Occurrence of pumice on raised beaches and Holocene shoreline displacement in the inner Isfjorden area, Svalbard

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Finds of pumice on raised beaches in the inner Isfjorden area are reported. Pumice is abundant in two zones, and four levels can be distinguished in some areas. The highest lying level has the greatest concentration of pumice and is dated to a maximum of 6,500 years B.P. Tentative correlations with pumice levels from other places in Svalbard indicate approximate ages of 6,000, 4,100, and 3,100 years for the lower levels in inner Isfjorden. A shoreline displacement curve based on the pumice levels and on 10,000 year old driftwood is presented.

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Introduction

Scattered finds of pumice on raised beaches were reported by several expeditions visiting Svalbard in the previous century, e.g. Parry (1828), and Nordenskiöld (1863, 1874). The first systematic study of this subject was conducted by Donner & West (1957) followed by Blake (1961), who introduced the radiocarbon dating method to pumice investigations in Svalbard. Schytt *et al.* (1968) presented an isobase map for the 6,500-year-old shoreline in Svalbard, based mainly on pumice observations. Later, Boulton & Rhodes (1974) and Salvigsen (1978, 1981) studied pumice on raised beaches and dated several levels where pumice was abundant.

To my knowledge only Peder Knape has reported finds of pumice on raised beaches in the inner Isfjorden area. De Geer (1896) and other scientists reported pumice which was most likely found near the present shore. Knape (1971) found pumice 21 m above sea level at Bjonapynten between Tempelfjorden and Sassenfjorden. Balchin (1941), Feyling-Hanssen (1955) and Péwé *et al.* (1982), among many others, have made detailed studies of raised beaches in inner Isfjorden, but without reporting pumice. It is also a striking fact that only one record exists of pumice finds elsewhere on the west coast of Spitsbergen (Salvigsen 1984).

The main purpose of this paper is to present finds of pumice in an area where they have not previously been reported. A Holocene shoreline displacement curve has also been drawn, based on pumice observations and two new radiocarbon dates.

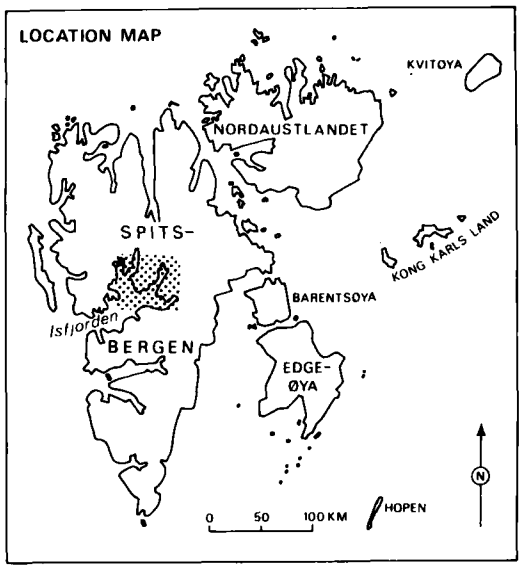

Fig. 1. Location map of Svalbard.

Field observations

The Quaternary geology of Billefjorden and Dicksonfjorden was studied in 1981, and pumice was looked for in raised beach areas where con-

