this stage of analysis Prøsch-Danielsen & Bondevik (2003) concluded that layer E may be interpreted as a tsunami event ca. 9800 yr BP.

Mapping of littoral forms

Until the initiation of the RennFast project our knowledge of littoral forma within the Rennesøy municipality was based on early works made by Rekstad (1908) and Kaldhol (1941). Today these works are of great importance as modern agriculture in the area has destroyed former beach ridges. In connection with the RennFast project we got a new opportunity to map present littoral

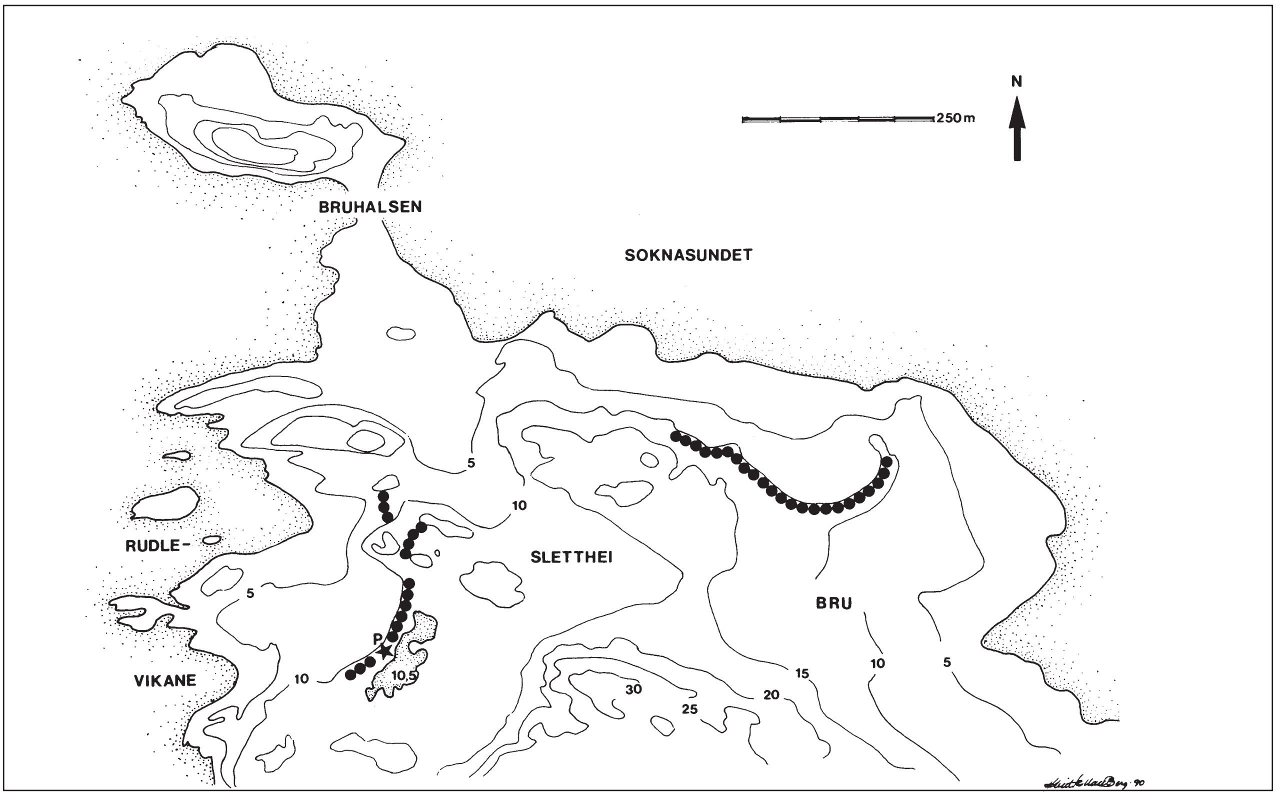


Fig. 31. The location of the beach ridge (10.5 m a.s.l.) at Rudlevikane on the western part of the island Bru, Rennesøy municipality in Rogaland county (Prøsch-Danielsen 1993a).

Fig. 32. The beach ridge at the island Bru, Rennesøy municipality in Rogaland county, facing southwards (photo: Lisbeth Prøsch-Danielsen 1993a).

Fig. 33. A section through the beach ridge at Bru, Rennesøy municipality in Rogaland county. The dark, thin humus layer can easily be seen beneath the beach sediments (photo: Lisbeth Prøsch-Danielsen 1993a).

forms; beach ridges (accumulation), notches and terraces in unconsolidated sediments (erosion) (Prøsch-Danielsen 1993a). Beach ridges are formed during accumulation. In 1940, Fægri postulated that the level of mean-tide could be stipulated 2-3 m below the upper limits of the observed beach ridge. However, resent studies (Sollid *et al.* 1973) have showed that beach ridges can be built up to 7 m above the present shoreline, preferably during periods of extreme storms (giving higher wave energy) and a high tide/spring tide and often during a long time scale (Møller 1999, 2002).

Raised beach ridges and terraces within Rennesøy can be divided into three distinct groups dependent on hight above present sea-level; the first group of littoral forms is observed between 24.5 m and 30 m a.s.l. The littoral forms in this group can either be related to the Bølling regression phase or the Younger Dryas transgression/early Preboreal regression phase. Two sets of younger (Holocene age) beach ridge systems have been built up in Rennesøy. The second group has an upper limit of beach ridges 14-15 m a.s.l., while the third group are found at the 10-11 m contour lines (Fig. 30). Due to land uplift the second group has to be the oldest one, probably built up during the Tapes maximum when high tide reached up to 12 m above present sea-level. The third group has to be the youngest one.

With relevance to the age of the third group, special attention should be paid to one of these younger beach ridges, at Rudlevikane, on the western side of the island of Bru (Figs. 30, 31 and 32). The crest of the ridge is 11 m a.s.l. A fresh cross section, 1.7 m high and 16.5 m wide was exposed mainly consisting of 10-15 cm large cobbles resting on top of a 2.5 cm humus layer (Fig. 33). The humus layer was analysed for pollen and radiocarbon dated. The results showed a vegetation of shore meadow plants that was dated to 5285±105 yr BP (T-8819). It was not possible to detect whether the upper part of this humus layer was intact or had been eroded. However, *the date shows that the ridge was built up after 5300 yr BP. The presence of the humus layer suggests that the ridge was built during a transgression.*

Shore-bound and transgressed archaeological sites

Until the last part of the 1970s no archaeological sites from the Late Paleolithic or the Early Mesolithic (10,000-9000 yr BP) had been surveyed in Rogaland. Only stray finds of artefacts had been collected (Bang-Andersen 1988b, 1996). The lack of sites was regarded as a paradox since the coastal area of Rogaland was deglaciated already 15,000 yr BP to 14,000 yr BP (Anundsen 1985). Since then, advanced shore level studies combined with an increasing number of archaeological investigations led to the discovery of more than 30 Early Mesolithic sites in the Boknafjord areas (e.g. Gjerland 1990, Høgestøl 1995, Løken 2000, Juhl 2001). Further south on Jæren, the complete lack of Mesolithic sites (dated prior to 7000 BP), can be due to the lack of research, but also due to secondary disturbances caused by pronounced land-sea alterations (Bang-Andersen 1995). On South Jæren these early shore-bound sites may now be located at the present sea-level, or even below present sea-level.

Sites between 13 m and 20 m a.s.l

During the RennFast project (Høgestøl 1995), test pits were dug along the road alignment between 2 and 40 m a.s.l. Due to these intensive investigations, nine sites comprising an artefact inventory belonging to the Early Mesolithic were found on the Galta peninsula, between the bays Galtavågen and Nørrvågen, in the northwestern part of Rennesøy (Figs. 1 and 34). These sites are situated between the 13 and the 20 m contour lines. The oldest Ahrensburg points usually dominate at sites lying highest in the landscape, while the younger simple lanceolates, some produced with microburin technique, make up the majority at the lowest lying sites. Based on the artefact inventory and the sea-level displacement curve all sites may be older than 9500 yr BP. The artefact inventory is sharp or only slightly water-rolled which implies that these sites were not affected by the late Tapes transgression or other long-lasting marine events.

The Galta loc. 3 site – artefacts redeposited in beach sand and gravel

The Galta loc. 3 site is different from the rest of the sites, because the artefacts are found in beach sand and gravel and have rounded edges (water-rolled). The site (Fig. 34) was surveyed in 1988 (Høgestøl 1995, Høgestøl *et al.* 1995, Prøsch-Danielsen & Høgestøl 1995). Unlike previous non-stratified Late Palaeolithic and Early Mesolithic sites in Rogaland the material from this site was re-deposited in a beach sediment sequence. Based on these observations, the thought arose that the site had been flooded during the Younger Dryas, which implied that this site could be the oldest remnants of humans in Norway. This exceptional find led to an extensive archaeological excavation in 1990. The excavation was performed in two separate areas, A and B (Fig. 35). The main purpose of the investigation was to obtain age estimates for the site occupation. Unfortunately, no organic material for radiocarbon dating related to the artefacts, was found. Thus the only reasonable age estimates were obtained by artefact typology and by relating the sediments to the constructed local sea-level displacement curve (Prøsch-Danielsen 1993a).

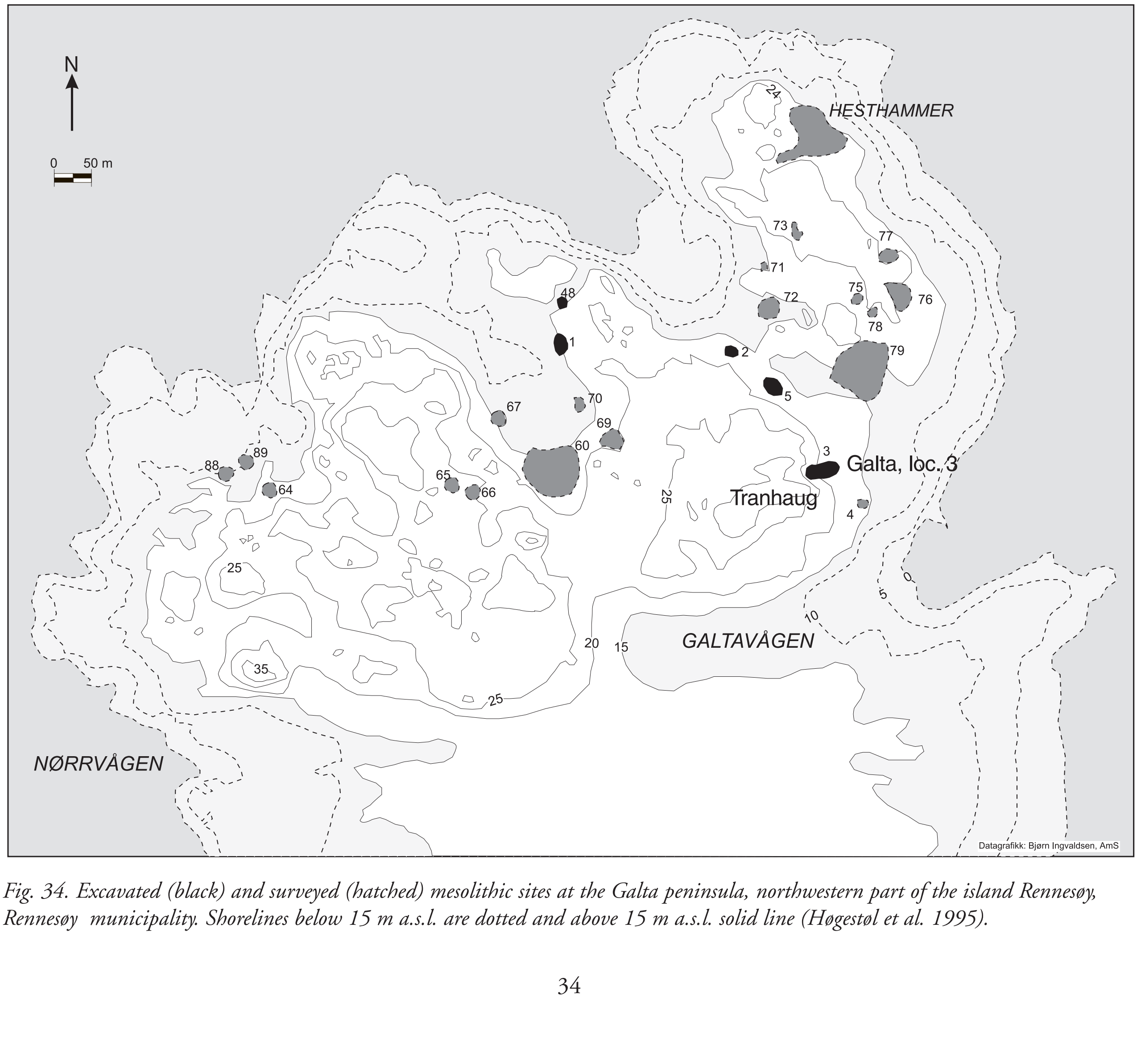


Fig. 34. Excavated (black) and surveyed (hatched) mesolithic sites at the Galta peninsula, northwestern part of the island Rennesøy, Rennesøy municipality. Shorelines below 15 m a.s.l. are dotted and above 15 m a.s.l. solid line (Høgestøl et al. 1995).

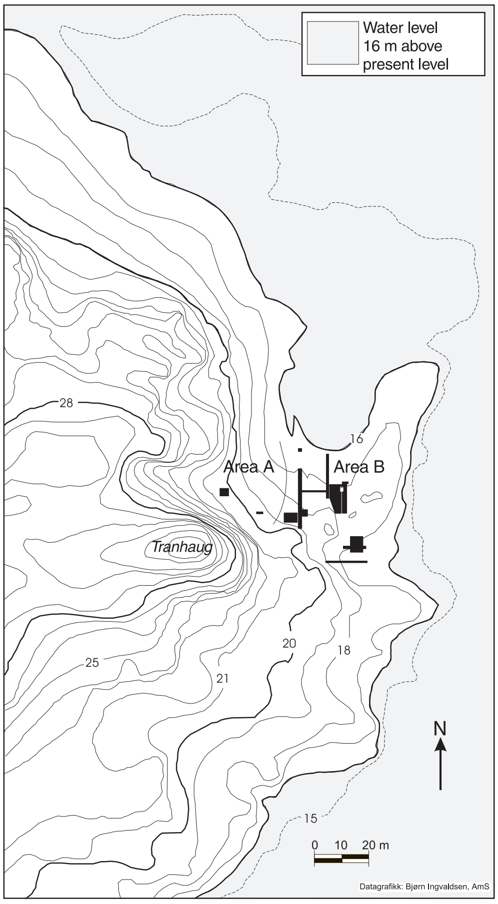


Fig. 35. The topography at the Galta site with a shoreline 16 m a.s.l. The 28 m level shows the situation at the Younger Dryas transgression maximum, app. 10,400-10,200 yr BP. The excavated areas in black (Høgestøl 1995).

The area with flint artefacts stretches from 16 to 20 m a.s.l. in a cove on the eastern slope of Tranhaug. Just below the cove, the bedrock forms a natural threshold toward the sea in the east. Here the landscape flattens forming a boggy 'trough' between 15 and 16 m a.s.l. northeast of the archaeological site. Further downward the bedrock slopes gently to the present sea-level.

The excavated area including trenches covered 134 m^2. Based on the archaeological material we (Prøsch-Danielsen & Høgestøl 1995) proposed the site to be older than 9500 yr BP and younger than the onset of the Ahrensburgian epoch, which is younger than 10,300/10,200 yr BP in Denmark (Fischer 1978, 1991). Some of the artefacts were water rolled and/or patinated while others were pristine, indicating that the artefacts have been deposited at different times. Therefore, it has been concluded that the site has been occupied at least twice. In an attempt to better understand how these artefacts originally were distributed a refitting study was initiated (Fuglestvedt 1993, 2005). Preliminary results indicate that both horizontal and vertical refits were possible. As neither the archaeological material nor any organic material could offer an exact age estimate of the Galta site, the sediments had to be studied in detail to delimit the time of occupation.

The description and interpretation of the vertical sediment section are based on a visual evaluation made in the field, grain-size analysis and grain-orientation (Lars Magnus Fält, notes). The vertical-section is described from the bottom upwards (Fig. 36a).

The stratigraphical sequence consists of three units:

Unit 1: Greyish till. The gravely and sandy till is compact with a maximum thickness of 3 m. Some worked flint material is found at the upper boundary of this unit.

Unit 2: Yellowish brown to rusty-red beach gravel. The unit comprises pebbles and large, well-rounded cobbles (10-25 cm) in a hard packed bimodal poorly sorted sandy gravel. The unit varies in thickness. The lower boundary is erosive.

Unit 3: Yellowish brown sandy gravel. In the upper excavated area (area A) the sandy gravel is unstratified. In area B the bimodal-sorted sandy gravel to gravely sand is stratified, consisting of weakly dipping beds intercalated with sand beds (sand runs) (Figs. 36a and 36b). The layer is up to 70 cm thick. The unit thins out towards the bedrock threshold at 16-17 m a.s.l. Here the natural 'trough' formed by the bedrock threshold has functioned as a sediment trap. In the sandy gravel, rounded, disc-shaped pebbles, varying from 2.5-6.0 cm, are abundant. These pebbles are imbricated and orientated, a-axis dipping towards NE, secondly in a SE direction. This implies that the prevailing wind and/or wave direction is coming from NNW.

Artefacts and worked flint material are found throughout both unit 2 and 3.

The grey till (Unit 1) was deposited before the area was deglaciated about 14,000 yr BP (Anundsen 1985, Paus 1988).

The beach sequence comprises two facies, unit 2 and 3:

Unit 2 represents a lower beach face during which the beach was not directly affected by the swash processes. It resembles the cobble layer of Postma & Nemec (1990) formed in the lower storm-berm zone under a transgression phase and the cobble layer described by Postma & Cruickshank (1988) formed subtidally under a regression phase. *Unit 2 is probably generated under severe wave-energy conditions, i.e. under powerful, storm-induced conditions.* This unit may have been developed

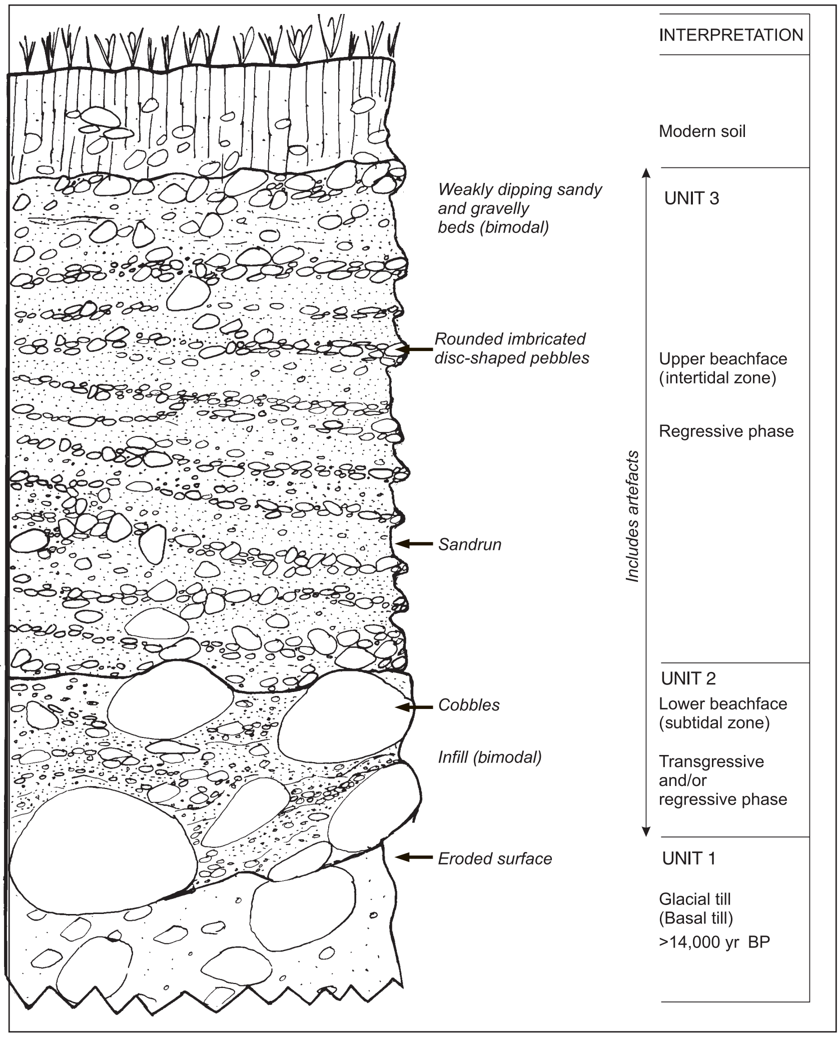


Fig. 36a. Stratigraphic outline and interpretation of the vertical section in area B at the Galta loc. 3 site at the Galta peninsula, Rennesøy municipality (Prøsch-Danielsen & Høgestøl 1995).

Fig. 36b. A section of the stratified beach sequence in area B at the Galta loc. 3 site (see Fig. 11). Sand runs are distinct and marked in unit 3 (white vertical line) (photo: Terje Tveit in Prøsch-Danielsen & Høgestøl 1995).

subtidally during marine transgression and/or a regression.

Unit 3 represents an upper beach face during which the beach was directly affected by swash. The sediments show similarities to the imbricate-disc zone of Postma & Nemec (1990) formed during a rising sea-level, and the imbricate-disc zone of Postma & Cruickshank (1988) formed during a lowering of the sea-level. In the studies referred to above the sediments are deposited in the upper intertidal and/or supratidal zone. Imbrication is inferred to be the result of swash- and backwash-related processes. The intervening sand layers represent ´sand runs' on the gravely beach. Sand runs are produced when particles move over the surface by swash and backwash in the foreshore environment (Postma & Nemec 1990). It is assumed that unit 3 represents deposition during a regression phase as it is generally agreed that the preservation potential of transgressed gravely sandy beaches is considered low.

The relative sea-level change (Fig. 37) clearly delimited where man could settle or hunt at the Galta peninsula during the various periods. Flint material recovered from the archaeologically excavated areas between 16 and 20 m a.s.l. provide the limits of the occupation. However, Tranhaug (33.7 m a.s.l.) that is the highest point in the area gives the extreme upper limit. As the archaeological material does not provide a more precise age estimate than "younger than 10,300/10,200 yr BP and older than 9500 yr BP", the key to the dating problem had to be found by relating the sediments to the sea-level displacement curve. Due to the fact that the artefacts were re-deposited in beach sediments, it necessarily implies that

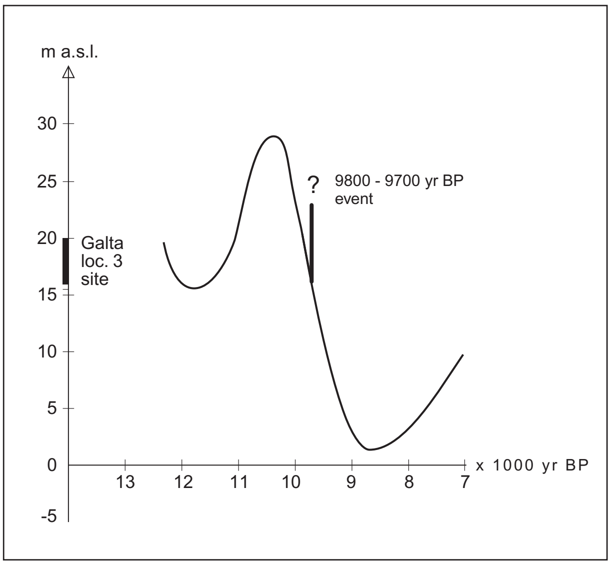


Fig. 37. The sea-level displacement curve for the Galta peninsula, Rennesøy municipality, during the Late Weichselian and the Early Holocene time periods (Prøsch-Danielsen 1993a). The suggested tsunami event 9800-9700 yr BP is marked.

the time of occupation must be *contemporary with or older than* the time when the actual beach sediments were deposited. Geological two scenarios are possible: The site had been transgressed by the Younger Dryas transgression, or the artefacts were redeposited together with the minerogenic material in the beach zone during the following Younger Dryas/Early Preboreal regression.

According to the constructed sea-level displacement curve for Galta, the 16 to 20 m level was inundated prior to 11,000 yr BP due to the rise in sea-level caused by the Younger Dryas transgression. During the Younger Dryas maximum the sea-level reached the 28 m contour line and Galta became an island where Tranhaug appeared as a rock awash not suitable for habitation. This implies that the Galta site could have been inhabited in a time interval before and/or after the time of the Younger Dryas maximum sea-level. However, the typology of the artefacts are younger than the Younger Dryas maximum, so the Galta site must have been inhabited in late Younger Dryas or during the early Preboreal chronozones.

The sea had regressed to the 20 m level at approximately 10,000 yr BP and to the 16 m level at approximately 9800-9700 yr BP. This leads to the conclusion that the minimum age of the site(s) is c. 9800 yr BP while the maximum age is ca 10,000 yr BP, which is also in accordance with the types of projectile points that were recovered.

The occupation may be contemporary with or more likely older than the deposition of the intertidal beach sequence in unit 3. The fact that the bulk of the flint material is found in the upper three layers of the stratified sequence, may indicate at least two occupations at the site.

The main problem with the Galta site is to explain how the artefacts were re-deposited and incorporated into the beach deposits. The obvious case would be that this happened during a transgression. This has been discussed above and it is impossible since the artefacts are younger than the Younger Dryas transgression maximum and no Early Preboreal transgression is known in this region. The artefacts must have been transported downwards to the shore by gravity or fluvial activity.

A third possibility is introduced, namely that the settlement site was eroded and the artefacts transported to the beach by a flood wave (tsunami) and later incorporated into the beach sediments. In the outer Boknafjord area several submarine slides have been observed. One of these with a volume of $28x10^6$ m^3, occurred at the seabed just 3-5 km NNW of the Galta peninsula, and was directed straight towards it. The results of radiocarbon dating indicate that this slide occurred at the time of the settlement or shortly after (Prøsch-Danielsen *et al.* 2005, Bøe *et al.* in prep.).

The distribution of the artefacts indicates that younger artefacts are found higher up in the beach sequence than the oldest diagnostic artefacts. This may be explained by a younger settlement phase, when the sea had regressed to approximately the 16 m level.

It is concluded that the site(s) has been reworked during a period of erosive storm waves or stroke by an erosive flood wave ca 9800-9700 yr BP with waves coming from a NNW direction (Prøsch-Danielsen *et al.* 2005, Bøe *et al.* in prep.).

Transgressed sites between 3 and 12 m a.s.l.

In Rogaland few mesolithic sites dated to 9300-6500 yr BP have been excavated. They are usually difficult to discover. In the Boknafjord area as well as in the Jæren area further south (region B) the Tapes transgression have distorted most or all of the strictly shore-bound sites from this time interval. However, not all sites have been destroyed. Before the RennFast project 10 flooded sites in region A and B had been excavated of which three sites, Sunde, Hå and Lego, will be discussed later. All sites were either sealed by the Tapes transgression beach ridge or covered by fine-grained marine sediment layers (Bang-Andersen 1995).

In Rennesøy, a total number of 22 transgressed sites were discovered during test-excavations. In contrast to the Early Mesolithic sites, these sites were located along the new road alignment indicating a more extensive use of the landscape. All sites were found in the beach zone from 3 to 12 m (the majority between 3 and 5 m) above the present shoreline (Høgestøl 1995). The artefact inventory gives the impression of specialized purpose camps used one time, and then primarily in connection with fishing and perhaps hunting for sea mammals. Artefacts were heavily water-rolled and interbedded/incorporated in marine sediment layers and it appeared that all sites were heavily disarranged. This implies that the site and artefact inventory have been exposed to severe wave action over a long time-interval which may indicate that the following transgression was a slow and long lasting process.

The constructed sea-level displacement curve (Fig. 27) seems to be in accordance with the height and date of the sites; eleven sites have been dated between 9000 and 8000 yr BP (most between 9000 and 8500 yr BP), three sites between 9500 and 9200 yr BP and three sites in between 8000 and 7000 yr BP. The last five sites could not be precisely dated as seen from the artefact inventory and lack of organic material. Water-rolled material is encountered at sites situated up to 11-12 m a.s.l. (sites 6a/b, 9, 53 and 63) but not in other Middle- and Late Mesolithic sites situated above this level.

Sørbø loc. 63 – artefacts younger than 5200 yr BP incorporated in beach sediments

At one locality, Sørbø loc. 63 (Figs. 1 and 30), the artefact material is incorporated throughout a beach ridge sequence (Høgestøl 1995). The site is located between 10.3 and 11.2 m a.s.l. At least three occupations can be recorded. Based on the artefact inventory the two oldest occupations can be dated to the Early Mesolithic (9500 yr BP) and the Middle Mesolithic (8000 to 7100 yr BP). The youngest occupation can be typological dated to the Early Neolithic (younger than 5200 yr BP) due to the finds of diagnostic artefacts; e.g. a tagged point with an A1-retouch and a scraper with abrupt retouch. Approximately 43% of the material is water-rolled. With relevance to this work it should be noted that water-rolled flint material belonging to the Mesolithic occupations (blades and flakes) have partly been recycled and used by the later Neolithic population, and that the "new fresh" retouch also show signs of being slightly water-rolled. Due to these observations *Høgestøl (1995) suggested that the Tapes transgression could have been double-peaked, and that the second peak was younger than 5200 yr BP.* This is in agreement with the date of humus (5285±105 yr BP (T-8819)) below the beach ridge at Rudlevikane, Bru. The situation for the shore-bound sites is summarized in Fig. 27.

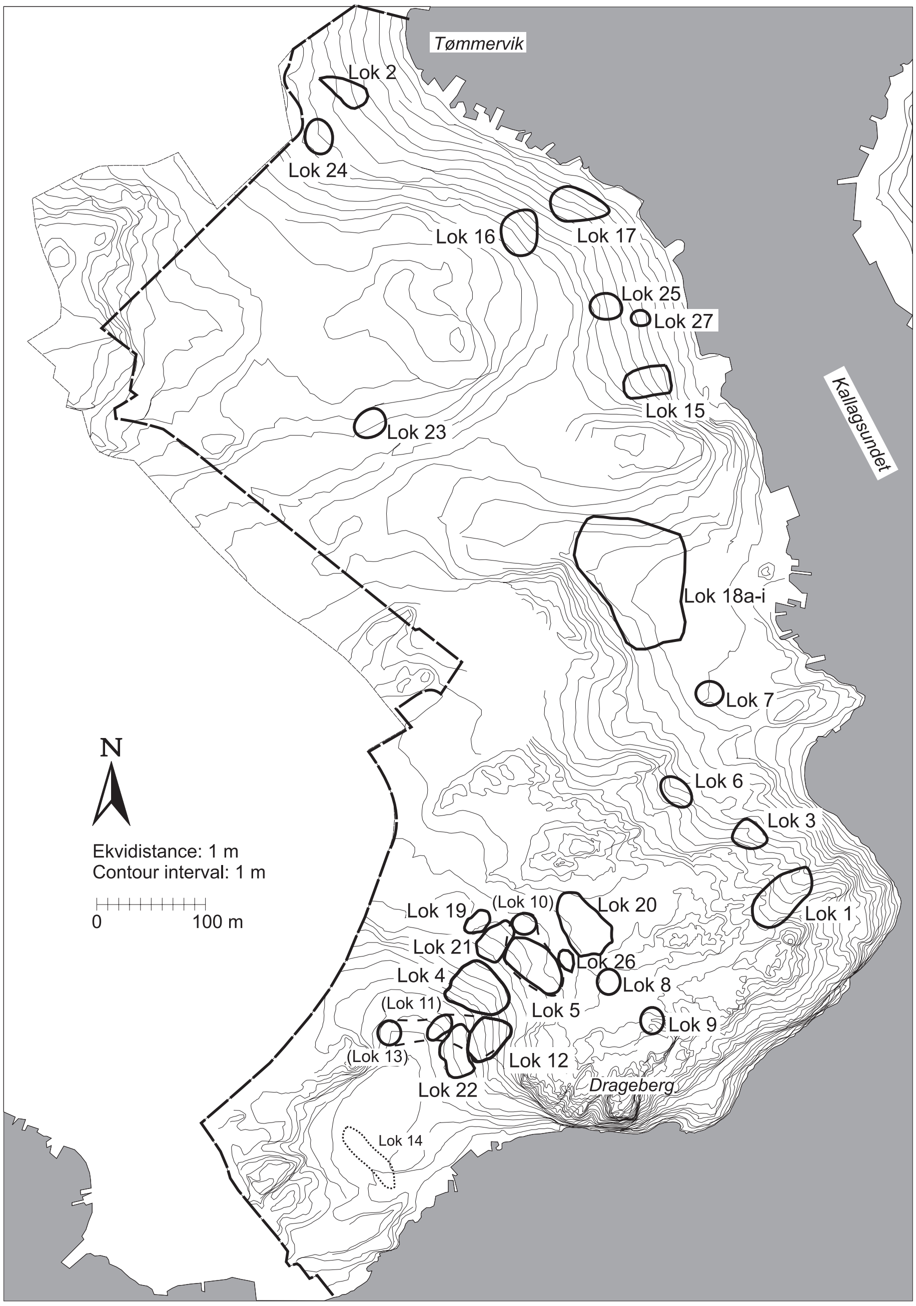
Austbø on Hundvåg in the Byfjorden area.

In connection with a development plan of an area of 45 ha on the east side of the island Hundvåg in the municipality of Stavanger (Fig. 1), 17 Stone Age sites were surveyed and excavated in between 1987 and 1990 under the supervision of the archaeologist Berit Gjerland (Fig. 38) (Juhl 2001). Stone Age sites were abundant within the rather small project area and covered all periods. Sites from all periods were investigated, though some from the periods Early and Middle Mesolithic and the Middle and Late Neolithic were investigated more thoroughly. The main focus on the research project was to study the exploitation of the area in a long time run, and the development and changes in the prehistoric settlement pattern through time.

Hundvåg is covered by Quaternary deposits and has almost a continuous cover of marine shore deposits (Wangen *et al.* 1987). Its highest altitude is 35 m a.s.l. The island has many inlets and bays representing natural harbours, and the Stone Age sites seem to be localised close to marine and coastal resources.

The two Early Mesolithic sites found at Austbø on Hundvåg, situated between 12 and 18 m a.s.l., are not transgressed. However, it is not possible to date them more exactly than to the time interval between 10,000 and 9500 yr BP.

Fig. 38. All sites recorded and surveyed at Austbø on the island of Hundvåg, Stavanger municipality, southwestern Norway (Juhl 2001).



