Holocene shoreline displacement at Agardhbukta, eastern Spitsbergen, Svalbard

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Salvigsen, O. & Mangerud, J. 1991: Holocene shoreline displacement at Agardhbukta, eastern Spitsbergen, Svalbard. *Polar Research 9(1)*, 1–7.

An emergence curve based on nine radiocarbon dated samples of mosses, shells, whale bones and driftwood has been constructed for Agardhbukta. Beach sediments and delta deposits were found up to c. 50 m above sea level, and the oldest date goes back to about 10,000 yrs BP. However, the possibility of a higher marine limit cannot be excluded. The Agardhbukta curve shows a nearly linear uplift during the entire Holocene. It differs from the western Spitsbergen curves, where a transgression occurs, and is more similar to curves from areas further east in the Svalbard archipelago.

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Agardhbukta is located on the eastern coast of Spitsbergen at about 78°N (Fig. 1). During a 5-day visit in 1982, we collected datable material from different raised beach levels at Belemnitsletta and Væringsdalen north of the bay (Fig. 2).

The bedrock has been mapped by Birkenmajer (1980). A prominent, narrow structural level is visible at the foot of the mountains 15–30 m above sea-level. It correlates with the top of the weathering resistant, predominantly sandstone sequence of the late Triassic – lowest Jurassic De Geerdalen Formation.

The altitude of the samples was levelled from the mean tide level with a hand held instrument and should be correct to the nearest half metre, except for sample 17.

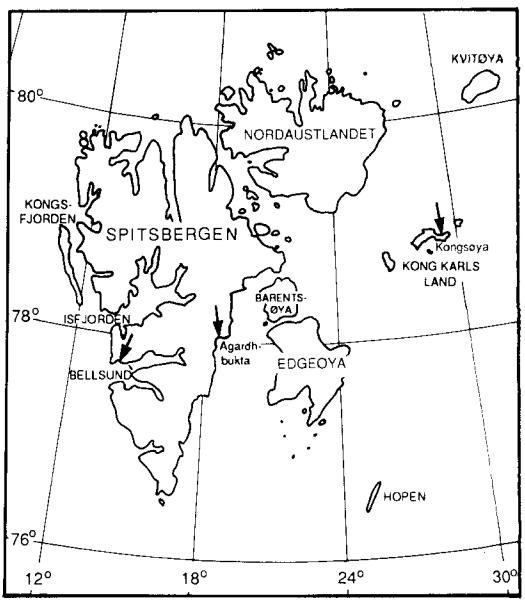

Fig. 1. Location map Svalbard. The sites for the curves in Fig. 8 are marked with arrows.

Description of sites and dated samples

The description is organized according to the elevation of the samples, starting with the highest.

Sa82-17. Væringsdalen

Along the eastern bank of the river in Væringsdalen, just downstream from the creek from Daudbreen, is a 150 m long and up to 20 m high section in a raised delta. The lowermost part consists of 4 m fine-grained sediments, mainly silt and clay. Most of this unit was covered by slumped and frozen sediments, but small sections showed nearly horizontal laminae and a distinct coarsening-upward from clay/silt in the lower part to sand in the upper. No fossils were found in these beds. The boundary between the horizontal beds

