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JERZY GIŻEJEWSKI & WALDEMAR ROSZCZYNKO

Offshore sedimentation in the Hyttevika Bay, South Spitsbergen

ABSTRACT: In the intertidal and offshore zones of the Hyttevika Bay (South Spitsbergen) two phases of deposition are recognizable. During the first one, the accumulation results from melting of sea ice blocks and a calf ice whereas during the second phase the successive generations of beach ridges and beach sediments are formed in a shallow offshore zone. These phases are noted in raised marine terraces as a bipartity of their sediments. Basing on that, an evolution model of the sediments of raised marine terraces and discussion on their age are presented.

INTRODUCTION

The studies were carried through in the Hyttevika Bay as far as the shores of the Dunøyane Archipelago in south Spitsbergen. Several echo-sounding profiles and under-water observations with scuba-diving method were done (Text-fig. 1), and samples of undisturbed sediments were collected.

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SHORE ZONE STRUCTURES

Close to the recent shoreline in the Hyttevika area there are two raised marine terraces at 2—4 m aHT and 7—12 aHT (Birkenmajer 1958, Jahn 1959). These terraces are composed of gravels, consisting of pebbles of vein-quartz, quartzites and quartzitic sandstones. There are also some pebbles of gneisses and schists. The material at the terrace surfaces is well rounded and the pebbles are spherical. Above the terraces there are monadnocks built of more resistant inserts of quartzites; the de-

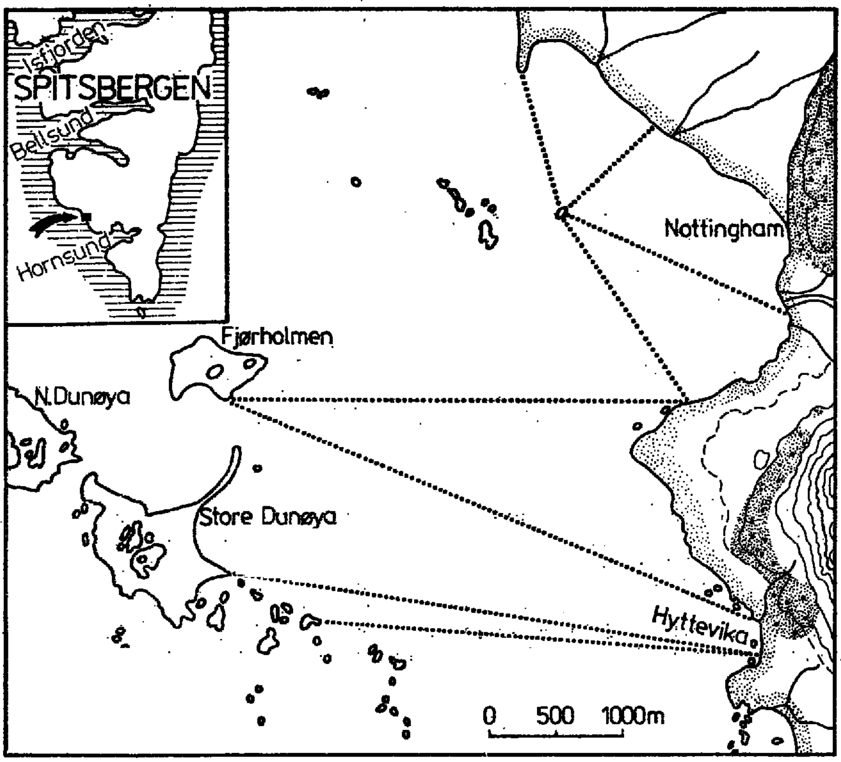
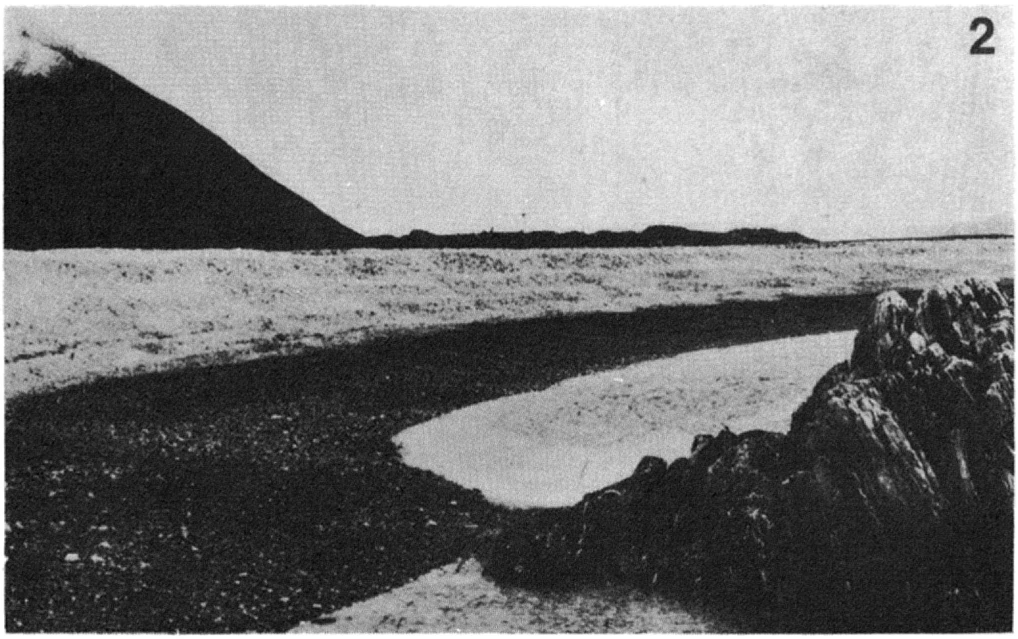