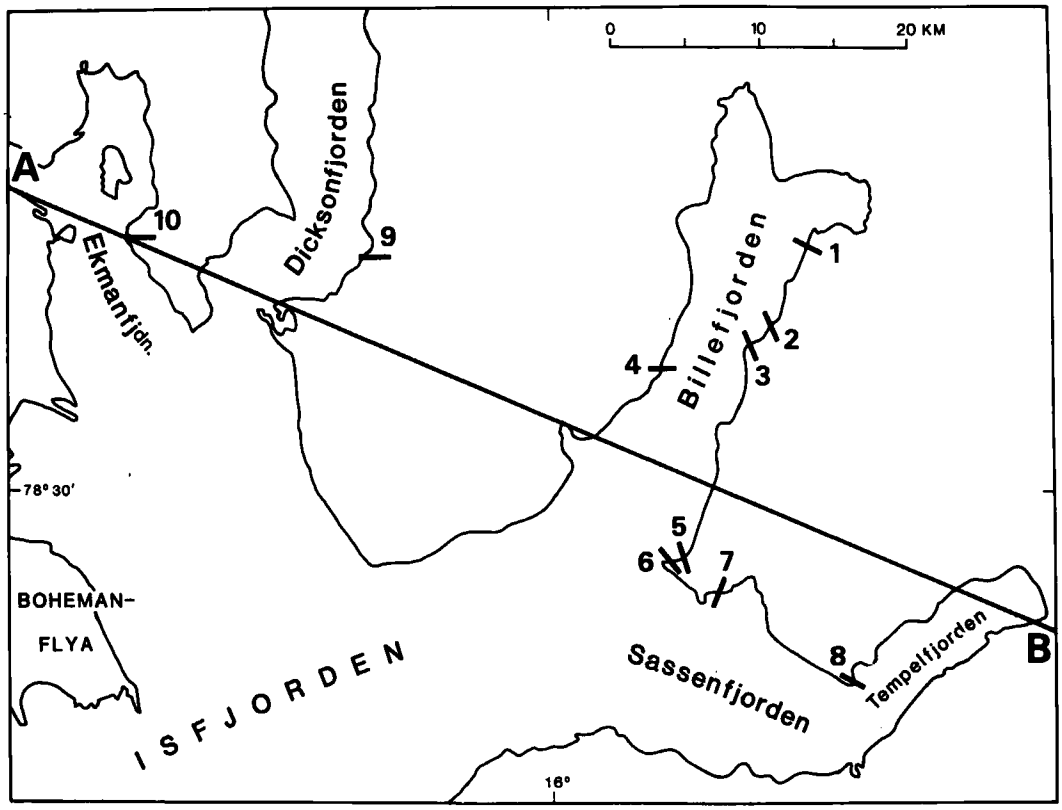

Fig. 2. The inner Isfjorden area showing the sites where pumice was observed. See Table 1 for site names.

ditions seemed promising for such finds (Fig. 2). The altitudes were measured by precise levelling from an estimated mean tide level. Three altimeter determinations (Paulin) are also included. Sites and altitudes of observed pumice levels are shown in Table 1 and Figs. 2 and 3.

Pumice was observed to be abundant around an elevation of 10.8 m at Blomesletta (10), between Ekmanfjorden and Dicksonfjorden, where undisturbed raised beaches exist. In Dicksonfjorden, however, most of the raised beaches are covered by vegetation and it is impossible to find pumice there. Only one locality, Myggdalen (9), has bare, undisturbed beaches at an appro-

Table 1. Pumice observations.

Location of site	Altitudes in m above mean tide level		
1. Brucebyen	(6)	9.0 – 10.2	*17.5*
2. Ekholmvika		*14.4*	15.6 – *17.0* – 18.3
3. Kapp Ekholm	5.3 – *6.2*	7.5 – *8.3* – 8.4	
4. Alvrekdalen			15.9
5. Mytilusbekken		(7)	
6. Gåsodden		9.9	*19.5* – 20.5
7. Gipsvika		7.6 – *10.0* – 11.3	(17)
8. Bjonapynten			21
9. Myggdalen		6.7	14.1
10. Blomesletta		6.7 – 7.7	9.8 – *10.8* – 12.0

For location, see Fig. 2. Altitude numbers connected by dashes define range of pumice. Altitudes with specially high concentration of pumice are in italics, while altitudes in brackets were measured by Pauline altimeter.

priate altitude; two levels with pumice were observed, at 14.1 m and 6.7 m above sea level. Pumice has probably been deposited extensively on the beaches of Dicksonfjorden during the Holocene. However, most of the beaches have either been destroyed by subsequent slope processes or have become covered by vegetation, so it is unlikely that many new finds will be made in this fjord. The area between Dicksonfjorden and Billefjorden is also characterized by rich vegetation, and no pumice was found there at all. The occurrence of pumice on the western side of Billefjorden is very limited, with only five pieces being discovered near the mouth of Alvrekdalen (4).

