

# Holocene shore displacement at Nappstraumen, Lofoten, North Norway

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Studies of raised shore features and  $^{14}\text{C}$  datings at Nappstraumen suggest two transgression phases in the Holocene, represented by the 9 m shoreline from the mid-Atlantic (6500–6000 YBP) and the 6 m shoreline from the early Subboreal (c. 4500 YBP). The total rise in the shore level from the mid-Boreal to the mid-Atlantic has probably been at least 12–13 m.

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This article presents and discusses new data concerning the Holocene shore displacement at Nappstraumen, the sound between the islands of Flakstadøy and Vestvågøy in Lofoten (Fig. 1).  $^{14}\text{C}$  datings of shells, submarine peat layers and pre-historic cave dwellings are compared and discussed in relation to raised shore features in the area.

The bedrock at Nappstraumen is Precambrian gneiss. The lowland areas of Vestvågøy are a typical strandflat covered by sediments, especially in the area below the marine limit. On Flakstadøy the terrain is steep and mostly with exposed bedrock. The Nappstraumen area was ice-free during the Late Weichsel, probably from around 17–16,000 YBP (Møller 1982).

Earlier relevant studies of raised shore features in Lofoten include Grønlie (1940, 1951), Møller & Sollid (1972), Bergstrøm (1973) and Møller (1982). Utne (1973) excavated the Storbåthallaren (Fig. 1 C) and  $^{14}\text{C}$  dated a pre-historic cave dwelling 7–8 m above the present shore level, which is thus of special interest for this study. A shore displacement curve drawn by Marthinussen (1962) for Ramså on Andøya (one of the islands of Vesterålen) is also of special interest for closer comparison and discussion of the data from Nappstraumen (Fig. 1 B).

## Raised shore features

Distinct raised shore features are registered in several localities in the area around Nappstraumen (Fig. 1 C, Table 1). The highest marks made by the sea in post-glacial time – *the marine limit* – vary a great deal in height from north to south.

In the north, beach ridges lie 12 m above mean tide level (m.t.l.) and represent the marine limit (Kollvika, loc. 2). In Petvika (loc. 8) and Sennesvika (loc. 9) in the south, the marine limits at terraces are 20 m and 23 m above m.t.l., respectively.

Features used to determine marine limit and lower shorelines in this study were tops of beach ridges and the inner breaks of slope on terraces. According to Møller & Sollid (1972), these shore features in Lofoten and Vesterålen at present lie  $2.5 \pm 1.3$  m and  $1.8 \pm 0.4$  m above m.t.l., respectively. Local conditions such as exposure, prevailing wind direction, fetch, offshore gradient, tidal range and parent materials influence the height variation of these shore features. Thus, adjustments (reductions) have to be made to make the raised shore features comparable (Table 1). Local mean tide level (m.t.l.) was used as base level for the height measurements.

At Nappstraumen, distinct beach ridges and terraces, lower than marine limit, are registered at two heights, 12 m and 7 m above m.t.l. which, when correlated to mean tide level, form the 9 m and 6 m shoreline (Table 1). The shore features at the 9 m level are, in most places, the most prominent in this area, and correspond to a distinct shoreline (Tapes) with a gradient of 0.14 m/km in Lofoten and Vesterålen (Møller 1982, p. 22, Fig. 9).

## Radiocarbon dates

Several  $^{14}\text{C}$  datings from the area around Nappstraumen can be correlated and discussed in connection with the 9 m and the 6 m shoreline (Table 2).