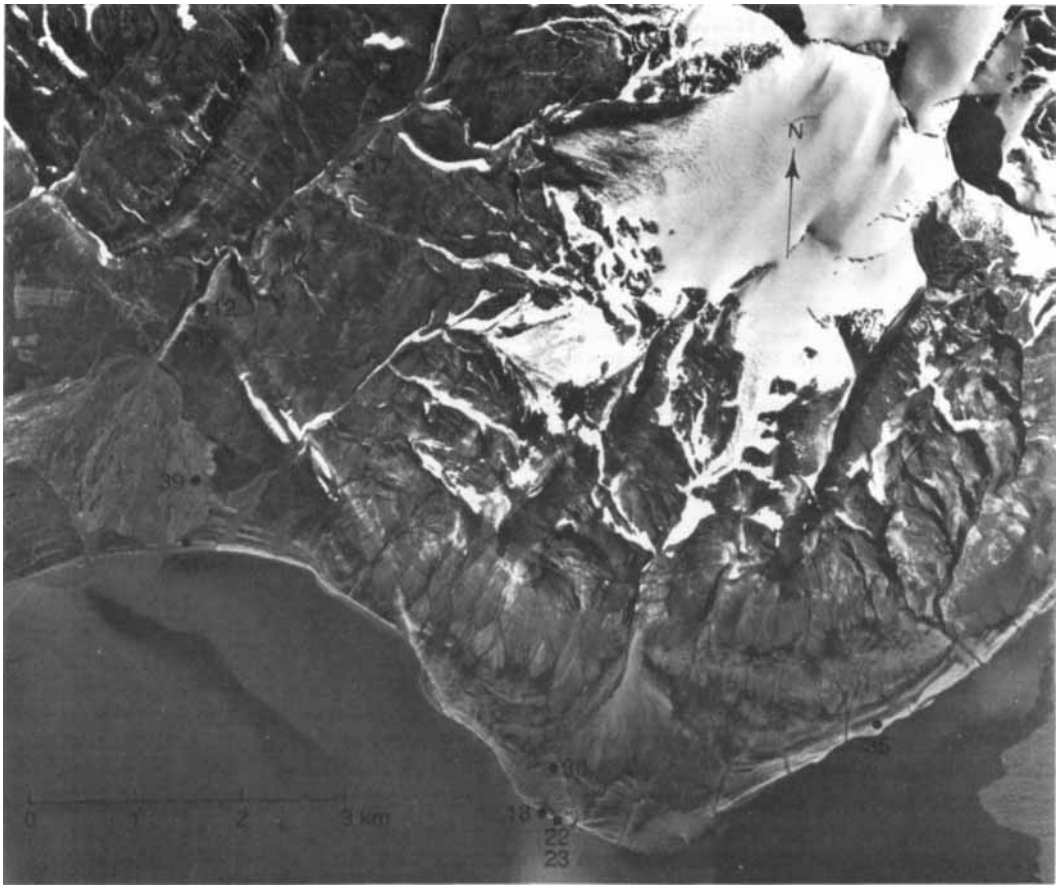

Fig. 2. Vertical aerial photograph of the northern Agardhbukta area with field sample numbers superimposed. Photo: Norsk Polarinstitutt. S71 6071.

Fig. 3. A part of the section in Væringsdalen. In the foreground the fine-grained sediments, covered by slumped material and snow. The foresets are seen in the upper part. The spade in the center of the photo is one metre.

and the foresets in the upper part was not exposed. Still we assume the horizontal beds to be bottomsets related to the foresets above.

Most of the section consists of regular foresets of well-sorted sand and gravel (Fig. 3). The angle of dip is between 21° and 30°, and the strike between 104° and 214° for 11 measurements at different stratigraphic levels. This means that the direction of deposition was downvalley Væringsdalen, with a component from E towards the centre of the valley.

Small plant fragments, mainly mosses, occur in the foresets. Most of the plants are concentrated within a stratigraphic level of one metre, where they occur both as scattered individual stems and in conglomerations. Most of the identifiable fragments belong to the moss *Polytrichum commune* Hedw. (Hans H. Blom, written comm. 1985) which is presently common in the warmer parts of Spitsbergen (southern and inner fjords), but which has also been reported from near Agardhbukta (Arne Frisvold, oral comm. 1990).

The mosses were dated to 9,870 ± 140 yrs BP (T-4937, Table 1). They were probably deposited at that time from a living position further upstream, and thus they should also reveal the age of the delta and the corresponding sea-level. However, there are two problems in determining the elevation of that sea-level.

First, the topsets have been removed along the entire section. The altitude of the top of the section thus indicates only a minimum sea-level elevation. However, the top of the section is part of a large terrace which apparently extended across the entire valley when it was formed. We find it most likely that this terrace represents the delta plain, and thus the sea-level which would correspond to the described foresets. There are no remnants of higher deltas.

The second problem in determining the elevation of the sea-level is simply our poor altitude measurement. Due to the long distance from the sea, difficult sight conditions, and long time elapse between barometric readings, the accuracy of our measurement is difficult to estimate. We measured the top of the section to be 45 m above sea-level, and the corresponding sea-level should then have been some metres higher.