The raised beaches on the eastern side of Billefjorden consist in several places of beach ridges on sloping plains as described by Feyling-Hanssen (1955) and others. Pumice was observed at five localities as well as in one locality at Gipsvika (7) between Billefjorden and Tempelfjorden.

The highest concentration of pumice was found at Blomesletta (10), where pumice pieces were more concentrated than I have seen at any other site in Svalbard. In many places more than 10 pieces could be found in 1 m^2. High concentrations of pumice were found at four different levels in the area of Ekholmvika (2) and Kapp Ekholm (3).

The colour of the pumice on the raised beaches in inner Isfjorden can be characterized as greyish black with shades of brown. There is no colour difference between the different pumice levels in Isfjorden, and the pumice there seems to have the same colour as the pumice elsewhere in Svalbard. The pumice pieces are of varying size though usually less than 8 cm in diameter. The largest piece found in inner Isfjorden is approximately 15 cm in diameter.

Pumice levels

Fig. 3 shows a distance diagram where pumice sites and altitudes have been projected perpendicular to a plane (A–B in Fig. 2). The direction of this projection plane is approximately perpendicular to the 6,500 year isobase presented by Schytt *et al.* (1968). As expected the altitudes of observed pumice do not fall on straight lines in the projection plane, but are grouped in a way that indicates two pumice zones in inner Isfjorden (Fig. 3). The vertical distribution of pumice in these zones is considerable, and it seems likely that this also represents a spread in deposition time. It is usually possible in the field, however, to distinguish distinct, main levels where pumice is most abundant. These concentrations of pumice are considered to represent synchronous events.

Several problems make it difficult to determine the exact tilt of pumice levels in an area as small as the one dealt with here. Some uncertainty is attached to the determination of the mean tide level in each site where pumice was observed. The main problem, however, is that the actual pumice sites have had varying exposure to the waves, and the pumice has therefore been deposited at different heights above mean tide level. The slope of the shore and offshore topography are important factors in determining the elevation at which pumice will be deposited.

The highest pumice was found at Gåsodden (6) which faces southwest and has no protection against storm waves from the mouth of Isfjorden. Most of the other raised beaches with pumice have been formed under conditions of shorter fetch, i.e. waves coming across the fjord or from the head of the fjord, and on these beaches pumice has not been thrown as high as at Gåsodden.

Within the pumice zones (shaded in Fig. 3), straight lines (a and c) have been drawn to show tentatively the approximate tilt of the two levels with the highest pumice concentration in inner Isfjorden. Below both these levels there are indications of additional pumice levels (b and d). These two less distinct levels appear most clearly in the Ekholmvika–Kapp Ekholm area.

Age determinations and correlations

The highest or main pumice level in Svalbard has been radiocarbon dated using wood and whale bones associated with this level (Blake 1961; Knape 1971; Boulton & Rhodes 1974). Its average age is 6,500 years and a similar age was also expected for the highest pumice in Isfjorden. This was confirmed by a date on *Mytilus edulis* shells from Gåsodden (6). The main pumice level there has an elevation of 19.5 m, and scattered pieces of pumice were found up to 1 m higher. The shell fragments were sampled from the surface, 18.1 m above sea level, and gave an age of 6,440 ± 80