Fig. 1. Sketch-map of Hyttevika Bay and Nottingham Bay in south Spitsbergen; dotted lines indicate the echosounding profiles

pressions filled with terrace sediments have been formed along the exposures of schists and phyllites. The bedrock is represented by the Deilegga Group of the Late Precambrian Hecla Hoek Succession (Radwański & Birkenmajer 1977). The bedrock in the offshore is of a similar structure.

During the observations, a tidal range in the Hyttevika Bay was equal 1.5 m and a mean width of the tidal flat from 20 to 30 m. This zone has a uniform concave profile (Text-fig. 3*A*). The sediments are composed of sands and gravels with silty-organic intercalations, comprising the kelp remains, mainly of the *Laminaria* type.

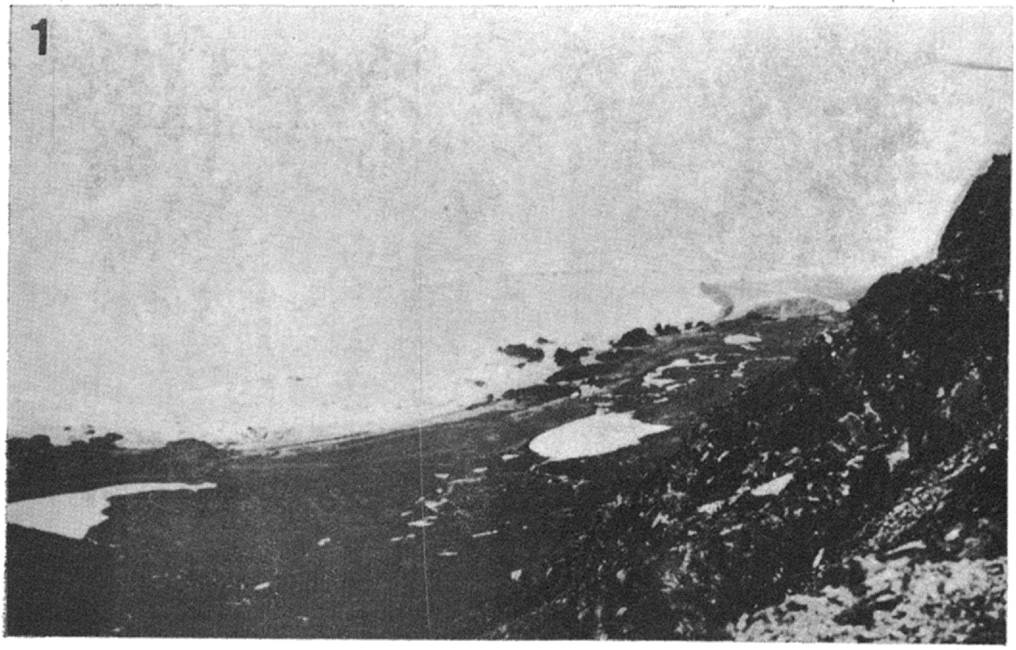
The offshore from Hyttevika to Store Dunøya possesses a very uniform profile. Two rows of skerries (*I* and *II* in Text-fig. 2 and Pl. 1, Fig. 1), are arranged along the strike of quartzitic inserts (Pl. 2), similar