All shore-bound Middle Mesolithic sites (9000-7000 yr BP) were transgressed by the sea. Juhl (2001) stressed that *since the material was little affected by water rolling the artefacts from the sites had to be quickly incorporated into the shore sediments during the following transgression*. The sites themselves are however strongly affected by the transgression as seen from the horizontal dispersion of the flint material, especially at loc. 15 (5.7 m -10.6 m a.s.l.) and loc. 17 (4 m -8.7 m a.s.l.). One site, loc. 2 (6.6-10.4 m a.s.l.), turns out to be well preserved and less extended. The flint material was also here little affected by water rolling, and hazelnut shells, charcoal and burnt bones were well preserved in the transgression horizon. The locality has been dated to 7755±45 yr BP (T-8877) and 7465±125 yr BP (T-8884) on burnt hazelnut shells. It is interesting to note that the transgression horizon, 30-40 cm thick, is described as *consisting of several stratigraphical layers.* These dates give the maximum age for the Tapes transgression reaching the 6.5 m contour line.

Diagnostic artefacts of the Late Mesolithic (7000-5200/5100 yr BP) have been recorded at five sites; loc. 4/ 12, 5, 6, 9 and 24, of which loc. 5 and loc. 9 is not strictly shore-bound. Loc. 6 (11-13 m a.s.l.) contained few chronologically diagnostic elements, but most likely the site belongs to the beginning of the Late Mesolithic. The artefacts were found in a sandy/gravely layer. The author (Juhl 2001) does not discuss whether the site has been transgressed or not. At loc. 24 finds were made both in the topsoil and in the shore sediments underneath. This locality is situated 10-11 m a.s.l., which is below the Tapes maximum in the area. The site seemed little affected by the transgression, although some water-rolled material was found. Juhl (2001) suggested that if the site really was tied to the shore, it was more likely in use after than before the transgression. The material of loc. 4 is mixed and dispersed by ploughing (see below). It is rather difficult to get any good impression of these sites, e.g. whether they are transgressed or not. However, two possible wall ditches (loc. 4/12) belonging to houses or huts have been dated to 5430±ð100 yr BP (T-8364) and 5290±ð70 yr BP (T-8365) and they are *not* destroyed by any later transgressions.

From the Early Neolithic (5200/5100-4600 yr BP), three sites have been found; loc. 3, 4/12A+B and 9 (none of them are shore-bound), of which loc. 9 and 4/12A have produced diagnostic artefacts. Neither loc. 3 situated 12 m a.s.l. nor loc. 4/12A+B situated between 7.5 m and 13.2 m a.s.l. have been affected by a transgressions layer and is disturbed by modern ploughing. On loc. 12B Late Mesolithic material was found exclusively in the ploughed topsoil. On loc. 4 a cooking pit has been dated to 4970±80 yr BP (T-8436) and on loc.12A a cooking pit and charcoal from the cultural layer have been dated to 4860±100 yr BP (T-8443) and 4760±60 yr BP (T-8438) respectively. Hazelnut shells from a possible fireplace at loc. 3 have been dated to 4895±190 yr BP (T-8892). This revealed that the Early Neolithic sites had not been transgressed.

To sum up: The Tapes transgression reached the 10.5 m contour line after 7500 yr BP. Loc. 2 may have been transgressed rapidly and perhaps exposed to different marine events. During the regression, the shoreline reaches 9 m prior to 5430 yr BP and 7.5 m prior to 4800 yr BP. *A double-peaked transgression is not proven. Early Neolithic sites are not transgressed.*

The Stavanger peninsula

Knut Fægris three major systems of raised beaches

Raised beach ridges are a marked feature within the landscape on the northwestern part of the Stavanger peninsula (Fig. 39). This is especially seen in the Randaberg peninsula where raised beach ridges have been recorded up to 26 m a.s.l.

The oldest sea-level studies on the Stavanger peninsula were performed by the geologists Øyen (1903), Reusch (1907) and Bjørlykke (1908). In their works, field observations, both forms and soil sections, are well presented, but the time perspective is difficult because of the lack of absolute datings. Fægri's work from 1939 (Fægri 1940) was the first attempt to put the different raised beach ridges into a system. He combined field observations with studies on microfossils in basins and mires, which led to a better knowledge as concerns the sea-level displacement in the Jæren region in both time and space. He separated the beach ridges into four groups and at least three major systems of raised beaches in the Randaberg peninsula. The four groups are; the upper level, the Alvevatn level, the middle level and the Tapes level. He postulated the sea-level (mean tide level) to 2-3 m below the summit of the beach ridges at the time of formation.

The upper level: Fægri observed three beach ridges in between 25.6 m and 26.2 m at the farms Randaberg and Grødem and at the Viste plateau. The beach ridges were distinct and represented a shoreline around the 24 m contour line. In his summary, Fægri (1940:169-170) correlated this oldest system with a sea-level of 19 m a.s.l. in the Tananger peninsula. Sjulsen (1982) suggested that the Holeheia terrace (15 m a.s.l.) in Central-Jæren belonged to this level. It was impossible to date this level by pollen analysis. This first beach system then dropped, 0.7 m/km from the north to the south along the coast of Jæren.

The Alvevatn level: Four beach ridges were observed. Two of them were large, one situated near Gjertrudmyra in Randaberg (22.9 m a.s.l.) and the second at the southern part of the Viste plateau (21.5 m a.s.l.). The others were small, located at Hauge and Vistnes (21.6 m a.s.l., later levelled to 20.5 m a.s.l. by Thomsen 1982b). The middle shoreline is estimated to approximately 19 m above present sea-level. Fægri emphasised that the enormous beach ridges had been built up over a long time caused by a marine transgression, which he called the Alvevatn transgression. In his summary, Fægri (1940:169-170) correlated this system with a sea-level of 14 m a.s.l. at the Tanager peninsula and 9 m a.s.l. in Central-Jæren (see region B, Tananger peninsula). Using pollen analysis on sediments from the bog Gjertrudmyra and the lake Alvevatn (see discussion below) in Central-Jæren, he placed this transgression at a time "before Allerød". In a later study at Kulebergmyra (= Fægri's old locality "Viste Sjøbad"), Thomsen (1982b) placed this transgression to the transition between Allerød and Younger Dryas, based on pollen analysis and radiocarbon datings. This second sea-level system drops sharply with 0.5 m/km from north to south along the coast of Jæren.

The Late Weichselian isobases crossed the coastline at different angles. This is in contrast to the Holocene isobases that more or less follow the coast.

The middle level: Notches have been observed in slopes in unconsolidated sediments near Bø (16-17 m a.s.l.) and

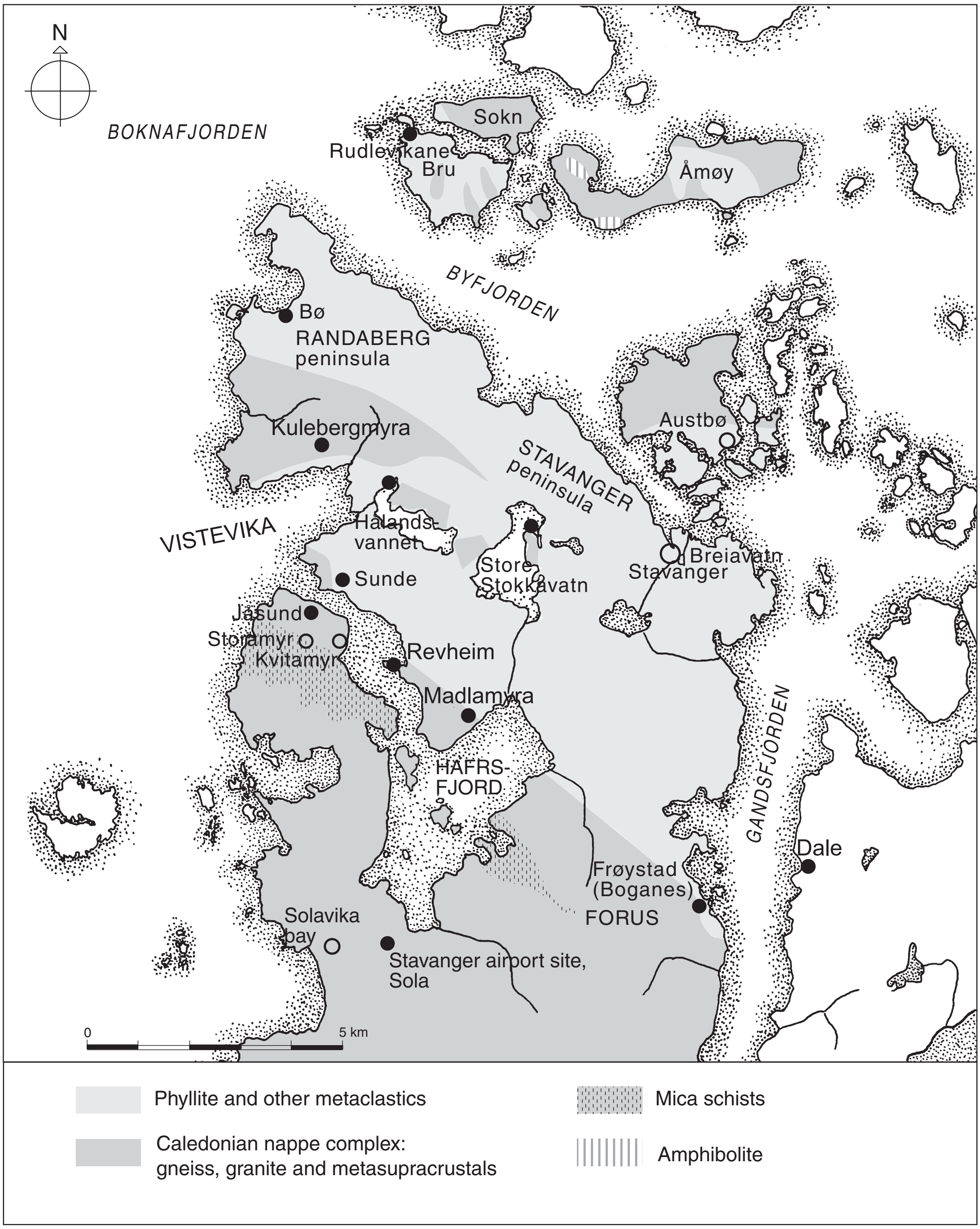


Fig. 39. Map showing the investigated localities (black dots) mentioned in the text from the Stavanger and the Tananger peninsula, northern part of Jæren, southwestern Norway. Underlying bedrock is indicated (after Prøsch-Danielsen 2002).

at Viste (16.2 m a.s.l.). One small beach ridge has also been recorded between Viste and Vistvik with an upper limit of 17.1 m a.s.l. Fægri (1940) was not able to date this stagnation in sea-level. It did not fit into his general sea-level model, which indicated a rapid regression after the Alvevatn level. He therefore suggested that this event was a Late-Glacial phenomenon not related to iso/eustasi.

The Tapes level: The third system of raised beach forms, the Tapes level, can be followed as very distinct landforms, mostly as gravely ridges, from Randaberg in the north (11-12 m a.s.l.) to Central-Jæren (7-8 m a.s.l.) and Ogna in the south (6 m a.s.l.). In the western part of Randaberg, beach ridges can be followed almost continuously from Tunge (10.6 m a.s.l.) in the north, southwards through Bø and Vistnes on 10.8 m a.s.l. and on 11.5-12.7 m a.s.l., Viste (12.3 m a.s.l.) and Sunde (Fægri 1940). *Fægri (1940:135-137) didn't distinguish between the different "Tapes beach systems" because as he said it is rather complex and too complicated to separate and put into a rigid system. However, despite of this he postulates that there had been at least two different peaks during the Tapes transgression, and that the youngest one was the highest* (Tapes maximum 9-11 m a.s.l.). This postulate was based on field observations and among others on a soil sequence at Hølen further south in Jæren and a section from Bø in Randaberg (Figs. 39 and 40).

The section from Bø (Fig. 40) is situated 9.9 m a.s.l., where one of the beach ridges dips into a mire. The stratigraphy was from bottom upwards; a limnic dy, a peat layer, a marine sand layer and on top a peat layer comprising an alder carr. According to the pollen diagrams from Jæren, Fægri placed the transition between the pollen definated zones IX/X (Atlanticum/Subboreal) in the middle of the lowermost peat layer, which imply that the marine sequence could be dated to Subboreal (the youngest peak). Fægris zones are strictly biostratigraphical pollen zones, and his zone boundary IX/X (rise in Quercetum mixtum) has a radiocarbon age of ca 6500 yr BP (Prøsch-Danielsen 1993a). Thus, *this sequence only indicates one marine transgression after 6500 yr BP.*

During World War II, Fægri continued his pioneer work by studying lacustrine environments in Bømlo further north along the coast in Hordaland (Fægri 1944a). Here he got new evidences for a double-peaked Tapes transgression. In some of the basins, Eidestjønn, Aurebettjønn and Nordre Djupadalsmyr, two distinct marine events could be recognized. The stratigraphical profiles were as follows; an upper silty marine gyttja, a sequence

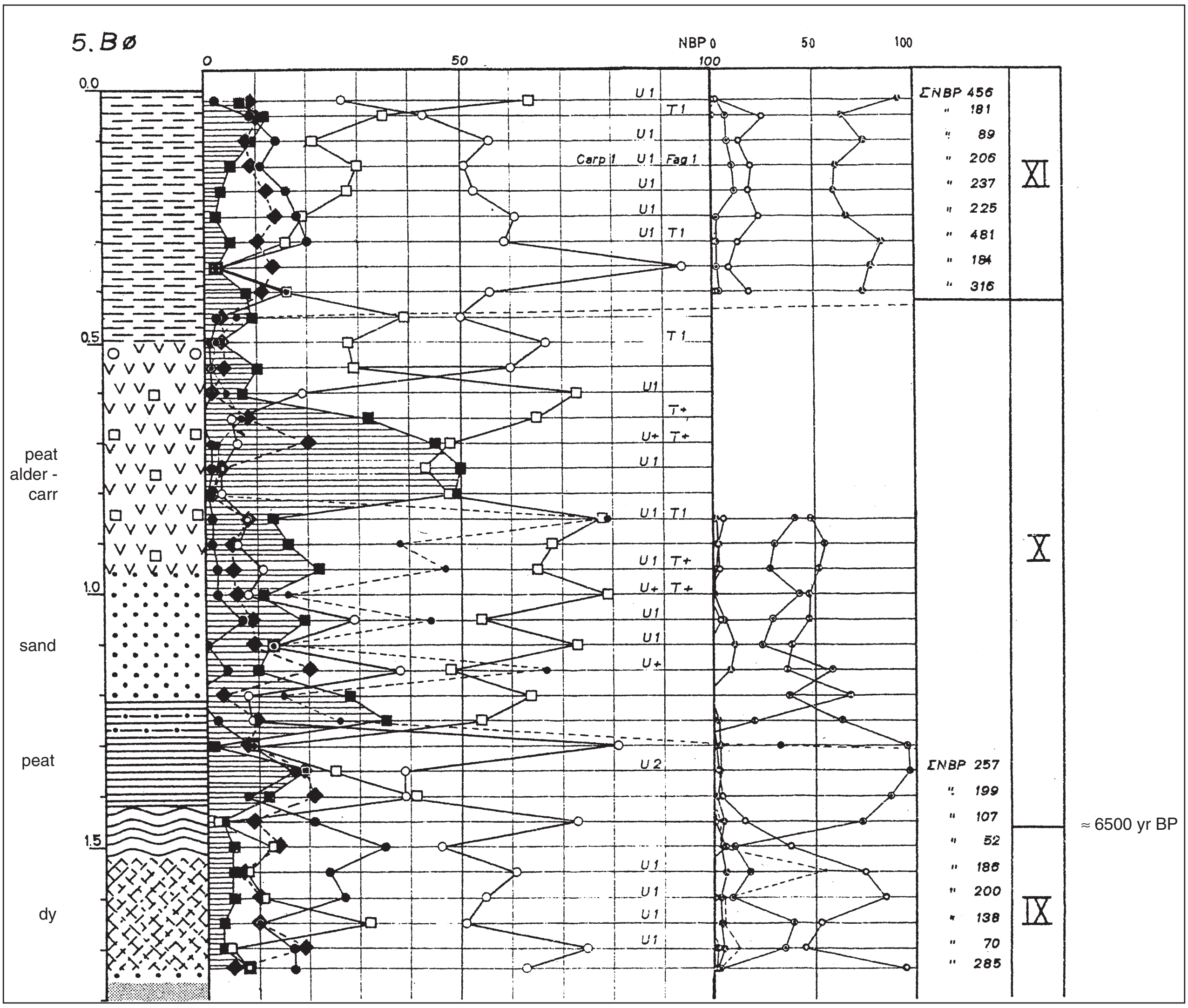


Fig. 40. Due to this pollen diagram from Bø in the municipality of Randaberg, northern part of Jæren, Fægri postulated that there had been two different peaks during the Tapes transgression and that the marine deposits represented by the sand layer in this diagram belonged to the youngest one (Fægri 1940). Unfortunately, today one can only state that this marine layer is younger than 6500 yr BP (the author).

with clasts of gyttja, twigs and shell fragments resting on marine sand (with shell fragments). Later on, this sequence was interpreted as representing one long-lasting marine event, e.g. the Tapes transgression (Kaland 1984). A double-peaked Tapes transgression is also suggested from North-Jæren (Thomsen (1982a). Despite that her assumptions is based on one basin only (Hålandsvannet), she presented two possible courses for the Holocene sea-level displacement curve, the first one with a maximum at 6000 yr BP, the second with a maximum at 5000 yr BP. Bondevik (1996) reinterpreted the work in Bømlo and showed that *Fægri's lower sequence at Bømlo represented a tsunami facies, the group B facies, deposited by the Storegga tsunami around 7200 yr BP, while the second peak represented the Tapes transgression.*

To sum up: Fægri proposed the upper system of raised beaches to be the marine limit (ML) at Randaberg and Tananger at North Jæren, the Alvevatn system to be the marine limit in Central Jæren as far south as Reve, and the Tapes level to be the marine limit south of Reve. Thus the Late Weichselian and the Holocene shore levels intersect near Reve. At least in Hordaland, Fægri's (1940) double-peaked Tapes transgression was reinterpreted to one marine freak event, the Storegga tsunami (7200 yr BP) and one later genuine (eustatic) sea-level rise. In the Randaberg peninsula, Fægri (1940) was able to separate two sets of Holocene Tapes peaks, but not to date them.

Sea-level displacement studies by Hanne Thomsen at North Jæren

The Late Weichselian sea-level displacement and Preboreal regression minimum

Thomsen resumed the work of Fægri in 1977 as part of a research program at the Museum of Archaeology, Stavanger (Thomsen 1982a). Thomsen constructed a Late Weichselian sea-level displacement curve for North-Jæren based on diatom-, algae- and pollen analysis and radiocarbon dates from four basins; Kulebergmyra (18.5 m a.s.l.), Madlamyra (14.5 m a.s.l.), Store Stokkavannet (11 m a.s.l.) and Hålandsvannet (7 m a.s.l.) (Fig. 39).

Thomsen concluded that the upper marine limit found in North-Jæren, 25-26 m a.s.l. that corresponds to Fægri's (1940) first beach system, the upper level, must be older than 13,100±190 yr BP (T-2565). Then followed a regression throughout Bølling and Older Dryas chronozones. It reached down to 11-14 m a.s.l. in Allerød chronozone before a short lived trangression to approximately 21 m a.s.l. occurred at the transition between Allerød and Younger Dryas chronozone, approximately 10,800 yr BP. This corresponds to Fægri's (1940) second beach system, the Alvevatn level. Later, Anundsen (1985) adjusted this trangression maximum level to the 22 m contour line at approximately 10,500 yr BP in the same area. After the Younger Dryas transgression the sea-level displacement curve then drops quickly through Younger Dryas and Preboreal chronozones to a regression minimum of approximately 5 m a.s.l., (Thomsen 1982b) (Figs. 9 and 10). However, in 1996 Bang-Andersen wrote: "*At Revheim in Stavanger (Fig. 39), a thoroughly sea-washed site recently came to light just 1.5 m a.s.l. Even if archaeological field investigations have not yet been performed, and the lithic material is of modest extent, the occurrence of unifacial flint cores together with a pronounced macrolithic blade- and flake technology gives clear indications of a Preboreal age. Assuming that this is correct, the artefact material should either have been redeposited from a higher-lying, still undiscovered settlement site – or the lowest regression level must be 4-5 metres lower than indicated by geology*" (Bang-Andersen 1996). Later, Bang-Andersen's (1996) assumption has been verified by the find of another Preboreal site at Dale, east of Høgsfjorden (Bang-Andersen 2003). This site is situated between –0.5 m below the present shoreline and + 0.5 m above the present shoreline. Unless this site has been exposed to later tectonic movements along the "Gandsfjord-fault" *these observations speak in favour of a regression minimum in Preboreal below present sea-level at least south of the border between region A and B (see also region B, C and D).*

The Holocene sea-level displacement

Thomsen's work picked up small fluctuations during the Tapes transgression phase, based on the study of diatom- and pollen analysis and radiocarbon dates from two basins; Store Stokkavatn (11 m a.s.l.) and Hålandsvannet (7 m a.s.l.) (Thomsen 1982b, unpublished diagrams 1978-1979). The stratigraphical sequence throughout a raised beach ridge at Sunde (9-10 m a.s.l.) was used to construct the Holocene Tapes transgression course in this region (Thomsen 1982a, Braathen 1985). The sites will be discussed separately.

Store Stokkavatn

The outlet of Store Stokkavatn is situated 11 m a.s.l. It drains through a long, narrow natural channel, Madlaforen, which must have appeared as a narrow and shallow inlet of the Hafrsfjord in the Late Weichselian (Fig. 17). Thus, the Store Stokkavatn has been sheltered against storms from the North Sea. Sampling was done approximately 100 m from the outlet of Lille Stokkavatnet, at a water depth of 3 m.

The lithostratigraphy of Store Stokkavatn shows till with boulders at the bottom, below 7.80 m. The stratigrahy is as follows (m below surface):

3.00 - 5.90 m	gyttja
5.90 - 6.02 m	stratified clay gyttja
6.02 - 6.05 m	gravel
6.05 - 6.90 m	clay gyttja
6.90 - 7.20 m	clay
7.20 - 7.40 m	clay gyttja
7.40 - 7.80 m	clay

The sediment section was checked for diatoms. Only marine taxa were encountered below 6.10 m and only fresh water diatoms above 5.80 m. The basin was isolated from the sea at the transition between the Younger Dryas and Preboreal chronozones. Isolation was dated at level 5.85-5.90 m to respectively 10,440±310 yr BP (T-2567B) and 9150±190 yr BP (T-2567A) on gyttja, where the oldest fraction (B, insoluble in NaOH) was interpreted to be the most correct (Thomsen 1982b). *Store Stokkavatn was not influenced by any younger marine events, and its threshold 11 m a.s.l. therefore gives the maximum upper limits for the Tapes transgression in the area.*

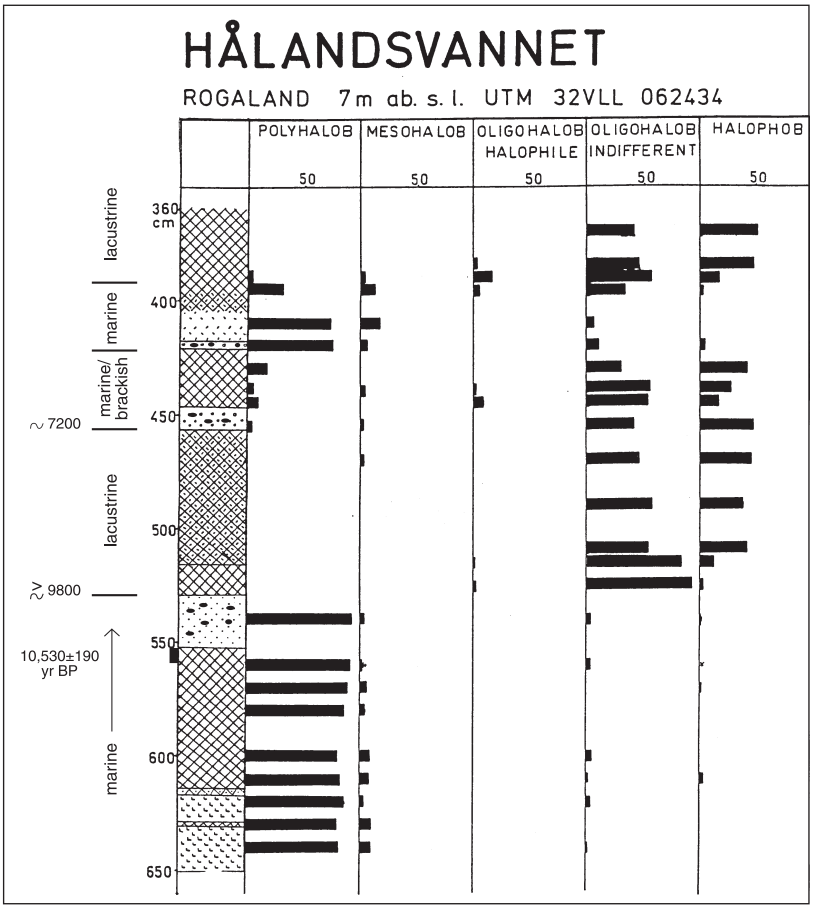


Fig. 41a. A simplified diatom diagram from Hålandsvannet, (analysis: Hanne Thomsen, unpublished. Drawing: Aud Simonsen). The diatom taxa are put into five groups of salinity by using Hustedt's system (Hustedt 1957). In this system the polyhalobous species prefer a salinity higher than 30 ‰, the mesohalobous species prefer a salinity between 0.2 ‰ and 30 ‰. The oligiohalobous halophilous species prefer salinity below 0.2 ‰ and have their optimum in slightly brackish waters. The oligohalobous indifferent group prefers salinity below 0.2 ‰, but has its optimum in lacustrine waters. The halophobous species do not tolerate salt water.

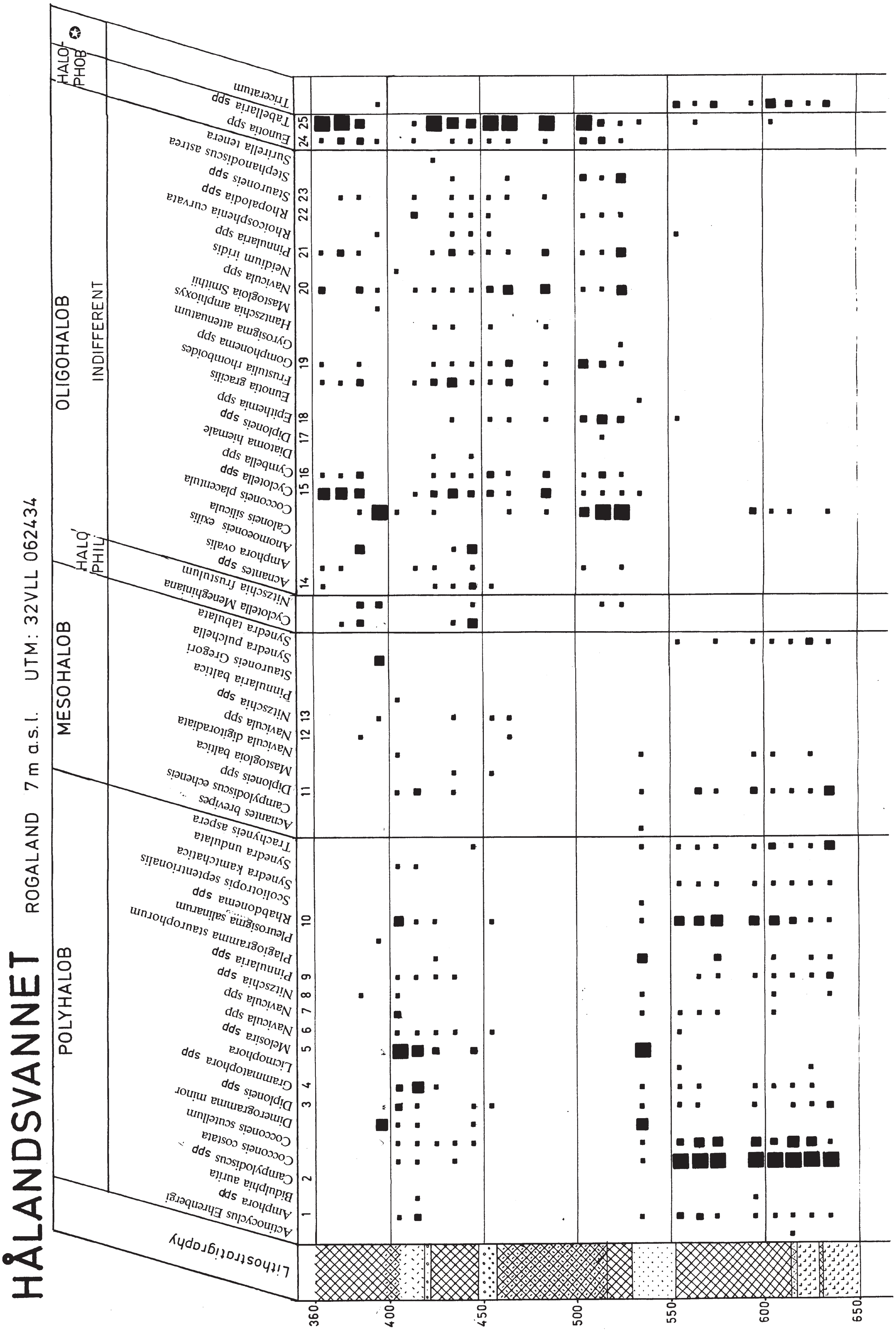
Fig. 41b (right page). A complete diatom diagram from Hålandsvannet, the Stavanger peninsula, northern part of Jæren (analysis: Hanne Thomsen, unpublished. Drawing: Aud Simonsen).

Polyhalobous species:
1. *Amphora* sp. *(A. ostrearia, A. proteus, A. terroris)*
2. *Campylodiscus* sp. *(C. angularis, C. lorenzianus)*
3. *Diploneis* sp. *(D. smithii, D. subsincta)*
4. *Grammatophora* sp. *(G. oceanica, G. serpentia)*
5. *Melosira* sp. *(M. ornata, M. sulcata)*
6. *Navicula* sp. *(N. abrupta, N. albinensis)*
7. *Navicula* sp. *(N. forcipata, N. lyra, N. praetexta)*
8. *Nitzschia* sp. *(N. angularis, N. constricta, N. obtusa, N. socialis)*
9. *Pinnularia* sp. *(P. quadratera, P. trevelyana)*
10. *Rhabdonema* sp. *(R. arcuatum, R. minutum)*

Mesohalobous species:
11. *Diploneis* sp *(D. didyma, D. interrupta)*
12. *Navicula* sp. *(N. elegans, N. peregrina)*
13. *Nitzschia* sp. *(N. scalaris, N. sigma)*

Halophilous species:
14. *Acnanthes* sp. *(A. maxima, A. microcephala)*
15. *Cyclotella* sp. *(C. antiqua, C. comta, C. stelligera)*
16. *Cymbella* sp. *(C. affinis, C. turgida, C. ventricosa)*
17. *Diploneis* sp. *(D. elliptica, D. ovalis)*
18. *Epithemia* sp. *(E. sorex, E. turgida, E. zebra)*
19. *Gomphonema* sp. *(G. acuminatum, G. constrictum, G.* spp.*)*
20. *Navicula* sp. *(N. bacilliformis, N. cocconeiformis, N. cryptocephala, N. dicephala, N. hungarica, N. pupula, N. radiosa)*
21. *Pinnularia* sp. *(P. mesolepta, P. microstauron, P. trigonocephala, P. undulata, P. viridis)*
22. *Rhopalodia* sp. *(R. gibberula, R. parallela)*
23. *Stauroneis* sp. *(S. anceps, S. nobilis, S. phoenicenteron)*

Oligohalobous species:
24. *Eunotia* sp. *(E. arcus, E. parallela)*
25. *Tabellaria* sp. *(T. fenestrata, T. flocculosa)*


HÅLANDSVANNET
ROGALAND 7 m a.s.l. UTM: 32VLL 062434
POLYHALOB
MESOHALOB
OLIGOHALOB
INDIFFERENT
HALO-PHIL
HALO-PHOB
Lithostratigraphy
360
400
450
500
550
600
650

Hålandsvannet – three sand and gravel layers in marine sediments

Hålandsvannet on the other hand, does not have a sheltered position. It is situated inside the bay of Kvernavika, 2 km north of the Hafrsfjord. The threshold of Hålandsvannet (7 m a.s.l.) is solid rock and the outlet faces towards the North Sea (Fig. 39). The sampling site, however, lies in a sheltered bay at the northern end, with a water depth of 2.25 m. Samples were collected in 1978 (Thomsen 1982a, 1982b, unpublished diagrams 1978-1979).

