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Physical geography of the region between the Billefjorden and Austfjorden

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Interaction of marine glacial and lacustrine processes throught morphogenesis of the region between Billefjorden and Austfjorden, central Spitsbergen

ABSTRACT: Geomorphic relationships characteristic of the region between the Billefjorden and Austfjorden display a high degree of complexity. The relationships result from palaeogeographical changes which took place during the Late Pleistocene and Holocene. A topographic expression is the product of glacial, marine and lacustrine processes. In view of the gathered observational information and the ^{14}C date of 8.120 ± 60 yr BP (Gd-1900) provided in 1987 on marine shells found in glacial deposits between Hoglandvatnet and Ålandvatnet, inferences can be made as to a large extent of marine processes in the study area during the major part of the Earlier Holocene.

Key words: Arctic, Spitsbergen, palaeogeography.

Introduction

The region between the Billefjorden and Austfjorden occupies a special position in the contact zone between the strongly glaciated north-western portion of Olav V Land and the slightly glaciated eastern portion of Dickson Land (Stankowski 1987, 1988).

A northward-directed ice stream issuing from Mittag-Lefflerbreen flows over considerably diversified bedrock. Its morphologic characteristics are nunataks of Framstaken, Heclastaken, Furystaken. Because of the bedrock features, there are generally westward-oriented small-sized streams in spite

of the overall north direction of ice movement. They flow towards the foot of Trikolorfjellet and Odellfjellet, and block the outlets of glaciated Cambridgedalen and non-glaciated Ålanddalen. The zone of contact between glaciers and rock massifs of changing extent provides a lot of evidence which permits preliminary general interpretation of palaeogeographical changes of Late Pleistocene and Holocene age, occurring in the study area.

The palaeogeographical approach is based on the interpretation of the Norwegian air photos of 1961, a reconnaissance survey carried out in 1984 and research conducted in the summer of 1987. The resulting data contain many bits of evidence for complex palaeogeographical development of the study area.

Observational information and an outline of palaeogeography of the region between the Billefjorden and Austfjorden

The imprints of marine morphogenesis are encountered in the rock relief features of the region between fjords and in supraglacial material of present-day glaciers.

Supraglacial mantles over Balliolbreen found at 300—320 m a.s.l. are largely composed of marine pebbles (*cf.* Fig. 1). The same material is encountered in debris outcrops on sliding planes over which an ice stream from Balliolbreen combined with an ice stream from Cambridgebreen passes. Also the marginal zones of both glaciers contain abundant material of marine origin. The above evidence suggests that the glaciers erode relief features and marine deposits which formerly occurred in bedrock of at least their present-day middle part.

The occurrence of raised old marine relief features in an extension of Austfjorden appears to be suggested by high-lying flats in Ålanddalen and beaches on the east-facing slopes of Odellfjellet at the north margins of Sentinelfjellet and Trikolorfjellet. Detectable traces of sea action can be found up to the height of 250—160 m a.s.l. The high-lying flats were not liable to remodelling by glacial processes. There are now no grounds for determining the age of marine processes responsible for their formation.

In the north-western portion of the region between fjords, at the foots of Odellfjellet, there are glacial deposits containing shells at the height of about 170—150 m a.s.l. Shells of Astarte borealis are most often encountered. The incorporation of marine material into glacial deposits is indicative of glacier expansion and considerable restriction of the sea extent. Mittag-Lefflerbreen expanded northwards and simultaneously, its westward-running lateral streams abutted against Odellfjellet and Trikolorfjellet. The glacier