1 — General view of Hyttevika Bay at low tide

2 — Small bay, south of Hyttevika Bay; several generations of gravelous beach ridges are visible

1



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1 — General view of shore zone, south of Hyttevika Bay; skerries are emphasized by breaking zones

2 — Skerries in Nottingham Bay at low tide to those forming the monadnocks at the shore. They are separated by vast depressions with slight bottom inclinations (*cf.* Text-fig. 2). Between the skerries *I* and *II* the bottom is composed of pebbles, cobbles and boulders, from several to several dozen centimetres in diameter. All of them are usually spherical, rarely flattened. In the latter case, they are lying flat on the bottom; their roundness in offshore sediments is worse than that of beach and tidal flat deposits. There are only some fine-grained sediments. The sand occurs in patches, a few square

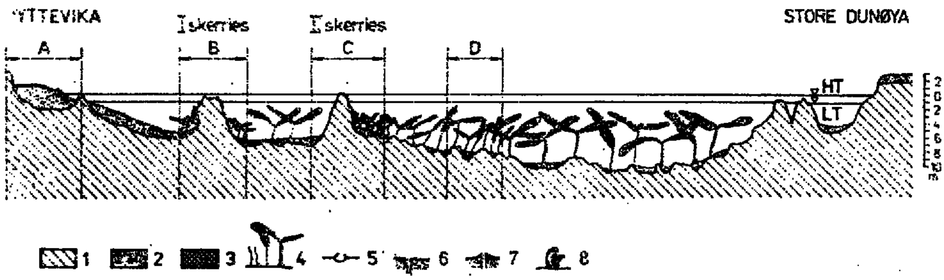


Fig. 2. General cross-section of the offshore between Hyttevika and Store Dunøya; A—D detailed cross-sections, presented in Text-fig. 3 *A—D*

1 bedrock, *2* sandy and gravelous deposits, *3* soil with tundra vegetation, *4* kelp, *5* Ascidiae, *6* tubular Polychaeta, *7* tubular Polychaeta with dwelling monticules, *8* sponges

metres each, deposited mainly at the skerry feet. Amidst pebbles and boulders there appears some silty and clayey matrix, coming from glacial rivers that enter Isfjeldbukta, Skoddebukta and Nottinghambukta; it is transported from there by wind-generated currents.

Between the skerries *II* of the Hyttevika Bay and the nearshore skerries of Dunøyane (*cf.* Text-fig. 2) there is an offshore zone with a maximum depth of about 10 m. The bottom is built there of low rock ridges, about 0.5 m high. The depressions amidst them are partly filled with angular, coarse-grained sediments of a very bad sorting. Sands are very rare and occupy small areas. The thickness of the sediment cover in this zone is much varying and it is generally small (*cf.* Text-figs 2 and 3*C—D*).

The greatest changeability of the sedimentary environment is noted just close to the skerries. The latter protect the bottom sediments from waves. At the inland side of the skerries there are greater patches of fine-grained sandy and silty deposits noted in the offshore zone. At the surface of these sediments there occur different wave and wave-current ripples. On the other hand, at the skerry feet there is no accumulation, even no single rock fragments which could come from the destruction of these skerries.