The lithostratigraphy of Hålandsvannet shows bedrock at the bottom. The stratigraphy is as follows (m below surface):

2.25 - 3.87 m	algae gyttja
3.87 - 4.17 m	fine detritus gyttja with twigs and seeds
4.17 - 4.22 m	gyttja, sand and gravel
4.22 - 4.45 m	algae gyttja
4.45 - 4.57 m	coarse, sand and gravel layer
4.57 - 5.25 m	fine detritus gyttja grading into diatomite (5.16-5.25 m)
5.25 - 5.52 m	sand with some pebbles
5.52 - 6.16 m	stratified gyttja with plant remains
6.16 - 6.90 m	clay gyttja with lenses of gyttja
6.90 - 8.60 m	clay with shell fragments

The diatom diagrams (Figs. 41a and 41b) demonstrate that the clay and gyttja layers at the bottom of the sequence are marine. At 5.52 m the sediment changes abruptly from marine gyttja to a 0.27 m thick sand layer with some pebbles. This layer also contains a distinct marine diatom flora but with different species compared to underlying zone. At 5.25 m there is a sharp boundary to the overlying gyttja that has a distinct lacustrine diatom assemblage. The ^{14}C analyses were made on gyttja from the upper part of the marine gyttja at 5.50 m, which gave an age of 10,530±190 yr BP (T-3143). Thomsen (1982a) assumed that this radiocarbon date gives the maximum age of the first regression, and that the marine sand layer above this gyttja probably belongs to the isola-

Hålandsvannet, Randaberg, Rogaland, 7.00 m asl.
Core II incl. lower part of core I

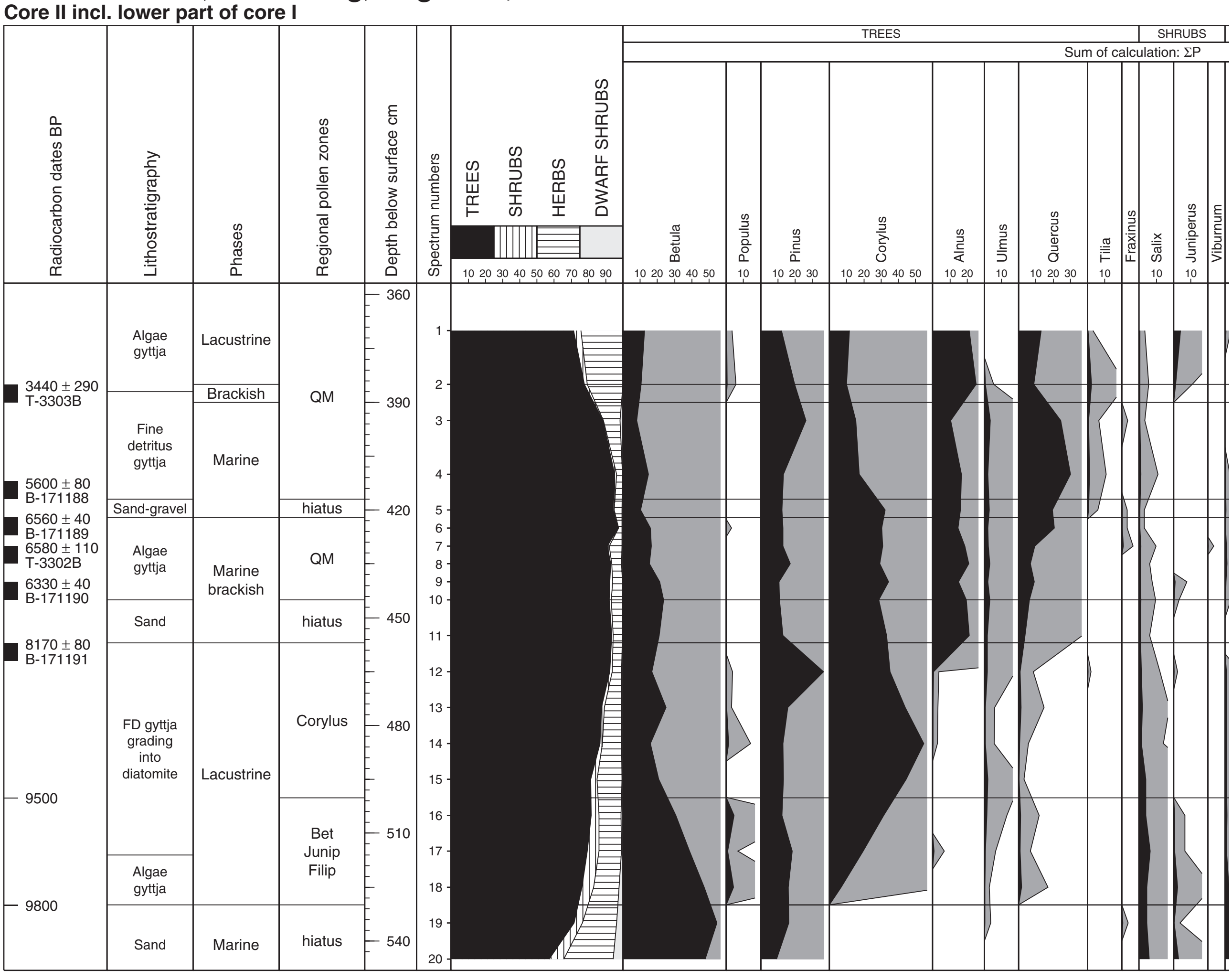


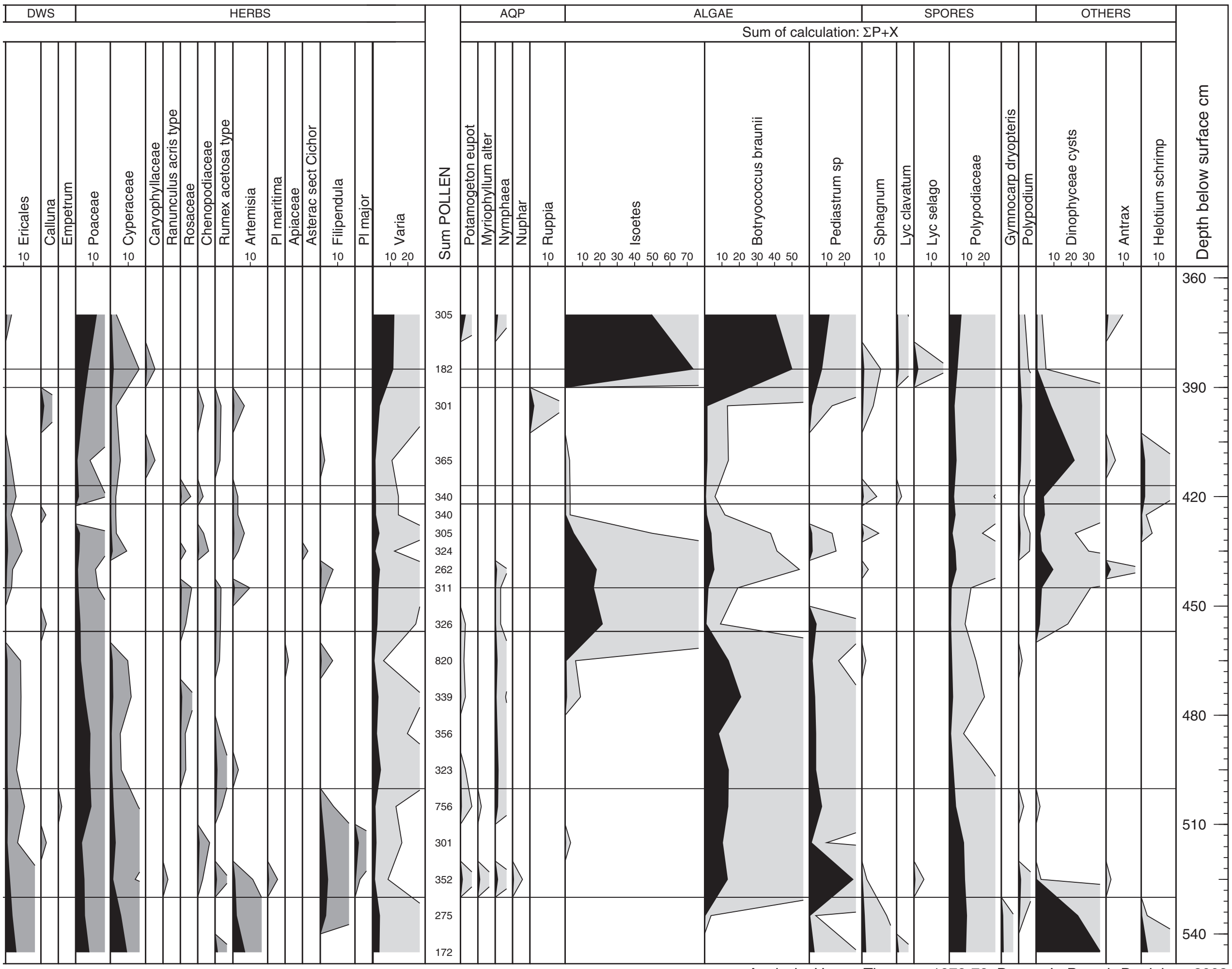
Table 2. Radiocarbon dates from Hålandsvannet (Thomsen unpublished data (T-numbers), Prøsch-Danielsen & Bondevik 2003 (ß-numbers))

Lab.no.	**cm below surface**	**Material dated**	**Radiocarbon age (yrs BP)**	**Dated event**
T-3303B	385.0-390.0	Algae gyttja/ fine detritus gyttja	3440±290	Final isolation
β-171188	412.0-417.0	Marine gyttja	5600±80	Min. age marine event 3 (probably too old)
β-171189	422.0-427.0	Algae gyttja	6560±40	Max. age marine event 3
T-3302B	430.0-435.0	Algae gyttja	6580±110	Min. age marine event 2
β-171190	440.0-445.0	Algae gyttja	6330±40	Min. age marine event 2 (probably too young)
T-171191	457.0-462.0	Lacustrine fine detritus gyttja	8170±80	Max. age marine event 2
T-3143	550.0	Marine gyttja	10,530±190	Max. age of 1. isolation/regression

tion phase with disturbed minerogenic deposits. *There is also the possibility that this sand layer represents a disturbance by a freak marine event dated to ca. 9800 yr BP.*

The pollen assemblage (Fig. 42) in the lacustrine layer above indicates an early Preboreal *Betula-Juniperus-Filipendula* (birch-juniper-meadow-sweet) flora from 5.25 to ca. 5.00 m followed by a *Corylus* (hazel) zone. In a pollen diagram from Rennesøy (Prøsch-Danielsen 1993a)

Fig. 42. Percentage pollen diagram from Hålandsvannet, Randaberg municipality (7.0 m a.s.l.) (analysis: Hanne Thomsen 1978-79, unpublished. Drawing: Prøsch-Danielsen 2003).



Analysis: Hanne Thomsen 1978-79. Drawn: L. Prøsch-Danielsen 2003

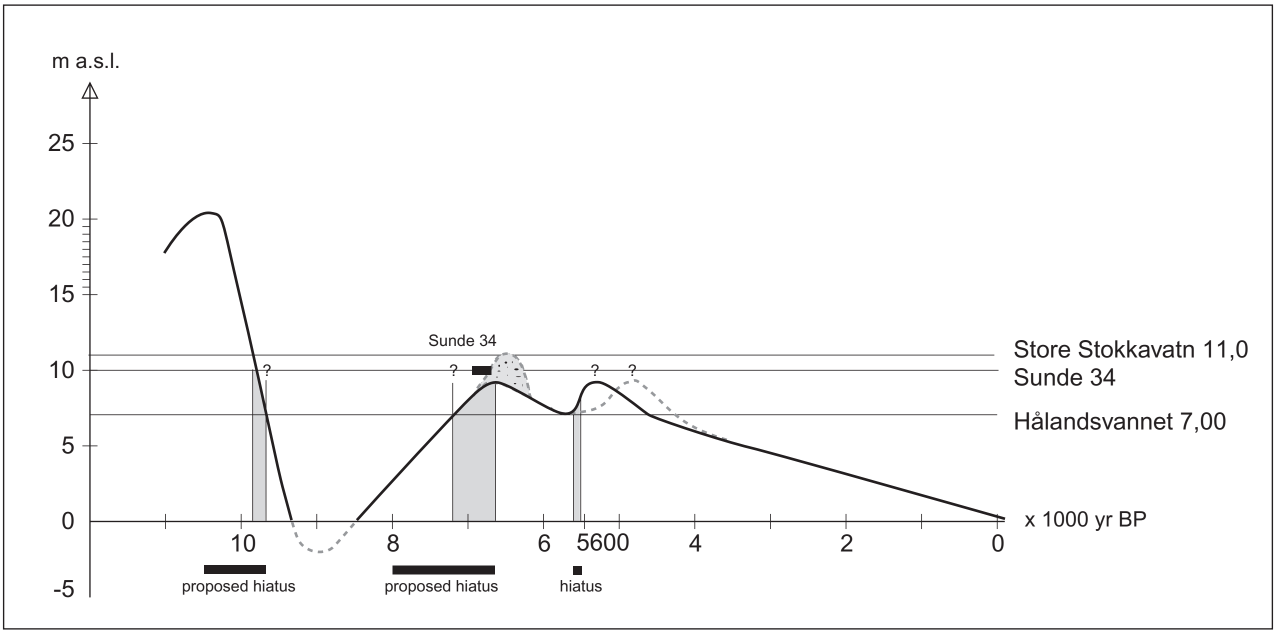


Fig. 43. Proposed sea-level displacement curve for Hålandsvannet, Randaberg municipality (7.0 m a.s.l.). Additional information from Store Stokkavatn (11.0 m a.s.l.) and the site Sunde 34 (9-10 m a.s.l.), both Stavanger municipality, is added. The sea-level course during the regression minimum in Preboreal chronozone is not known (stippled). The alternative course during the second Tapes transgression is also stippled (Prøsch-Danielsen & Bondevik 2003).

these zones represent the time interval from 9800-9500 yr BP and from 9500-8100 yr BP respectively.

There is another sand layer between 4.57 and 4.45 m. The abrupt rise in alder (*Alnus* sp.) (Fig. 42) from below to above the sand layer indicates erosion and a hiatus. Pebbles of phyllite are found within the sand, which indicate erosion from the western lake border (Fig. 39), a higher sea-level and/or higher wave energy. Both the sand layer and the algae gyttja (4.45-4.22 m) resting on top of it indicate a marine/brackish diatom flora, but still with dominance of oligohalobous species that have their optimum in slightly brackish or lacustrine waters. This event seems to be of short duration. The sand layer is ^{14}C dated to be younger than 8100 yr BP and older than 6500 yr BP. *It is tempting to correlate this to the Storegga tsunami dated to 7350-7250 yr BP* (Bondevik *et al.* 1997b).

The third sand and gravel layer with pebbles and of phyllite is between 4.17 and 4.22 m. This layer is younger than 6560±40 yr BP and older than 5600±80 yr BP. The 5600 yr BP radiocarbon date is older than expected, because the pollen diagram reveals forest clearance from this level onwards. In Rogaland the first pronounced forest clearance started ca 5000 yr BP at the transition between the Mesolithic and the Early Neolithic (Prøsch-Danielsen & Simonsen 2000a, 2000b). A second alternative course for the sea-level displacement as concerns this third sand and gravel deposits is therefore stippled in Fig. 43.

The stratigraphy in Hålandsvannet reveals three sand and gravel layers. According to the ^{14}C-dates, the layer in the middle of the stratigraphical sequence has an age that corresponds in time to the Storegga tsunami. If it was deposited due to that tsunami, the two other sand and gravel layers might also be tsunami layers, the lower deposited around 9800 yr BP and the younger dated to ca. 5600 yr BP. The sedimentological characteristics of the sand layers are not very different. All three beds are located at the transition from marine to brackish-lacustrine environment in the basin. The sand layers could *thus* have something to do with the connection and re-connection of the basin to the sea, the two youngest sand layers caused by the Tapes transgression. To solve this problem, more fieldwork is needed.

In 1914, Gjessing (1920) surveyed an Early Late Mesolithic site at the southern border and near the outlet of lake Hålandsvannet. This site was situated 3-4 m above the water-level. In 1914 the water-level was estimated to 6 m above present sea-level, today the treshold is measured to 7 m a.s.l. This means that the site today is situated between 10-11 m a.s.l. Artefacts are heavily water-rolled and patinated which implies that the site must have been transgressed. The age is estimated to approximately 7000 BP (Bang-Andersen pers. comm.). This verifies that the Tapes transgression reached the 10-11 m niveau (see Sunde site 34 below and Fig. 20). The site will be affected by the forthcoming plans of a new public footpath through the area, and will probably be excavated alredy during the summer 2006.

One, possible two, strictly shore-bound and transgressed sites at Sunde

At Sunde, situated at the northern bank of the narrow inlet of Hafrsfjord on the SW side of the Stavanger peninsula (Fig. 39), several hectares of cultivated soil had through the years yielded numerous fragments of flint, mainly of Neolithic appearance (Thomsen 1982a, Braathen 1985). In 1979 the municipality of Stavanger presented plans for house building in the area, which led to an interdisciplinary research project. The flint bearing area seemed to be mixed, either totally destroyed by sea transgression or by modern land-use. With the sea-level curve for North-Jæren in mind, the investigation was concentrated to a 0.5 m thick and barely discernible fossil beach ridge situated between 9-10 m a.s.l. A trench dug through this beach ridge revealed a 5-15 cm cultural layer underneath the beach ridge deposits.

The stratigraphy throughout the beach ridge was as follows (Fig. 44): Overlying the basal till there was a coarse sand layer from the Preboreal regression phase, about 10,000-9000 yr BP. On top of this sand layer was a peat layer, and partly based on this peat, partly on eolian sand, the cultural layer appeared. This layer was sealed by the beach ridge deposits and partly by a sand layer.

The upper part of the peat layer has been dated to 8260±320 yr BP (T-3716). Thomsen (1982a) suggested that the sand layer has been built up when sand blown by the wind covers parts of the peat formed behind the beach ridge. Thus the campsite was situated both on sand and on peat. The cultural layer contained charcoal, burnt hazelnut shells and Mesolithic artefacts, which fitted within the "Microblade Tradition". Several site features were identified; possible traces of a stone-lined tent ring, postholes and four distinctive hearths – one placed indoor, three outdoor. Four radiocarbon dates from this cultural layer gave the ages: charcoal (Rosaceae) 6710±240 yr BP (T-3535), burnt hazelnut shells 6910±100 yr BP (T-3536), charcoal from hearth no.1 (underneath stones) 6600±110 yr BP (T-3715) on *Betula/Alnus* and (in between the stones) 4930±210 yr BP (T-3714) on *Corylus/Betula* respectively. Both Braathen (1985) and later Bang-Andersen (1995) interpreted the youngest date to be incorrect. Since only a minor part of the material is water-rolled and patinated, they assumed that the settlement period was relatively short, possibly two hundred years or so.

Also at Sunde there is a time lag between peat layer (8200 yr BP) and cultural layer (6900 yr BP). During the habitation (6900-6600 yr BP), storm level must have been less than 9.5 m a.s.l. The available data material also implies that the maximum transgression must be younger than 6600 yr BP.

Braathen (1985) concentrated the study on the homogenous, more or less "clean" artefact inventory representing the Late Mesolithic site and did pay attention to the slightly younger Early Neolithic element. However, charcoal from one of the hearths no. 1, which obviously was situated beneath the beach ridge and which obviously was younger (4930±210 yr BP) than the Tapes transgression, may belong to this younger Early Neolithic habitation. The material was displaced all over the area and was also mixed with the Mesolithic artefacts (Braathen 1985). This mixing could be due to modern ploughing.

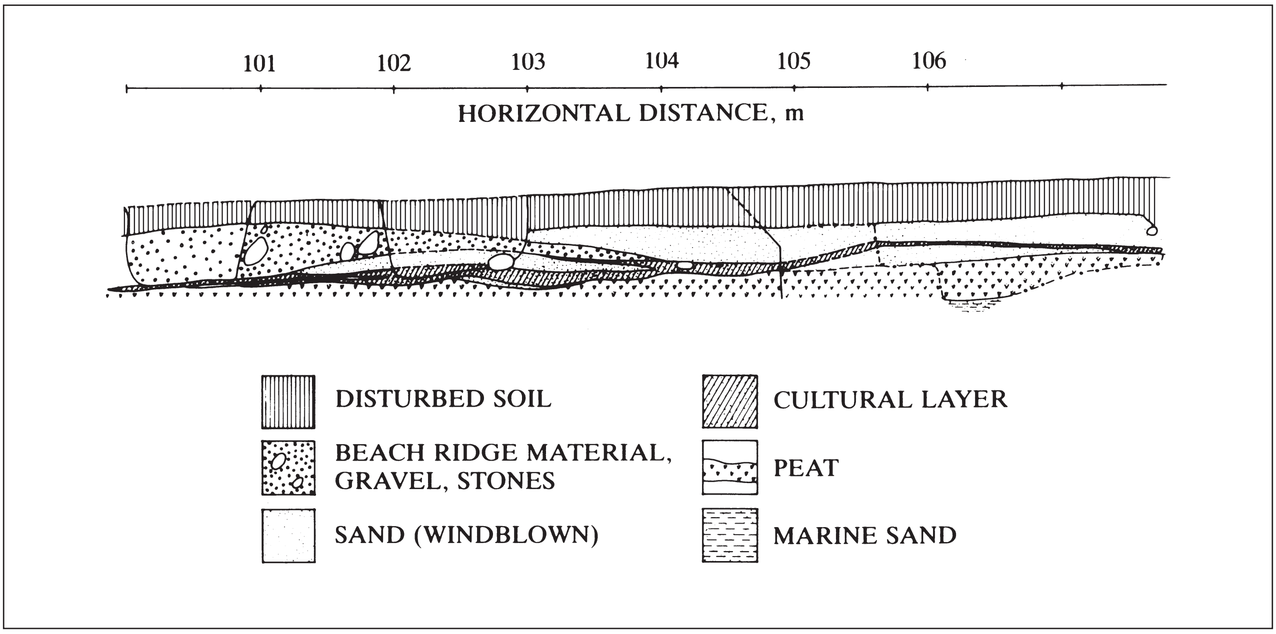


Fig. 44. A stratigraphic section through the beach ridge at Sunde, Stavanger municipality, northern part of Jæren (Sunde 34, profile Y 20) (Thomsen 1982a).

One transgression phase younger than ca 6600 yr BP has been recorded. The shoreline possibly remained at the 9-10 m level for more than 1000 years or there is a possibility that the youngest Neolithic habitation elements were struck by a second marine event, which moved beach deposits and eolian sand containing both the Mesolithic and the Neolithic artefacts up the slope (alternative courses for the sea-level displacement curve are given in Fig. 43).

Strictly shore-bound and transgressed sites at Frøystad (called Boganes) south of Stavanger – Stone Age artefacts in beach gravel separated by a humus horizon

In 1995 the municipality of Stavanger presented a development plan for industrial purposes at Frøystad situated south of the bay Boganesvika and the island Gauselholmen facing Gandsfjorden in the east (Moseng 1995, 1996) (Figs. 1 and 39). Three separate Stone Age sites were recovered in beach deposits 8-10 m a.s.l. at Boganes loc.1. The artefact bearing layers covered an area of approximately 2000 m^2 that again separated two areas of visits. A nearly blurred beach ridge was discovered. The beach ridge sequence was approximately 60-70 cm thick, where the uppermost part was disturbed by modern activities.

The stratigraphy in the beach ridge was as follows (from bottom upwards) (Fig. 45): A basal silty sand layer (D), a lower compact sandy gravely beach deposit, 30 cm thick, with Middle Mesolithic artefacts (C), covered by an incoherent sandy humus layer, 1-2 cm thick, containing seven flint artefacts (B) and a second layer of sandy gravely beach deposits, 20 to 30 cm thick, containing both Late Mesolithic and Early Neolithic artefacts (A). A peat layer sealed the beach ridge deposits.

In the lower beach deposit, the Middle Mesolithic (9000-7000 yr BP) artefacts were heavily water-rolled and found vertically throughout the entire layer. Moseng (1995) suggested that the Middle Mesolithic site had been eroded and that the artefacts had been incorporated in the beach deposit during the following Tapes transgression. The heavily water-rolled artefacts bear witness to a slow and long lasting process. The next humus horizon (B), sealed between the two beach deposits, was thin and incoherent. Although it lacked diagnostic artefacts, it was interpreted as remnants of a cultural layer and fossil soil surface originally inhabited by a Late Mesolithic population (7000-5200 yr BP). It represented a temporary standstill or a regression phase between two transgressions or between the Tapes transgression and a second marine event occurring during the preceding regression phase. During this second marine event, the cultural layer was worked up and the artefacts (Late Mesolithic) incorporated in the next upper beach deposit (C). Layer C contained diagnostic artefacts (eight bipolar cores) belonging to this Late Mesolithic population and did also have a sparse Early Neolithic element (three tagged points with an A1-retouch, 5200-4600 yr BP). 16 % of the Late Mesolithic artefacts were water-rolled, while the Early Neolithic artefacts were pristine. Moseng (1996) assumed that the site was inhabited in Early Neolithic shortly before the site was inundated a second time during the Tapes transgression.

These observations suggest that three settlement periods have been recorded at loc.1. *Moseng (1995) suggested that the Tapes transgression had been double-peaked,*

Fig. 45. A soil profile through the beach ridge at Frøystad (called Boganes), Stavanger municipality, separated into two units by an incoherent sandy humus layer (photo: Åge Pedersen).

and that the second event started sometimes after the Late Mesolithic (7000-5200 yr BP) occupation of the site.

Stokkavatn at Forus south of Stavanger – submerged pine stump layer

The former lake Stokkavatn (10 m a.s.l.) was located app. 10 km south of Stavanger. It was situated between Hafrsfjord in the west and Gandsfjorden in the east (Figs. 1 and 39). The lake was rather shallow and was drained for agricultural purposes in the period 1908-13. It covered 4500 acres and drained eastwards through a narrow brook into the Gandsfjorden. At the lake borders, in some trenches, a 1.5-2.0 m thick peat layer rested on top of a marked pine stump layer. A pine stump has been dated to 5675±60 yr BP (T-8902) (Thomsen, unpublished). This implies that the level of the lake was lower in a period before ca 5650 yr BP. Thomsen assumed that the rise in water level was caused by a rise in the groundwater table caused by the rising Tapes transgression. However, lake Stokkavatn remained as lacustrine water during the Tapes transgression.

Stokkavatn dates the upper limit for the Holocene transgression in this region to 10 m a.s.l. At Forus, the maximum of the transgression is younger than ca 5650 yr BP.

Breiavatn, Stavanger

Breiavatn is a small lake with a threshold of 4.2 m a.s.l. today located in the centre of Stavanger city (Fig. 39). The sediment series was sampled and analysed in 1972 in an attempt to throw light on the settlement history of Stavanger. The lake was once situated at the northern part of a rather narrow valley in a rocky phyllite landscape (today in the middle of the town centre) with a patchy morainic cover, where the top layers were reworked by marine activity. A pollen diagram made from the sediment series (Simonsen 1972, Prøsch-Danielsen & Simonsen 2000a) covers a time span of approximately the last six thousand calendar years.

The sediment cores reveal a marine sequence from the bottom to 565 cm, followed by a brackish phase from 565 to 550 cm and an upper lacustrine phase. The transition from marine to brackish conditions was dated to 3090±160 yr BP (T-1165), while the final isolation was dated to 2580±100 yr BP (T-1341) from the lacustrine part of the contact at 545 cm. The threshold at Breiavatn is at a low level. This implies that it is not suitable to pick up the small variations and fluctuations in the Tapes transgression course from sediments in this lake.

Region B

The Tananger peninsula

Knut Fægri's mapping of littoral forms in the late 1930s

The upper level?: Fægri (1940) found two diffuse notches in unconsolidated sediments (basal till). These terraces were situated 25.7 m a.s.l. and between 21 and 26 m a.s.l. near Slethei at Risavika (Fig. 46). However, Fægri was not quite satisfied with putting them into the first beach ridge system (see page 40).

The Alvevatn level: The second beach ridge system was observed at two separate levels. The uppermost reliable marine niveau was found in a soil section near Hogstad approximately 20.1 m a.s.l. (Fig. 46). At Rise he found a well-developed beach ridge 16.0 m a.s.l. and an accumulation terrace 16.3 m a.s.l. Fægri put forward the idea that they represented the Alvevatn level (here 16-20 m a.s.l.). He did not find the middle level in this peninsula. Perhaps the 16 m contour line represents this middle level.

In 1922, Holmsen (1922) discovered some beach ridges between "Sandnes, Sola and Bore" at the 21.5 m contour line, but these were not recovered by Fægri.

The Tapes level: Fægri (1940) also recognized the third beach ridge system, which according to him belonged to the Tapes transgression. On the southern side of Riseviken he found a small beach ridge 9.4 m a.s.l. From Kolnes – S. Tjora – Hogstad he found a well-developed beach ridge at approximately 11.1-11.8 m a.s.l.

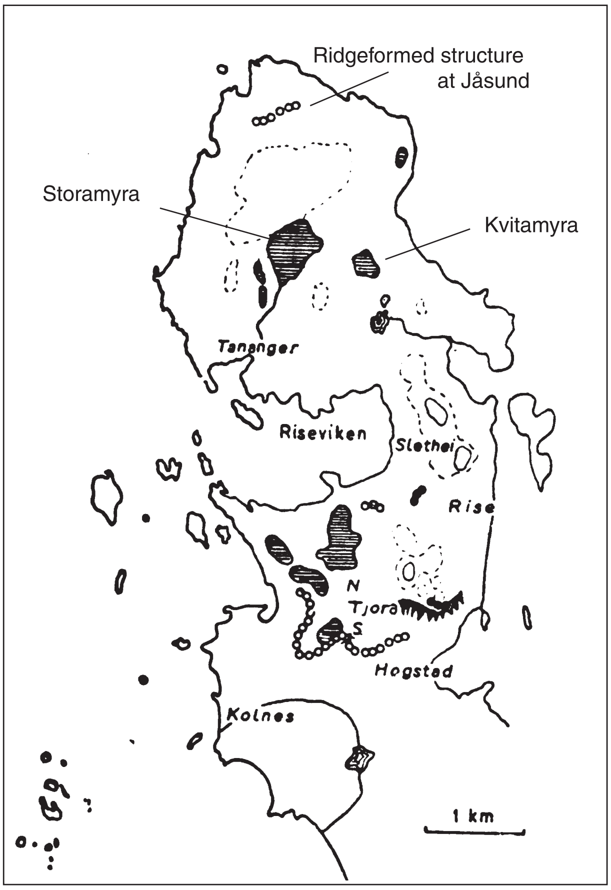


Fig. 46. Late Weichselian (filled circles) and Holocene (open circles) beach ridges and terraces at the Tananger peninsula, Sola municipality, northern part of Jæren (after Fægri 1940), including the localities Storamyra, Kvitamyra and the ridgeformed structure at Jåsund.

A controversial ridgeformed structure at Jåsund

In the late 1970s the municipality of Sola presented a development plan for the northern part of the Tananger peninsula. The actual area is situated close to the inlet of Hafrsfjord at the farm Jåsund. The area was surveyed by the Museum of Archaeology, Stavanger, in the proceeding years (Thomsen, investigated 1980, unpublished). Due to this survey and with the ongoing sea-level studies of the northern part of Jæren in mind, the museum used the opportunity to study a raised ridgeformed structure at Jåsund that is situated 17.5 to 19 m a.s.l. The ridge was mapped in 1901 (Helliesen 1902) and later Fægri (1940) postulated the ridge to be of Late Weichselian age.

The structure stretches continuously 1 km in a SSW-NNE direction, approximately 500-600 m inside the bay of Skiftesvik in an area rich in unconsolidated deposits (Figs. 46, 47 and 48a). Half way in the NE end the structure is ramified into two branches; one branch continues at the 19 m contour level, the other slightly lower at the 17.5 m contour line (Fig. 47). The structure is weakly discernible (at least in summer time covered by grasses) and a small pond and peat have accumulated inside the ridge. There are no beach ridges at lower levels in the area.

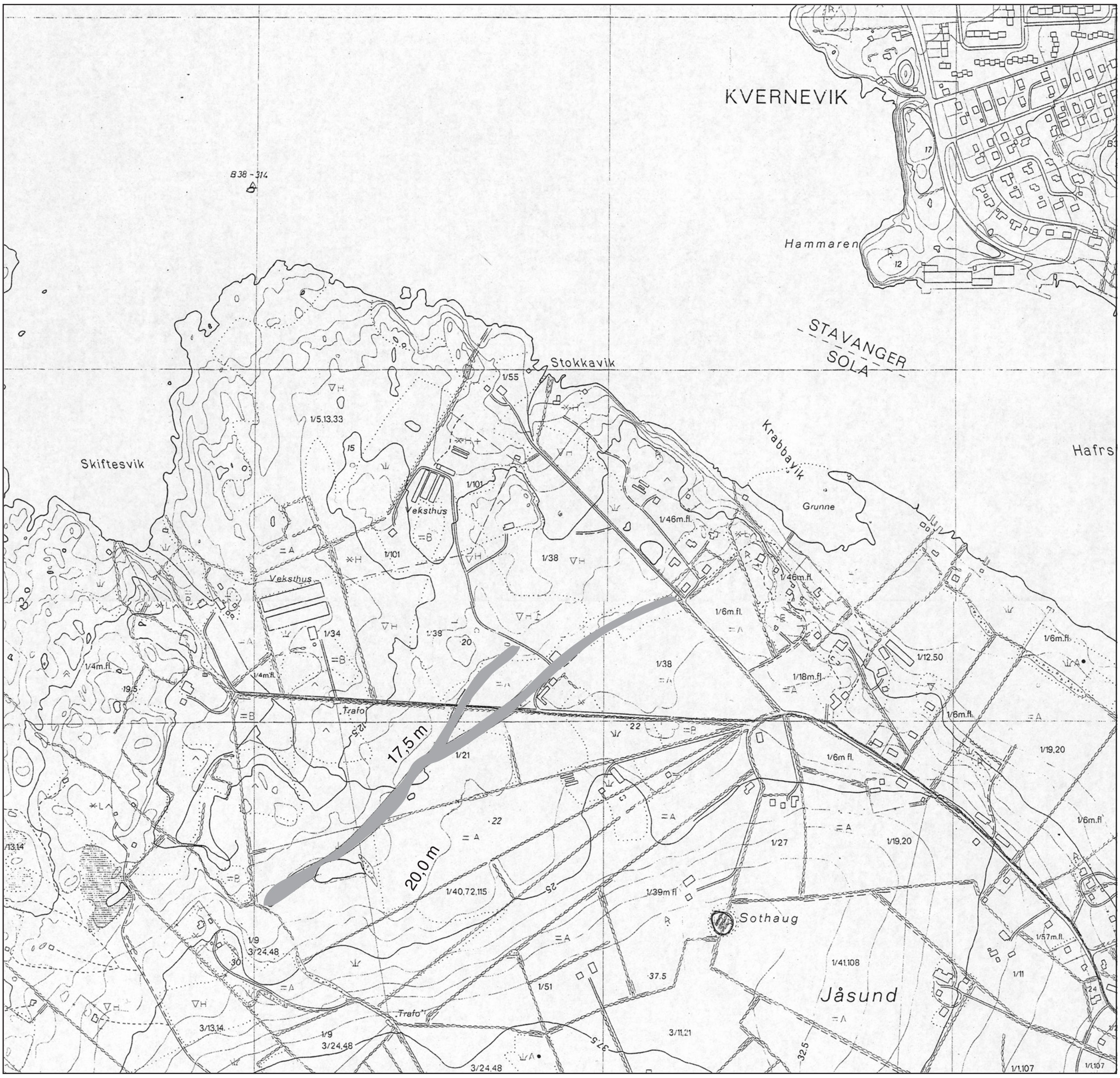


Fig. 47. The braided ridgeformed structure at Jåsund, the Tananger peninsula, Sola municipality, northern part of Jæren, is situated between 17.5 m -19.0 m a.s.l. inside the bay of Skiftesvik (drawn on Land-use map).

In 1980 a hydraulic excavator dug two trenches through the structure in the SSW end. It rested on till with a high clay content. The material in the structure can be separated into two distinct layers: Both layers revealed a typical bimodal beach ridge sequence with gravel and rounded pebbles (diameter 3-5 cm) (Fig. 48b) where the minerogenic material was packed together with sand and lumps of gyttja. The upper layer also contained lumps of humus and well-preserved macroscopic twigs of birch (*Betula pubescens*), alder (*Alnus glutinosa*), willow (*Salix* sp.) and oak (*Quercus* sp.), at least down to 50 cm below the surface. The humus lumps were analysed for pollen. Surprisingly, it revealed a pollen assemblage that characterizes mixed oak forest with oak (*Quercus*), elm (*Ulmus*), birch (*Betula*), alder (*Alnus*) and hazel (*Corylus*). This pollen assemblage corresponds to the warmth demanding flora associated with the Atlantic and the Subboreal chronozones, and definitely not with a Late Weichselian pollen flora. Twigs were radiocarbon dated to 4580±190 yr BP (T-4018), an age that confirmed the pollen analysis. Nevertheless, this unexpected age raised a set of possible questions and explanations. Among them – is the structure the result of:

1. two separate marine transgressions, one Late Weichselian and one Holocene?
2. a local neotectonic movement/faulting in the late Holocene?
3. storm activities reaching 7-10 m higher in this area

Fig. 48a. A hydraulic excavator is digging a trench through the ridgeformed structure at Jåsund, Sola municipality. Picture towards northeast (photo: Hanne Thomsen).