Sa82-12. The mouth of Væringsdalen

Before entering the main valley, the river in Væringsdalen cuts through coarse beach sediments which comprise ridges and terraces up to about 50 m above sea level. Fragments of shells were found in a few places, but only in one locality were they so frequent that material for a conventional radiocarbon date could be obtained. Fragments of *Mya truncata* and *Balanus* sp. were collected about 2 m below the surface of a former beach 36.5 m above the present sea-level. The fragments were small but thick and of good quality for the dating which gave 9,040 ± 140 yrs BP (T-4938). Because molluscs live at some water depth, the shells give a maximum age for the sea-levels corresponding to the altitudes where they occur.

Table 1. Radiocarbon dates from the Agardhbukta area, organized according to elevation above the present sea-level. All samples are corrected for isotopic fractionation deviating from $\delta^{13}C = -25‰$ PDB. For whale bones and marine shells a reservoir age of 440 years is subtracted (Mangerud & Gulliksen 1975). Thus all ages in the table should be directly comparable and show 'conventional terrestrial ages'.

Sample	Lab. no.	^{14}C age	$\delta^{13}C‰$ PDB	M a.s.l.	Material	Location
17	T-4937	9,870 ± 140	−26.3	50 (?)	Mosses	Væringsdalen
12	T-4938	9,040 ± 140	1.6	36.5	Shell	Væringsdalen
13	T-4940I	590 ± 70	−13.7	27.0	Bone	Væringsdalen
13	T-4940II	540 ± 60	−15.8	27.0	Bone	Væringsdalen
13	T-4940	560 ± 45	(Mean of the two measurements)			
35	T-5126	6.810 ± 110	−15.4	24.0	Bone	Belemnitsletta
30	T-4939	6,450 ± 70	*	20.5	Wood	Belemnitsletta
23	T-5125	5,330 ± 100	†	16.0	Shell	Belemnitsletta
22	T-5128	4,990 ± 100	−17.0	16.0	Baleen	Belemnitsletta
18	T-4942	4,690 ± 100	*	15.0	Wood	Belemnitsletta
39	T-5127	800 ± 70	−15.9	3.0	Bone	Agardhbukta
38	T-4941	810 ± 80	*	1.5	Wood	Agardhbukta

* $\delta^{13}C$ not measured. Standard value of −26.1‰ used for correction.

† $\delta^{13}C$ not measured. Standard value of 1.0‰ used for correction.

Fig. 4. The whale vertebra on the 27 m terrace in the mouth of Væringsdalen which according to dating must have been carried 2 km inland. The whale died 560 ± 45 radiocarbon years ago (T-4940) which gives the calibrated age AD 1400–1455, when using the 2.0 program for marine samples and ΔR value 70 ± 25 of Stuiver and Reimer (1986). The knife is 20 cm.

Sa82-13. The mouth of Væringsdalen

On a prominent terrace, 27 m above present sea-level, we found two large whale vertebrae. One was partly buried by the sediments and by vegetation that had grown on and around it. The other vertebra was lying more on the top of the sediments but this was also partly overgrown (Fig. 4). The latter vertebra was the best preserved and therefore selected for dating. Because of the unexpected low age (Table 1), another sample from the same vertebra has also been dated. The mean value of the datings is 560 ± 45 years BP (T-4940), and the conclusion is that somebody must have carried one, probably two, vertebrae 2 km inland from near the present shore. The sample is irrelevant for the main purpose of this study, but it demonstrates how difficult it is to exclude such samples before they have been dated.

Sa82-35. Belemnitsletta

Sample from a whale rib found almost completely embedded in the sediment of a prominent beach ridge terrace in the eastern part of Belemnitsletta. Several vertebrae were found nearby, probably belonging to the same skeleton. The level was determined to be 24 m above sea-level, and the radiocarbon dating yielded 6,810 ± 110 yrs BP