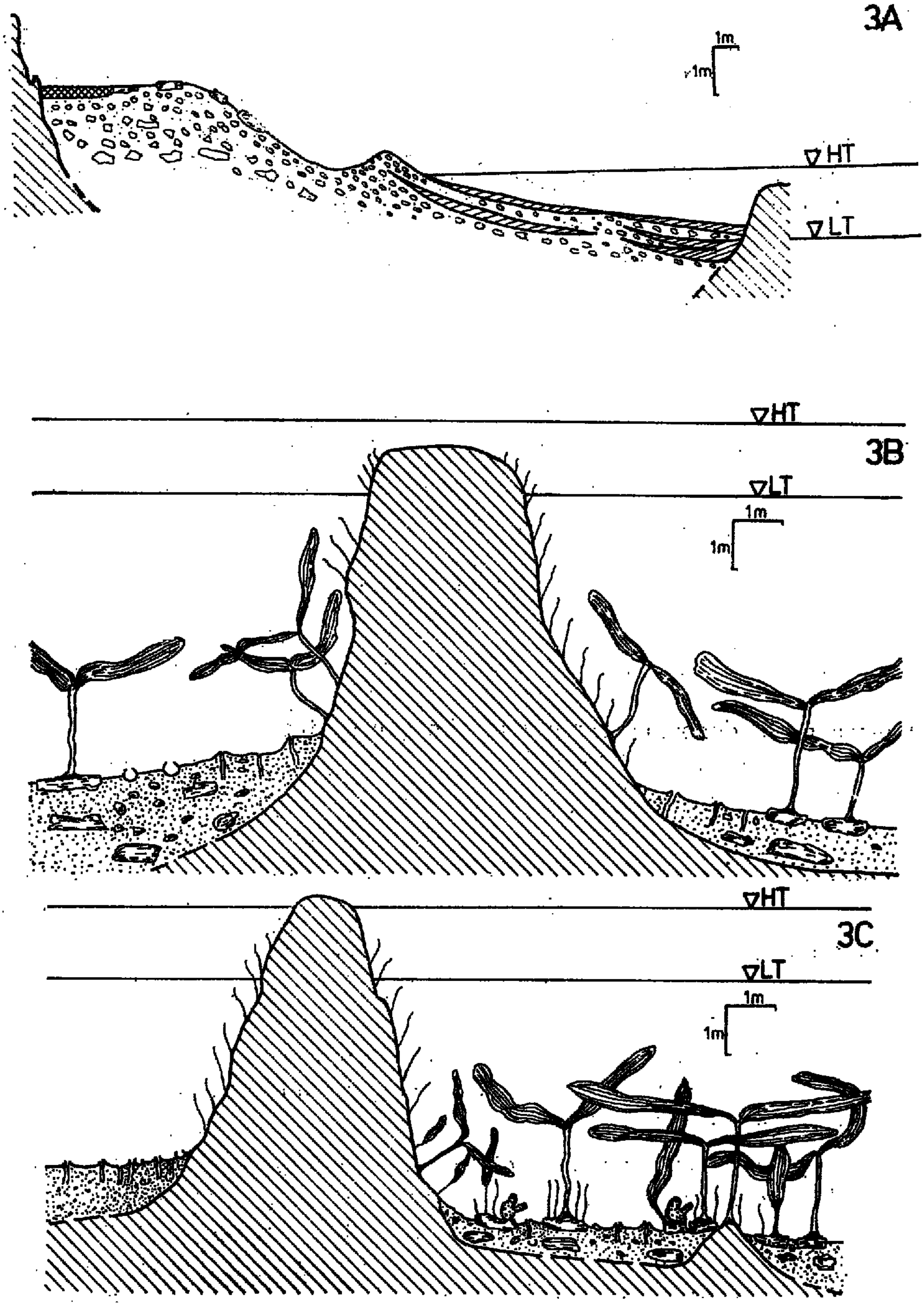
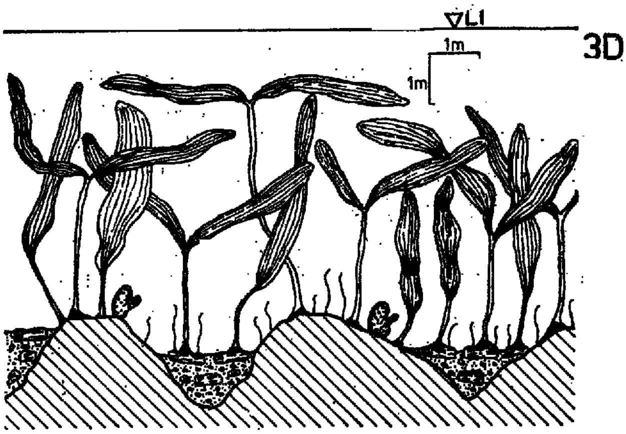