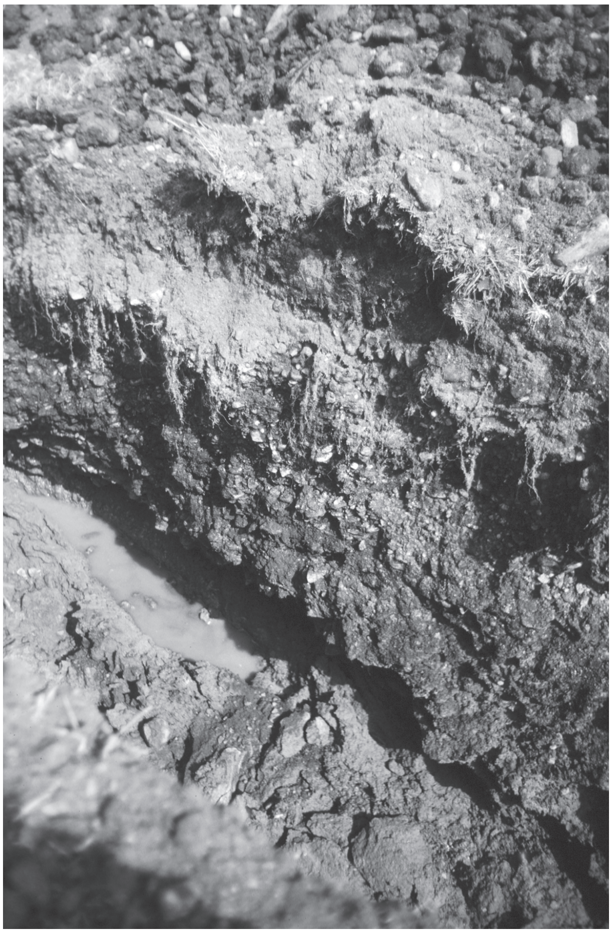


Fig. 48b. A soil profile through the ridgeformed structure at Jåsund, Sola municipality. The structure rests on till with a high clay content (photo: Hanne Thomsen).

than in its counterpart at Sunde, Viste, Solavika and Tjora?

4. a tsunami event in early Subboreal chronozone?
5. redeposition?
6. a diamicton accumulation or terminal moraine?
7. a diamicton accumulation pushed up by sea ice in Late Weichselian?

The main problem is to explain how lumps and twigs (having an age of about 4600 yr BP) have been incorporated in the beach gravel 17.5 to 19 m a.s.l. The contemporaneous sea-level in North-Jæren (Thomsen 1982a) is found at ca. 9 m, a difference of up to 10 m. The question is: How were these young particles (lumps and twigs) deposited together with the beach gravel sediments at this elevation?

According to all other data, to explain the separate branches as two separate marine transgressions is unlikely. The maximum Holocene sea-level is found ca. 10 m below this beach ridge.

In 1982 Thomsen (1982b) proposed that this unexpected ^{14}C date obviously demonstrated an unexpected upheaval (2) of the Holocene shoreline compared with that in Randaberg and Central-Jæren, and that the only explanation could be differential faulting within the Tananger peninsula. This possibility is unlikely because this event should then have been recorded at Kvitamyr (12 m a.s.l.) 2 km further to the east on the Tananger peninsula (Fig. 46). There are no evidences in this filled-in lake sediments to suggest such an event.

Storm activity reaching 7-10 m above the high tide level is unlikely (3), because other sites with similar exposure in the area do not show such a high reaching storm level.

A tsunami event (4) could have eroded the lumps and the twigs and transported them to an old beach ridge and deposited them in reworked gravel on top of the ridge. If this is the case then we would expect to see this event other places too. So far we have no indication of such an event. At present we have no answer to why and how this young organic material was encountered within the structure and what the structure really represents. Point 6 or 7 seems to be the most reasonable explanation.

Storamyr

Storamyr at the northern part of the Tananger peninsula (Fig. 46) is a large boggy area, today a protected nature reserve, with a threshold approximately 22 m a.s.l. draining S-SW. It is situated 1 km south of the structure at Jåsund. Preliminary samples were collected for sea-level displavement studies in 1979 and 1984 (Thomsen diary, unpublished) with a 54 mm piston corer down to maximum 5.5 m below the surface. The lithostratigraphy of Storamyra shows from bottom upwards: clay and clay-gyttja below 2.5 m, diatom gyttja up to 1.5 m and on top a well humified peat sequence. The diatom analysis revealed no marine indications. A lacustrine sequence beneath the terrestrial peat layer, and the transition between Late Weichselian and Holocene is put to 2.25 m below the surface based on pollen analysis. *Storamyr, 22 m a.s.l., was not affected by any transgressions during the Late Weichselian or the Holocene.*

Kvitamyr

Kvitamyr (Fig. 46) is situated 12 m a.s.l., 1 km south of the inlet of Hafrsfjord on the eastern side of the Tananger peninsula. The boggy area has a sheltered position, inside the bay of Melsvika, facing the Hafrsfjord to the east. On the NE border, a small moraine ridge dams Kvitamyr. A modern rubbish dump and a roadway nearby have partly destroyed the locality. Preliminary samples were collected in 1980 (Thomsen diary, unpublished) with a 54 mm piston corer down to 6.30 m. The lithostratigraphy of Kvitamyra shows from bottom upwards: clay-gyttja below 3.50 m, silt and sandy algae gyttja from 3.50 to 2.50 m, then follows a 10 cm thick sand layer and on top a brown algae gyttja.

Shell fragments revealed a marine assemblage below 4.50 m, and a lacustrine diatom assemblage is recorded above this level (no diatoms are recorded in the sand layer). A Late Weichselian flora as seen from pollen analysis has been recorded up to 2.50 m, e.g. up to the sand layer. From this level a Holocene sequence is recorded.

Kvitamyra was transgressed during the Late Weichselian transgression but was not affected by the later Tapes transgression or any other marine events in the late Holocene. However, *the sand layer may represent a short marine event in the early Holocene or be the result of erosion locally.*

The Stavanger airport Sola site

Background

In 1984 the Museum of Archaeology, Stavanger, excavated test pits in the forthcoming roadway leading to a new terminal for the Stavanger airport, at Sola SW of Stavanger. Test pits gave positive results including artefacts ranging in time from the Mesolithic to the Late Neolithic. These discoveries led to an interdisciplinary excavation project in 1985 involving archaeologists and natural scientists. During the excavation, an intersecting pattern of plough-marks was found which enlarged the range of human activity at the site to Late Bronze Age.

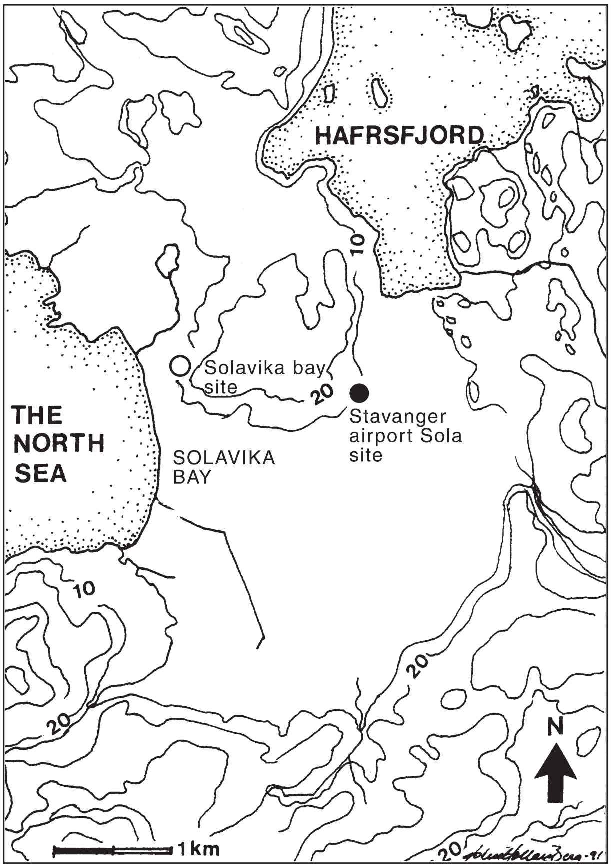


Fig. 49. Map showing the location of the excavated site at the Stavanger airport Sola, situated in the northern part of a plain covered by eolian deposits, and the Solavika bay site, Sola municipality, northern part of Jæren (Prøsch-Danielsen 1993b, Selsing & Mejdahl 1994).

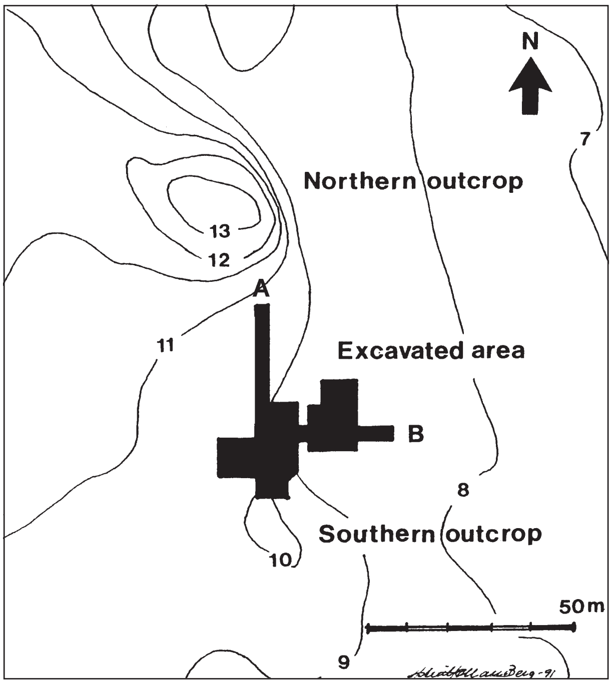


Fig. 50. The excavated area (shaded) with present day topography (m a.s.l.) at the Stavanger airport Sola site, Sola municipality. Trench B and the northern and southern rock outcrop are marked (Prøsch-Danielsen 1993b).

Special emphasise and attention was directed forwards solving chronological problems as concerns both the archaeological material and the bio- and lithostratigraphy in the soil profiles (Skar 1985, Selsing 1987, Prøsch-Danielsen 1993b, Selsing & Mejdahl 1994).

The site

The Sola airport site is situated in the northern part of Jæren, located at one of the plains of eolian sand deposited through prehistoric and historic time (Wangen *et al.* 1987), 2 km inside the sand dune area at the Solavika bay, facing the North Sea in the west, and south of the Tananger peninsula (Figs. 39 and 49). Hafrsfjord borders the plain in the north. Today, the surface varies between 8-14 m a.s.l. Two bedrock outcrops were exposed in the research area, a southern and a northern rock outcrop reaching respectively 10 m and 13 m a.s.l. (Fig. 50).

Field work

Test trenches were excavated with a hydraulic excavator. The youngest artefacts were found at the base of and partly incorporated into a peat layer, which was covered by a thick layer of eolian sand. A hydraulic excavator therefore removed this sand layer. The artefact-bearing

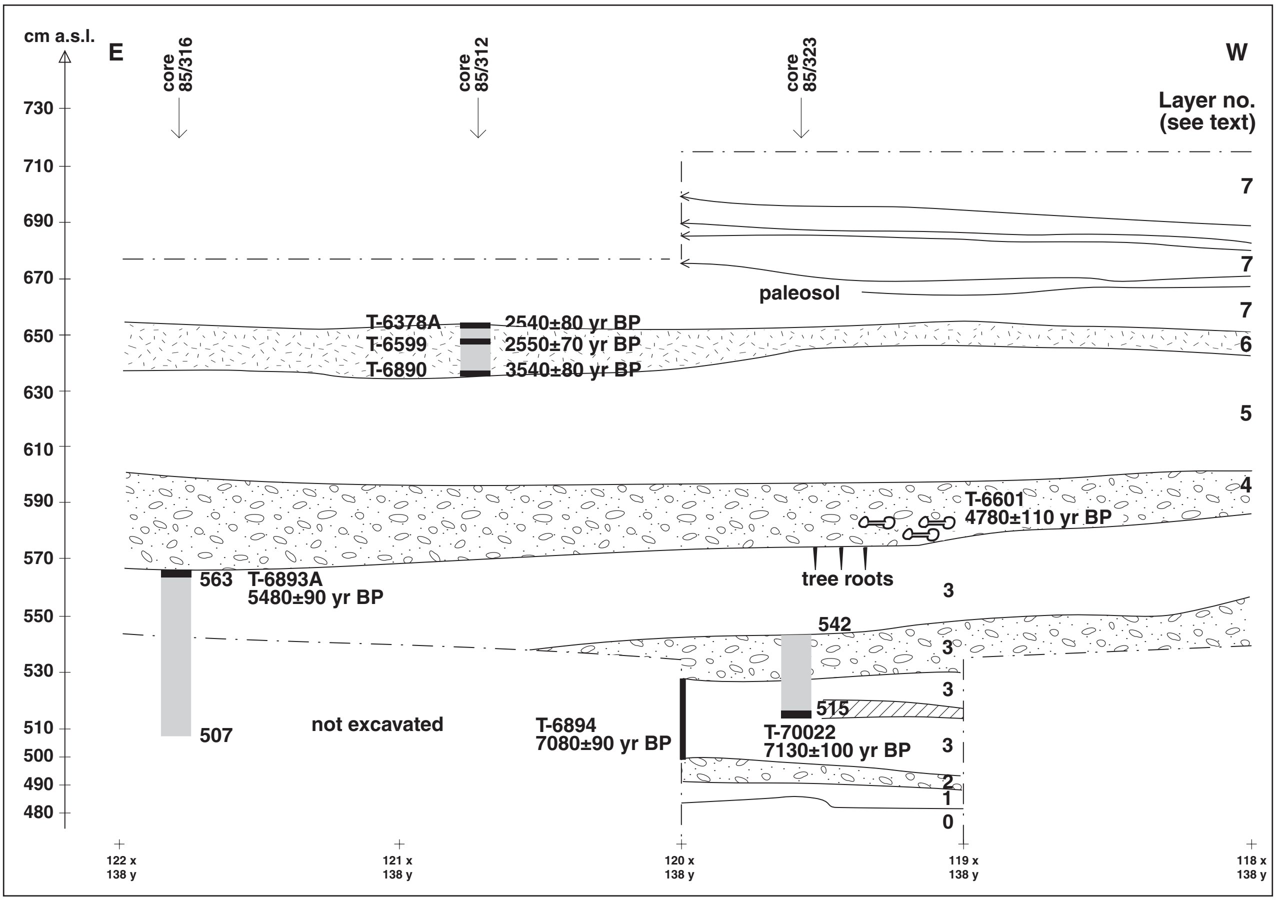


Fig. 51. Stratigraphic section from trench B (118-122x/138y) at the Stavanger airport Sola site, facing southwards where the position of the pollen samples and cores are indicated (soil profile: Skar 1985, otherwise Prøsch-Danielsen unpublished, 1985).

Fig. 52. Photo of a soil section (111-121x /138y) in trench B at the Stavanger airport Sola site, showing layer 5 to layer 7 (photo: Terje Tveit).

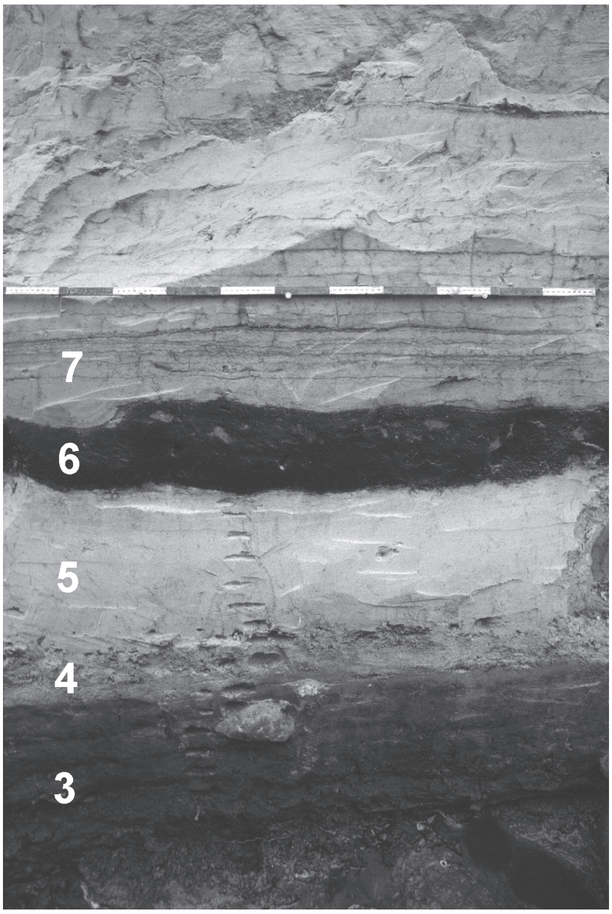
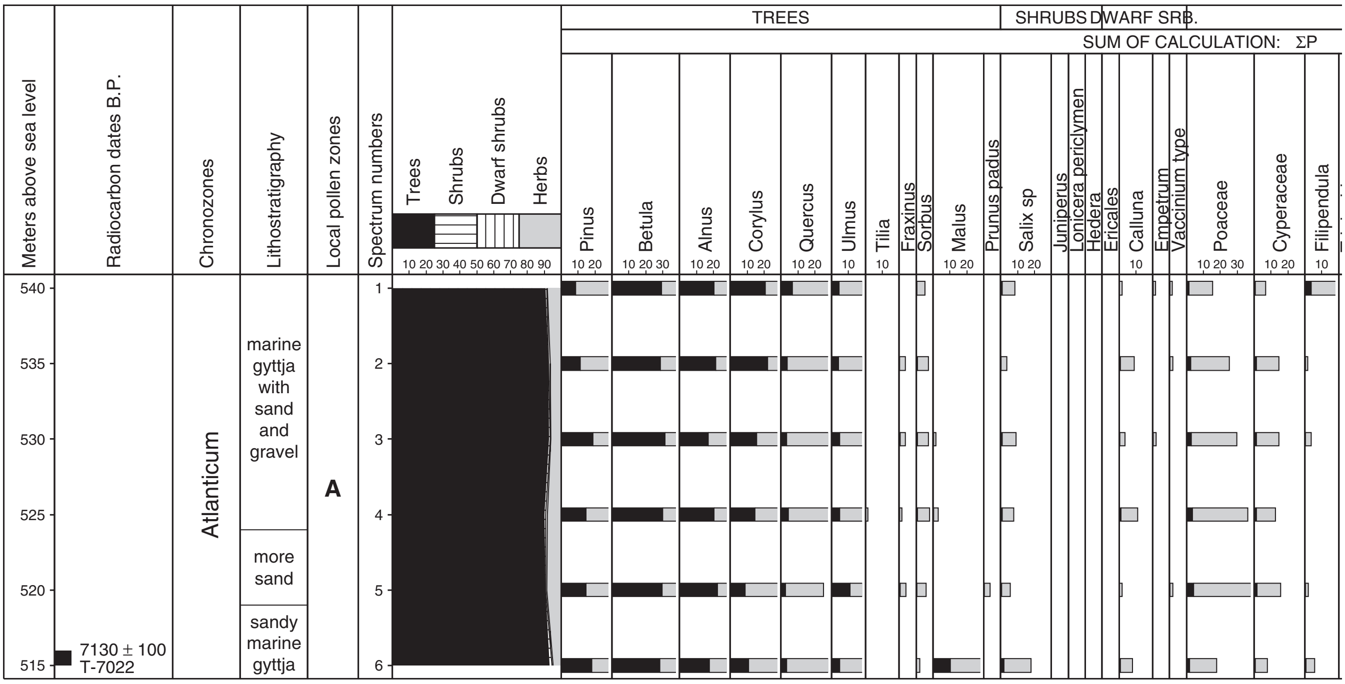


Fig. 53. Photo of a soil section (119-120x /138y) in trench B at the Stavanger airport Sola site, showing layer 3 to layer 7 (photo: Terje Tveit).

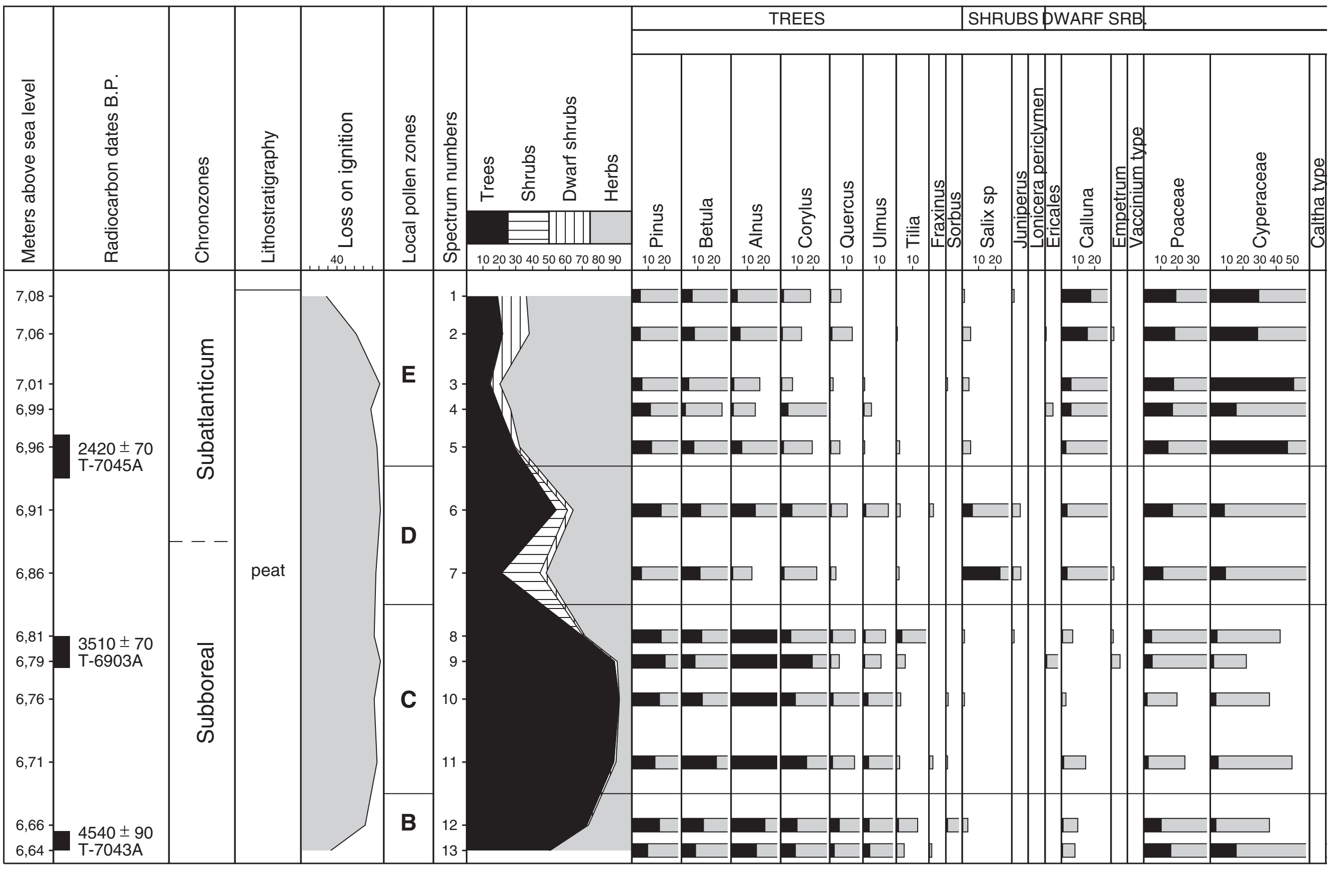
layers covering a total of 300 m^2 were then manually excavated and documented by profile and plane drawings and levelling. In addition to test trenches, the information of the lithostratigraphy in an area of 250x300 m was obtained from 39 boreholes drilled with a soil auger (Selsing 1987).

Stratigraphy
Trench B and the southern rock outcrop separated the investigated area in a western and an eastern part, where the most complete stratigraphical sequence was found on the eastern slope (Fig. 51). It revealed a Holocene sequence (probably from the Boreal chronozone to present day) resting on top of a basal till. Both terrestrial (upper sequence) and marine layers (lower sequence) characterized the sediments. The lithostratigraphy is partly described and discussed in Skar (1985), Selsing (1987), Prøsch-Danielsen (1993b) and Selsing & Mejdahl (1994), but these papers mainly focused on the terrestrial and youngest layers. In this study, focus is paid on the marine

The Sola airport site, Sola, Rogaland, Norway.
119.6x/138y- core 85/323



The Sola airport site, Sola, Rogaland, Norway.
90x/100y - core 85/324



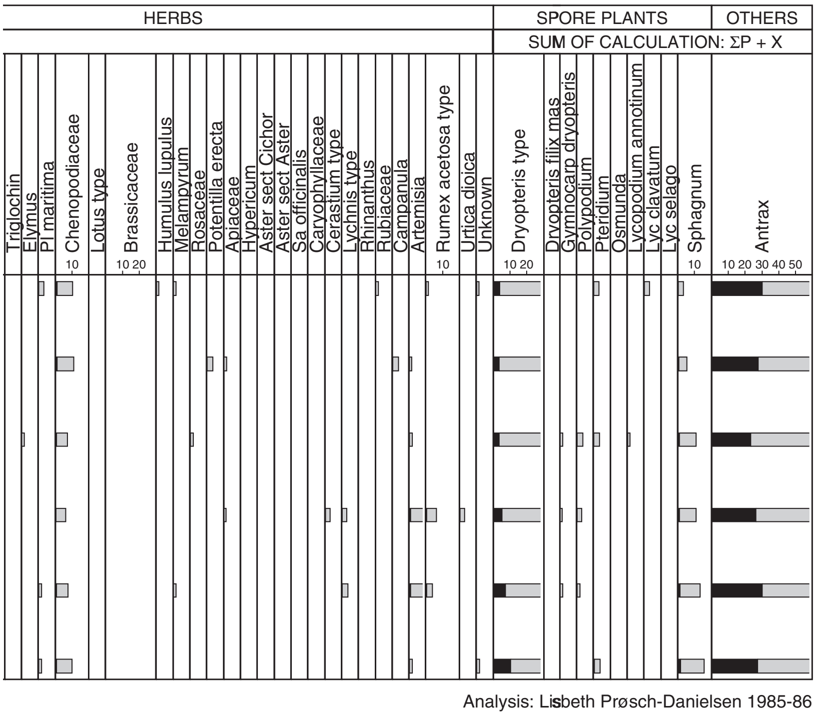


Fig. 54. Percentage pollen diagram from the marine gyttja layer (layer 3) at 119.6x/138y at the Stavanger airport Sola site (analysis: Lisbeth Prøsch-Danielsen 1985-86).

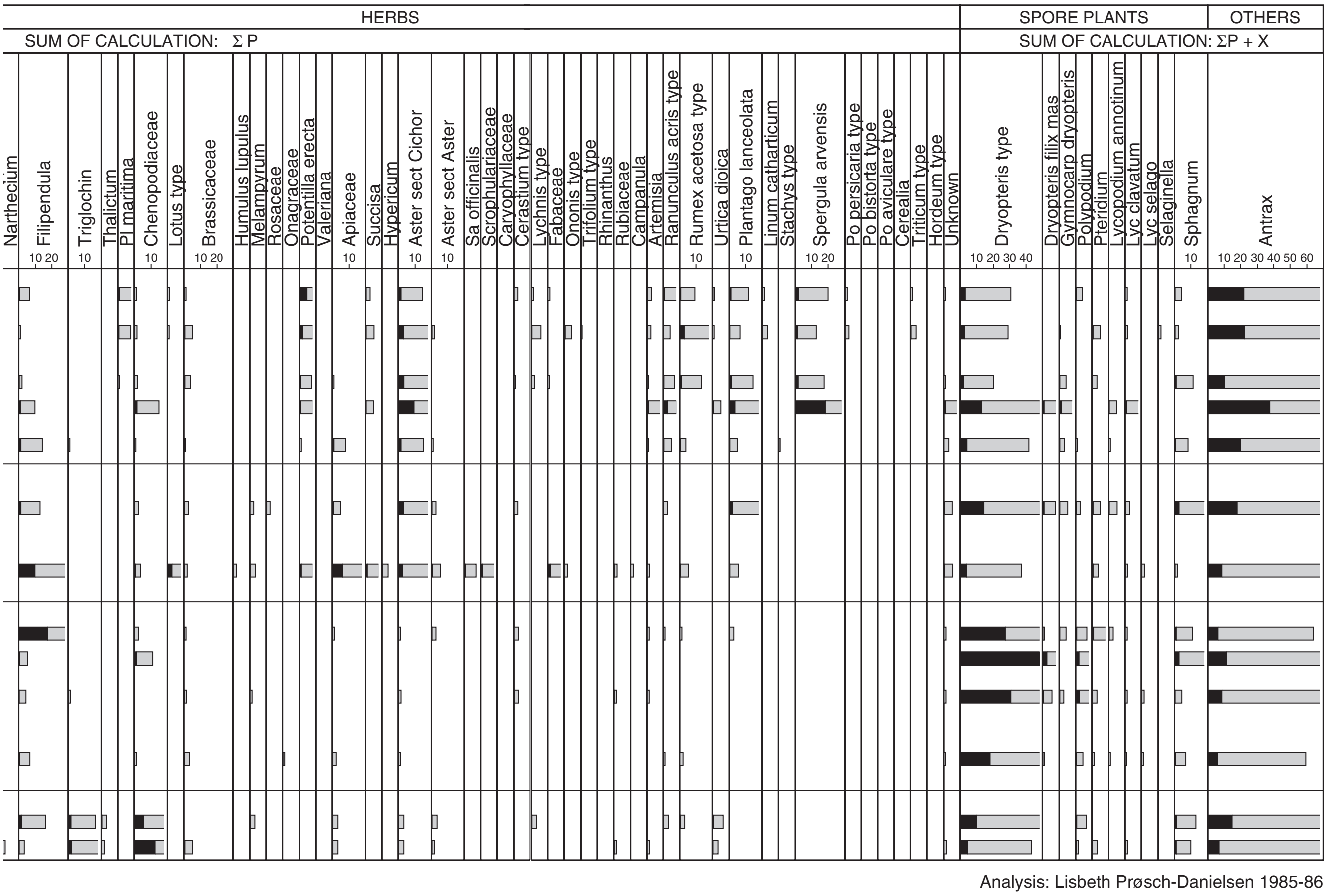


Fig. 55. Percentage pollen diagram from the peat layer (layer 6) at 90x/100y at the Stavanger airport Sola site (Prøsch-Danielsen 1993b).

Table 3: Radiocarbon dates from the Stavanger airport Sola site.

Lab. no.	Layer	Depth m a.s.l.	Material dated	Radiocarbon age (yrs BP)	Dated event
T-6379A	7	Lower part	Paleosol, 115x/144y	2190±80	Lower paleosol
T-7045A	6	6.97-6.995	Peat, core 85/324	2420±70	Rise of *Spergula arvensis*
T-6903A	6	6.78- 6.81	Peat, core 85/324	3510±70	1. appearance of *Plantago lanceolata*
T-7043A	6	6.61- 6.64	Peat, core 85/324	4540±90	Peat bottom
T-7043A	6	6.61- 6.64	Peat, core 85/324	4360±80	Peat bottom
T-6378A	6	6.52- 6.54	Peat, core 85/312	2540±80	Peat top
T-6599A	6	6.48- 6.495	Peat, core 85/312	2550±70	First Cerealia record
T-6890A	6	6.38- 6.40	Peat, core 85/312	3540±80	Peat bottom
T-6600A	6	7.57-7.54	Charcoal of *Salix* (willow) and *Betula* (birch).	4890±100	Peat bottom
T-6891	4	Upper part	Burnt hazel nutshells	4930±90	Upper part, marine gravel
T-6601	4	Lower part	Bone of *Astragalus* sp. (deer)	4780±110	Lower part, marine gravel
T-10888	4	Lower part	Bone of *Astragalus* sp. (deer)	3995±180	Lower part, marine gravel
β-171185	3	Upper part	Roots of *Alnus glutinosa*	4320±70	Upper part
T-6893A	3	5.615- 5.63	Marine gyttja, core 85/316	5480±90	Top marine gyttja
β-171187	3	Upper part	Humerus of *Phoca vitulina* (common seal)	4950±40	Upper part, marine gyttja
β- 171186	3	Middle	Teeth of Sus scrofa (wild boar)	6110±40	Marine gyttja
T-6894	3	5.15- 5.27	Hazel nutshells (bulk sample), sample 85/314	7080±90	Bottom marine gyttja
T-7022	3	5.15- 5.16	Marine gyttja	7130±100	Bottom marine gyttja

sequence and in addition new information and interpretations are added and discussed.

The bedrock consists of mica schist, which in some places is covered by till. Note that on the western slope of the southern rock outcrop, tree roots penetrate into the upper part of the till. The till is here separated from the next layer of gravel by an erosional surface.

The eastern section (trench B, 119x-120x/138y, coordinates in Fig. 51) consisted of seven layers, which are, from bottom to top: A sandy layer (1), a layer of gravel with stones (2) covered by marine gyttja (3), marine gravel (4) and marine sand (5). The sequence continues with a layer of terrestrial peat (6) followed by eolian sand with paleosols (7) at the top (Figs. 52 and 53).

Layer 1. – The till is some places overlain by a thin, up to 6 cm, poorly sorted sand layer

Layer 2. – The gravely layer with stones is poorly sorted and up to 8 cm thick.

Layer 3. – The sandy marine gyttja is present from 5.0 m up to 6.1 m a.s.l. In the middle of the gyttja there is a layer of gravel from app. 5.40 m to 5.50 m a.s.l. The gyttja is layered and contains marine molluscs, hazel nutshells and Late Mesolithic artefacts as well as animal bones and teeth from mammals, birds and fishes (Skar 1985). A bone fragment (humerus) from common seal (*Phoca vitulina*) and a tooth (molar/premolar) from wild boar (*Sus scrofa*) have been identified by Anne Karin Hufthammer and dated to 4950±40 yr BP (ß-171187) and 6110±40 yr BP (ß-171186) respectively (Table 3). The layer consisted of organic and sand (mica schist) lenses sandwiched on top of each other, dipping towards east. Between layer 3 and layer 4 there is an erosional angular unconformity. Also roots of black alder (*Alnus glutinosa*) (identified by Aud Simonsen) penetrating into the upper part of the marine gyttja have been cut of discordantly. A piece of root has been dated to 4320±70 yr BP (ß-171185).