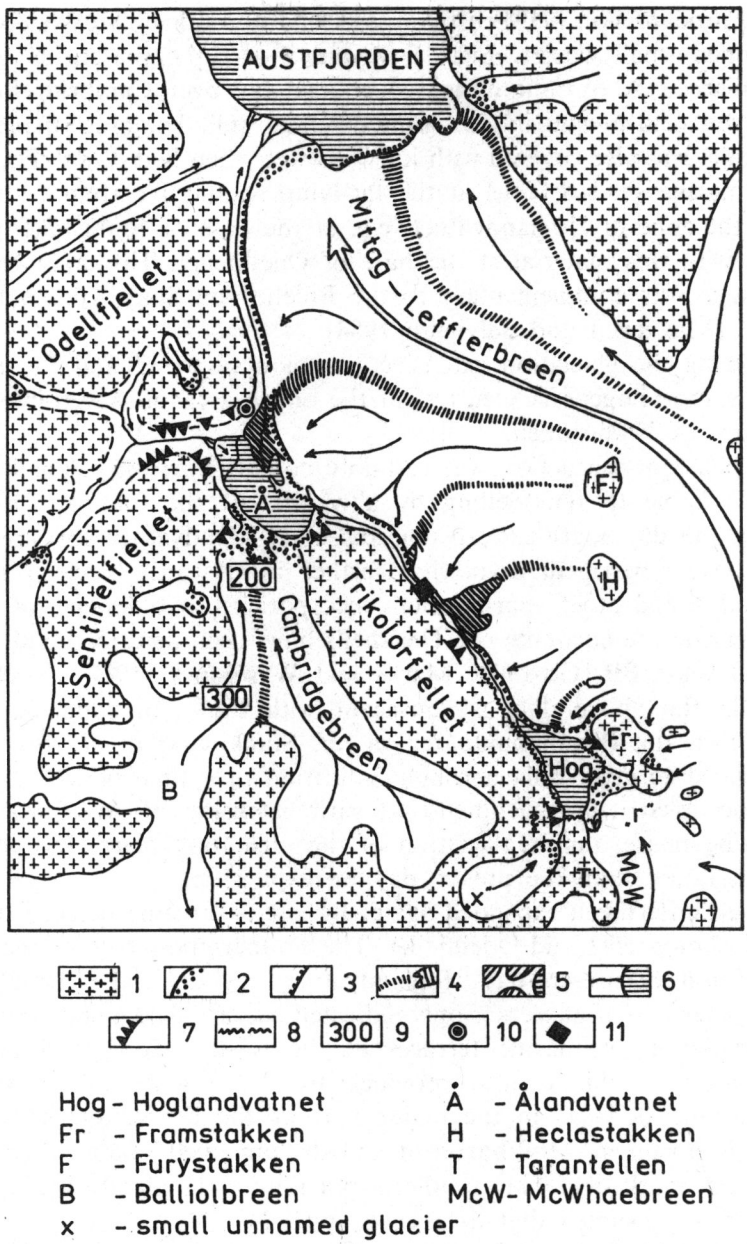

Fig. 1. Geomorphological sketch-map of the region between the Billefjorden and Austfjorden 1: rock massivs, 2: glaciers (arrows indicate ice movement directions), 3: ice cliffs, 4: medial moraine belts and extensive zones of supraglacial material, 5: non-glaciated valleys and fjord coastal areas, 6: fjords, lakes and streams, 7: marine bench remnants, 8: lake terraces, 9: ordinates for sites of occurrence of marine pebbles, 10: tills containing older-generation fauna, 11: site of marine fauna dated to about 8.000 years BP

occupied a depression between two crests of Framstaken. McWhaebreen and an unnamed small glacier (Fig. 1) expanded over the present-day basin of Hoglandvatnet. A continuous ice cover also lay over Cambridgebreen and Balliolbreen, and presumably in Ålanddalen as well. The area of present-day Ålandvatnet was also covered with ice. Tills were then laid down. They do not contain marine shell detritus at the far-lying southern extremities of Austfjorden (the zone of Hoglandvatnet, e.g. at the base of Framstaken) but are enriched with this material at the base of Odellfjellet. This may imply that the advance was complementary to the Billefjorden Stage known from the literature (Mangerud and Salvigsen 1984).

Following the glaciation extensive recession occurred and the processes of marine morphogenesis recurred in the entire area of Austfjorden as far as the foot of Framstaken.

This phase of sea action was certainly not of short-wave length. Glacial relief was liable to remodelling by abrasion. At the foot of Framstaken at the present-day south-eastern margins of Hoglandvatnet abrasion marine terraces have developed. Somewhat farther morthward, between Hoglandvatnet and Ålandvatnet, marine shells incorporated to sediments of the later glacial episode are encountered. The shells have been described and dated to 8.120±60 years BP (Gd-1900: Marks and Wysokiński 1987). It should be noted that the above date is consistent with those on zoogenic material derived from the Petuniabukta region (*cf.* Stankowski *et al.*, *this volume*). This single date gives only a rough indication of a time period over which the sea occupied a far-reaching southward extension of Austfjorden. After that marine phase, major glaciation of the area took place. Its extent was somewhat larger than the present-day ice expansion.