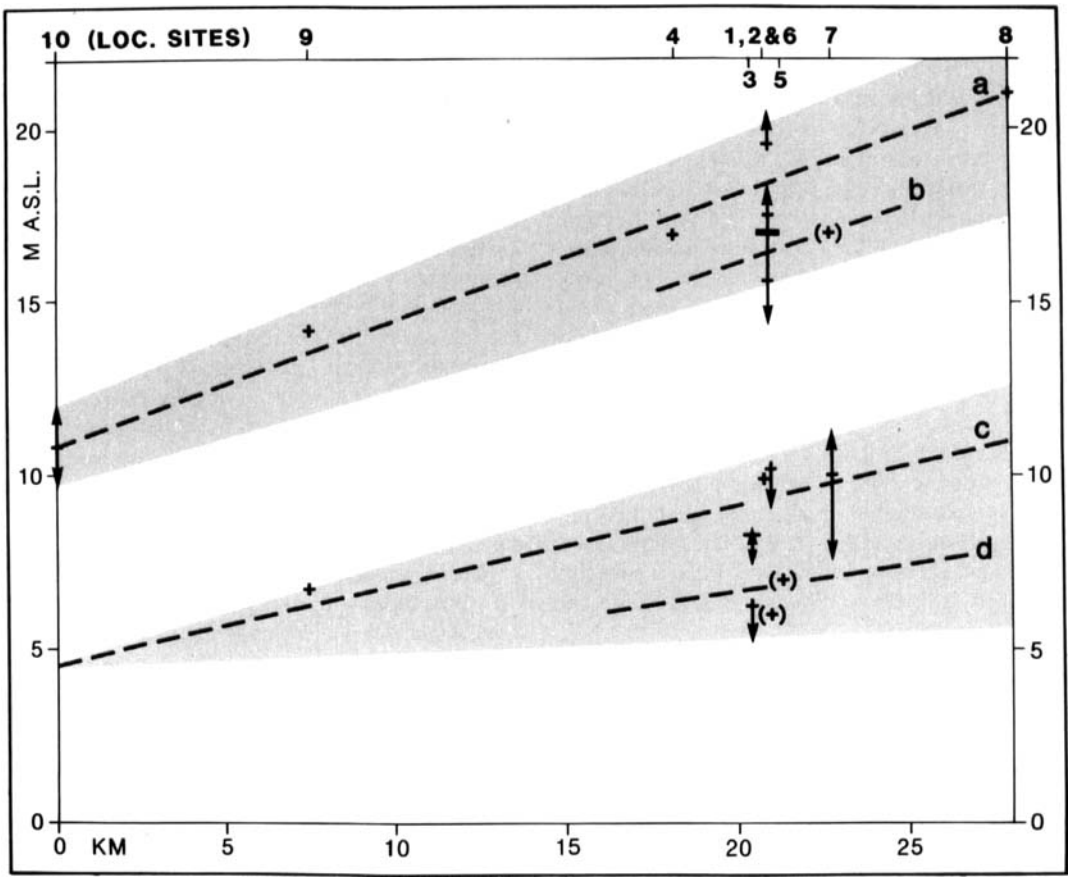

Fig. 3. Distance/elevation diagram of pumice observations in inner Isfjorden. Projection axis is line A–B in Fig. 2. +: Precisely levelled pumice observation, (+): Pauline determined pumice observation. Vertical arrows show the height range of pumice associated with each of the pumice levels. Pumice occurs mainly in two zones (shaded), and within them four levels, a–d, have been distinguished.

years B.P. (T-4628). The mussel *Mytilus edulis* is generally restricted to shallow water, often within the intertidal zone, and has proved to be a species which can be used to date the position of former sea levels (Donner *et al.* 1977). It therefore seems likely that the dated sample represents molluscs living contemporaneously with, or shortly before, the deposition of pumice at Gåsodden. The main pumice level, a, exists in inner Isfjorden, and 6,500 B.P. is considered a maximum age.

The lower pumice levels in Isfjorden have not been dated because suitable material for their exact dating was not found. However, probable correlations and ages will be discussed. Boulton & Rhodes (1974) distinguished a pumice level a few hundred years younger than the main horizon on the north coast of Spitsbergen. In inner Isfjorden, too, there are indications of a pumice level deposited shortly after level a. It is most clear in Ekholmvika (2) where the vertical distance between a and b is 2.6 m, indicating that the lowest pumice could have been deposited about 6,000 years ago. At some sites level b may well be hidden due to the spreading of pumice below level a, e.g. at Blomesletta (10).