The lower part of layer 3 is radiocarbon dated (bulk sample of hazel nutshells) to 7080±90 yr BP (T-6894) at 120x/138y, and the lower part of core 85/323 sampled at 119.6x/138y in the same unit is radiocarbon dated to 7130±100 yr BP (T-7022). The top of the marine gyttja unit has been dated to 5480±90 yr BP (T-6893A). The layer has also been analysed for pollen that confirm the radiocarbon dates (Fig. 54).

Layer 4. – The marine gravel layer on top of the marine gyttja contains artefacts of Early Neolithic age and finds of animal bones and teeth. Bones from deer (*Astragalus* sp., identified by A.K. Hufthammer), found in the lower part of this layer, has been dated to 4780±110 yr BP (T-6601) and 3995±180 yr BP (T-10888). However, on the eastern slope burnt hazel nutshells on the upper part of this layer have been dated to 4930±90 yr BP (T-6891) (see Fig. 51), a date that fits well with T-6601.

Layer 5. – There is an erosional contact between layer 4 and layer 5 marked by a few mm-thick iron precipitate. Layer 5 varies in thickness between 35 cm and 40 cm and is a light grey homogenous sand layer. Organic matter or artefacts suitable for dating this layer were not found. The bottom of the layer has been TL dated to 3500±350 years (R-853502). Selsing & Mejdahl (1994) suggested that this layer had been deposited close to or at the beach, proposed to be either marine or eolian sand deposits. Granulometric analyses show that the sediment is mainly well-sorted fine sand, not possible to distinguish from the clearly eolian deposits in layer 7. However, Klemsdal (1969) has studied samples of marine and eolian sand at the coast of Møre and his conclusion was that these sediments could not be separated by means of grain size analysis alone. It is therefore suggested that this unit is marine sand.

Layer 6. – A dark brown terrestrial peat overlies the marine sand (pollen diagram, Fig. 55). The layer thins out towards the rock outcrops. The peat layer varies in thickness and reach up to 80 cm just west of the southern outcrop. The bottom of a peat section, core 85/324, is here dated to 4540±90 yr BP (T-7043A) and 4360±80 yr BP (T-7043B), while the youngest and upper part of the peat in trench B, core 85/312, is dated to 2540±80 yr BP (T-6378A). Artefacts belonging exclusively to the Middle Neolithic Period were found at the base of – or incorporated in the peat layer. Charcoal (willow and birch) collected together with artefacts at the base of the peat layer is dated to 4890±100 yr BP (T-6600A). When the peat with the Middle Neolithic artefacts was removed, a series of tilled grooves were observed. They penetrated the peat layer and were interpreted as plough-marks, reflecting cultivation dated to the time interval 2550-2200 yr BP (Prøsch-Danielsen 1993b).

Layer 7. – Eolian sand with paleosols. A thick layer of eolian sand covers the peat. The thickness varies between 1.5 and 2.25 m. Paleosols are found at different levels within this eolian sand, especially in the lowermost part. These paleosols appear as dark layers sandwiched between levels of wind blown sand. The lowermost paleosol is dated to 2190±80 yr BP (T-6379A). This gives the minimum age of the top of the peat and the maximum age of the start of eolian activity in the area.

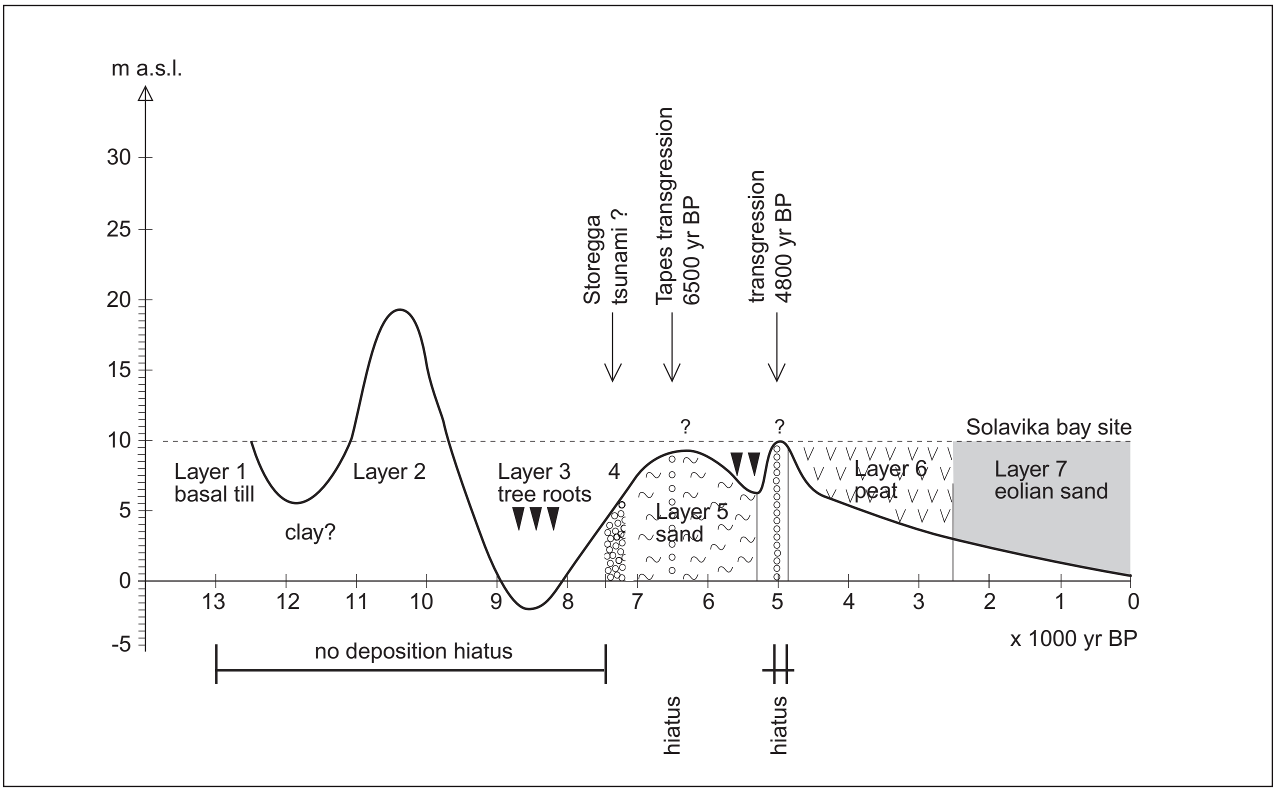


Fig. 56. The sea-level displacement curve for the Stavanger airport Sola, Sola municipality, northern part of Jæren. Information from the Solavika bay site and the results from the sediment sequences at the Stavanger airport Sola site are added to the figure (the terrestrial sequences above the mean tide level, the marine sequences below the mean tide level) (interpretation by Prøsch-Danielsen).

Interpretation, discussion and the sea-level displacement curve

The basal till was deposited before the area was deglaciated, close to 13,000 yr BP (Thomsen 1982b). It has earlier been assumed that the next two layers, the poorly sorted layers comprising sand and gravel (layer 1 and 2), were deposited during the Younger Dryas transgression and regression phase (Selsing 1987). However, the tree roots found in the upper part of the till on the western slope are eroded and sealed by the gravely layer (layer 2). The tops of the roots are recorded between 5 m and 6 m a.s.l. (Fig. 10, in Selsing 1987) which point out that these trees grew on the site later than the Younger Dryas transgression and/or regression phases, most probably during the Holocene regression minimum in the late Preboreal and early Boreal chronozones. The trees have later been submerged. It is therefore suggested that the sand and gravel layers have been deposited during a marine event after the Holocene regression minimum but prior to 7130±100 yr BP (T-7022). It also locates the regression minimum below the 5 m level (Fig. 56).

The sandy marine gyttja that contains marine molluscs and Late Mesolithic artefacts was deposited during the Tapes transgression phase, ranging in time from 7130±100 yr BP (T-7022) to 5480±90 yr BP (T-6893A). The gyttja indicates shallow water and a sheltered location. Finds of Late Mesolithic artefacts cover an area of minimum 7500 m^2 on the SW and E slopes of the southern rock outcrop. The artefact distribution pattern and inventory (Skar 1985, Selsing 1987) shows a pronounced shore-bound site location and a maritime adaptation, and it confirms that the southern rock outcrop (10 m a.s.l.) was not submerged at that time as people necessarily had to settle or live above the shoreline. This is also confirmed by a continuous peat sequence at the Solavika bay, 10.12 m a.s.l. The bottom of the peat layer at the Solavika bay site has been dated to 7120±110 yr BP (T-5720) which implies that neither the Tapes transgression nor other "freak" events reached the 10 m contour line later than 7100 yr BP in the area (Haraldsen 1983, Ugland 1984, Danielsen 1986).

The 10 cm continuous gravel layer that separates the marine gyttja into two units has been deposited sometime between 7080±90 yr BP (T-6894) and 5480±90 yr BP (T-6893A). The depositional environment demands a pulse of water with high energy with strong current. This situation could be achieved during Tapes maximum. At that time seawater flowed from the Solavika bay into the Hafrsfjord or vice versa and flooded the area.

A regression phase followed after the Tapes maximum. Alder (*Alnus*) documented and rooted in the upper part of the marine gyttja shows that local stands of alder colonized the shore margins that emerged at the borders of the southern rock outcrop. At this stage, it is not possible to explain why the later collected alder roots obtained a young date of 4320±70 yr BP (ß-171185). Perhaps these sampled alder roots belong to the upper peat layer no. 6.

However, an alder community requires a certain amount of humus and confirms that the sea regressed below the 6.10 m contour line. However, a terrestrial sequence is absent within the marine gyttja layers. The absence of this "estimated" layer could best be explained by the observed erosional discordance between layer 3 (marine gyttja) and 4 (marine gravel layer). The marine gravel layer must have been deposited in a strong current flowing through the area, a situation that also requires that the barriers/thresholds against the sea have been broken. It is therefore suggested that a new marine episode in the Early Neolithic/Early Subboreal chronozone took place. The marine gravel layer contains finds of animal bones, teeth and artefacts from an Early Neolithic occupation ca 4900-4800 yr BP. Mapping of the sediments by the auger sampler (Fig. 8 in Selsing 1987) gave definite limits for this occupation. The Early Neolithic settlement site seems to have been clustered on the southern rock outcrop. However, artefacts are distributed and redistributed covering an area of approximately 2500 m^2 extending both west- and eastwards. The animal bones represent a marine as well as a terrestrial fauna and may well be the waste products (kitchen middens) that have been dropped on the shore or in the sea by the early Neolithic habitation. Selsing & Mejdahl (1994) suggested that these waste products indicate a deposition near or at the beach during a transgression. However, the remnants is probably not "intentionally" thrown and deposited into the gravel layer, but rather washed into the marine sediments when seawater swept over the southern rock outcrop and the Early Neolithic settlement site. Layer 4 deposits are found up to 9 m a.s.l. in the investigated area (Fig. 11 in Selsing 1987). The population then left the area. No artefacts or traces of these people is encountered in the next layer, the sand layer (5), that has been deposited near or at the beach during the preceding Tapes regression phase. T-7043A shows that the sea-level was below 6.6 m a.s.l. before 4500 yr BP in the area. Accumulation of terrestrial peat started soon after the third marine event. The top and bottom of the peat layer are time transgressive and the peat formation started southwest of the southern rock outcrop within an area with a depression in the marine deposits.

Charcoal associated with artefacts from the Middle Neolithic (Skar 1985) at the base of the peat layer, is dated to 4890±100 yr BP (T-6600). This information implies that the Early Neolithic occupation and the third marine event must have been of short duration.

Three marine events have resulted in the deposition of *gravely layers and erosive surfaces. In conclusion, a strong current must have passed across the sites at these times. The oldest event, after the regression minimum and before 7130±100 yr BP, is probably the result of the Storegga tsunami*. The sea-level was relatively low at that time and the deposits truncated tree roots and rests directly on till. Both the ^{14}C date and the erosional unconfirmity suggest this interpretation

Then followed the Tapes transgression phase with a first maximum probably ca. 6500 yr BP. A second gravely layer demanding a pulse of water with high energy and/or strong current was then deposited. The sea then regressed.

The youngest event occurred at the maximum of the Tapes transgression and might have happened when the sea-level reached a critical level that opened a tidal connection between Hafrsfjord and Solavika bay. When the relative sea-level regressed the tidal current ceased. This connection could have re-opened during the second transgressive phase at ca. 4800 yr BP or as a result of a "freak" event at this time. Both explanations would produce a strong current across the site that is needed to explain the erosion and re-deposition of artefacts and bones. At present, a short-lived rise in sea-level is the best explanation to layer 4.

The Solavika bay site

In 1983 a new sewage pipe was needed for the Sola beach hotel. A hydraulic excavator dug a trench down the slope from the Sola hill to the Solavika bay (Figs. 1 and 49). The trench revealed a Stone Age site dating back to 8500±240 yr BP (T-5321) (hazel nutshells) situated underneath a thick soil section comprising several peat and eolian sand layers sandwiched on top of each other (Haraldsen 1983). Three soil sections (upper level/surface from 11.72 m to 14.31 m a.s.l.) were sampled with special emphasise on the age, the genesis and the origin of eolian deposits (Ugland 1984, Danielsen 1986, Selsing & Mejdahl 1994). One of the soil sections (no. 83/205+P7), revealed a sequence of alternating wind blown sand and peat layers with a 48 cm thick peat sequence at the bottom resting on a marine sand and gravel layer, which was assumed to have been deposited once during the Tapes transgression. This lower boundary is levelled to 10.12 m a.s.l. The bottom of the peat layer has been dated to 7120±110 yr BP (T-5720). *This implies that a marine sequence was deposited prior to 7120 yr BP, and that neither the Tapes-transgression nor other later "freak" events reached the 10 m contour line later on at this site.*

The Central-Jæren area (Region B1)

The Figgjo estuary

In 1982, the Museum of Archaeology, Stavanger, surveyed prehistoric sites in the vicinity of Ølstervatn due to IVARs (Interkommunalt vann, avløp- og renovasjon) plans for expansion and a new waste disposal site near the Figgjo estuary (Figs. 1 and 57). In connection with this survey, Thomsen (1983) used an auger sampler to study the lithostratigraphy along several transects in order to reconstruct the past topography at different periods in the area. At least two beach ridge systems are present in this area. The oldest one, the Late Weichselian beach ridge system (9-12 m a.s.l. rising from south to north), dams up several lakes: Alvevatn, Tangarvatn, Mosvatn and Ølstervatn (Figs. 57 and 58). The youngest beach ridge system(s) that are/is parallel to the coast (9-10 m a.s.l.) accumulated during the end of the Tapes transgression. Just south of Tangarhaug, six separate beach ridges have been recorded, the outermost situated 5.5-6.0 m a.s.l. (Sjulsen 1982) (Fig. 58).

Another problem is due to the fact that the landscape has been subjected to dramatic changes since the 1860s. Several of the lakes have been lowered (Harvalandsvatn

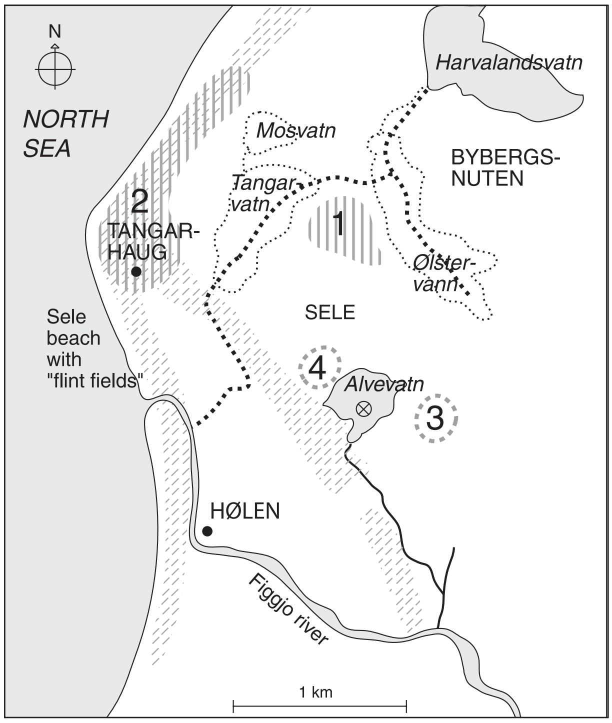


Fig. 57. Location of Alvevatn, Klepp municipality, central part of Jæren, dammed by the inner Late Weichselian beach ridge. Lakes present at AD 1890 are stippled. In addition the location of the "Sele flint-fields" and four areas with either ancient monuments (1-2) or prehistoric sites (3-4) are drawn (Prøsch-Danielsen & Sandgren 2003).

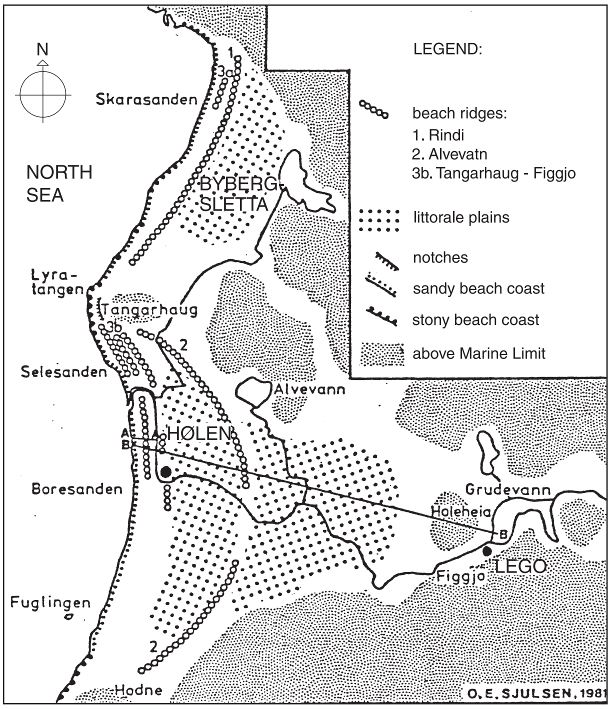


Fig. 58. Littoral forms at the Sele-Bybergsletten area, central part of Jæren, southwestern Norway, see legend. Areas above the marine limit (ML) are shaded (Sjulsen 1982).

and Alvevatn) and some have been drained (Bang-Andersen 1986) (e.g. Tangarvatn/Selevatn, Mosvatn and Bybergsvatn/Ølstervatn) (Fig. 57). Today the lakes drain southwards. The area is also well known because of eolian activity in historical as well as pre-historical time. However, this area is of great interest as seen both from a geological and from an archaeological point of view, so the work got high priority.

Several archaeologists have pointed out that this particular landscape probably was the most densely populated area in Jæren during the Mesolithic and the Neolithic Periods (e.g. Gjessing 1920, Lillehammer 1988, Møllerop 1989, Bang-Andersen 1999). Several Mesolithic dwelling sites have been discovered and some of them excavated along the river Figgjo, one of three major waterways in Jæren (Bang-Andersen 1995). One of these sites, the Lego sites I + II, will be described below. In the Late Mesolithic, Sele was a large wetland area with favourable conditions for water birds, fish and seals. Some of the richest sites, called the "Sele flint-fields" (Gjessing 1920) have been recorded from the estuary of the river Figgjo, trending northwards across Tangarhaug and along the banks of the former Tangarvatn/Selevatn. In the area, the finds of artefacts is ranging in time from the Mesolithic to the Bronze Age.

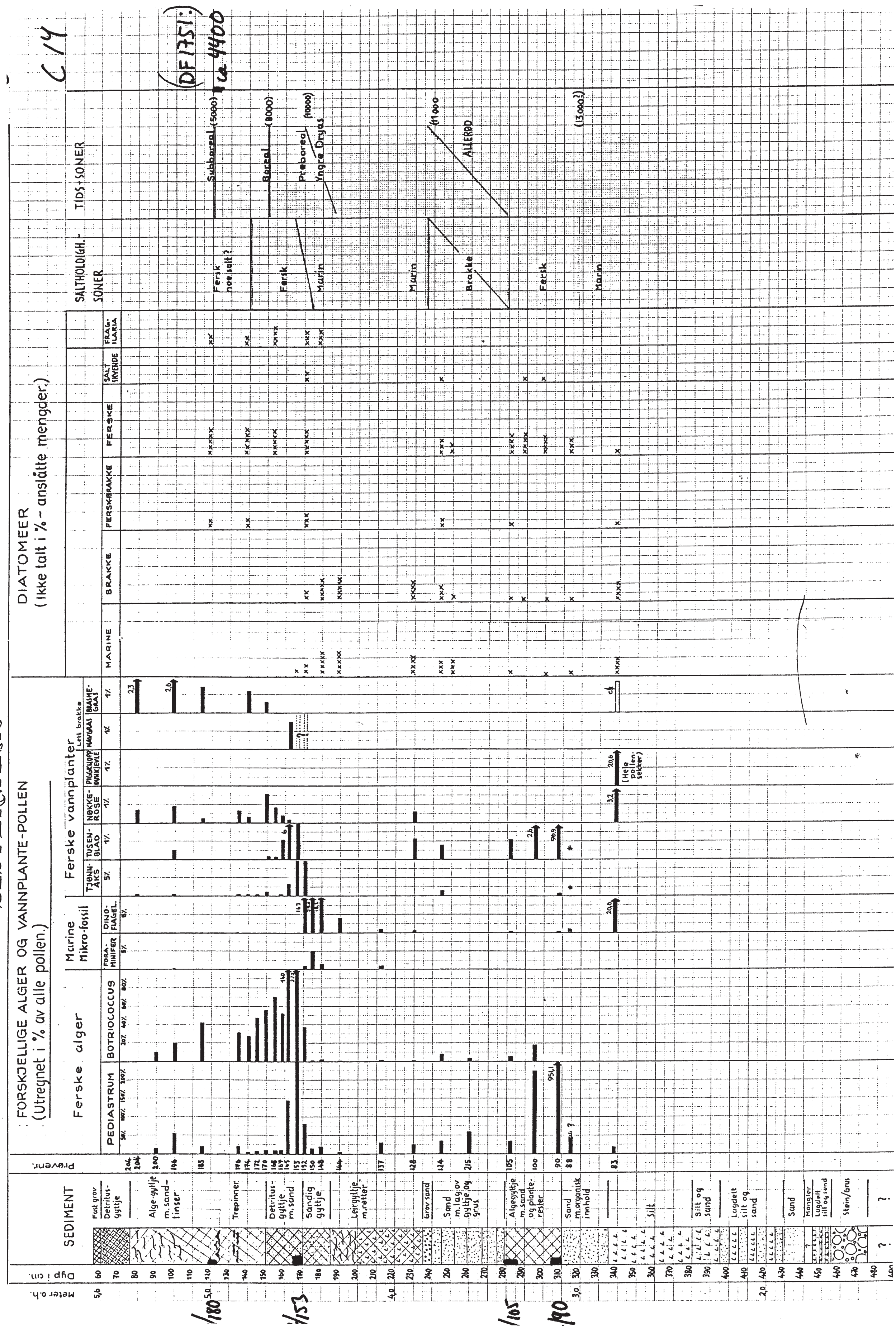
Coring was done by NOTEBY, using a 54 mm piston corer, during a six days period in April/May 1982 (Thomsen 1983). The samples have been analysed for pollen and diatoms. Several transects were drilled near the northern border of Ølstervatn, along the "old and new" Sele channel and throughout the eolian plain of Bybergsletten. In an internal report, Thomsen (1983) stressed that the results achieved by the coring had to be looked upon as preliminary and that new samples were necessary to be able to draw well-built conclusions. Unfortunately, this has not been followed up. For the sake of brevity only the most important observations and conclusions will be referred to.

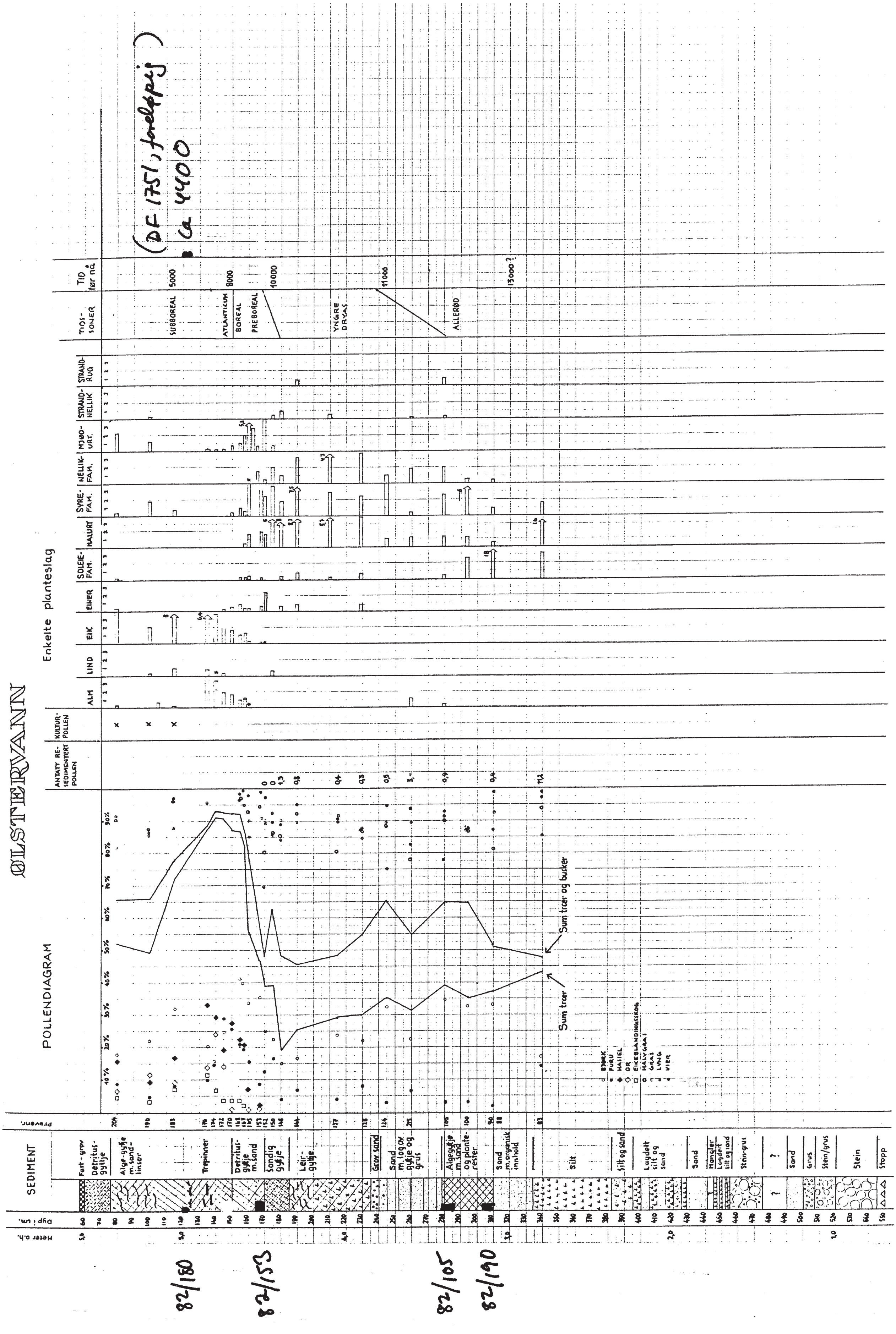
Ølstervatn

The surface is today 5.6 m a.s.l. A 5.5 m sediment sequence was recorded. The diatom flora from Ølstervatn recorded from bottom upward a marine-lacustrine-brackish-marine-lacustrine sequence (Figs. 59 and 60). The lower sediment sequence comprised solely minerogenic sediments of glaciofluvial origin with marine sand on top (3.10-5.50 m a.s.l.). The algae gyttja situated between 3.10-3.40 m a.s.l. contains a lacustrine diatom flora. The lower part of the lacustrine gyttja is dated to 12,920±260 yr BP (T-7566A) and the upper part to 11,370±90 yr BP (T-7567A). This implies that Ølstervatn was a fresh water lake between ca 13,000 yr BP and ca 11,400 yr BP. Then the lake was transgressed by the Younger Dryas transgression that reached the 3.40 m contour line slightly younger than 11,370±90 yr BP (T-7567A). Finally, Ølstervatn was isolated from the sea 10,160±220 yr BP (T-7565A) (4.5 m a.s.l.) and became a fresh water lake (gyttja layer with sand). *These two dates also give absolute maximum and minimum dates for Fægris "Alvevatn-level" (Fægri 1940).* This Younger Dryas and Early Preboreal (chronozones) gyttja layer with sand show some disturbances, as seen from the pollen curve for hazel (*Corylus avellana*). The influx of hazel pollen suddenly disappears and the sediments seem to have been mixed or disturbed. The author (Thomsen 1983) assumed that this was caused by an unknown local disturbance. On the other hand, sand lenses recorded in the upper freshwater gyttja were assumed to represent the start of eolian activity in the area (Thomsen 1983). This event was dated to 4560±150 yr BP (T-6784A).

Fig. 59 (right page). Algae, aquatic plants and diatom diagram from Ølstervatn at Sele-Bybergsletten, Klepp municipality, central part of Jæren (Thomsen 1983).

Fig. 60 (on page 66). Percentage pollen diagram from Ølstervatn at Sele-Bybergsletten, Klepp municipality, central part of Jæren (Thomsen 1983).


ØLSTERVANN
FORSKJELLIGE ALGER OG VANNPLANTE-POLLEN
(Utregnet i % av alle pollen.)
Ferske alger
Marine Mikro-fossil
Ferske vannplanter
DIATOMEER
(Ikke talt i % – anslåtte mengder.)
MARINE
BRAKKE
FERSKBRAKKE
FERSKE
SALTHOLDIGH.-SONER
TIDS-SONER
SEDIMENT
Dyp i cm.
Meter o.h.
Prøvenr.
C 14
(DF 1751:) ca 4400
Subboreal (5000)
Boreal (8000)
Preboreal (10000)
Yngre Dryas
ALLERØD
(13000?)
Fersk
Marin
Brakke


ØLSTERVANN
POLLENDIAGRAM
Enkelte planteslag
SEDIMENT
Sum trær og busker
Sum trær
82/180
82/153
82/105
82/190

Sele channel

A total of eight cores within two transects were investigated. Coring point no. 1, near the southern border of lake Tangarvatn and landwards the Late Weichselian beach ridge, was chosen for further studies. A 7 m sediment sequence was recorded (Fig. 61). The sequence (7.35 m a.s.l.) is as follows:

7.35 - 1.35 m a.s.l.	sand layer with some thin paleosols (+ charcoal)
1.35 - 1.05 m a.s.l.	dark brown, humus layer (+ charcoal)
1.05 - 0.45 m a.s.l.	rounded pebbles and gravel layer
0.45 - 0.05 m a.s.l.	gyttja layer
0.05 - m a.s.l.	cobbles

The lower gyttja layer has been dated to 11,710±240 yr BP (T-7563A) and 12,110±300 yr BP (T-7563B). This gives the maximum age for the start of the Late Weichselian transgression approximately 0.50 m a.s.l. The gyttja layer was covered by a 60 cm thick beach ridge sequence containing some humus (landward part of the beach ridge) dated to 11,990±230 yr BP (T-7562B). Later on, the beach ridge built up to 11-12 m a.s.l. A humus layer accumulated inside the beach ridge, and it contained pollen of tree species associated with a warmth-demanding flora. Unfortunately, two radiocarbon dates from this layer are essential different, 11,750±160 yr BP (T-6782A) and 2790±100 yr BP (T-6783). This points to disturbances and a hiatus before the sand drift started. Nevertheless, the youngest date gives a maximum date of the sand drift at this site.

Bybergsletten and Harvalandsvatn

The eolian plain Bybergsletten is today situated 9 m a.s.l. (Fig. 58). A total of 16 cores within three transects were investigated (Thomsen 1983). Coring point no. 8, near Sandmarka and just inside the Late Weichselian beach ridge, was chosen for further studies. The stratigraphy is as follows:

9.00 - 7.25 m a.s.l.	sand layer with paleosols
7.25 - 6.25 m a.s.l.	peat layer
6.25 - 5.25 m a.s.l.	sand layers with twigs
5.25 - 4.90 m a.s.l.	not sampled ?
4.90 - 4.10 m a.s.l.	coarse sand grading into fine sand downwards
4.10 - ? m a.s.l.	silt and clay?

The peat layer at 5.30 m a.s.l. has been dated to 4860±50 yr BP (T-6779) (Fig. 62). The pollen assemblage represents an open forest vegetation (mixed oak forest) with light demanding species like ribwort plantain (*Plantago lanceolata)* and heather (*Calluna vulgaris)*. The numerous finds of pollen of the water-plant water-lily (*Nympheae* sp.) indicate the presence of a water body nearby. It is therefore interesting to note that the northern border of the lake Harvalandsvatn is situated app. 500 m southeast of the coring point. *If lake Harvalandsvatn had a threshold 10 m a.s.l., as before the lowering in 1903, it would have flooded the eolian plain at Bybergsletten. This implies that the lake Harvalandsvatn had a lower threshold in early Subboreal chronozone than before the lowering in 1903. This is also in accordance with earlier finds of an inundated peat layer with tree stumps (Pinus sylvestris) in lake Harvalandsvatn (Holmsen 1922). Holmsen assumed that this rise in the ground water table and thus the lake threshold was caused by a rapid event that dammed up the outlet near Moen (south of Hellestø).*

The four lakes Ølstervatn, Tangarvatn/Selevatn, Alvevatn and Mosvatn have been dammed by a Late Weichselian beach ridge, which was built up during the Younger Dryas chronozone (from 9 m in the south to 12 m in the north).

