Past glaciation and sea levels on Bjørnøya, Svalbard

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Bjørnøya has a very thin cover of unconsolidated Quaternary sediments. Glacial erratics of local origin are spread throughout the lowland areas, and glacial striae indicate glacial movement which was centred in the middle of the island. No traces of the Barents Sea ice sheet have been observed on Bjørnøya, nor has there been any postglacial emergence of the island. Lake cores date the deglaciation of the lowlands to ca 10,000 BP, and peat deposits on high mountains show that these were deglaciated before 8700 BP.

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Introduction

The reconstruction of the Late Weichselian ice sheet in the Barents Sea area is still largely based on indirect evidence, such as the pattern of isostatic rebound, undated moraine ridges, general lithostratigraphy and the distribution of overcompacted diamicton (Elverhøi et al. 1993; Lambeck 1995). The objective for the present study was to gather new information on glacial features and former sea levels from Bjørnøya, which with its position on the western edge of the Barents shelf may provide key information in the Late Weichselian discussion.

Bjørnøya is the southernmost island in the Svalbard archipelago, 250 km south of Spitsbergen and 440 km north of the Norwegian mainland (Fig. 1). The island is 20 km from south to north, 15 km from west to east, and has a total area of 178 km^2. It is situated on a submarine plateau with depths of less than 100 m. The predominantly soft rocks of Bjørnøya are highly affected by wave abrasion, and the coasts therefore consist almost entirely of steep cliffs (Høgvard & Sollid 1988).

The island can be divided into three geomorphologic regions (Fig. 1): the northern plain containing about 700 shallow lakes, the southern mountains which attain an altitude of 440 m a.s.l., and the eastern mountain, Miseryfjellet, with its highest peak at 536 m a.s.l.

The northern plain is a typical strandflat (Nansen 1922), most extensively developed at about 35 m a.s.l. Most of the lakes are small and only a few metres deep, and they are the result of selective glacial erosion.

The southern parts of the island consist of dolomites, limestones and shales, while the northern plain and Miseryfjellet are mainly built up of coal-bearing sandstones and limestones (Horn & Orvin 1928; Worsley & Edwards 1976). Karst phenomena are common in the limestone areas. Large scale features such as dolines, subterranean drainage, caves and surface collapse features occur in several places.

U-shaped valleys, such as Ymerdalen (Fig. 2) in the southern part of the island, demonstrate former glacial activity.

The permafrost is 60–70 m thick, and the upper 0.75 m thaws during the summer (Horn & Orvin 1928).

This paper is based on one month's fieldwork in 1993. Transport in the field was exclusively by foot, and the entire island was surveyed. Exact positions of observations were obtained by a GPS receiver.

Glacial sediments and erratics

The island is covered by a thin and discontinuous layer of Quaternary sediments, and large autochthonous block fields characterise much of the sandstone areas of central Bjørnøya (Fig. 3). A thin (0.5–1.0 m) diamicton is locally exposed in sections along the coastal cliffs. Due to its composition and in many cases direct presence above