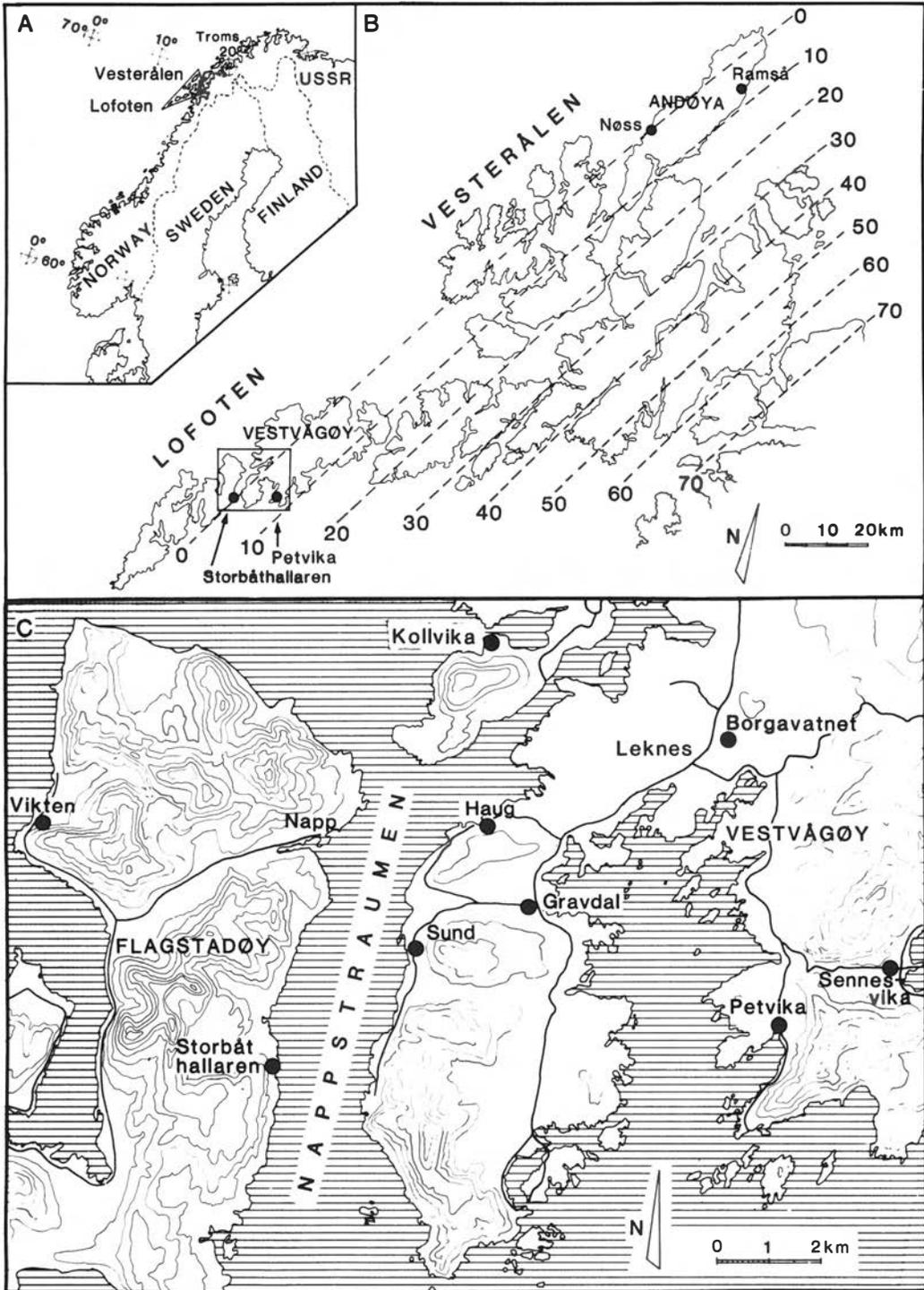
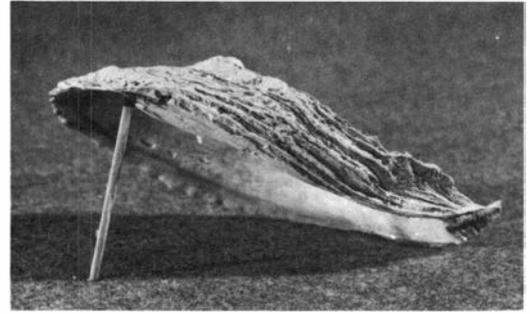


Fig. 1. A: Map showing the location of Lofoten and Vesterålen. B: Isobases of the Main shoreline in Lofoten and Vesterålen after Møller (1982). C: The investigated area at Nappstraumen.