Next to level a, level c is the most prominent pumice level in inner Isfjorden. It may possibly be a correlative of Boulton & Rhodes (1974) level c on the north coast of Spitsbergen, dated by them at 4,000–4,150 years B.P. Similar ages have also been found for pumice-bearing strandlines in North Norway and Britain (Binns 1967). An alternative correlation in Svalbard is with the pumice level on the southern coast of Nordaustlandet, dated to about 4,500 years B.P., and it

is possible that the lower pumice level along Hinlopen is also from that time (Salvigsen 1978). The upper pumice level in Kong Karls Land was dated to about 5,200 years B.P. (Salvigsen 1981), but up to now this level has only been found as a local level on Kongsøya. At present, ages of about 4,100 and 4,500 years are therefore most plausible for level c in Isfjorden.

The lowest pumice, level d, was only found as a distinct level at Kapp Ekholm (3), but at other sites a few pieces of pumice can probably be correlated with this level. The best guess for a correlative to this level in Svalbard is probably the lowest pumice level in Kong Karls Land, dated at about 3,100 years B.P. (Salvigsen 1981).

In addition to finds of pumice in the two raised pumice zones in inner Isfjorden, several pumice pieces were usually found inside the modern shingle ridges on the same level as, or below, the crest of these ridges. Pumice on this level is in many cases difficult to distinguish from other slag products having reached the shores of Spitsbergen. This pumice near the present shore cannot be established as a synchronous level.

This study and previously referred studies from other parts of Svalbard indicate at least six pumice levels younger than 6,500 years. They are very difficult to correlate from one site to another, and radiocarbon dating from as many localities as possible is desirable. It is clear that during the Holocene there were several episodes when large amounts of pumice drifted ashore in Svalbard and it seems likely that more pumice can be found there than in other Arctic areas with raised beaches.

Holocene shoreline displacement

Two new age determinations plus the recently discovered pumice levels make it possible now to present a new emergence curve for Billefjorden (Fig. 4). A piece of driftwood (*Larix occidentalis*) associated with the 65 m level at Kapp Ekholm (3) was dated to 10,030, 140 years B.P. The main pumice level, a, at Ekholmvika (2) is another fixed point for the shoreline displacement curve. Its altitude is 17 m and its age is 6,500 years, as indicated previously. Pumice levels b, c, and d have already been correlated to ages of 6,000, 4,100, and 3,100 years respectively, and these ages are used for the levels in the Ekholmvika–Kapp Ekholm area. Fig. 4 shows an idealized

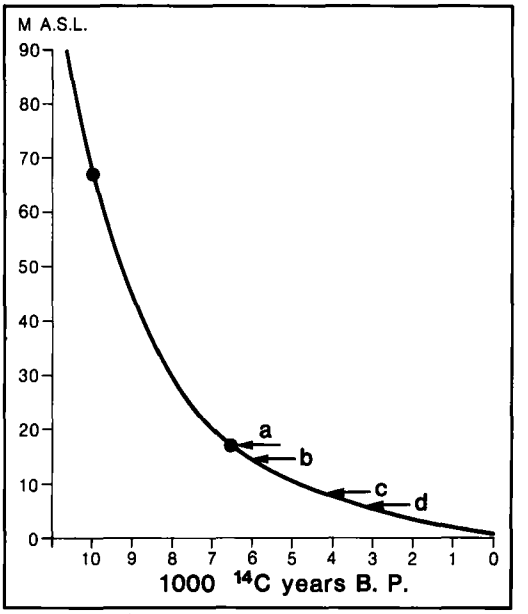

Fig. 4. Shoreline displacement curve for the Kapp Ekholm–Ekholmvika area in Billefjorden, based mainly on radiocarbon dates and pumice observations. Two radiocarbon dates and four pumice levels are shown.

shoreline displacement curve through the above-mentioned levels and ages.