Fig. 3. Detailed cross-sections of the offshore of Hyttevika Bay; for location and explanations see Text-fig. 2



BENTHIC ORGANISMS; THEIR DISTRIBUTION AND SIGNIFICANCE

The skerries and their nearest surroundings create the most differentiated biotic environment. The skerries are overgrown by kelp, the morphologic variability of which is connected with depth changes. Close to the surface there are filamentous algae and representatives of the order Fucales, in deeper zones the great algae of the order Laminariales predominate. The laminarids prevail also at the bottom flattenings where they overgrow the bedrock outcrops as well as loose rock fragments. In this zone they are accompanied by fine red algae and few sponges. Patches of fine-grained sandy and silty sediments are devoid of vegetation but they are densily inhabited by burrowers, represented mainly by the taxonomically unrecognized Polychaeta. Some of the form the pipes, locally frequenting the sediment. The other polychaetes form dwelling sandy monticules, which occur also at these bottom fragments where the sediment is composed of sand and gravel. Due to their activity a secondary concentration of sand in dwelling monticules is noted. The sand comes from amidst pebbles and boulders, and thus a certain sediment selection is noted. The Ascidiae and burrowing bivalves are relatively rare in the top layer of the sediments (Text-fig. 3*B*—*D*).

In the zone between the skerries *I* and *II* of Dunøyane, the laminarids form almost a compact cover, 2—3 m high (Text-fig. 3*D*) that protects the bottom sediments from waves during the growing phase. In the sediments subjected to waves as well as in those covered by thick vegetation, no concentrations of plant remains were noted. The algal thalluses, detached from the bottom by waves, are transported towards the shore and deposited on a tidal flat and at the beach.

SEDIMENTARY PROCESSES IN THE OFFSHORE ZONE

The thickness of a sedimentary cover in the offshore zone is small and greatly varies. The thickest series appears between the shoreline and the I*st* skerries; at a far distance from the shore the sediments fill locally the bottom depressions. In the tidal flat there are sandy and sandy-gravel deposits (Text-fig. 3*A*). A very changeable dynamics in this zone causes the opposite evolutionary trends in pasticulor subzones — an erosion predominates at concave transversal profiles, whereas an accumulation — at the shore with numerous generations of beach ridges. (Pl. 1, Fig. 2). There is a periodical sedimentation of laminarid remains or even, overlying of these sediments by sands and gravels, connected with storm attenuation phases.

The beach and the tidal flat supply with deposits for sedimentation in the neighboring area, spreading as far as the I*st* skerries. In this area, the sedimentation occurs mainly due to the wave and wave-generated current transport. In the further offshore where coarse-grained sediments, with an admixture of other fractions of varying roundness and decidedly bad selection, fill the bedrock depressions, the sedimentation rate is considerably slower. As the first skerry row makes up an evident obstacle that protects against a sediment supply from the shore, the sediments outside the I*st* skerries are thought to have been deposited due to the ice-rafted transport. Shore-ice blocks carry the better rounded and selected sediments from the beach and the tidal flat whereas a calf ice from the Torell Glacier and the Hornsund glaciers carries a non--rounded vari-grained sediment. For that very reason the offshore deposits are very changeable, and their sedimentation rate is low.