Table 1. Heights of shore features at Nappstraumen, Lofoten.

Loc. No.	Locality Name	UTM Ref.	Type of feature	Levelling point	Marine limit	Height above m.t.l. (in m)	Adjusted height to m.t.l. (in m)
1	Vikten	298592	Terrace	Break of slop		10	8
2	Kollivika	384625	Ridge	Top	x	12	9
	Kollivika	383625	Terrace	Break of slop		7	6
3	Borgavatnet	433607	Terrace	Break of slop		9	9
4	Haug	381589	Terrace	Break of slop	x	15	12
5	Gravdal	391575	Terrace	Break of slop	x	16	15
	Gravdal	393574	Ridge	Top		11	9
	Gravdal	395575	Terrace	Break of slop		7	6
6	Sund	369568	Terrace	Break of slop	x	16	13
7	Storbåthallaren	342545	Terrace	Break of slop		7	6
8	Petvika	439556	Terrace	Break of slop	x	20	19
	Petvika	441550	Ridge	Top		12	9
	Petvika	441549	Terrace	Break of slop		7	6
9	Sennevik	460560	Terrace	Break of slop	x	23	21
	Sennevik	463560	Ridge	Top		12	9
	Sennevik	464560	Terrace	Break of slop		7	6

Fig. 2. *Ostrea edulis* found in Borgavatnet, Vestvågøy (68°7'N, 13°38'E).

*Borgavatnet* (Fig. 1 C), which is just outside Leknes, was drained and emptied through a tunnel in 1975. Shells of *Ostrea edulis* (Fig. 2) were found (Ringstad) in the sand and gravel about 6 m above m.t.l. and  $^{14}\text{C}$  dated to  $5980 \pm 100$  YBP (T-4195). Before it was drained, *Borgavatn's* surface was 8 m above m.t.l. and was thus a salt-water lagoon at the time of the 9 m shoreline.

*Petvika*, 6 km south of Leknes (Fig. 1 C), has a long, shallow bay towards the south west in which layers of peat and humus have been found from 2 m below to 5 m above m.t.l. (Moe 1975). Remains of *Betula pubescens* were found among other organic material covered by littoral sand and gravel, which indicates a transgression. In 1982 the submarine peat layers were studied more closely by the author. A sample from the bottom of the peat layer, 2 m below m.t.l., was dated to  $8350 \pm 60$  YBP (T-4732 a). A sample of birchwood was taken from the top of the layer, 1 m below m.t.l. and dated to  $8040 \pm 180$  YBP (T-4731).

Pre-historic dwellings at *Storbåthallaren*, 5 km south of the ferry quay at Napp on Flakstadøy (Fig. 1 C) have been studied in detail by Utne (1973). The cave has an overhang 70 m long and 5–20 m deep and is about 9 m high along the outer edge. In front is a beach terrace about 7 m above m.t.l. Eight samples of shell and charcoal were taken from a cultural horizon 7–8 m above m.t.l., and the  $^{14}\text{C}$  datings (Table 2) indicate two periods of human use, the first from  $5250 \pm 80$  YBP to  $4740 \pm 140$  YBP and the second from  $2460 \pm 70$  YBP to  $2060 \pm 80$  YBP. One dating of  $4000 \pm 800$  YBP is considered unreliable by Utne (1973, p. 70).

## Holocene shore displacement

Storbåthallaren and Petvika near Nappstraumen are geographically on the same Main shoreline isobases (Fig. 1 B) as Nøss and Ramså in Vesterålen, where Marthinussen (1962) for the last locality has drawn a preliminary shoreline displacement curve. These two areas have thus probably undergone the same, or nearly the same, shore displacement during the Holocene. In Fig. 3, the  $^{14}\text{C}$  datings and the heights of the two distinct shorelines at Nappstraumen are compared with Marthinussen's (1962) Ramså curve. The main features of the Holocene shore displacement at Ramså is a regression sequence in the Preboreal and early Boreal, a transgression sequence in the Atlantic and the early Subboreal, and finally a regression sequence in the late Subboreal and the Subatlantic. The transgression sequence is divided into four Tapes transgression maxima:

Table 2. Radiocarbon datings of items found at various heights in Lofoten and Vesterålen.