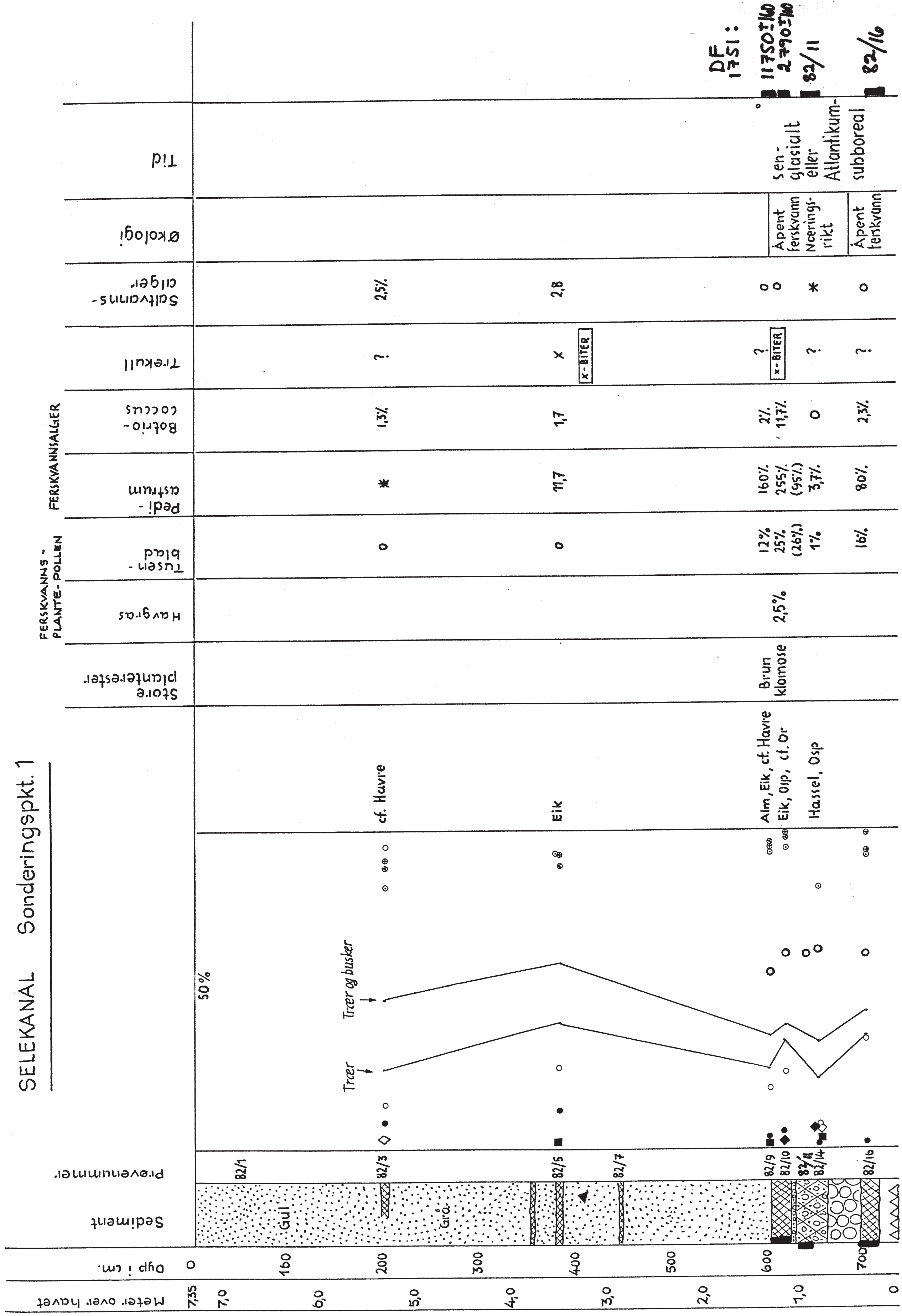
Three of the lakes, Ølstervatn, Tangarvatn and Mosvatn, previously drained northwards, passing Bybergsletten to Moen (south of Hellestø). At least Ølstervatn, Alvevatn and Tangarvatn were not flooded during the younger Tapes transgression. The thresholds prior to the lowering in 1903 and 1953 were respectively; 10.0 m, 10.2 m and 10.0 m a.s.l.

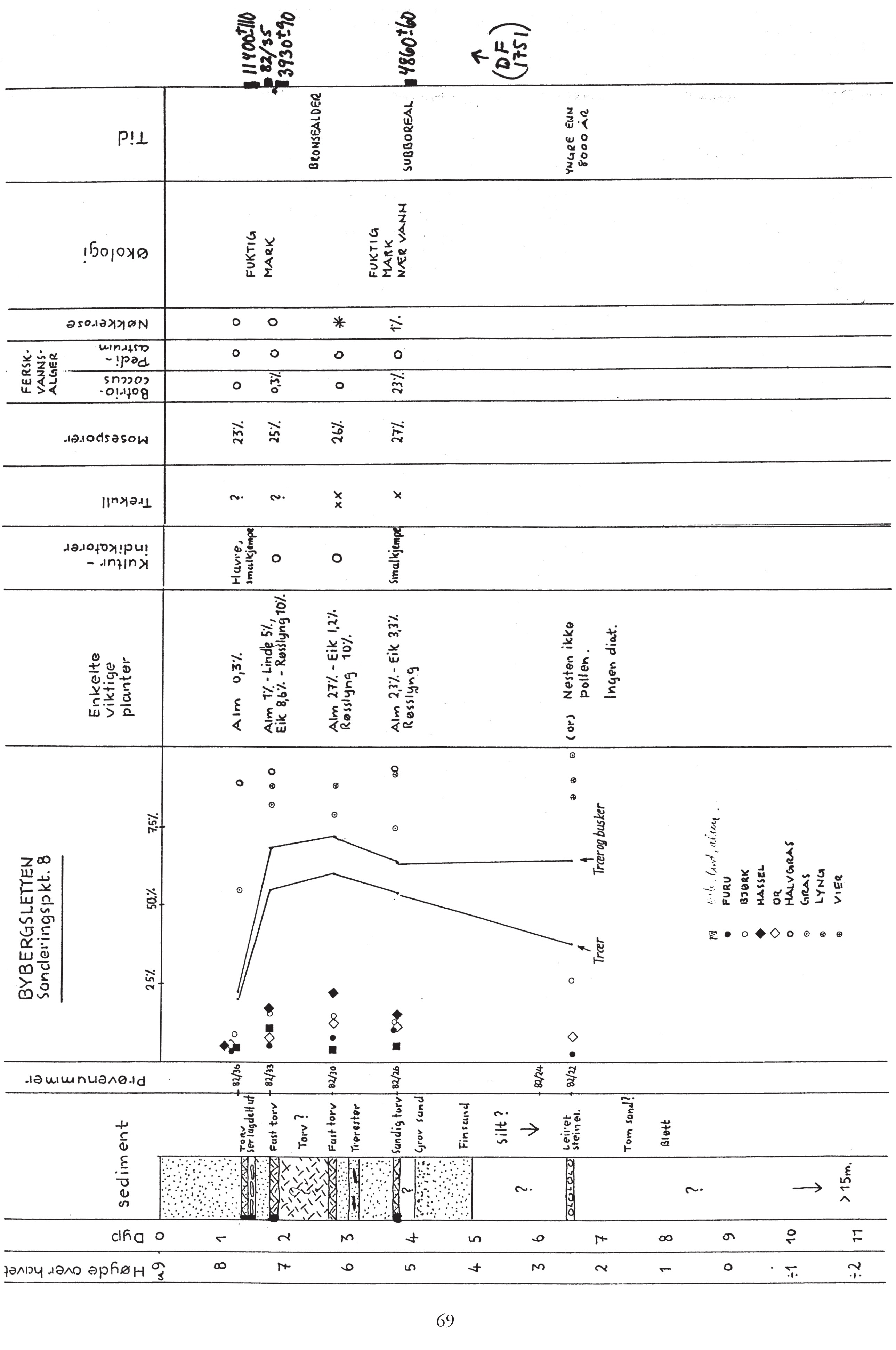
The results from the lithostratigraphy reveal a rise in lake thresholds during the Tapes-transgression and/or a later marine event. This is also observed in lake Harvalandsvatn (Holmsen 1922) and can be caused if:

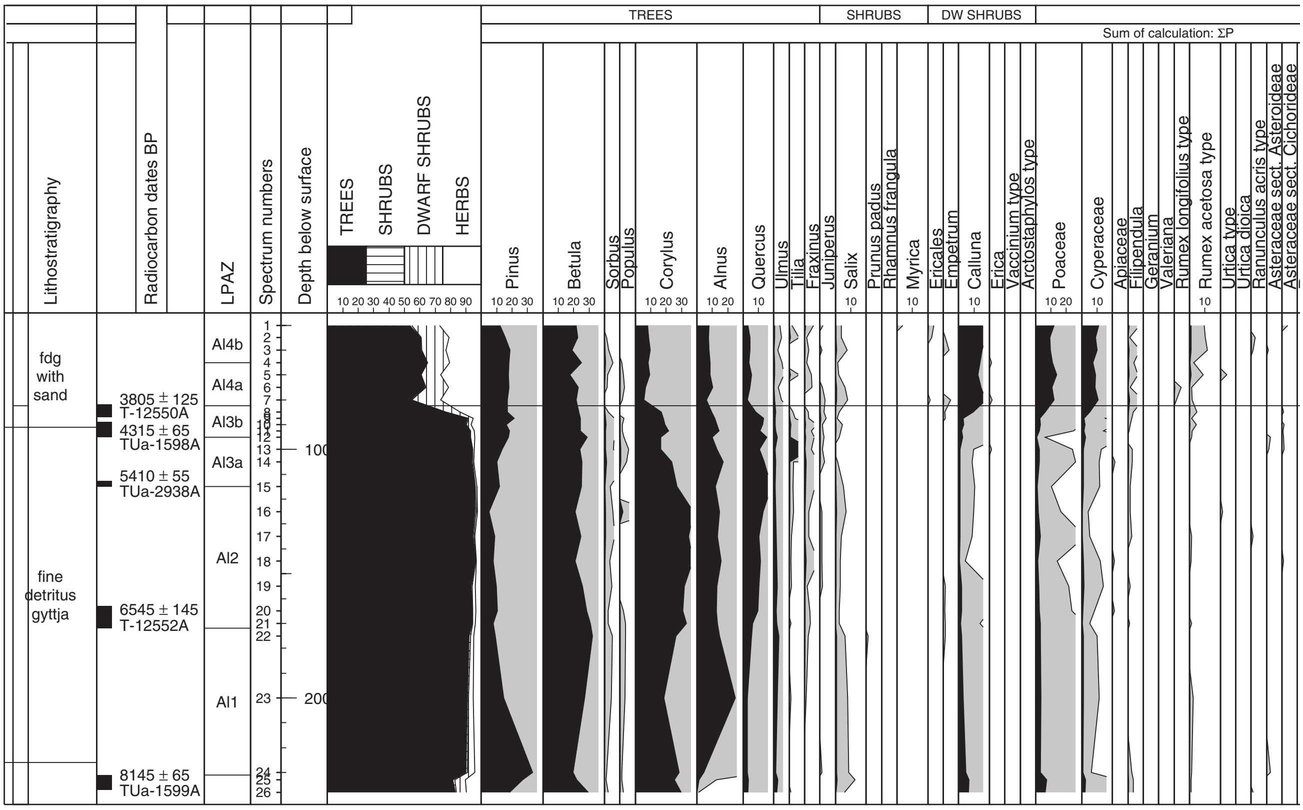
- the building-up of a younger beach ridge system (parallel to the Late Weichselian beach ridge system from Lyratangen to Moen) prevented a breakthrough of saltwater into the lakes.
- the outlet at Moen was dammed up either by peat deposits, by eolian sand or by people.

Fig. 61 (on page 68). Simplified percentage pollen diagram from Sele channel at Sele-Bybergsletten, Klepp municipality, central part of Jæren (Thomsen 1983).

Fig. 62 (on page 69). Simplified percentage pollen diagram from Bybergsletten at Sele-Bybergsletten, Klepp municipality, central part of Jæren (Thomsen 1983).


SELEKANAL Sonderingspkt. 1
Meter over havet
Dyp i cm.
Sediment
Prøvenummer
Store planterester
Havgras
Tusenblad
Pediastrum
Botriococcus
Trekull
Saltvannsalger
Økologi
Tid
FERSKVANNS-PLANTE-POLLEN
FERSKVANNSALGER
50%
Trær
Trær og busker
cf. Havre
Eik
Alm, Eik, cf. Havre
Eik, Osp, cf. Or
Hassel, Osp
Brun klamose
x-BITER
Åpent ferskvann
Næringsrikt
Sen-glasialt eller Atlantikum-subboreal
DF 1751 :
Gul
Grå
Stein
82/1
82/3
82/5
82/7
82/9
82/10
82/11
82/14
82/16


BYBERGSLETTEN
Sonderingspkt. 8
Tid
Økologi
Nøkkerose
FERSK-VANNS-ALGER
Pedi-astrum
Botrio-coccus
Mosesporer
Trekull
Kultur-indikatorer
Enkelte viktige planter
Prøvenummer
Sediment
Dyp
Høyde over havet
11400±110
82/35
3930±90
4860±60
DF 1751
BRONSEALDER
SUBBOREAL
YNGRE ENN 8000 ÅR
FUKTIG MARK
FUKTIG MARK NÆR VANN
Havre, smalkjempe
Smalkjempe
Alm 0,3%
Alm 1% - Linde 5%, Eik 8,6% - Røsslyng 10%
Alm 27% - Eik 1,2% Røsslyng 10%
Alm 23% - Eik 3,3% Røsslyng
(or) Nesten ikke pollen.
Ingen diat.
25%
50%
75%
Trær og busker
Trær
FURU
BJØRK
HASSEL
OR
HALVGRAS
GRAS
LYNG
VIER
82/36
82/33
82/30
82/26
82/24
82/22
Torv Ser lagdelt ut
Fast torv
Torv ?
Fast torv
Trerester
Sandig torv
Grov sand
Finsand
Silt ?
Leiret steinel.
Tom sand?
Blett
>15m.



Alvevatn

Alvevatn is a small lake situated approximately 1 km east of the coastline and the estuary of Figgjo, 10.2 m a.s.l. (Fægri 1936, 1940, Thomsen 1983) (Fig. 57). At present the threshold is 9.4 m a.s.l. The original lake body covered approximately 60,000 m^2. In the south, a Late Weichselian beach ridge dams Alvevatn. The area south of Alvevatn is covered by active and inactive dunes and marine shore deposits.

Background and fieldwork

Alvevatn was investigated by Prøsch-Danielsen in 1995 in order to reveal the deforestation pattern and heath establishment in the area (Prøsch-Danielsen & Simonsen 2000a). Thus the main problem was not to study the sea-level displacement in the area. Magnetic and carbon analysis were also applied in order to record human impact or natural soil erosion in the area (Prøsch-Danielsen & Sandgren 2003).

Sediments were collected using a 10 cm diameter Russian peat corer. The coring was carried out from a raft and the sediments were described according to the scheme of Troels-Smith (1955) and Munsell (1973) to a depth of approximately 250 cm. In the field, the sediment sequences showed a brown, highly organic humic sediment resting on a basal layer of sand and silt. Minerogenic particles were visible in the upper part of the fine detritus sequence. The stratigraphical description of the sediment section is given in Table 4.

The pollen diagram is divided into two major units, a forested stage (including LPAZ A1 to LPAZ A3) and a heathland stage (LPAZ A4) (Prøsch-Danielsen & Simonsen 2000a, Prøsch-Danielsen & Sandgren 2003) (Fig. 63). Human impact has been recorded from LPAZ A1 3 to the top.

The results from the pollen analysis and the magnetic susceptibility analysis have been combined and interpreted in Fig. 64. During the Mesolithic (LPAZ Al 1 and Al 2) very low magnetic concentrations occur and indicate a stable environment with little or no soil erosion. From around 6000 yr BP however, there is an interval (depth 155-126 cm) of slightly higher ARM and SIRM values. This points to a period of somewhat increased erosion but the age is so early (Late Mesolitic) that this event excludes agrarian activity as a likely explanation as far as we know today. During the Tapes transgression large areas close to the lake were flooded, and during the subsequent regression phase vast areas became prone to wind erosion as they were lacking a protecting vegetation cover. The increased magnetic concentrations in this interval most probably can be explained as a result of eolian activity during this period before the soil was re-stabilised by new vegetation, which is represented by the lower magnetic concentrations above (Prøsch-Danielsen & Sandgren 2003).

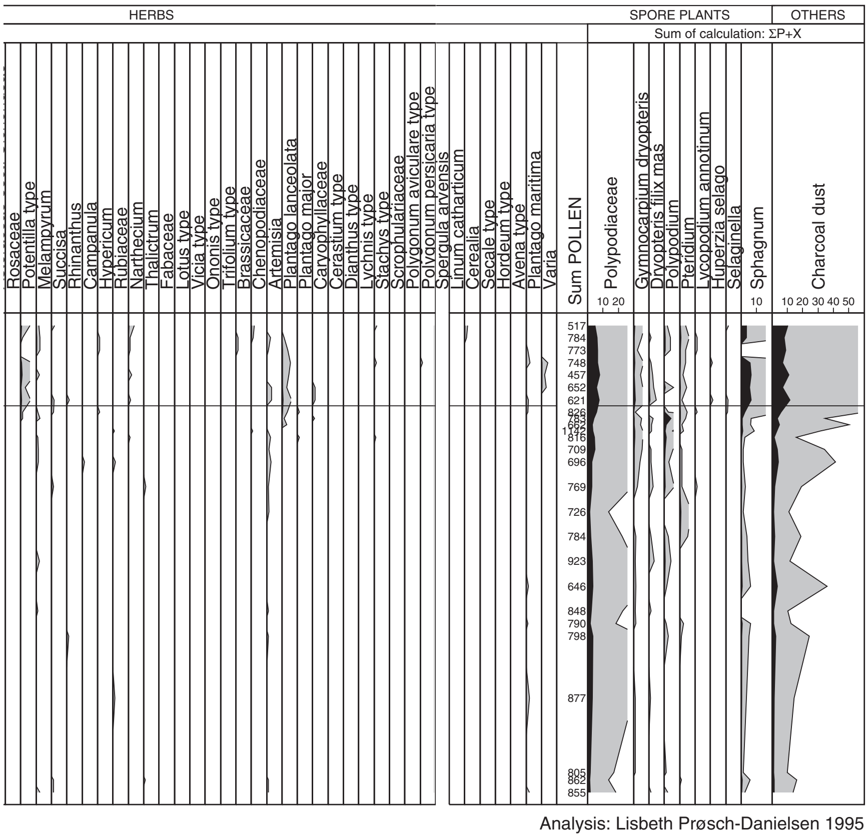


Fig. 63 (left). Percentage pollen diagram from Alvevatn, Klepp municipality, central part of Jæren (Prøsch-Danielsen & Simonsen 2000a, Prøsch-Danielsen & Sandgren 2003).

Fig. 64 (below). Compilation and interpretation of the results achieved by pollen and magnetic analyses for Alvevatn, Klepp municipality, central part of Jæren. Natural and man-made disturbances are given in the column to the right (Prøsch-Danielsen & Sandgren 2003).

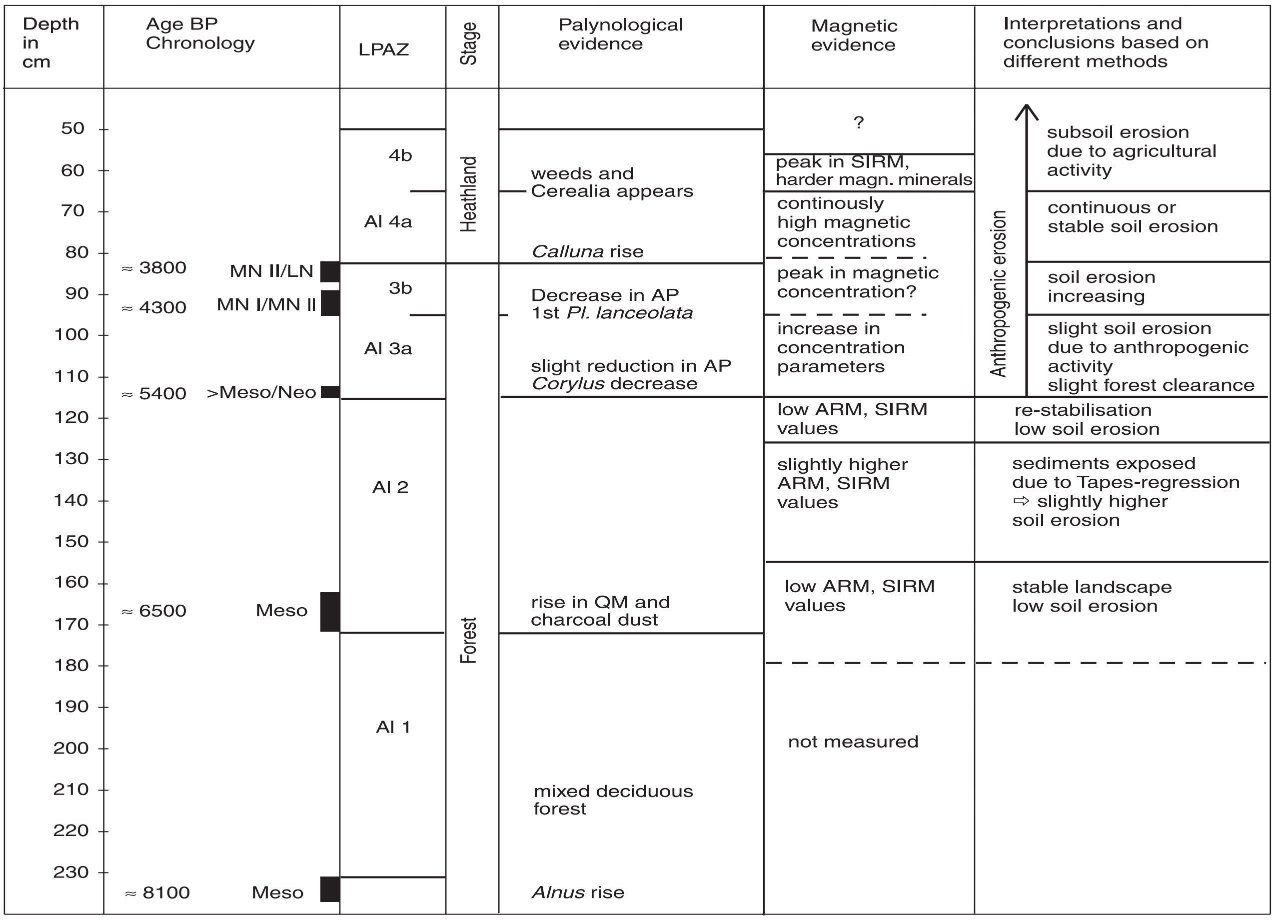


Table 4. Stratigraphical description and colour from Alvevatn according to Troels-Smith's system (1955) and Munsell (1973).

Depth in cm below water level	Physical characteristics	Constituents	Colour	Type
50-91	Lim.s.4, nig.3, strf.0, elas.1, sicc.2	$Ld^{1}2$, Dg1, $Dh^{2}1$, Ag+, Ga+	10YR 3/1	Fine detritus gyttja with sand
91-226	Lim.s.0, nig.3^{-}, strf.0, elas.1, sicc.2	Dg2, $Ld^{1}2$, Th+ (Ag+)	10YR 3/2→ 3/3	Fine detritus gyttja (light or dark stripes, homogenous from app. 1.30 m)
226-249	Lim.s.0, nig.3^{-}, strf.2, elas.1, sicc.3	$Dh^{1}2$, Dg2	2.5YR 3/2	Fine detritus gyttja (sandy from 2.26-2.35 m)
249-252	Lim.s.0, nig.3^{-}, strf.1, elas.2, sicc.2	$Ld^{1}3$, Dg1	10YR 3/3	Fine detritus gyttja
252-265	Lim.s.2, nig.3, strf.1, elas.2, sicc.2	$Dh^{1}2$, Dg2 (Ga+)	10YR 3/2	Fine detritus gyttja. From 259 cm downwards with sand
265-268	Lim.s.1, nig.1, strf.0, elas.0, sicc.2	Ga3, Ag1, Th1	5Y 4/1	Sand

In Fægri's classical work from Jæren (1940) he used the pollen diagram from Alvevatn as a standard diagram that covers all periods back to the Older Dryas/Allerød transition. However, neither Fægri's study nor this "modern investigation" (Prøsch-Danielsen & Sandgren 2003) picked up and dated the oldest sediments in the basin, which obviously could have given a minimum date for the formation of the beach ridge and thus solved the problem with "the Alvevatn level".

The modern pollen diagram (Prøsch-Danielsen & Sandgren 2003) covers a time span from the Mesolithic until recent times. As seen from the pollen diagram, and with relevance to the present study, *Alvevatn has not been transgressed or affected by any other marine events since ca 8145 yr BP. Slight soil erosion is recorded in a time interval between ca 6500 yr BP and ca 5400 yr BP due to the exposure of sediments nearby during the Tapes regression.*

Hølen – Fægri's proof of a double-peaked Tapes transgression

The Tapes beach ridge system (app. 8.7 m a.s.l.) follows approximately 150 m inside and parallel to the coast, stretching from Tangarhaug in the north to Hodne in the south. It is broken by the river Figgjo, separating Selesanden and Boresanden. Hølen is situated approximately 500 m inside the coastline, upstream the estuary of Figgjo (Fig. 58). Fægri (1940) investigated a soil section with an upper level 4.6 m a.s.l. from Hølen. The stratigraphy recorded a gyttja layer sandwiched between a lower marine sand layer and eolian sand on top (Fig. 65). The sand layer was deposited when the sea flooded the "bay" perhaps in Boreal/Early Atlanticum chronozones. The lagoon were later dammed by beach ridges and isolated from the sea. The gyttja layer developed inside the beach ridges. It was analysed for both pollen and

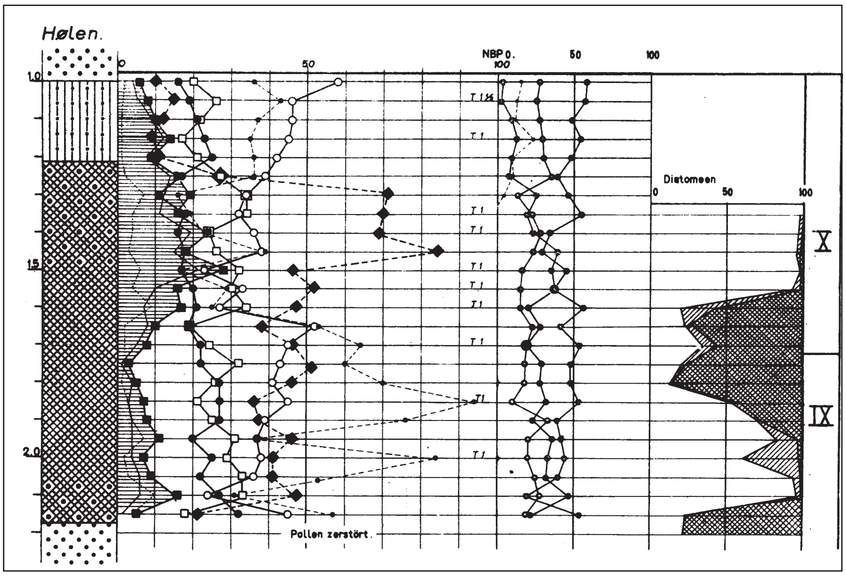


Fig. 65. Due to this pollen diagram from Hølen at Sele, Klepp municipality, central part of Jæren. Fægri postulated that there had been two different peaks (marine phases) during the Tapes transgression (Fægri 1940).

diatoms, and recorded a lower brackish phase and an upper marine phase. *This was according to Fægri (1940) the best proof for a double-peaked Tapes transgression.* Fægri estimated the lower and thus oldest marine event to zone IX (Atlantic biozone), and he estimated the second and youngest event to have taken place in a time interval around the transition IX/X (according to Fægri the Atlanticum/Subboreal biozone transition). The second event took place at the same time as the beach ridges (also described by Fægri 1940) were formed at Bøvannet and Vistnes in the Randaberg peninsula. This rise in mixed oak forest has been dated to 6545±145 yr BP (T-12552A) in a pollen diagram from Alvevatn nearby (Prøsch-Danielsen & Sandgren 2003, see Fig. 63), which put Fægris transition IX/X backwards in time, into the Atlanticum chronozone.

The first marine event, represented by the beach sand reached at least up to 3 m a.s.l. in the area. At Bore, the first marine phase is present as lagoon sand at 3 m a.s.l. The lagoon reached Holeheia but not further inland.

The transgressed site at Lego (I + II)

The Mesolithic site at Lego is situated approximately 4 km upstream from the estuary of Figgjo (Fig. 58). It lies on the southern side of the river outlet from Grudavatn, a shallow lake with present water-surface 2.5 m a.s.l. The Lego site consists of two excavated areas situated, Lego I and II, 15 m apart and separated by a shallow depression in the sandy river plain. The upper part of the find bearing layers varies between 4.5 and 5.5 m a.s.l. Harald Egenes Lund investigated the site in 1937-1938, but the results have never been published. The geological history of the Lego site is well known from the pollen analytical work of Fægri (1940, 1944b).

The stratigraphy was as follows: Both sites revealed distinct cultural layers resting directly on a sandy or gravely layer. At Lego I, superimposed layers were not preserved due to later wave erosion from Grudavatn. The cultural layer at Lego II was covered by a thin layer of marine gyttja, sometimes by a thin layer of marine sand, followed by a thicker formation of diatom rich sediments (Fig. 66). The transition between the cultural layer and the marine gyttja was sharp. The cultural layer has recently been radiocarbon dated applying burnt hazel nutshells to: 7590±120 yr BP (T-7140) Lego I and 7680±150 yr BP (T-7139) Lego II (Bang-Andersen 1995). The artefacts from the two sites are typological homogenous. According to Fægri, the sites were then flooded by the "Second Tapes transgression". The lower marine gyttja layer was dated by pollen analysis to biozone IX (Atlantic) just before the transition between biozone IX and biozone X, e.g. slightly older than 6500-6600 yr BP (according to Prøsch-Danielsen & Simonsen 2000a). This transgression flooded Grudevatn and the Figgjo river valley up to ca 7 m a.s.l. Bang-Andersen (1995) presented a possible alternative interpretation that the thin marine sand layers are the deposits of a tsunami, which effected parts of the West Norwegian coastline approximately 7200 yr BP. Fægri's (1940) alternative however is more likely, as the marine gyttja layer on top of the site will not be built up during a tsunami. Tsunami events are destructive forces. However, this layer has not been radiocarbon dated, so it is not possible to set a fixed time interval for these deposits.

The sea-level during the period of the mesolithic settlement (ca 7600 yr BP) is unknown but can hardly have been more than ca 2 m higher than today. *Only one transgression is recorded.* The transgression maximum was younger than ca 7600 yr BP. Fægri (1940) assumed that this was the "Second Tapes transgression", but this assumtion is not necessarily correct. During this event, the saltwater lagoon covered all of Grudavatn and Skadsvatn.

A raised beach ridge at Nærlandsheimen and Høylandsvatn – two marine phases separated by a brackish water phase

In 1987 a trench was dug through a beach gravel deposits, which is part of the Tapes-beach ridge system stretching from Revtangen in the north southwards to

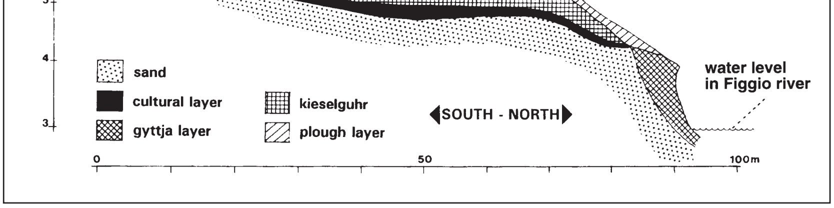


Fig. 66. Partly reconstructed cross-section S-N through the Lego site, Klepp municipality, central part of Jæren, perpendicular to the riverbed. The vertical scale is exaggerated 10 times (Bang-Andersen 1995, simplified after Fægri 1940).

Nærlandsheimen and the Hå River (Thomsen 1987, unpublished notes) (Fig. 1). At this site, the beach ridge system is situated 500 m inside the present coastline at the bay called Saltebukta. This part of the coast is a classical sandy beach coast. Today, the Tapes-beach ridge system can be seen as smooth ridges parallel to the coast. They have dammed up a former lagoon (now Høylandsvatn) formed between the NNE-SSW smooth hills of Høyland in the south and the esker ridges at Nedre Salte in the north during a raising sea-level in Boreal-Early Atlanticum chronozones. The investigated beach gravel deposit is up to 3 m thick. The background for this investigation was the find of an in-situ shell layer of the molluscs *Mytilus edulis*, *Littorina litorella* and *Patella vulgata*, which could give a maximum age of this beach ridge system.

Stratigraphical description and interpretation

The soil section was described by Hanne Thomsen (topographical archive, unpublished notes) and the sedimentologist H.-E. Stølum (the Norwegian Petroleum Directorate). The shells were found in-situ on top of a gravely layer, 6.0 m a.s.l. This gravely layer was approximately 50 cm thick with some cobbles up to 20 cm in diameter. It was found isolated in a sand profile from the channel to Høylandsvatn. It is interpreted as representing a storm deposit. Above the shell layer, a coarse sand layer (quarts particles and shell sand) with mega-ripples was deposited. Mega-ripples are deposited between the upper and lower stream regime. The riffles appear as cosets, which demand a relatively high rate of deposition. On top of this layer is a layer of pure quarts-sand, truncated by an erosion contact and indicating a hiatus. This layer represents either a tidal channel deposit or deposits from storm activities in the upper beach zone. Thomsen and Stølum prefer the first explanation and interpretation since the soil profile is situated close to the inlet. The upper sediments comprise a 2 m thick sand layer.

A bulk sample of shells has been dated to 6750±90 yr BP (T-7424). Stølum suggested that the shells have grown in the littoral zone, with a shoreline maximum 2 m higher than this shell layer. *This implies that the shore-line was 6-8 m above the present shore-line at ca 6750 yr BP which also gives the maximum date for the formation of the beach ridge system in this particular area.* The transgression of the site corresponds to the onset of the lagoon phase, which resulted in the formation of Høylandsvatn.

The former lake Høylandsvatn lay approximately 12 km south of the Figgjo River and 2-3 km north of the Hå River. The height of the lake before draining in 1904 was 3.5 m a.s.l. while its shallow lake bottom was 1.7 m a.s.l. Fægri (1940) described the damming beach ridge west of Høylandsvatn as a "plateau", with a maximum height of 6.5 m a.s.l. South of the lake, he found wave cut erosion marks 6.8 m a.s.l. According to diatom analysis, *Fægri found two marine phases separated by a brackish water phase.* It is also worth to note that when lake Høylandsvatn was drained in 1904, a 30 cm thick compact layer of seawrack was found beneath a 1.5 m sand and gravel layer in a beach ridge sequence ("Havrinden") (Sommerschield 1905). This layer probably represents a stormy episode or another catastrophic event. Unfortunately, this layer has not been dated.

Fægri concluded that the first phase was the highest, but we do not know the reasons for his conclusion. He also placed the end of the first marine phase at the transition between the biozones IX and X, e.g. his transition between Atlanticum and Subboreal chronozones based on the rise in mixed oak forest. Recently this rise in mixed oak forest has been dated to 6545±145 yr BP (T-12552A) in lake Alvevatn, 12 km further to the north (Prøsch-Danielsen & Simonsen 2000a).

Lake Høylandsvatn was dammed by the Tapes beach ridge with a maximum age of ca 6750 yr BP. A younger marine event has also been recorded at this site, but no dating elements are yet present.