DEVELOPMENTAL MODEL OF OFFSHORE SEDIMENTS

Basing on observations in the Hyttevika Bay and in the neighboring bays where beach sediments form many generations of beach ridges accreted towards the sea (Pl. 1, Fig. 2), the following evolution scheme of offshore sediments can be presented that results in a formation of marine terraces.

During the first phase, the sedimentation in the offshore zone is limited to the sediments falling down from melting shore ice blocks and calf ice (Text-fig. 4*A*). A gradual shallowing of the offshore due to deposition, results in an increased influence of wave processes on the bottom. In the sedimentary sequences this change is marked by an appearance of better rounded and selected material (Text-fig. 4*B*). An uplifting of the bottom due to isostatic or neotectonic movements accelerates this process.

The upper part of the terrace sequence consists of sediments formed in the intertidal and beach zone. A lower part of the section is formed in the intertidal zone by waves, wave-generated currents and tidal

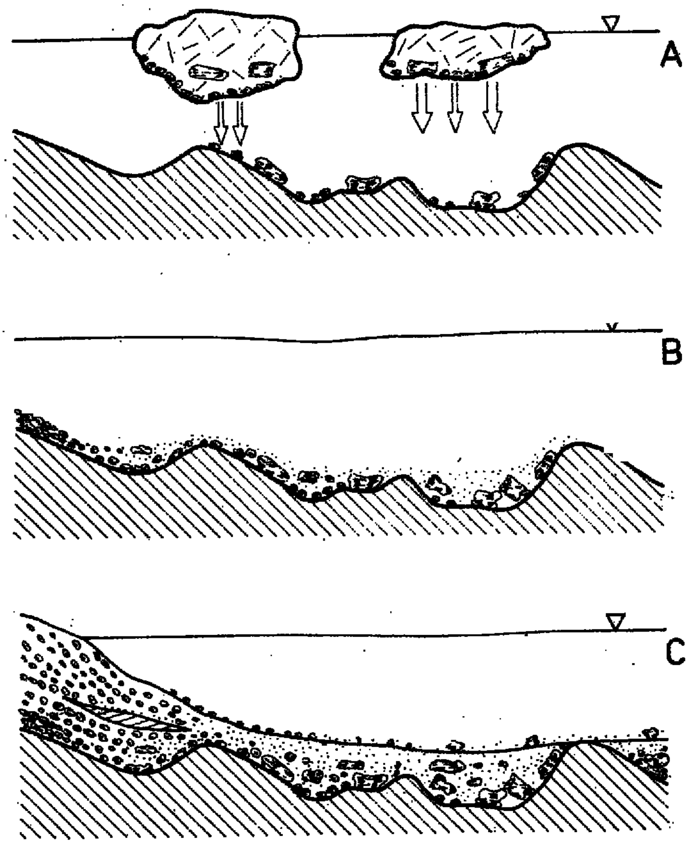


Fig. 4. Stages of the offshore development in Hyttevika Bay; explanation in the text

currents, the upper one is the result of accumulation of successive generations of beach ridges (Text-fig. 4C). It is therefore apparent that the scheme presented by Birkenmajer (1960) for the formation of marine terraces by an accretion of beach and storm ridges during synchronous land uplifting, shows only the last phase of the evolution of terraces.

This scheme illustrates well an evolution of the 8.5 m terrace sediments in the Marmorneset area, reported by Birkenmajer (1960). Only the presence of detritus of bivalve shells and acorn bornacles in the sediments seems surprising as they are not observed in the present offshore and beach zone.

ORIGIN OF THE BEDROCK SURFACE IN OFFSHORE ZONE

Morphologic features and shading of the bays by Dunøyane and Dunøyskjera demands for a possibility of the formation of the present offshore bottom by a conventional abrasion. There are two possible ways to explain an origin of the offshore bottom in this area.