A shoreline displacement curve based on five shell dates from different sites along the eastern shore of Billefjorden was published by Feyling-Hanssen & Olsson (1960); see also Feyling-Hanssen (1965) and Péwé *et al.* (1982). Their curve shows somewhat older ages for the higher beaches than the curve presented here. This is partly due to the fact that the apparent age of recent shells in Svalbard, about 500 years according to Mangerud & Gulliksen (1975), had not been subtracted in the dates of Feyling-Hanssen & Olsson. In addition, it should be remembered that shells are usually older than the levels at which they are found. The curve in Fig. 4 is in agreement with two whale bone dates from Billefjorden, U-506 and U-2077 in Olsson *et al.* (1967, 1969).

Because of the few dated points this curve does not 'catch' possible minor transgressions, but it can nevertheless be used for approximate age determinations of Holocene shorelines in Billefjorden.

The marine limit is at least 90 m at Kapp Ekholm, and an extrapolation of the curve will give an age of between 10,500 and 11,000 years

for the marine limit at this site. The coastal morphology of the inner Isfjorden area indicates that vertical land movements today are insignificant, if indeed they occur at all.

Discussion and conclusions

Binns (1967, 1971) has done the most thorough studies of the distribution and origin of pumice on raised beaches in Northern Europe and the Western Arctic. The new finds of pumice in inner Isfjorden support the conclusion that the pumice has been transported to its present position by the surface currents of the Gulf Stream System. The extensive, distinct pumice levels found in Svalbard (and elsewhere) and the abundance of pumice on these levels indicate that the drift pumice originates from rather large volcanic eruptions. Comparative studies of chemical composition and mineralogy of the drift pumice and of the various possible centres have not produced conclusive evidence for the origin of the pumice (Binns 1967, 1971; Boulton & Rhodes 1974).

Radiocarbon dates indicate a close coincidence in time between eruptions of Hecla (Iceland) and major drift pumice accumulations (Binns 1967). However, the extensive distribution and the abundance of this pumice weighs especially against inland volcanoes like Hecla as a source. The sources of the drift pumice are probably to be found among the volcanoes which delivered their material directly into the sea, but knowledge about submarine volcanoes of the past is almost non-existent.

The new information about the main pumice level indicates that the 15 m isobase for the 6,500 year level in Schytt *et al.* (1968, Fig. 3) has a somewhat too westerly position in the Isfjorden area. Previous determinations of marine limits in the area have been confirmed. It decreases from about 96 m in Sassenfjorden to about 90 m in Billefjorden (Feyling-Hanssen 1965) and to about 62 m at Blomesletta (Péwé *et al.* 1982).

The emergence curve for Kapp Ekholm is similar to the curves presented by Feyling-Hanssen & Olsson (1960) and Péwé *et al.* (1982). It is an asymptotic curve showing that the glacio-isostatic rebound movement started before 10,000 B.P. The high rate of uplift between 10,000 and 8,000 years B.P. (average 1.9 m/century) slowed down to a much lesser rate (average 0.45 m/century) between 8,000 and 4,000 years.

In the latter period one or more transgressions are known from other areas (Donner *et al.* 1977; Synge 1980; Hjort 1981; Hafsten 1983). Feyling-Hanssen (1965) found evidence of, and raised the question about, transgressions in Billefjorden, but his conclusion was vague (p. 5): 'If a transgression, it seems probably to have taken place simultaneously with the late Atlantic–early Sub Boreal transgression known from many other localities, e.g. in northern Europe'. The new studies in inner Isfjorden have not brought any evidence of transgressions in this area. The pumice levels are not connected with especially well developed beaches. Neither has stratigraphic evidence been found of transgressions in any of the sea-facing cliff sections in Billefjorden, e.g. in Ekholmvika, where a cross section in the raised, ridge beach plain was described by Feyling-Hanssen (1955). Further investigations focusing on this subject are needed to get more information about possible Holocene transgressions in Svalbard.

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