Mittag-Lefflerbreen expanded again. Its lateral streams reached again the foot of Trikolorfjellet and Odellfjellet. The southernmost part of the sea bay in the region of present-day Hoglandvatnet was not liable to glaciation. Limited expansion of glaciers is only indicated by partial coverage, remodelling and aggradation of marine terraces at the western foot of Framstaken. An indication of this is also provided by the absence of young glacial landforms and deposits in the major part of the depression between two crests of Framstaken. McWhaebreen and the unnamed small glacier (X) did not expand markedly. The southern portion of Hoglandvatnet remained ice-free. It is presumed that a lake occupied it.

Throughout glaciation an ice stream became released from Cambridgebreen-Balliolbreen to join lateral streams issuing from Mittag-Lefflerbreen. At the junction, behing the north end of Trikolorfjellet, there was presumably a small lake basin with a high water stage. Another much larger basin of this type occurred in the lower part of Ålanddalen which was glaciated in the upper reaches only.

Glaciation of the study area after the marine phase indicated by marine

shells incorporated into glacial deposits and dated to about 8.100 years BP initiated the Late Holocene phase of limited changes in ice expansion in the region between the Billefjorden and Austfjorden. Its characteristics are oscillations reflected in ice recession and transgression, as well as in the operation of associated lacustrine processes affecting a changing spatial extent of lake levels.

Permanent activity of Hoglandvatnet gave rise to welldeveloped lake beaches which contributed partially to the remodelling of marine terraces at the western foot of Framstaken and transformation of the outermost glacier margins. Evidence for severe fluctuations of water level in Hoglandvatnet is contained in sets of well-developed outwash terraces and major alluvial fans present on the south side of the lake. The outer part of the McWhaebreen margins was remodelled by lacustrine processes. Nowadays water level in the basin becomes intermittently changed. This can be inferred from blanketing fine lake sediments which reach as far upward as 6 m above the water level of the summer of 1987 that approximated 170 m a.s.l. Such deposits occur in a narrow and deep zone of rapid McWhaebreen recession, detectable after 1961 (*cf.* Fig. 1 "r").

Ålandvatnet located at the junctions of many valleys where the extent lines of glaciers were lable to intense changes displayed high degrees of extent and water level dynamics. When Cambridgebreen joined the Mittag-Lefflerbreen ice, an intermittent lake with a high water stage may have occupied an area at the northern extremity of Trikolorfjellet where the ice balance was negative. Lacustrine beaches can be recognized there up to the altitude of about 200 m. The beaches are found within glacier marginal landforms.

Lake sediments, *i.e.* blanketing fine lake deposits, occur around Ålandvatnet at the altitude of 170 m a.s.l. They are indicative of a general tendency towards a fall in water level, which was marked when ice fronts were liable to oscilation. At the foot of Trikolorfjellet and Sentinenfjellet, as well as in the marginal zones of Cambridgebreen and the Mittag-Lefflerbreen lateral streams lacustrine beaches are dominant morphologic features. Outwash terraces and deltas developed at the mouth section of Ålandelva which drains the water from the Southamptonbreen and Manchesterbreen and non-glaciated Ålanddalen.

Nowadays, as late as after 1961, two new lake basins developed as a result of the retreat of Cambridgebreen. Because of withdrawal of the ice stream front from Mittag-Lefflerbreen, another basin was formed and Ålandvatnet received a new outflow track oriented directly northward. When the extent lines of the glaciers reached farther, an outlet for water issuing from Ålandvatnet was found at the immediate southern extremity of Odellfjellet. Within all the new basins, covering beaches have been produced. They coincide with a-few-metre fluctuations of water table level.