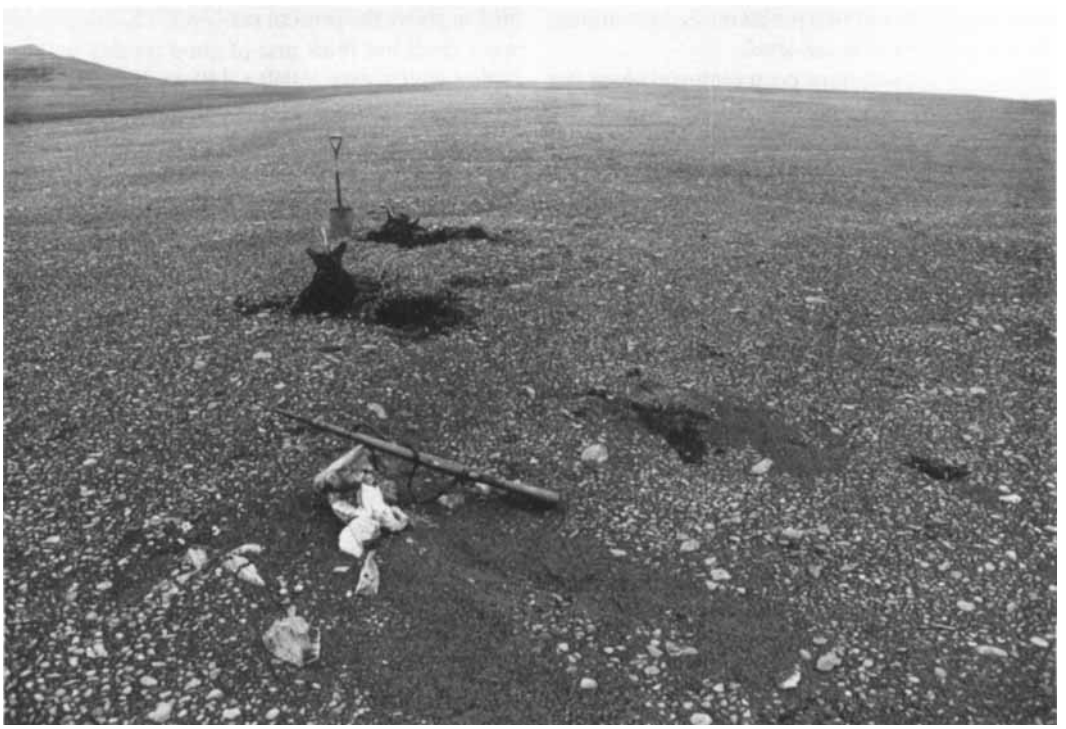

Fig. 5. The 24 m beach terrace on Belemnitsletta where whale bones are common.

(T-5126). The beach could be followed for several kilometres, and whale bones were common (Fig. 5).

Sa82-30. Belemnitsletta

Sample from a more than 5 m long log of *Larix sibirica*, with a diameter from 0.4 m to 0.2 m and with a large root system. The log was firmly anchored in beach sediments, and the quality of the wood was good. A sample from the outer part of the log was taken for dating and it revealed an age of 6,450 ± 70 yrs BP (T-4939). The level was 20.5 m above sea-level. Both driftwood and whale bones were abundant around this level, whereas neither was found between 20 m and 16 m above sea-level.

Sa82-22. Belemnitsletta

Sample from a 2.2 m long whale baleen in 3 m thick coarse beach sediments on top of a sea facing bedrock cliff. The sample was taken 1.5 m below the surface, which was 16 m above sea-level. The baleen was dated to 4,990 ± 100 yrs BP (T-5128).

Sa82-23. Belemnitsletta

Shell fragments collected in the same section as Sa82-22, 0.2–0.3 m above the whale baleen. The fragments were hard but so small that it was impossible to identify all. *Mya truncata* and *Balanus* sp. were present. The age was determined to be 5,330 ± 100 yrs BP (T-5125).

Sa82-18. Belemnitsletta

Sample from a 2 m long log with a large root, well-embedded in coarse beach sediments and identified as *Larix gmelini*. The level was 15.0 m above sea-level, and a sample from the outer wood yielded 4,690 ± 100 yrs BP (T-4942).

Sa82-39. Agardhdalen, east side of the river from Væringsdalen

Sample from 5.7 m long lower jaw of a large whale, partly incorporated in beach sediments east of the river coming from Væringsdalen. The quality of the bone was good and the age was 800 ± 70 yrs BP (T-5127). The level was 3 m above sea-level.