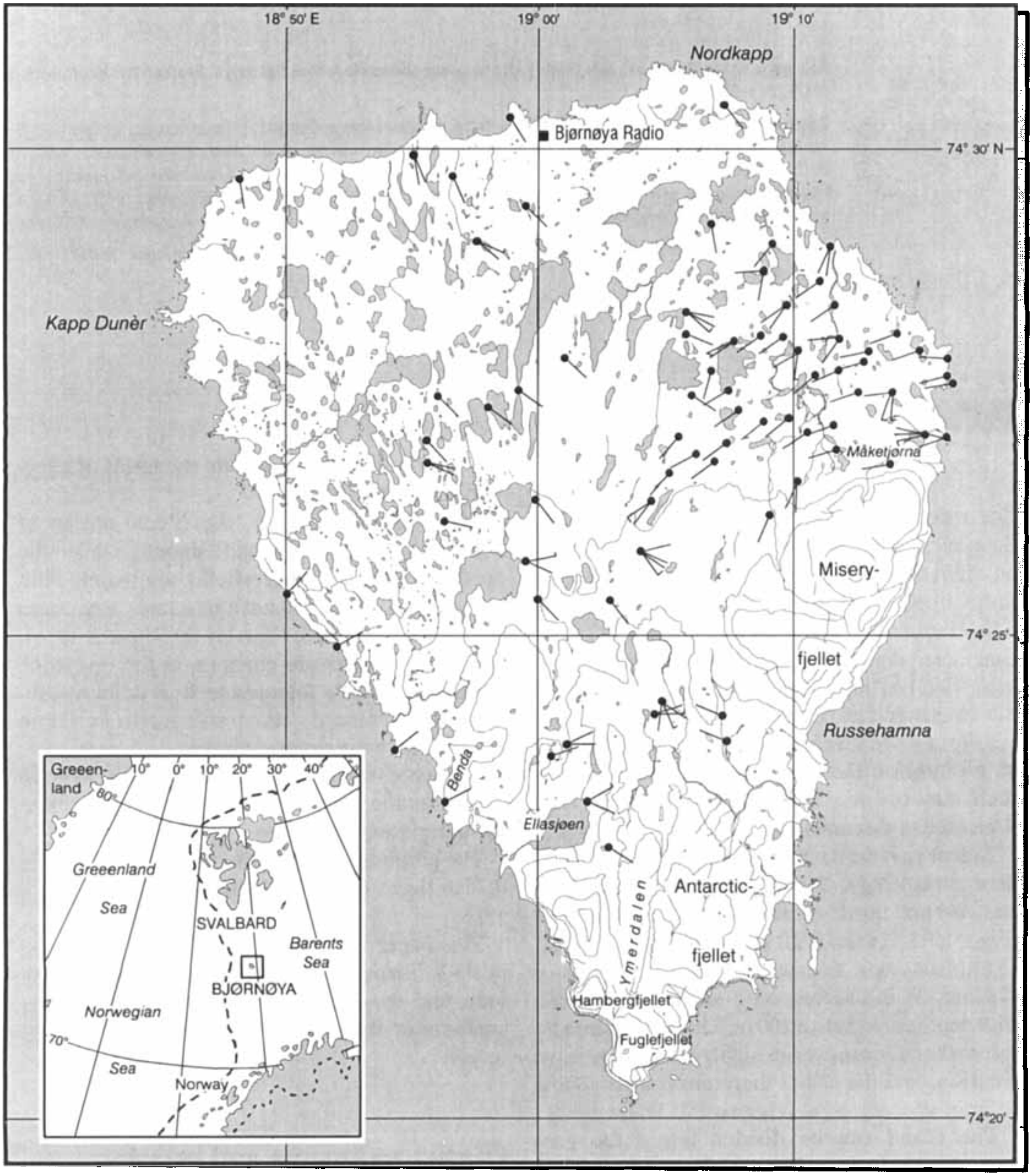

Fig. 1. Bjørnøya. Distribution of observed glacial striae on bedrock with indication of the direction of movement (toward the observation point, solid black circle). The dotted line on inset map is the 500 m contour line which indicates the position of the shelf edge.

Fig. 2. Bjørnøya seen from the south. The partly peat-covered mountain Hambergfjellet in the foreground, and the U-shaped valley Ymerdalen to the right of it.

glacier sculptured rocks, it is interpreted as a till, often disturbed by subsequent cryoturbation.

Numerous cobbles and boulders, some with glacial striae (Fig. 4), are found throughout the island, except in the upper mountain areas. The highest observations of erratics are from Antarcticfjellet, about 360 m a.s.l. (Fig. 5). Horn & Orvin (1928) also reported erratics on the northern plain, for example, a six-metre high heap of sandstones named Knorten south of Kapp Dunér, probably the frost-shattered remains of a very large sandstone boulder deposited there by glacial ice.

All erratics on Bjørnøya seem to be of local origin and have been transported only a short distance.

Traces of marine material on land should be expected if ice from a Barents Sea ice sheet had overridden the island during the last glaciation. During our extensive survey we thoroughly searched for shell fragments and other marine material, but found nothing of the kind.