The topographic expression of the region between the Billefjorden and

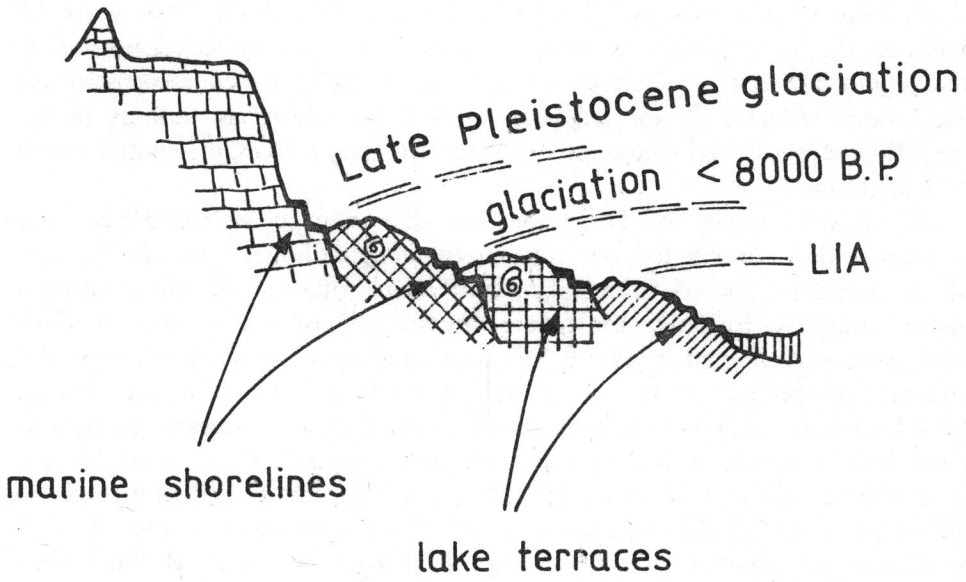

Fig. 2. Generalized sequence of glacial deposits, as well as marine and lacustrine relief features

Austfjorden, which retains the imprints of the Late Pleistocene and Holocene palaeogeographical changes is indicative of great complexity of the controlling processes. A comprehensive picture of changes in the study area morphology under the influence of marine, glacial and lacustrine factors is provided in Fig. 2.

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Streszczenie

Międzyfiordzie Bille-Aust zajmuje szczególną pozycję kontaktu silnie zlodzonej północno-zachodniej części Olav V Land i dosyć słabo zlodowaconego wschodniego obrzeża Dickson Land. Rzeźba i właściwości geomorfologii obszaru uwarunkowane zostały późnoplejstoceńskimi i holoceńskimi procesami glacjalnymi, morskimi i limnicznymi (*por.* fig. 1).

Na zboczach dolin do wysokości 250—260 m npm stwierdzono obecność poziomów morskich nie przeobrażonych glacjalnie. Również w materiale supraglacjalnym Billiolbreen do rzędnych około 300 m npm licznie występują otoczaki morskie.

Po starej, bliżej nieokreślonej fazie morskiej zaznaczyła się dosyć ekstensywna glacjacja. Wyrazem są osady glacjalne „starszej generacji" wyścielające dolne części dolin. Wskutek deglacjacji w rozległym przedłużeniu Austfjorden, aż po strefę dzisiejszego Hoglandvatnet powróciły morfogenetyczne procesy morza. Doszło do uformowania abrazyjnych poziomów morskich — np. u podnóża Framstaken (*por.* fig. 1). W morzu tego okresu rozwijało się życie biologiczne czego wyrazem są muszle morskie wydatowane metodą ^{14}C na 8120 ± 60 lat BP; Gd-1900 (Marks i Wysokiński 1987).

W wyniku kolejnej umiarkowanej glacjacji obszaru doszło do częściowego przemodelowania i przykrycia przez osady i formy glacjalne poziomów morskich u podstawy Framstaken. Zoogeniczny materiał morski włączony został do utworów glacjalnych — stanowisko pomiędzy Hoglandvatnet i Ålandvatnet (*por.* fig. 1).

Począwszy od środkowego holocenu na analizowanym obszarze mają miejsce okresowe drobne awanse i recesje lodowców. Zmienne zasięgi lodowców stały się podstawą powstania i przemian zbiorników jeziornych. Morfologiczne oddziaływanie tych zbiorników zaznaczyło się półkami jeziornymi.

Morfologiczny wyraz międzyfiordzia jest skutkiem przemian paleogeograficznych późnego plejstocenu oraz holocenu i odznacza się poważną złożonością działających procesów.