Sa82-38. Agardhdalen, east side of the river from Væringsdalen

Sample from a 13 m long driftwood log, with a root-diameter of 0.5 m and a top-diameter of 0.25 m, identified as *Pinus silvestris*. It was partially anchored on fine-grained beach sediments with the top protruding into the river. A sample from the outer part of the log yielded 810 ± 80 yrs BP (T-4941). The level was only 1.5 m above the present sea-level.

Driftwood frequency and species

Only small areas with well-preserved raised beaches exist in the area. At the mouth of Væringsdalen there are beaches between 25 m and 50 m above sea-level, but no driftwood or whale bones were found, except the young vertebra, No. 13. Belemnitsletta has areas with very well-developed beaches between 15 m and 30 m above sea-level. But along the shore there is a 15 m high cliff cut into bedrock which made it impossible to obtain datable material on lower levels.

The observations and datings of samples from Belemnitsletta indicate that whales stranded on and driftwood reached the shores of Agardhbukta during the whole period from about 6,500 to 4,500 yrs BP. A special 'log level' was identified between 20.5–21.5 m above sea-level and dated to c. 6,500 yrs BP (T-4939). Five logs from this level were determined to be 2 *Larix gmelini*, 1 *Larix sibirica*, 1 *Picea mariana* and 1 unidentified *Picea* sp. This supports the hypothesis that conditions for the drifting of wood to Svalbard were most favourable around 6,500 yrs BP (Häggblom 1982).

Several logs were also found about 15 m above sea-level, and two of them were identified as *Larix gmelini* and *Pinus strobus*. Our observations are in agreement with earlier results showing that most driftwood on eastern Svalbard is coniferous wood of Siberian origin, but that some logs of American origin have also reached the coasts of Svalbard (Häggblom 1982).

Driftwood is also deposited in Agardhbukta today (Fig. 6), and some driftwood is found on the low-lying plain up to one kilometre from the coast. The dated *Pinus silvestris* had an age of about 800 yrs, but a probably much younger, more than 3 m long oar (*Fraxinus* sp.) was also

Fig. 6. Driftwood log helped by drifting sea-ice, arriving on the northern shore of Agardbukta on July 30, 1982.

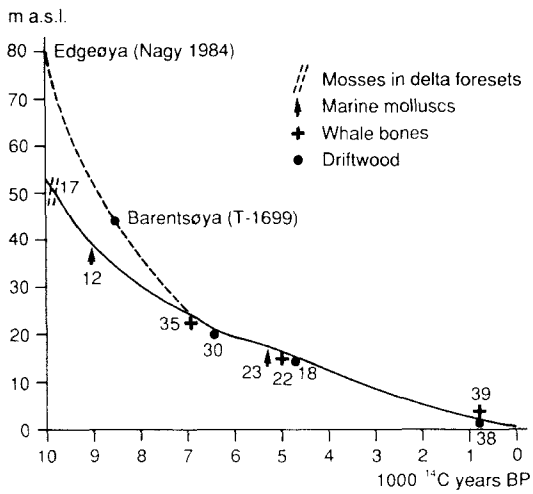

Fig. 7. Relative sea-level curve for Agardhbukta (full line), tentative above 25 m. The stippled curve is based on dates from Barentsøya and Edgeøya, some 60 km to the east. The 'real' Agardhbukta curve above 25 m could be expected to fall somewhat between the two curves shown here.

found about one km from the shore. This area, which also today can be flooded by the sea during spring tide, seems to have a mixture of wood with different ages younger than 1,000 years, suggesting that the relative sea-level has been very close to the present sea-level for nearly the last 1,000 years. Eurola (1971) collected 19 samples of driftwood at low levels in Agardhbukta. They were identified as 9 *Larix* sp., 8 *Picea* sp., 1 *Pinus* sp. and 1 *Populus* sp.

Emergence curve

The radiocarbon dates have been plotted in a time-elevation diagram, Fig. 7, and constitute the basis for the sea-level curve. There are no dates between 4,500 and 1,000 yrs BP, and this is therefore an uncertain period. Before 7,000 yrs BP there are only two dates. The shells (sample 13) provide only a minimum elevation for the sea-level, and the altitude of sample 17 is uncertain as discussed above.