Fig. 3. Blockfield area from central Bjørnøya.

Fig. 4. Striated boulder from the interior of Bjørnøya. Compass for scale.

No sub-till sediments, or other unconsolidated sediments suspected to be older than the last glaciation, were found.

Glacial striae

The distribution of observed glacial striae shown in Fig. 1 gives a true image of the quantitative and spatial occurrence of glacial striae on Bjørnøya. Glacial striae were probably first observed by A. G. Nathorst in 1870 (Nathorst 1899), on the westernmost capes of the island. One of these capes still has the name Rifleodden (Räffeludden) which means "striation cape". The map of Horn & Orvin (1928) shows the direction of glacial striae observed at about ten different sites. Sætersmoen & Hovden (1984) made observations on the Quaternary geology of Bjørnøya, and their unpublished report contains another forty observations of glacial striae, mainly from the middle and western parts of the island. We searched the entire island for glacial striae and made about one hundred new observations (Salvigsen & Slettemark 1993, 1994).

The glacial striae on Bjørnøya are best pre-

Fig. 5. Erratic block on Antarcticfjellet.

Fig. 6. Striated sandstone surface near Måketjørna, easternmost Bjørnøya. Glacier movement from the W (from the left on the photo). Compass for scale.

served in the sandstone areas, whereas the limestone surfaces seem to have no potential for long time preservation. Most of the striae were found after digging, brushing and washing bedrock surfaces (Figs. 6 and 7), and only a few sites with exposed striations were found on sandstone surfaces north of Miseryfjellet.

Ice movement directions were in most cases determined from small scale stoss and lee morphology, but crescentic gouges and large scale features such as roche moutonnées were also used.

No glacial striae occur in the mountainous areas of southern and western Bjørnøya, due mainly to the high degree of weathering on rock surfaces there. The northwestern part of the island, with its limestones and calcareous sandstones, is mostly covered by swamps, and the potential for finding striae there is very limited.

One of the main objectives of our work was to determine whether or not Bjørnøya had been covered by or infringed upon by the last Barents Sea ice sheet. With respect to glacial striae, the coast from Miseryfjellet to Nordkapp was most interesting in this context, because any striae from the Barents Sea glacier in this area would be easy

Fig. 7. Crossing glacial striae from southwestern Bjørnøya, near Ellasjøen. Glacier movement from ENE and the SE (from the left on the photo). The pencil shows direction of the oldest striae, from the SE, and the compass shows the direction of the younger straie.

to distinguish from those formed by local glaciers. There are numerous roche moutonnées here with more or less well-preserved striae and other small scale glacial features. Crossing striae also occur in many places.

Nearly all the glacial striae on the eastern part of the island indicate ice movement from the island toward the E and NE, but a more detailed study of age relationship shows that also older striae from an ice movement toward the N are preserved in some places. They occur in lee positions and reveal a systematic pattern of development in this area. Further west, striae towards NW and S–SW are found, but they are also compatible with a local ice sheet centred in the middle of the island.

The glacial striae shown on the map are of course not all synchronous, but the age differences are probably not large. The striae in the periphery of the island may be somewhat older than those in the middle of the island.

The oldest striae seem to be from a glacier centred on the northern slope of Miseryfjellet. Most probably a successive displacement of the ice-divide to the middle of the island, northwest of Miseryfjellet, then followed. The most numerous traces of glaciation on Bjørnøya are from glaciers centred there. The greatest thickness of ice then probably occurred near the geographical centre of the island.

Most of the glacial features on Bjørnøya seem to be from rather rigid ice, and plastically sculptured forms and features do not occur. The glacial features indicate a modest thickness of the ice cover, and the highest mountains were not necessarily covered by this local ice cap.

The main conclusion, however, is that there are no traces of a Barents Sea ice sheet on Bjørnøya. The many observed glacial features only indicate activity from local glaciers. The presence of such a regional ice sheet on the island at an earlier stage cannot be ruled out, but if it existed, the activity of local glaciers has erased all traces of it.