The Central-Jæren area (Region B2)

A strictly shore-bound and transgressed site at Hå old vicarage

In 1984 a formerly unknown Mesolithic site of high research potential was discovered accidentally during the machine excavation of a 10x20 m house cellar at Hå old vicarage in Central-Jæren. The site was sealed underneath a two-metre thick beach ridge sequence. This led to archaeological and geological rescue work in the period 1984-1986, with special emphasise on the Mesolithic dwelling site and the beach ridge sequence above (Bang-Andersen & Thomsen 1993, Bang-Andersen 1995). From Hå old vicarage the beach ridge separates into two parts; one can be followed northwards, crossing the Hå River, the other extends westwards to the North Sea.

The site is situated on the southern side at the mouth of the river Hå (Figs. 1 and 67). This area belongs to the southern part of Lågjæren, region B2, characterized by ridges of unconsolidated deposits running parallel to the coast. One of these ridges, at Obrestad lighthouse, situated 1 km south of the site, has been investigated by Janocko (1997). This ridge, formed as a drumlin by the Norwegian Ice Stream "Skagerakmorenen"), has been eroded by marine processes, and appears as a wave erosion cliff today. It extends and dips northwards, with its northern limits at the Hå old vicarage.

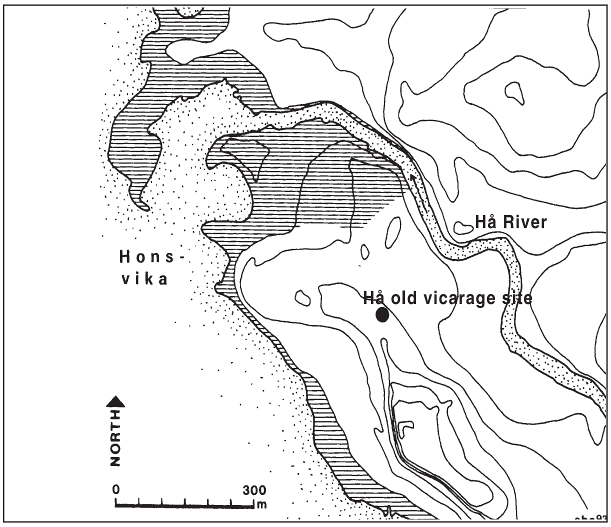


Fig. 67. Map showing the local setting of the Hå old vicarage site, Hå municipality, central part of Jæren. Former sea-level (2.5 m a.s.l.) near the southern Hå river mouth area is indicated by shading. Contour interval 2.5 m (Bang-Andersen 1995).

The excavated beach sequence (Figs. 68, 69a and 69b) was 1.8-2.6 m thick, and the uppermost part was disturbed by modern activities. The beach ridge appears as rather wide, up to 50 m across. The stratigraphy is as follows (from bottom upwards): A till layer (1), a humus horizon with Mesolithic artefacts (2) covered by a layer of beach deposits (3), another humus horizon without artefacts (4) and a second layer or horizon of beach deposits (5) covered by the uppermost humus top layer (6).

Description and interpretation

Layer 1. – Till. The basal layer represents an unsorted, hard packed, sandy till with cobbles up to 10 cm. This layer represents the northern outcrop of the drumlinoid ridge mentioned above.

Layer 2. – Sandy, humus horizon with artefacts. The humus horizon is situated approximately 6.5 m a.s.l. and varies in thickness between 5 cm and 25 cm (mean value 15 cm). The upper boundary is sharp and well defined. Artefacts, hazelnut shells and charcoal are found throughout the layer, and it appears as a continuous cultural layer. When the house cellar was dug, several cubic metres of deposits were removed from the site. Nevertheless, no less than 1900 artefacts were recovered from the remaining soil sections. The majority of artefacts are not water-rolled, while others are slightly water-rolled. Bang-Andersen (1995) thus assumed that the site has been deserted relatively shortly before inundation. The artefact inventory revealed a pure Middle Mesolithic site. This is also confirmed by three radiocarbon dates: 7950±90 yr BP (T-7137), 8140±90 yr BP (T-5972) and 8430±170 yr BP (T-7138). The Mesolithic site was established directly on the till in a time interval (ca 8400-8000 yr BP) when the shoreline was below the 6.6 m contour line (Fig. 70).

The humus layer was also analysed for pollen. The samples contained a pollen assemblage, which characterises shore meadow plants; e.g. Rubiaceae, Caryophyllaceae, *Rumex acetosa*-type (sorrel), *Armeria maritime* (sea thrift), Chenopodiaceae, Brassicaceae, grasses and wedges. Finds of pollen from hazel (*Corylus*), oak (*Quercus*)

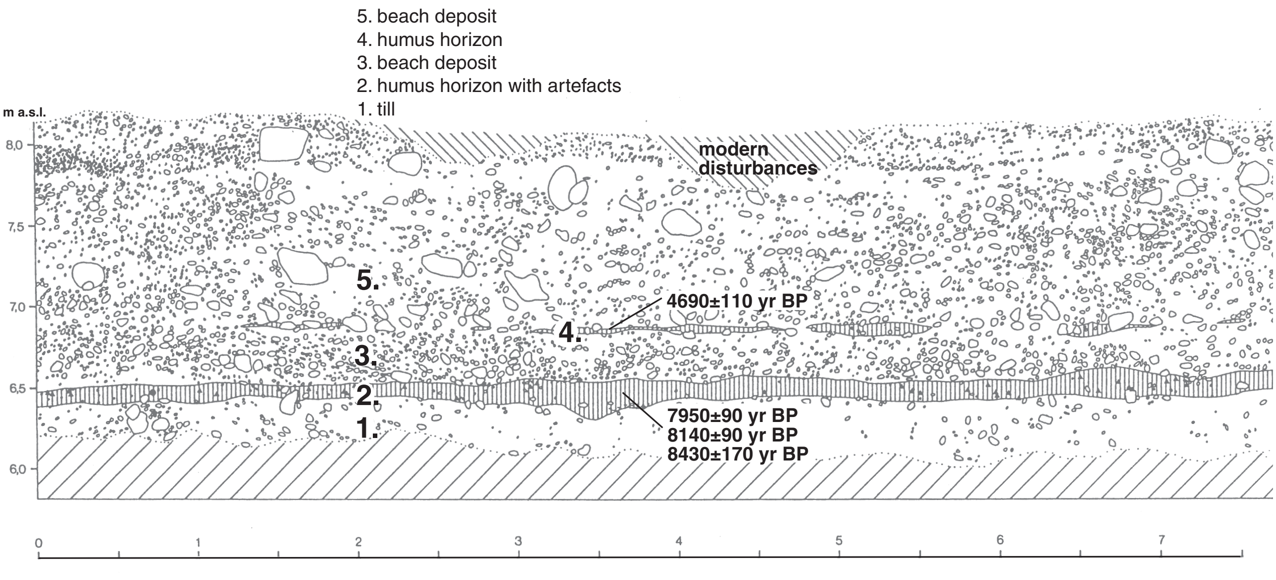
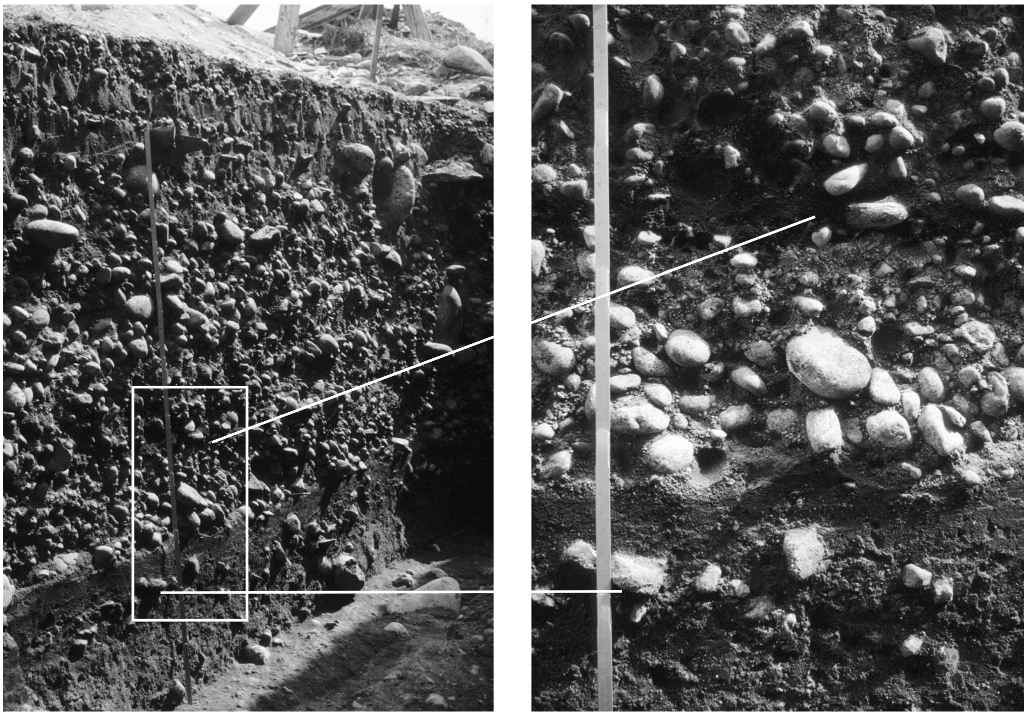


Fig. 68. Vertical soil section along the northeastern part of the transgressed Hå old vicarage site. An incoherent humus layer separates the two beach deposit sequences. A humus layer with exposed flint artefacts (triangles) can be seen in the lower part of the soil section (after Bang-Andersen & Thomsen 1993, Bang-Andersen 1995).



Figs. 69a and 69b. Photos of the beach ridge sequence at the transgressed Hå old vicarage site (photos: Sveinung Bang-Andersen).

and especially alder (*Alnus*) give a maximum age of approximately 8200 yr BP for the pollen assemblage thus confirming the radiocarbon dates.

Layer 3. – Beach deposits. The sharp lower boundary probably represents a hiatus. The beach deposits varies in thickness from 20 to 35 cm. It contains well-rounded cobbles up to 12 cm in diameter in a matrix of sand and pebbles.

The Tapes transgression started ca 9000 yr BP. According to Bang-Andersen & Thomsen (1993) and Bang-Andersen (1995), the site was interrupted and thus abandoned due to a gradual rise in sea-level, which according to them happened soon after ca 8000 yr BP. Then, beach gravel sealed the dwelling-site (6.6 m a.s.l.). This event took place once in the time interval between ca 7950 yr BP to 4690 yr BP (see below).

Layer 4. – Humus layer. Above layer 3, a dark brown sandy humus layer appeared, seen as an incoherent layer, approximately at 6.9 m a.s.l. The layer varies in thickness from 6 to 12 cm, typically 6-7 cm thick. No artefacts or charcoal particles were observed in the layer. Samples were analysed for pollen, and the result again recorded an assemblage of shore meadow species in addition to species associated with warmth demanding mixed oak forest. The humus layer has been radiocarbon dated to 4690±110 yr BP (T-6377A). This layer represents a standstill in the development of the beach ridge sequence, probably deposited during a regression phase.

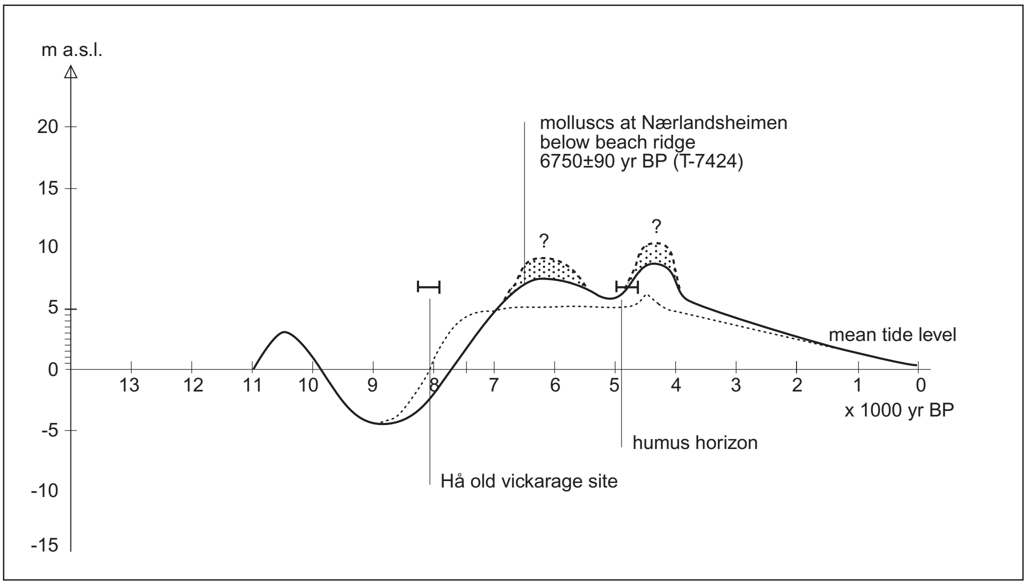


Fig. 70. The sea-level displacement curve for the area near the outlet of the Hå River, central part of Jæren. Stippled line = based on dates and observations by Bang-Andersen & Thomsen (1993), solid line = modified by Prøsch-Danielsen & Bondevik (2003).

Layer 5. – Beach deposits. The uppermost beach sequence is stratified and app. 200 cm thick. Some layers contain 10-15 cm well rounded cobbles in a sorted matrix comprising sand and pebbles. Another layer comprises hard packed rounded pebbles and cobbles 3-6 cm in diameter. These pebbles are disc-shaped and imbricated. After a stagnation, the transgression proceeded. The beach ridge formation exceeded and reached top-level 9-9.5 m a.s.l. This indicates that maximum sea-level in Holocene was reached by the second transgression or marine event sometimes after ca 4690 yr BP. Bang-Andersen & Thomsen (1993) stated that this deposit could have been built up rather rapidly.

Today, beach ridges are formed 3.0 m above mean sea-level in the area. With this in mind, a dwelling site 6.6 m a.s.l. requires at least a sea-level below the 3 m contour line in the time interval 8400-8000 yr BP. The cultural layer gives a maximum age for the formation of the beach ridge above the 6.6 m level and a maximum age for the Tapes transgression in this region.

The sea-level reached at least the 5 m contour line in the time interval between 8000-4700 yr BP. At least the inner part of the beach ridge had a sheltered position that allowed a humus layer to be formed around 4700 yr BP. In a period after 4700 yr BP the beach ridge formation exceeded and a second beach ridge sequence up to 10 m a.s.l. developed. This implies that the sea-level reached at least the 7 m contour line sometimes after 4700 yr BP. Bang-Andersen & Thomsen (1993) presented a sea-level displacement curve for Central-Jæren based on these dates and observations (Fig. 70, dotted line). This curve has been slightly modified by Prøsch-Danielsen & Bondevik (2003) (Fig. 70, solid line).

Shore displacement curve at Brusand based on geomorphological features

Bird & Klemsdal (1986) published a paper dealing with the geomorphology of the coastal zone of Brusand situated in the southernmost part of Jæren (Fig. 1). The authors focused on the barrier and lagoon at Brusand, and discussed the factors involved in their development. In this area where the tidal wave (range 0.2 m) and tidal currents are negligible, the formation of coastal geomorphological features are mostly influenced by the rising sea-level during onshore storms, and by the accompanying storm waves.

Their shore displacement curve for the area is shown in Fig. 71. This curve is based partly on geomorphological features and partly on information in Fægri (1940), Andersen (1960), Sjulsen (1982), Thomsen (1982b), Simonsen (1982) and Simonsen (pers. com.). The authors ascertain that the shore displacement curve is the result of the interaction between the isostatic rebound and eustatic variation in the Late Weichselian and Holocene; the isostatic rebound dominated in the early part while the eustatic rise dominated in the late part after the deglaciation. The oldest sequence, from ca 13,500 yr BP to ca 8000 yr BP, shows shore features varying from +7 m to -5 m. This implies that nearly all littoral forms produced during this time interval were destroyed during the preceding Tapes transgression, and that the surviving littoral forms originate from the Tapes transgression and the following regression phase. Based on field observations and available data they constructed a double peaked Tapes transgression with one peak around 6500 yr BP, while the second one was put around 4000 yr BP. The authors did not radiocarbon date the two marine events. Anyway, *their sea-level curve demonstrates a double peaked Tapes transgression.*

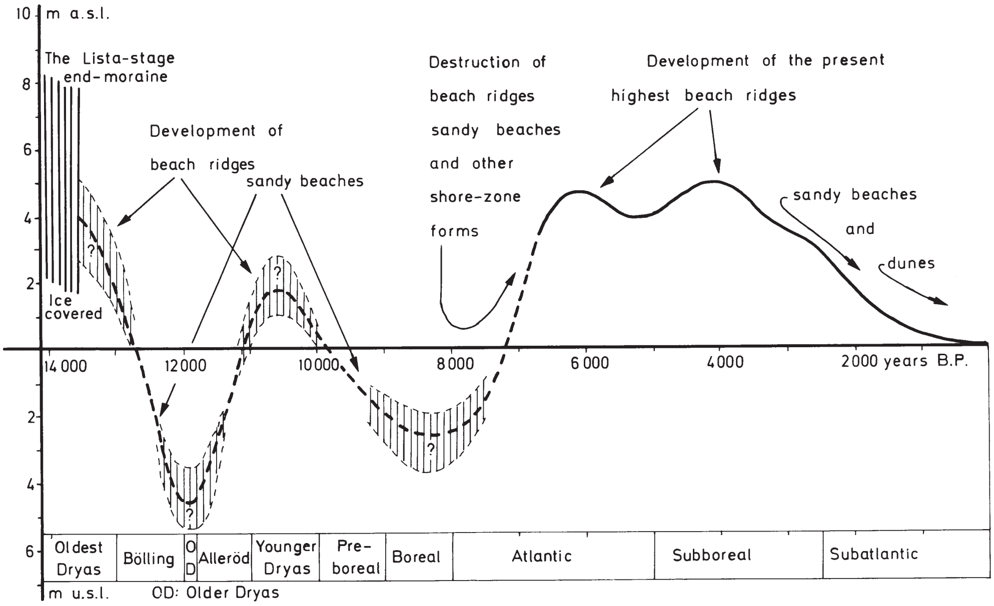


Fig. 71. Probable sea-level displacement curve for the Brusand area, Hå municipality, southern part of the Rogaland county, based on geomorphologic features and data given by Fægri (1940), Andersen (1960), Simonsen (1982, pers. comm.), Sjulsen (1982) and Thomsen (1982b) (from Bird & Klemsdal 1982).

Region C

The island of Eigerøy

Sea-level studies by Asbjørn Simonsen in the period 1970-82 – double peaked Tapes transgression

Between 1970 and 1982 extensive archaeological survey and excavations were carried out in the island of Eigerøy, due to the establishment of industrial enterprises, especially in the area around Gjedlestadvika (Fig. 72). These investigations were supplied by new registrations in 1987 due to additional and forthcoming plans for expansion (Bang-Andersen 1988). Both visible cultural monuments and Stone Age sites were abundant. Stone Age sites covered an area of 15,000 m^2. In addition to the archaeological investigations, studies on the natural vegetation history and the shore-displacement curve were given priority to put the archaeological sites into an environmental context (Simonsen 1972, 1975, 1982, 2005, Simonsen & Lye 1982, Bang-Andersen 1988, Prøsch-Danielsen & Simonsen 2000a).

The constructed sea-level curve (Fig. 73) is based on the stratigraphy in four basins: Gjedlestadvika (5 m a.s.l.), Vodlamyr/tjern (4 m a.s.l.), Podlamyr (2 m a.s.l.) and Gunnarstø (-3 m below present sea-level) (Simonsen 2005).

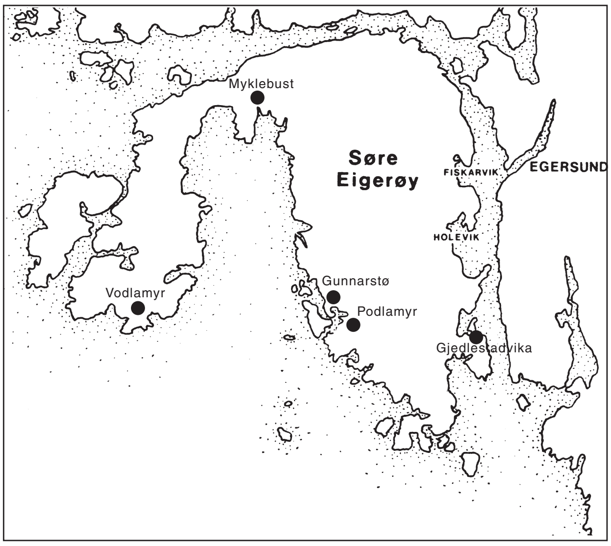


Fig. 72. Map showing the localisation of the investigated localities and basins done by Simonsen in the island of Eigerøy, Eigerøy municipality, southern part of the Rogaland county (modified map from Bang-Andersen 1988).

Gjedlestadvika (5 m a.s.l.)

The sediment sequence has been sampled from a 1 m deep infill basin situated approximately 25 m west of a Stone Age dwelling site (R-21) in the bay Gjedlestadvika. The sediment sequence rested on a gravely basal till. The stratigraphy was as follows (in cm below surface) (Fig. 74):

00 - 30 cm	peat (of grasses and sedges) including two charcoal layers
30 - 50 cm	olive green gyttja
50 - 75 cm	sand
75 - 100 cm	carr peat
100 cm -	gravel

The sediment section has been analysed for palynomophs (Simonsen 1972). The samples from the bottom layer present an in situ alder carr. The vegetation in the vicinity is dominated by pine and broad-leaved species as hazel (*Corylus avellana*) and birch (*Betula pubescens*) with an increasing element of species associated with mixed oak (Quercetum mixtum) forest in the upper part. The upper part of the carr peat has been dated to 5810±160 yr BP (T-1286), a date that also gives a maximum age of the following transgression. Then follows a marine phase as seen from the marine sand and marine gyttja layers. The pollen samples suggest a transition to a densely mixed wooded landscape with dominance of pine (*Pinus sylvestris*) and mixed oak forest, but still with stands of alder (*Alnus* sp.) and hazel (*Corylus avellana*). Forest clearance can be traced in the pollen diagram from the upper part of the marine gyttja. This is recorded as a reduction in pollen of pine (*Pinus sylvestris*) and an increase in NAP (non arboreal pollen).

In the uppermost peat layer, two distinct charcoal layers have been recorded. These layers have been interpreted as representing local forest clearances, in order to create pastures and heath land to feed the cattle and sheep (Simonsen 1972). The impact of husbandry is also verified by a decrease in AP (arboreal pollen) and the presence of pollen

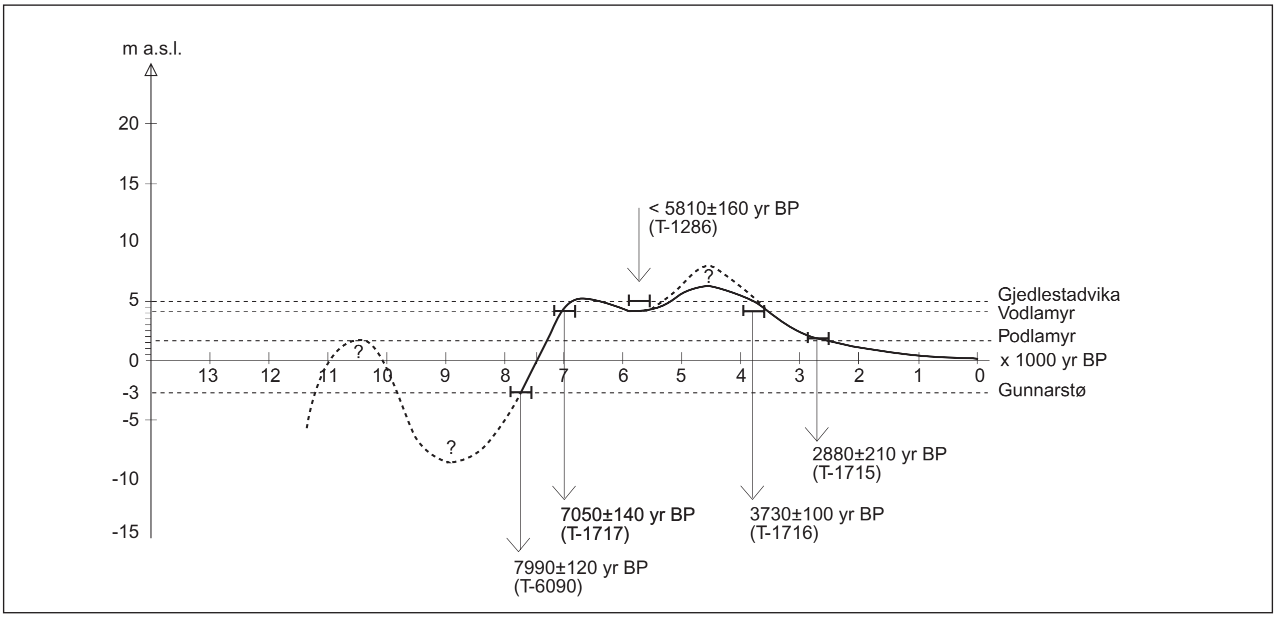


Fig. 73. A constructed sea-level displacement curve for the island Eigerøy, Eigerøy municipality, southern part of the Rogaland county, based on stratigraphical studies, radiocarbon dates and pollen analysis done by Simonsen in a time interval between 1970 and 1974 (based on data from Simonsen 1972, 1975, 1982, 2005, Simonsen & Lye 1982, Bang-Andersen 1988, Prøsch-Danielsen & Simonsen 2000a).

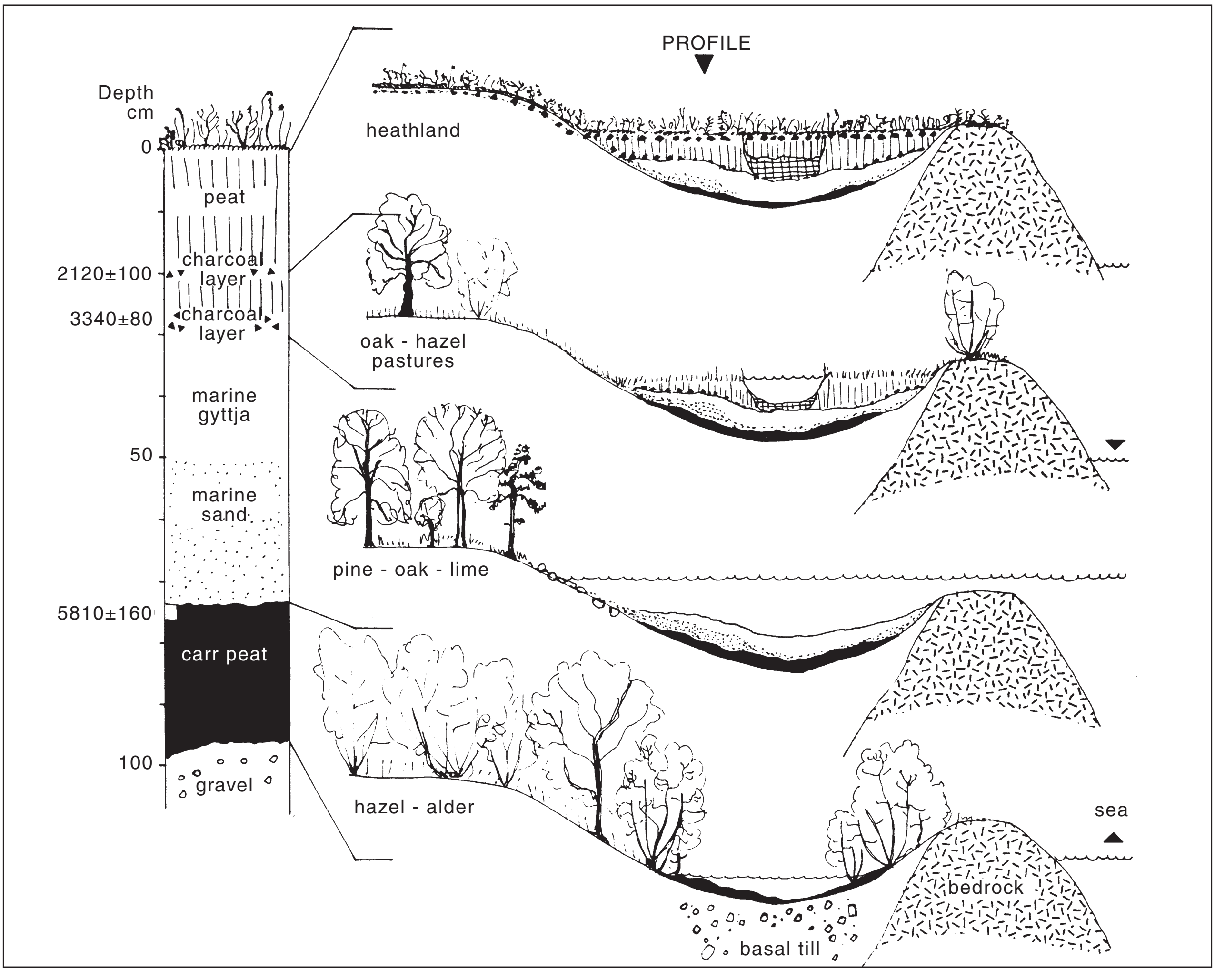


Fig. 74. A simplified reconstruction of the vegetation history and sea-level fluctuation at the locality Gjedlestadvika (5 m a.s.l.), Eigerøy municipality, based on sediment stratigraphy and pollen analysis (Bang-Andersen 1988).

of ribwort plantain (*Plantago lanceolata)* and great plantain *(P. major)* seen in the pollen diagram from the lower charcoal layer and upwards. This layer has been dated to 3340±80 yr BP (T-1167), a date that also gives a minimum age for the final isolation of the basin.

Vodlamyr/tjern (4 m a.s.l.)
The infill basin, Vodlamyr/tjern, is situated at the northwestern tip of the island, Eigerøy. It is situated in a rocky landscape with very little sediment cover except for the drumlinoid ridges (Garnes 1976). The locality is rather exposed, without protecting outer skerries. The stratigraphy was as follows (in cm below surface) (Prøsch-Danielsen & Simonsen 2000a:52):

30 - 50 cm	coarse detritus gyttja
50 - 135 cm	Magno caricetum peat
135 - 180 cm	gyttja
180 - 200 cm	gyttja with twigs
200 - 290 cm	fine detritus gyttja

The sediment section has been checked for palynomorphs. Only fresh water taxa were encountered below 250 cm. Between 250 cm and 100 cm (well into the terrestrial peat deposit) brackish and marine taxa were encountered. The transgression has been dated to 7050±140 yr BP (T-1717) while the isolation must have taken place prior to 3730±100 yr BP (T-1716).

Podlamyr (2 m a.s.l.)
The locality Podlamyr is a small infill basin situated in Løyningsvåg at the southeastern tip of the island. The stratigraphy was as follows (in cm below surface) (Prøsch-Danielsen & Simonsen 2000a:52):

00 - 60 cm	sedge peat
60 - 110 cm	carr peat
110 - 150 cm	coarse detritus gyttja with twigs
150 - 185 cm	sand with twigs
180 - 210 cm	detritus gyttja

The sediment sequence has been checked for palynomorphs. The lower detritus gyttja includes fresh water algae species and a fresh water pollen assemblage e.g. water-milfoil species *(Myriophyllum* sp.) and spiked water-milfoil, *(M. spicatum)*, bur-reed species (*Sparganium* sp.) and bogbean (*Menyanthes trifoliata).* The sand layer from 185 to 150 cm seems to indicate a hiatus, as seen from the abrupt rise in some of the curves for the tree species like pine (*Pinus),* alder *(Alnus)* and oak (*Quercus)* from this layer upwards. Both the sand layer and the coarse detritus gyttja with twigs reveal a marine algae flora and do have a high content of pollen from the brackish specie, tasselweed (*Ruppia)*. The hiatus has not been dated, but the pollen assemblage indicates a warmth demanding flora associated with Late Atlanticum and Subboreal chronozones. A terrestrial carr peat replaces the coarse, marine detritus gyttja, which represents the final isolation of the basin dated to slightly older than 2880±210 yr BP (T-1715).

Gunnarstø (-3m below present sea-level)
In 1980, Simonsen investigated the stratigraphy in a small bay at Gunnarstø near Løyningsvågen (Simonsen 2005). The basin had a submerged threshold 3 m below the present sea-level. At the coring point, sediments were found down to –7 m. The sequence could be divided into a lower marine phase, followed by a lacustrine phase and an upper marine phase. The lacustrine and upper marine phase were separated by a coarse sand layer with twigs and charcoal particles. Two samples have been radiocarbon dated from the fresh water sequence. The oldest sample gives a minimum age for the isolation of the basin; 9720±100 yr BP (T-6088B) and 9520±100 yr BP (T-6088A). The youngest sample also dates the immigration of hazel, 9240±120 yr BP (T-6089). The isolation of the basin is thus older than 9240 yr BP.

One radiocarbon date is available from the bottom of the upper marine gyttja layer. The sample has been collected just above the sand layer and gives a minimum date for the transgression of the basin. This event has been dated to 7990±120 yr BP (T-6090).

The area was deglaciated before 13,500 yr BP. This study is diminished because of the lack of suitable basins extending back to the Late Weichselian and Early Holocene periods. Nevertheless, some conclusions can be drawn dealing with this time interval. The marine limit (ML) in Late Weichselian was probably below the ML found in the Holocene, probably below the present +5 m contour line (Fig. 73). Simonsen (1975, 2005) suggested an Allerød regression to minimum 4 to 5 m below the present sea-level. In the diagram from Gunnarstø, a lacustrine phase was recorded in Allerød, which implies that the sea-level was below the minus 3 m contour line at that time.

The results from Gunnarstø confirm that the sea-level was below minus 3 m in the Preboreal and Boreal chronozones, at least from 9720±100 yr BP to 7990±120 yr BP. A considerable rise in sea-level is suggested for the Boreal and Atlanticum chronozones. The sea flooded Vodlamyr/tjern (4 m a.s.l.) 7050±140 yr BP. This event has not been recorded at the locality Gjedlestadvika (5 m a.s.l.). *Nevertheless, the marine sequence above the carr peat at Gjedlestadvika confirms that two marine events could be separated during the Tapes transgression in the area. It also verifies that the second event was the highest one reaching at*

Table 5. Radiocarbon dates from four basins at Eigerøy (Asbjørn Simonsen 2005).