(*i*) The bedrock surface is an exaration surface in the offshore zone (Text-fig. 5*A*), formed by a piedmont-shelf glacier originated due to

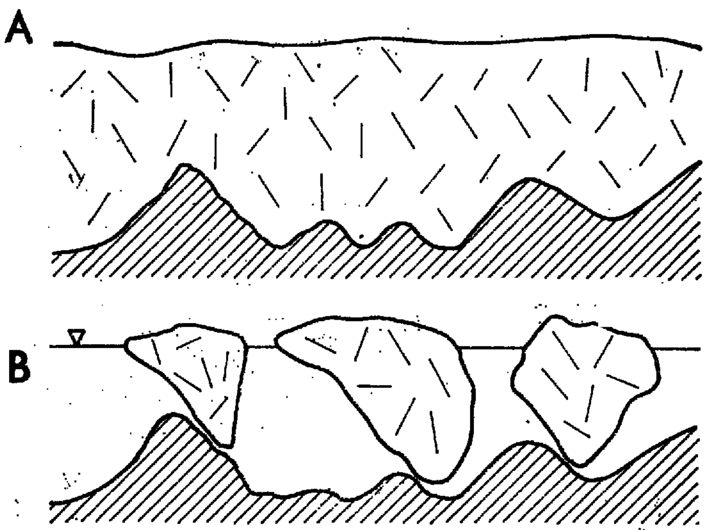


Fig. 5. Possible mode of origin of the offshore surface in Hyttevika Bay: **A** — as glacial exaration surface, **B** — as abrasion surface with marine-ice action

a coalescence of the valley glaciers (Werenskjold, Bratteggdalen and Steinvikdalen glaciers). For relation of the recent surface of the offshore bottom to the terraces, its formation should be connected with the last glacier advance (Jahn 1959b) but there is no evidence for such a far extent of the glaciers at that time (*cf.* Baranowski 1968; Kłysz & Lindner 1981; Lindner, Marks & Ostaficzuk 1982).

(*ii*) The offshore bottom is an abrasive platform, formed mainly by the sea ice (Text-fig. 5*B*). The abrasion was initiated at the sea level several metres higher than nowadays. It could correspond to the period 200—300 years B. P. (Jahn 1959a). The rate of these processes is sufficiently quick (*cf.* Fairbridge 1977) to build this platform during some hundred years.

Institute of Geology
of the Warsaw University,
Al. Żwirki i Wigury 93,
02-089 Warsaw, Poland

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J. GIŻEJEWSKI i W. ROSZCZYNKO

SEDYMENTACJA W STREFIE PRZYBRZEŻA ZATOKI HYTTEVIKA NA POŁUDNIOWYM SPITSBERGENIE

(Streszczenie)

W strefie przybrzeża zatoki Hyttevika na południowym Spitsbergenie (*patrz* pl. 1—2) przeprowadzono obserwacje podwodne i wykonano profile echosondażowe (fig. 1) w celu określenia morfologii dna i przebiegu współczesnych procesów sedymentacji *. Stwierdzono małą miąższość osadów w badanej strefie i ich bardzo nierównomierne rozmieszczenie. W osadach zaznacza się wyraźnie tendencja do wzrostu miąższości oraz stopnia obtoczenia i selekcji w kierunku linii brzegowej (fig. 2—3).

W oparciu o charakterystykę osadu i obserwacje przebiegu procesów sedymentacji stwierdzono, że zasadniczą rolę w powstawaniu pokrywy osadowej przy-

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* Pracę wykonano w ramach planu międzyresortowego *MR. I. 16. B.*

brzeża odgrywa wytapianie osadów z kier lodu morskiego i lodowcowego (fig. 4A). Stopniowe spłycanie przybrzeża zwiększa udział procesów falowych w transporcie i obróbce osadu (fig. 4B). W ostatnim etapie powstają piaszczysto-żwirowe osady równi pływowej i plaży (fig. 4C). W efekcie procesy te prowadzą do powstania morskiego tarasu akumulacyjnego (pl. 1, fig. 2).

Powierzchnia podłoża w strefie brzegowej mogła powstać bądź jako powierzchnia egzaracyjna lodowca szelfowego (fig. 5A), bądź — co wydaje się znacznie bardziej prawdopodobne — jako powierzchnia abrazyjna, w formowaniu której ważną rolę odegrała mechaniczna działalność lodu morskiego (fig. 5B).