Locality	Height below/above m.t.l. (in m)	Lab.No	Material	$^{14}\text{C}$ -age	Source
Petvika (2)	-2	T-4732A	Gyttja	$8350^{+60}$	This study
Petvika (1)	-1	T-4731	<i>Betula sp.</i>	$8040^{+180}$	*
Ramså, Andøya	9	T-4730	<i>Pinus sp.</i>	$6530^{+100}$	*
Borgavatnet	6 (8)	T-4195	<i>Ostrea edulis</i>	$5980^{+100}$	*
Storbåthallaren	7,5	T-1014	Charcoal	$5250^{+80}$	Utne (1973)
"	7,4	T-1018	Shell	$5080^{+90}$	*
"	7,6	T-1017	"	$4910^{+80}$	*
"	7,7	T-1198	Charcoal	$4740^{+140}$	*
"	7,3	T-1199	"	$4000^{+800}$	*
"	7,5	T-1016	"	$2460^{+70}$	*
"	7,7	T-1013	"	$2330^{+100}$	*
"	7,8	T-1200	"	$2060^{+80}$	*
Nøss, Andøya	7,4	T-266	<i>Picea sp.</i>	$4500^{+150}$	Marthinussen (1962)

T1–6600 YBP, T2–6230 YBP, T3–5500 YBP and T4–4500 YBP, the last of which had the highest relative shore level of about 8 m above m.t.l. (Fig. 3).

### *Regression minimum*

The submarine peat layer in Petvika, where the base at 2 m below today's m.t.l. is dated to  $8350 \pm 60$  YBP (T–4732 a), indicates that the mean tide level at that time must have been at least 3–4 m below today's m.t.l. This corresponds well in height and time with the supposed regression minimum in the Ramså curve, and studies from south-western Norway (Hafsten 1983). The dating  $8040 \pm 180$  YBP (T–4731) of the *Betula* sp. found in the top of the peat layer 1 m below today's m.t.l. indicates that the sea must have transgressed this level some time after 8000 YBP. This is also in agreement with the Ramså curve (Marthinussen 1962).

### *Transgression maximum*

The dating of *Ostrea edulis* at  $5980 \pm 100$  YBP (T–4195) from Borgavatnet, which in height is near the 9 m shoreline, does not fit the Ramså curve where the corresponding shoreline, T4, is dated to about 4500 YBP (Fig. 3). A recent dating (Møller unpubl.) of  $6530 \pm 100$  YBP (T–4730) of a piece of pine found on the 9 m shoreline at Ramså even indicates a greater age. These two datings from the mid-Atlantic indicate a total rise in the shore level of at least 12–13 m since mid-Boreal time. The highest shore level, the Tapes (*Littorina*) transgression maximum, seems to have occurred in the Nappstraumen area and in Vesterålen 1500–2000 years earlier than suggested by Marthinussen (1962). This interpretation corresponds with recent studies in south-western Norway (Stabell 1982, Hafsten 1983).

### *Early Subboreal transgression?*

The datings from Storbåthallaren (Utne 1973) do not fit the Ramså curve either (Fig. 3). The cave, which is about 8 m above m.t.l., has been used by humans from  $5250 \pm 80$  to  $4740 \pm 140$  YBP. The mean tide level in this period can thus have been at most 5–6 m above today's m.t.l. Marthinussen (1962) indicated a shoreline height for this period of 6–8 m above m.t.l. at Ramså which by comparison seems too high.