Lab.no.	Site m above or below sea level.	cm below surface	Material dated	Radiocarbon age (yrs BP)	Dated event
T-1286	Gjedlestadvika + 5 m a.s.l.	73-77	Lacustrine gyttja, carr peat	5810±160	Maximum age transgression
T-1167	Gjedlestadvika	28-30	Charcoal, broadleaved trees	3340±80	Human impact, minimum age regression
T-1285	Gjedlestadvika	20-21	Charcoal, broadleaved trees	2120±100	Human impact, heathland expansion
T-1717	Vodlamyr + 4 m a.s.l.	250-260	Detritus gyttja	7050±140	Start of transgression
T-1716	Vodlamyr	100-110	Magnocaricetum peat	3730±100	Start of deforestation, minimum age of isolation
T-1715	Podlamyr + 2 m a.s.l.	103-108	Coarse detritus gyttja	2880±210	Transition from marine to brackish conditions
T-1714	Podlamyr	52-56	Carr peat	2320±80	Start of deforestation, change from brackish to lacustrine conditions
T-6088A	Gunnarstø - 3 m b.s.l.	630-635	Lacustrine gyttja	9520±100	Isolation, regression in early Preboreal
T-6088B	Gunnarstø	630-635	Lacustrine gyttja	9720±100	Isolation, regression in early Preboreal
T-6089	Gunnarstø	595-600	Algae gyttja, lacustrine	9240±120	Immigration of *Corylus* (hazel), Lacustrine phase
T-6090	Gunnarstø	520-525	Marine gyttja	7990±120	Maximum age of isolation

least 5 m a.s.l. The first marine peak can be dated to a time interval between 7050±140 yr BP and prior to 5810±160 yr BP, probably ca 6500 yr BP, while the second marine peak can be dated to the time interval between 5810±160 yr BP and prior to 3730±100 yr BP.

Hidra in Vest-Agder

In the period 1985 to 1986 a Stone Age site was excavated in Kirkehamn at Hidra (Agder, Flekkefjord Tidende 1986) (Fig. 1). The excavation was made possible due to extension plans for the nearby cemetery. The Stone Age site contained artefacts of Late Mesolithicum-Early Neolithicum age, approximately dated to 6000-5000 yr BP. The artefact-bearing layer was sealed by a marine layer. This information confirms that a second marine event took place around 4800 yr BP. At Hidra however, the thought arose that there had been a local Flood (deluge) (Agder Flekkefjord Tidende 1986).

Region D

The Lista peninsula

During the period 1955-1957 and in 1966, professor Ulf Hafsten studied the sediments in several basins on Lista as part of a comprehensive pollenanalytical study of the southernmost coastal region of Norway. One of his principal objectives was to trace the Late Weichselian and Holocene shore displacement from Lista to Kristiansand (Hafsten pers. comm. in Nydal 1962). Hafsten's Lista localities (Fig. 75) were systematically chosen below or just above the presumed marine limit for the area and analysed for pollen. However, only the results from Høylandsmyr were published (Hafsten 1963). This was probably mainly due to the samples being too small for conventional radiocarbon dating at that time. When datings by accelerator mass spectrometry (AMS) became available, Hafsten decided to complete this work. Unfortunately he died in 1992 before this work was done. In 1993 Prøsch-Danielsen got the opportunity to fulfill Hafsten's work (Prøsch-Danielsen 1996, 1997).

In order to construct a sea-level displacement curve for a limited area, basins are normally studied and ranged according to their hight above present sea-level (Kryzwinski & Stabell 1984). However, it became apparent that this approach would be impossible for the low-lying Listalandet, due to the lack of suitable basins with a bedrock threshold. Continous fluctuations in unconsolidated deposits had obviously caused a shift in the basins thresholds. The study also suffered from the prescens of basins with a threshold below 3.77 m. In order to interpret the set of data, the basins had to be divided into groups dependent on exposure and coastal classification as defined by Klemsdal (1982) (Fig. 76) and height above sea-level (Fig. 77). A selection of seven basins has been litho- and biostratigraphically investigated and AMS dated when necessary. In addition, the results from two basins studied by Høeg (1995) and one by Gabrielsen (in Nydal 1962) have been included in the study of Prøsch-Danielsen (1996, 1997).

Fig. 75. Map showing the Lista peninsula, Farsund municipality in the county of Vest-Agder, with the assumed southernmost position of the ice front during the Lista stage and the Spangereid stage glacial events. Filled circles = pollen diagrams made by Ulf Hafsten (unpublished), published by Prøsch-Danielsen (1997). Filled squares = pollen diagrams made by Helge Irgens Høeg (1995).

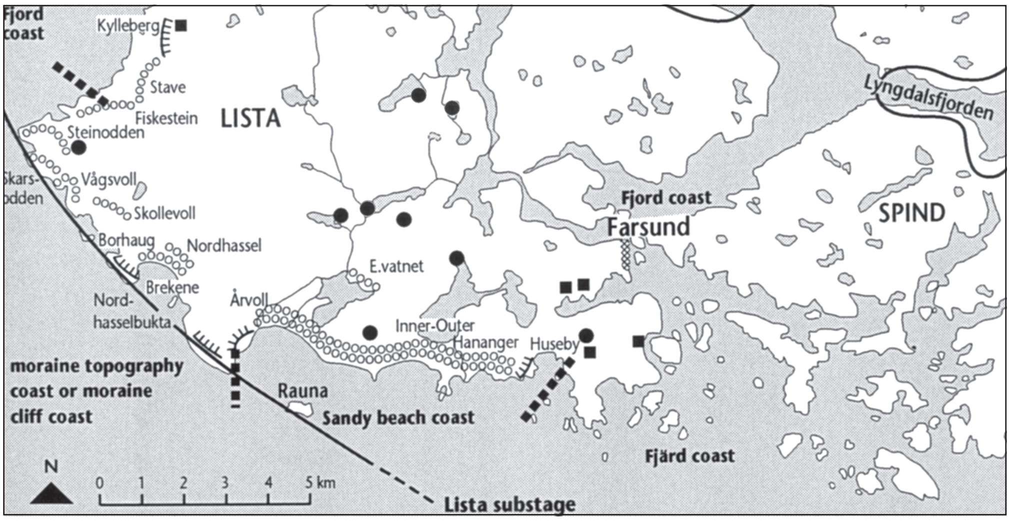


Fig. 76. Map showing the raised littoral forms at Lista, Farsund municipality in the county of Vest-Agder; beach ridges, notches or erosion terraces. Coastal classification is according to Klemsdal (1982) (Prøsch-Danielsen 1997).

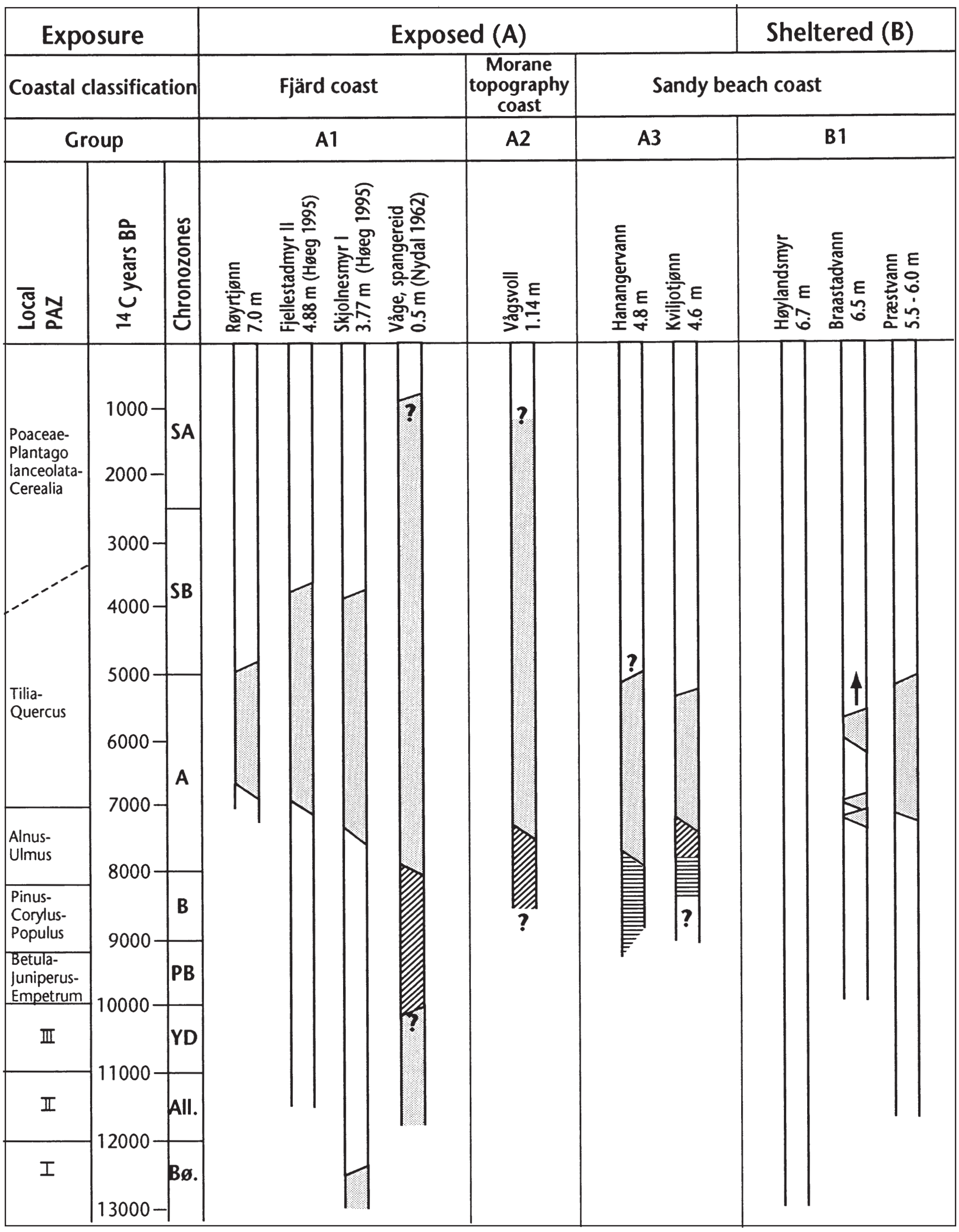


Fig. 77. Environmental changes at different localities on Lista and Spangereid, Vest-Agder county, based on Ulf Hafstens study (unpublished), Høeg (1995) and Gabrielsen (in Nydal 1962). The localities are grouped according to exposure, coastal classification and height above sea level.
White = lacustrine,
grey = marine,
diagonal lines = terrestrial,
horizontal lines = telmatic
(Prøsch-Danielsen 1997).

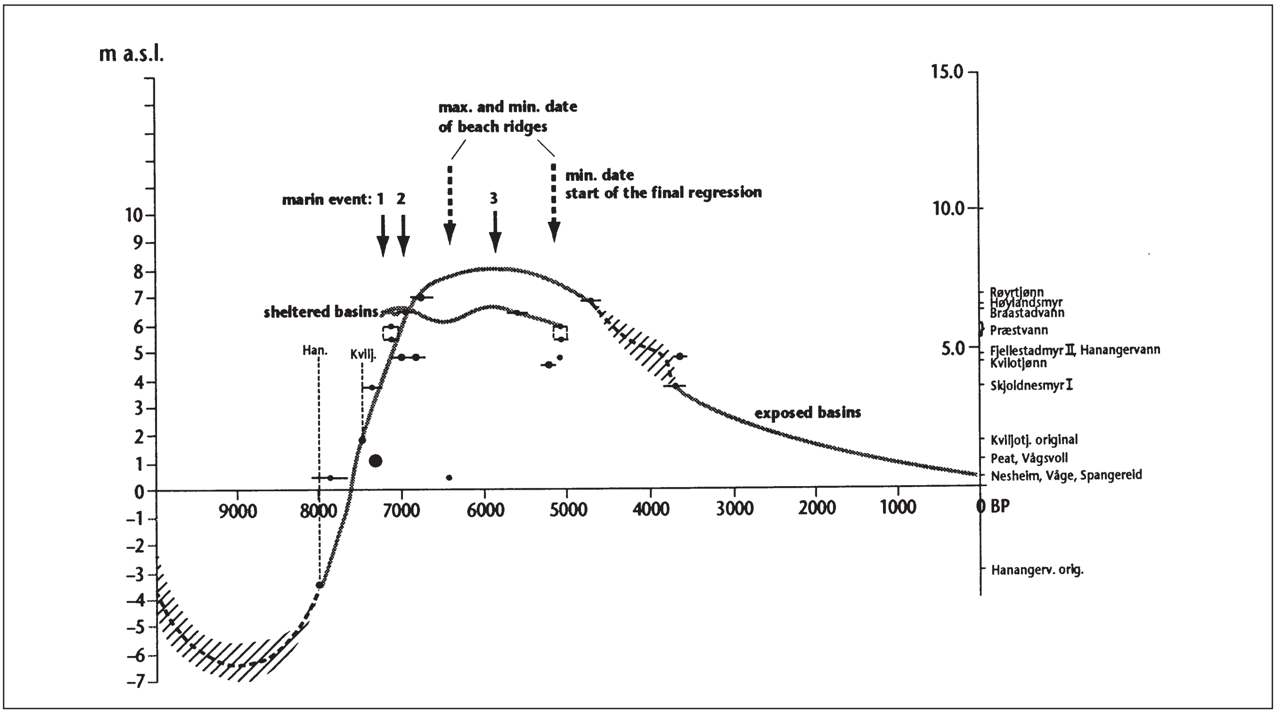


Fig. 78. The Holocene sea-level displacement curve(s) for sheltered and exposed localities at Listalandet, Vest-Agder county, southern part of Norway. Assumed position is hatched. The uncalibrated [14]C-dates from the various localities are shown with one standard deviation (Prøsch-Danielsen 1997).

Very few sediment sequences extend back to the Late Weichselian period. The constructed shore displacement curve(s) is (are) therefore restricted to the Holocene (Fig. 78). Nevertheless, some conclusions can be drawn about the Late Weichselian shore displacement (see Prøsch-Danielsen 1995). The maximum sea-level was situated between 3.77 m and 6.70 m during the Bølling chronozone. The marine limit is probably below the marine limit found in the Holocene (Hafsten 1979, 1983a, 1983b) as virtually none of the raised littoral forms can be directly related to the Late Weichselian period. From the Bølling chronozone until ca 7400 yr BP the sea was below 3.77 m. The Allerød regression minimum and Younger Dryas transgression maximum have not yet been identified, but submarine gyttja and peat found at the Nordhassel bay, situated in the western part of Lista, are thought to be of Late Weichselian or Early Holocene age (Holmboe 1909), most probably belonging to the late Younger Dryas chronozone.

In the Preboreal and Boreal chronozones, the sea-level regressed to at least –5 m, verified by lacustrine and telmatic and terrestrial sediments deposited during these periods in the bottom layers of Hanangervatn and Kviljotjønn (see Fig. 77). In Hanangervatn the telmatic peat layer is found between –5.1 m and –3.4 m (Prøsch-Danielsen 1997). A considerable rise in sea-level started in the last half of the Boreal chronozone and is first recorded from the exposed localities within the sandy beach coast mentioned above (Fig. 77). These sites then became shallow lagoons and later lakes. At Lista two sets of transgression courses are recognized closely related to exposure and coastal classification. Of all exposed localities only one transgression is recognized with a maximum at 6000 yr BP and with a marine limit just above the 7.0 m level. *At a well-protected locality, lake Braastadvann, three marine events are recorded at 7200 yr BP, 7000 yr BP and 6000 yr BP, all between 6.5 m and 6.7 m above present sea-level.* The first marine event in lake Braastadvann is slightly earlier than expected as compared to the basin's height above sea-level (see group A1, Fig. 77). *This first marine event may result from especially high waves generated by the Second Storegga landslide recorded at 7200 yr BP at the coast of Møre (Bondevik et al. 1987a, 1997b) or it may reflect a real transgression phase.* During the third event, beach ridges accumulated, forming a barrier enclosing the lagoons and isolating Præstvann, Hanangervann and Kviljotjønn. A syngression (levelling out) is suggested at ca 4000-3700 yr BP, followed by a slow regression to the present sea-level (Prøsch-Danielsen 1997). This may correspond to the syngression recorded at 4000-3000 yr BP in the Kragerø area (Stabell 1980).

Discussion and conclusions

Southwestern Norway has experienced a complex sea-level displacement. By compiling published and unpublished information it has been possible to form the general pattern and to recognize the local variations in the sea-level displacements along the coastal areas in southwestern Norway from the north towards the south and from the Late Weichselian to the present time (Fig. 79). The general lines already known have been improved and modified (Fig. 7 versus Fig. 79). Three marine events are suggested as short-lived marine events related to sudden changes in relative sea-level: One event in the Boknafjord area ca 9800-9700 yr BP, another marine event approximately 7200 yr BP observed in the Hafrsfjord area and probably at Lista, and a third event ca 4800 yr BP recorded from the Karmøy sound north in the Boknafjord area and further southwards along the coast of Jæren to Eigerøy. The questions are whether these are:

- Tsunami events
- Short lived sea-level fluctuations/transgressions or
- Unusually large storm surges

1. The 9800-9700 yr BP tsunami in the Boknafjord area

In the Boknafjord area four sites (Storavatn, Galta loc.3, Søre-Reianes and Hålandsvannet) indicate that a tsunami might have happened around 9800-9700 yr BP in this area (Fig. 80). At Galta, artefacts showing an Ahrensburgian assemblage dated to between 10200-9800 yr BP are water-rolled and incorporated in 100 cm thick beach deposits. At that time the isostatic uplift was very high and sea-level dropped by as much as 2m/100 years. The problem is to explain how these artefacts could have been incorporated in beach sand and gravel during this period of rapid regression. One possibility is that a tsunami inundated the settlement site, eroded artefacts and washed them into the sea close to the beach. Later the artefacts were captured by beach forming processes during the preceding regression. If this is true, then the run up is at least 3-4 m.

Storavatn shows a gravel bed with clasts of gyttja in marine sediments dated to some time before 9000 yr BP. This may represent a tsunami deposit that could record the same event.

Seismic investigations of the sea floor in Karmsundet and Skudesnesfjorden revealed the occurrence of large slide scars and associated mass-movement deposits in the Karmsundet Basin (Bøe *et al.* 2000). Also new seismic data from the Boknafjord area shows a large submarine slide to have occurred on the sea floor between the islands of Vestre and Austre Bokn and Rennesøy (Prøsch-Danielsen *et al.* 2005, Bøe *et al.* in prep.) (Fig. 80). These slides have not yet been radiocarbon dated, but according to Bøe *et al.* (2000) mass movements were triggered by faulting and/or seismic activity related to the postglacial isostatic rebound prior to and after the Younger Dryas ice re-advance. However, some slide scars in the Karmsundet Basin are related to the early part of Holocene. The volume of these slides – at least 20x10^6 m^3 released during a single event – could have generated a tsunami that inundated the shores around the Boknafjord. However, except for the Storavatn deposits, we have not found positive deposits/facies as described in Bondevik *et al.* (1997a) from this event that conclusively demonstrates that this tsunami really happened. On the other hand, indications and arguments given in this work points in the direction of a tsunami. Further work and especially new fieldwork with transects in basins situated just above mean tide level in the time interval 9800-9700 yr BP is needed to test and verify this idea.

2. The Storegga tsunami, 7350-7250 yr BP, less than 2-3 m run-up

Two sites show possible indications of the Storegga tsunami (Fig. 80); Hålandsvannet and the Stavanger airport Sola site. At Hålandsvannet the deposits are sand layers present in marine fine-gravel sediments, and are not a proof of any run-up above high tide sea-level.

The Storegga tsunami happened during the early part of the Tapes transgression. Any possible tsunami deposit in the area was later inundated by the rising sea during the preceding Tapes transgression and could have been eroded, re-deposited and covered by beach deposits.

A possible Storegga tsunami deposit above the Tapes transgression maximum level has not been observed. For instance, the stratigraphy in Store Stokkavatn situated 11 m a.s.l. (Fig. 1) does not reveal traces of a Storegga tsunami – only lacustrine gyttja have accumulated since Preboreal chronozone. As a conclusion, the Storegga tsunami in this area is probably less than the Tapes maximum level giving a possible run-up of 2-3 m. This is reasonable since the run-up in Bømlo to the north is 3-4 m (Svendsen & Warren 2001) and in Austrheim north of Bergen it is 3-5 m (Bondevik *et al.* 1997a, 1997b).

3. The 4800 yr BP event is not a tsunami but a result of a small sea-level rise – a transgression

Evidence of a 4800 yr BP marine event is mainly recorded from many of the beach ridges from Rennesøy to South-Jæren (Fig. 81). These beach ridges must have been accumulated during a sea-level rise. The arguments for this are:

- The beach ridges rest on humus/soil dated to 5200-4700 yr BP
- The beach ridges contain Early Neolithic (5200/5000-4600 yr BP) artefacts; some are slightly water-rolled and incorporated in the beach gravel.

These deposits have nothing to do with a tsunami for two reasons. 1). tsunamis are known to erode and are not known to build up beach ridges (accumulation instead of erosion) 2). the water-rolled artefacts indicate that some time must have been involved to wear down the edges of the flint tools. The conclusion is that the 4800 yr BP event recorded in Rogaland is a real transgression and that it does not reflect the same marine event as recorded by the tsunami deposits dated to 4800 yr BP by Bondevik (2002) on Shetland.

4. The 4800 yr BP transgression – increasing towards south

After compiling all observations concerning the 4800 yr BP event, from archaeological sites, beach ridges, basins and soil profiles, a pattern is recorded in the data (Fig. 81). On Rennesøy the 4800 yr BP beach ridges are found 3-4 m lower than the beach ridges formed during the first peak in the Tapes transgression ca 6500 yr BP. This second transgression levels out northwards, with a northern limit in the Karmøy sound and the Tysvær area. However, southwards towards Jæren, the 4800 yr BP transgression has formed beach ridges with an upper limit higher than the first peak in the Tapes transgression ca 6500 yr BP. These two peaks probably intersect in a zone along the coast of the Randaberg peninsula. By mapping raised beach ridges in the Randaberg area, Fægri (1940), also found two sets of ridges both lying 11-12 m a.s.l. which he put to "the Tapes level". He therefore postulated that there had been two peaks during the Tapes transgression, but as he said "*it is too complicated to separate them and put them into a rigid system*" in this particular area. Further south, in the Central part of Jæren, at the localities Hølen and Høylandsvatn, he also found evidences of a double-peaked transgression. This is later verified by sediment studies in Gjedlestadvika (Simonsen 2005). It has also been recorded at Lista in Vest-Agder, on the extreme southern coast of Norway (Prøsch-Danielsen 1996, 1997), though slightly earlier.

There is a west-east gradient. Two separate beach gravel deposits representing the Tapes transgression are encountered both in Tysvær and along Gandsfjorden. However, on Austbø in the middle fjord district (Fig. 81, open stars) there are sites and man-made structures dated to 5430±100 yr BP that are found on top of the Tapes beach ridges and gravel deposits (Juhl 2001). These artefacts, dated to the Early Neolithic, are not covered or incorporated in younger beach deposits. The 4800 yr BP event is present along the outer coast and levels out eastwards in the middle fjord district.

At present we do not have an elaborate theory to explain this event. This is the only known area in Norway where this event is present. The most likely cause is that this is related to an intricate balance between isostacy and eustasy after the deglaciation. The event is most distinct on the outer coast and southwards at the central part of Jæren. This area is postponed to low isostatic uplift where the 4800 yr BP beach ridge marks the marine limit. Any changes in eustatic sea-level will thus more easily be recorded in this area.

The revised shore displacement curves for Rogaland are given in Fig. 79.

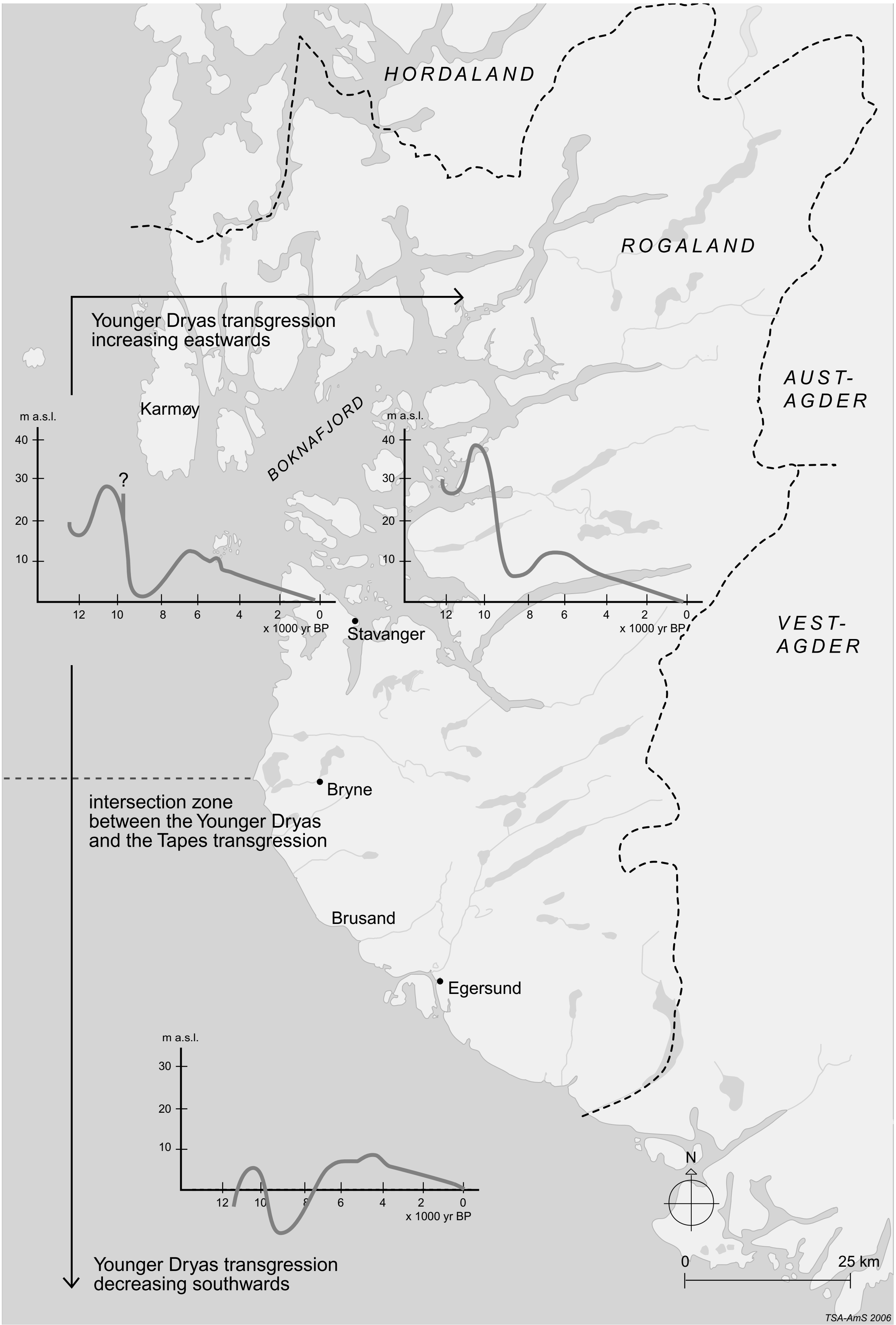


Fig. 79. Map showing the new E-W and N-S variations in the sea-level displacement curves for Rogaland, southwestern Norway (compared to Fig. 7).

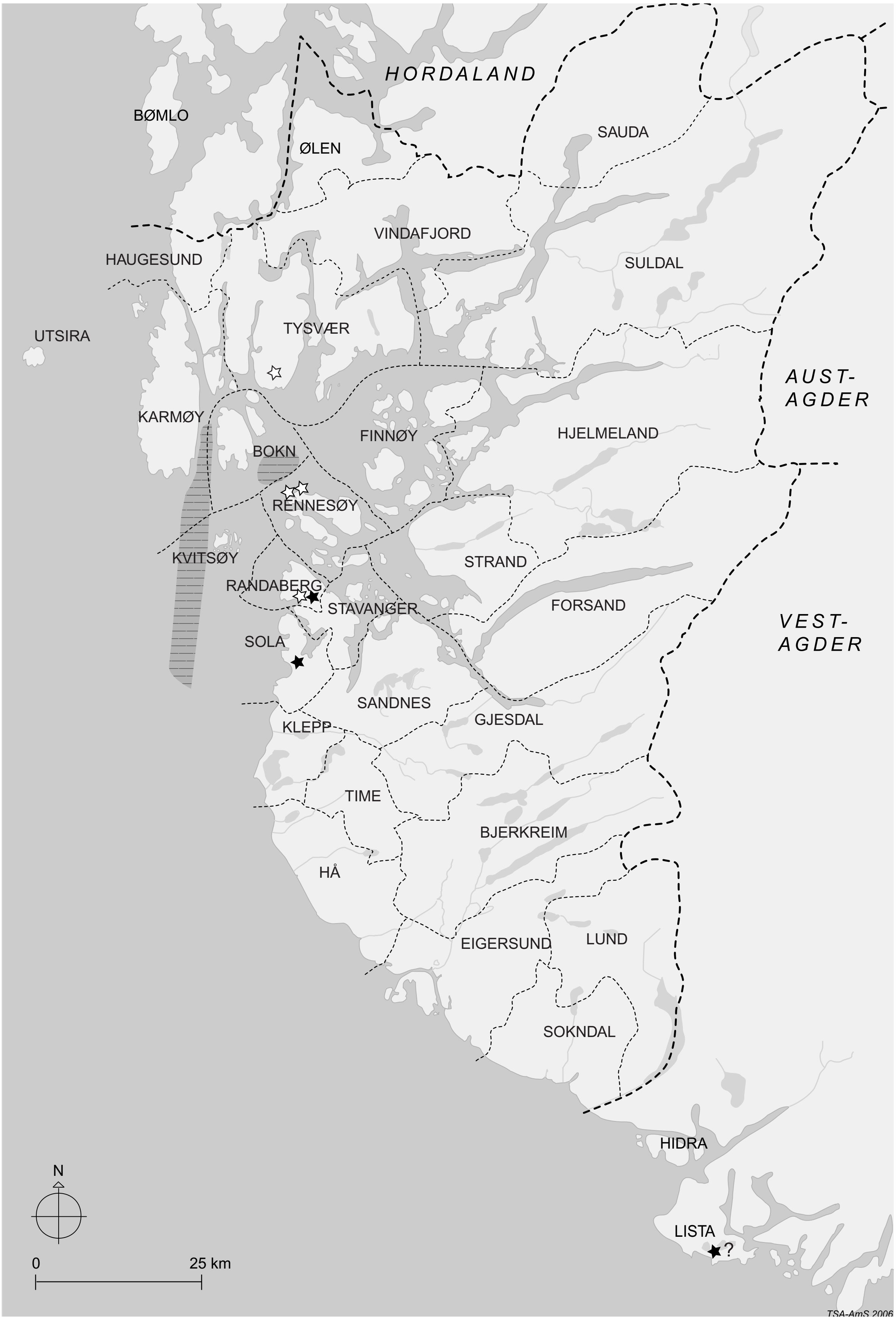


Fig. 80. Sites with positive evidences for a local tsunami 9800-9700 yr BP (white stars) and of the Storegga tsunami 7350-7250 yr BP (black stars) in southwestern Norway. The Karmsundet Basin with slide-scars and the Boknafjord slide scar with associated mass-movements deposits are hatched.

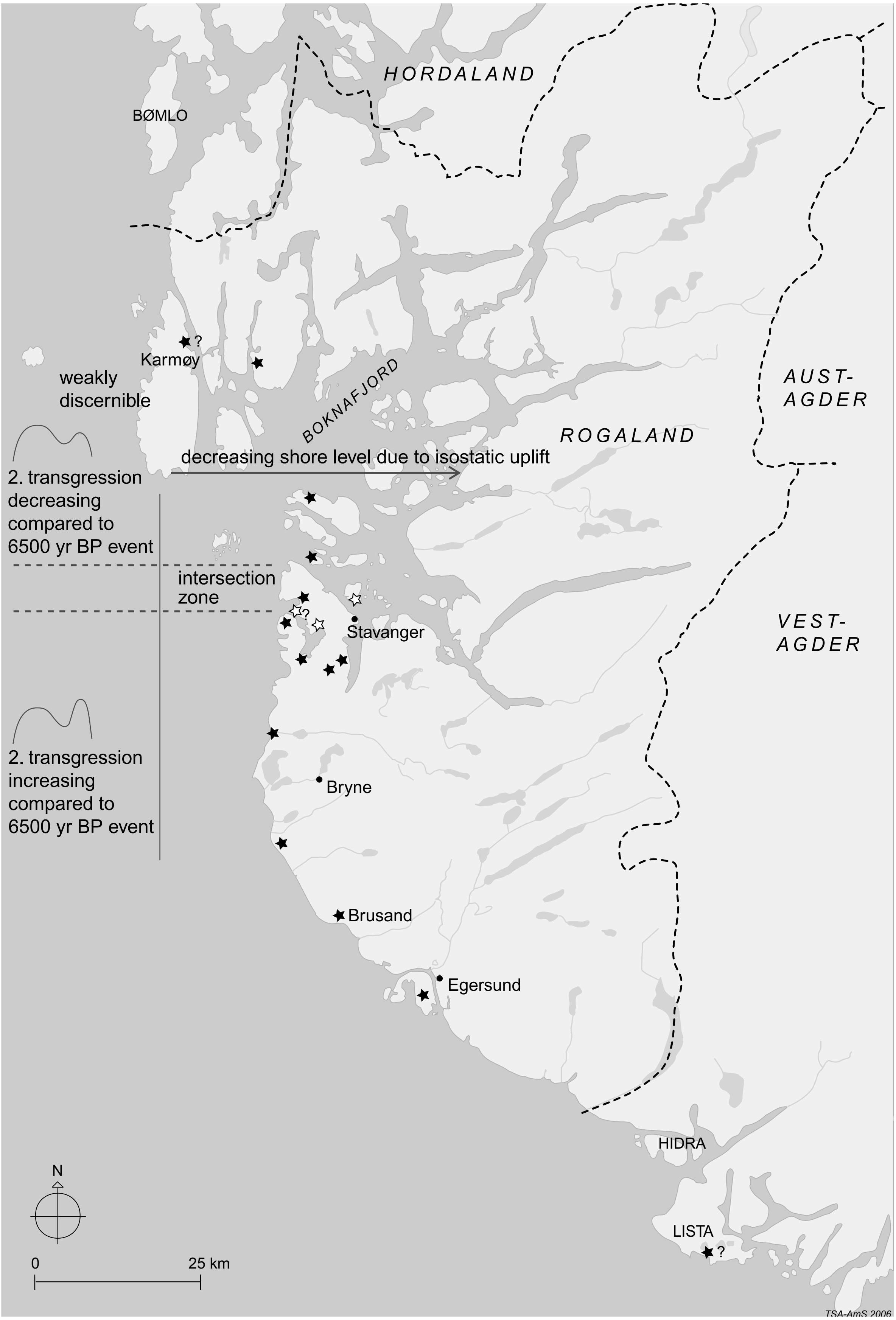


Fig. 81. Sites with positive evidence for a double-peaked Tapes transgression (filled stars) in southwestern Norway. Other sites with relevance to this topic (white stars).

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