Beach sediments were found up to 52 m above sea-level at the mouth of Væringsdalen, and this level possibly constitutes the post-glacial marine limit in the area. According to the curve its age is about 10,000 yrs BP. Glaser (1968) describes a level 55–60 m above sea-level in Agardhbukta and considers this to be the highest marine level there. A short distance to the west, in Kjellströmdalen between Agardhbukta and Van Mijenfjorden, the marine limit has been determined to be about 60 m above sea-level and from about 9,600 yrs BP (Elgersma & Helliksen 1986). To the east of Agardhbukta, on northern Edgeøya, Nagy (1984) has found foreset bedding up to 80 m above sea-level dated to about 10,000 yrs BP. On southern Barentsøya a driftwood log about 44 m above sea-level gave the age 8,570 ± 110 yrs BP (T-1699). These observations suggest that the curve for

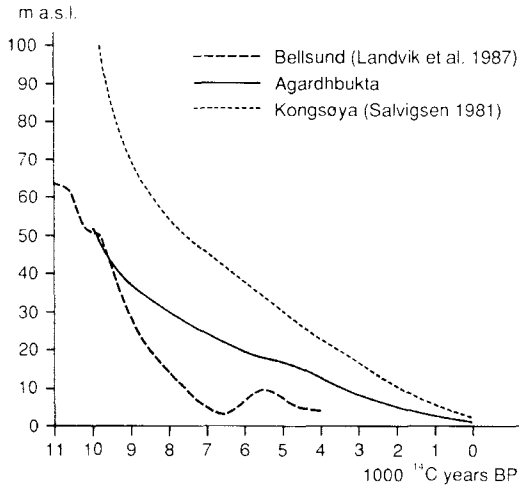

Fig. 8. Relative sea-level curves from Bellsund (Ytterdalen), Agardhbukta, and Kongsøya. The sites are marked in Fig. 1.

Agardhbukta could be somewhat higher and steeper in the older part than our dates indicate (Fig. 7).

In Agardhdalen three samples from peat in a push moraine 10 km from the coast have been radiocarbon dated (Punning et al. 1978), giving ages from about 10,600 to 9,500 yrs BP (Tln-232, Tln-233, Tln-234). If these dates are correct, our sea-level curve should start earlier than shown in Fig. 7. Compared with other deglaciation dates from eastern Svalbard, we find it unlikely that peat formation took place that early in Agardhbukta. We therefore suppose that the peat dates show ages which are too high, possibly because of contamination by old carbon.

Fig. 8 shows three curves with their locations lying on an almost straight line: Bellsund (Landvik et al. 1987), Agardhbukta and Kongsøya (Salvigsen 1981). These curves demonstrate the differences in emergence pattern between western and eastern Svalbard. The marine limit is at least 1,000 years older on the western coast of Spitsbergen than in eastern Svalbard, and most of the uplift on the western coast took place during the initial phase. The rate of uplift there then slowed down so much that a marine transgression occurred, but its dating is still a matter of discussion (Forman 1990; Salvigsen et al. 1990). After 5,000 yrs BP there has been little emergence on the western coast, and it has thus been impossible to date the shore movements there in detail. The eastern part of Svalbard has had a relatively high rate of uplift also in the middle and late Holocene, so high that it is difficult to trace any eustatic sea-level rise in the curves.

The conclusion is that the Agardhbukta curve shows the same uplift pattern as areas further east, e.g. Kongsøya and southern Edgeøya (Knape 1971), and seems to be different from the curves from the western coast of Spitsbergen.

Acknowledgements. – The Norwegian Polar Research Institute was responsible for the logistics in the field, and Nils Flakstad was our field assistant. The work of Jan Mangerud was financially supported by the Norwegian Council for Science and Humanities (NAVF). Leif M. Paulssen identified the wood species, and Hans H. Blom the mosses. Thore S. Winsnes contributed a driftwood log from Barentsøya for radiocarbon dating. The radiocarbon datings were performed under the direction of Reidar Nydal and Steinar Gulliksen at the Laboratory of Radiological Dating in Trondheim. The final version of the paper has benefitted from referee comments made by Svend Funder and Christian Hjort.

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