The use of Storbåthallaren ceased about

$4740 \pm 140$  YBP but started again about  $2460 \pm 70$  YBP. Is it possible that a transgression in the early Subboreal time made the cave uninhabitable? Several facts suggest this. Utne (1973, p. 67) wrote that during excavation a layer of pebbles containing limpet shells was found in the innermost part of the cave. This could mean that the cave was flooded after the first habitation. In a study of the vegetation succession of a bog near Petvika, Moe (1975) showed that there was a short period with birch wood ending at about  $4710 \pm 110$  YBP. The birch wood layer which was found covered by marine sand and gravel in Petvika therefore probably indicates a transgression after 4700 YBP (Moe 1975). Marthinussen's (1962)  $^{14}\text{C}$  dating of driftwood (*Picea*) at  $4500 \pm 150$  (T–266), supports this suggestion. The driftwood was found at Nøss on Andøya (Fig. 1 B) at an altitude of 7.4 m behind a beach ridge with the top nearly 9 m above today's shore level. The beaches at Nøss have a relatively high energy exposure (Møller 1982) towards ocean waves, so that a correlation factor (reduction) of at least 3 m to m.t.l. seems reasonable, and the height could therefore correlate fairly well with the 6 m shoreline. With reference to these facts, it is likely that there could have been a small transgression phase which formed the 6 m shoreline in Lofoten and Vesterålen in the early Subboreal time at about 4500 YBP.

A complete whale skeleton found on Sommarøy in outer Troms (Møller unpubl.) has been  $^{14}\text{C}$  dated to  $3870 \pm 90$  YBP (T–4196). The locality lies on the 25 m Main shoreline isobase (Andersen 1968), and at 8 m above m.t.l. Transferring this height and dating to Ramså, using the isobase system and equidistant shoreline diagram for Lofoten and Vesterålen (Møller 1982), shows that it corresponds fairly well with the Ramså shoreline displacement curve (Fig. 3).

Marthinussen's (1962) reconstruction and theory of four Tapes transgression phases in the Holocene does not correspond with the present evidence from Lofoten – Vesterålen, where two transgression phases are identified. Also, Marthinussen's (1960) shoreline sequence indicated that younger Tapes shorelines transgressed older Tapes shorelines in the outer coastal areas, whereas the inverse relationship holds for the inner fjord areas. This does not fit the regional correlation of the raised shore features in Lofoten and Vesterålen (Møller 1982), nor the present  $^{14}\text{C}$  datings from Lofoten – Vesterålen which indicate that the oldest Tapes transgres-

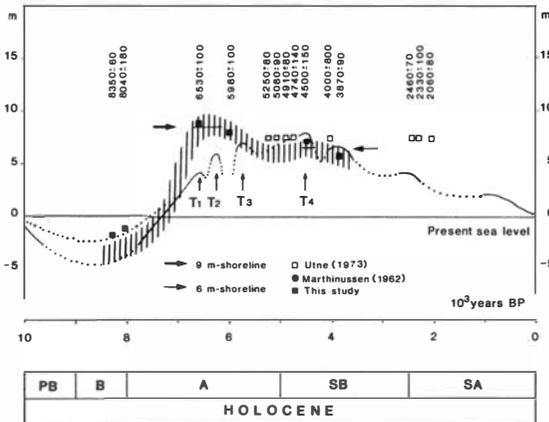


Fig. 3. <sup>14</sup>C datings and their heights related to the 9 m shoreline and the 6 m shoreline in the Nappstraumen area. The constructed shore displacement zone is compared with Marthinussen's (1962) preliminary Ramså curve which indicates four Tapes transgression maxima (T1-T4). PB-SA refer to chronostratigraphic subdivisions of the Holocene according to Mangerud et al. (1974).

sion was highest and formed a continuous isochrone shoreline both in inner and outer areas.

### Conclusions

Two distinct raised shorelines, the 9 m shoreline and the 6 m shoreline, are registered in the area at Nappstraumen in Lofoten. <sup>14</sup>C datings of shells, driftwood, submarine peat layers and pre-historic cave dwellings seem to indicate that these shorelines probably represent two Holocene transgression phases. The highest shoreline was probably formed in the mid-Atlantic time, 6500-6000 YBP, after a total rise in the shore level since mid-Boreal time of at least 12-13 m. The lowest shoreline was probably formed during a small transgression phase in early Subboreal time, about 4500 YBP.

If the <sup>14</sup>C datings and the interpretations presented in this study are correct, the highest transgression shore level in the Holocene at Napp-

straumen seems to have formed 1500-2000 years earlier than suggested by Marthinussen (1962) for this outer area of Lofoten and Vesterålen.

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