Age of the last deglaciation

We know little about the age of the glacial striae, but most probably they represent the latest deglaciation phase on the island. The best minimum ages for the deglaciation of Bjørnøya are from datings on lake sediments. The first lake corings on Bjørnøya were carried out by Hyvärinen (1968), who cored eighteen lakes and obtained five conventional radiocarbon dates between 8900 and 11,200 yrs BP. However, because of possible contamination with isotopically "dead" carbon from the local rocks, the accuracy of these dates could be questioned; Hyvärinen concluded that they at least suggested that the sediments in the Bjørnøya lakes covered the last 10,000 years.

During the PONAM 1993 expedition, new cores were taken from some of the previously cored lakes, and AMS radiocarbon dates on plant macro fossils (Bryophytes) gave ages up to 9800 years BP (Wohlfarth et al. 1995), confirming the conclusion of Hyvärinen (1968) that the sedimentation in the lakes started about 10,000 years ago.

On the summit plateau of Hambergfjellet (440 m a.s.l.) (Fig. 2), there is an extensive area of 1–3 m high, peat-covered and ice-cored hillocks (Engelskjøn 1987). Similar mounds also occur on top of Fuglefjellet (410 m a.s.l.). Dark brown peat, as well as underlying ice, are exposed by erosion in many places, but near-surface permafrost prevented further investigation by digging. The frozen peat or the ice lenses seem to rest directly on coarse limestone gravel. Samples of peat and moss remnants have been dated, and the bottom sample from a section on Fuglefjellet was dated to 8705 ± 120 BP (T-11227). This gives a minimum age for the first peat formation, and thus also for the deglaciation of the higher parts of Bjørnøya.

Sea levels

The first geologists who visited Bjørnøya found no traces of marine action higher than the present beach zone (Anderson 1900). Horn & Orvin (1928), however, advocated a contrasting view and concluded (p. 142), "The last movement of the land in post-glacial times consisted in a sinking to about 35 metres above the present level, followed by an uplifting to the present level." However, their observations of rounded pebbles interpreted to have been formed by beach processes are highly disputable and have never been confirmed by others.

Our investigations on Bjørnøya lead us to the conclusion that there are no traces of raised beaches on the island. In some places, especially along the coast north of Miseryfjellet, till-covered bedrock surfaces slope modestly and evenly towards the sea until they reach the present beach, revealing that after the deglaciation no sea levels occurred higher than that of the present. The same conclusion can be made from other sites on the northern and western coasts, where low land meets the sea. The area near the outlet of the small river named Benda, on the southernmost plain by the western coast, also demonstrates the non-marine character of the landscape above the present beach zone. At this site small, modern driftwood logs and other flotsam have been thrown by the waves up to 10 m above sea level, which as far as we know is the highest swell activity observed in Svalbard. Above that there are no traces of former sea levels. It can therefore be concluded that since the Late Weichselian deglaciation the eustatic sea level rise must have exceeded the isostatic recovery of Bjørnøya.

In 1864 Nordenskiöld placed an iron bolt in a rock outcrop in Russehamna (Fig. 1) and measured the contemporaneous sea level (see Horn & Orvin 1928). Accurate measurements and calculations were thereafter carried out in 1922 (Horn & Orvin 1928), and no change of sea level was found. At the same time, elevations of a number of triangulation points were determined in relation to the new sea level measurements. These altitudes have recently been compared with the results of tidal gauge measurements throughout one year, 1989–1990. The conclusion was the same as in 1922, that no measurable sea level changes have taken place on Bjørnøya in the intervening period (Trond Eiken pers. comm. 1995).

Conclusions

Only striae from local glaciers occur on Bjørnøya.

All displaced rocks found are from the island itself, and no sediments or rocks from the surrounding sea bed were transported onto the island during the last glaciation.

The Late Weichselian glaciation of Bjørnøya has been a local one, and the regional Barents Sea glaciation did not affect the island.

The likely age of deglaciation on Bjørnøya is about 10,000 yrs BP.

No raised beaches or other traces of sea levels higher than the present occur on Bjørnøya.

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