Gravel Fraction on the Spitsbergen Bank, NW Barents Shelf*

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The gravel fraction of the bottom sediment on the Spitsbergen Bank, located south of Svalbard in the NW Barents Sea, is composed predominantly of clastic sedimentary rocks, especially sandstone and shale. Between sampling stations the proportion of eight lithologic types is markedly different, ruling out the possibility of large-scale transport of the gravel by ice-rafting. Striated pebbles occur in small numbers: a few are exotic in composition, but most are similar to a non-striated rock-type at a given station. This suggests that the gravel was formed by reworking of previously deposited glacial material, which tends to be locally derived.

The sandstone pebbles in the gravel include a variety of petrographic types, most of which are identical or similar to sandstones of known stratigraphic position on Svalbard. Observations on Mesozoic rocks on Bjørnøya, Hopen and southern Spitsbergen, and on the distribution of pebbles as described herein, suggest that the Spitsbergen Bank is underlain by nearly flat-lying Mesozoic sedimentary rocks similar to those known on Svalbard. The overall structure is a gentle syncline; a southward continuation of the dominant regional structure of Spitsbergen.

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Introduction

The Spitsbergen Bank is approximately 200 by 350 km, elongated NE–SW, lying south of Svalbard in the NW part of the Barents Sea (Fig. 1). It includes Bjørnøya (Bear Island) at its SW end, and Hopen at its NE end. To the north it is separated from Spitsbergen by the Storfjord Trough, and to the south is the Bjørnøya Trough. The surface of the bank varies from rough to smooth, and generally lies 40–100 m below sea-level, though highs of 17 m occur in one area. The bank is covered by gravel, sand and shell material, with some large stones (cobbles and boulders) and clay. Bedrock crops out near Hopen. The Storfjord Trough reaches depths of over 300 m, and is covered by clay, locally with sand and gravel.

The present knowledge of the geology and superficial deposits of the Barents Sea is based mainly on work carried out by Soviet scientists, summarised in English by Klenova (1966) and Emelyanov et al. (1971). Dibner et al. (1970) described Lower Carboniferous to Late Cretaceous/Paleocene fossiliferous limestones dredged from 21 stations in the Barents Sea. As Soviet workers (op. cit.) maintain that the bottom sediment is locally derived, as opposed

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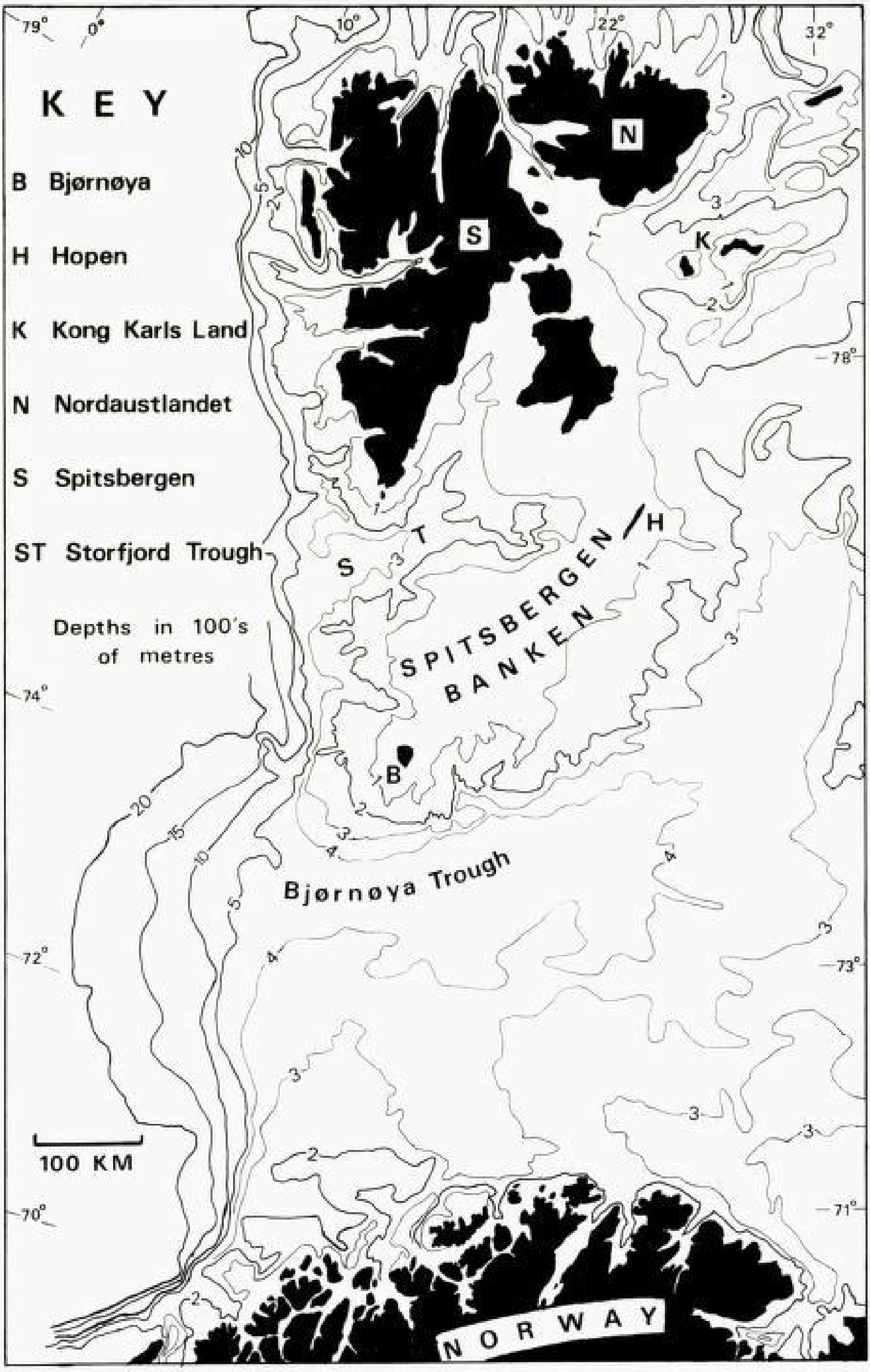

Fig. 1. Spitsbergen Bank and surrounding area.

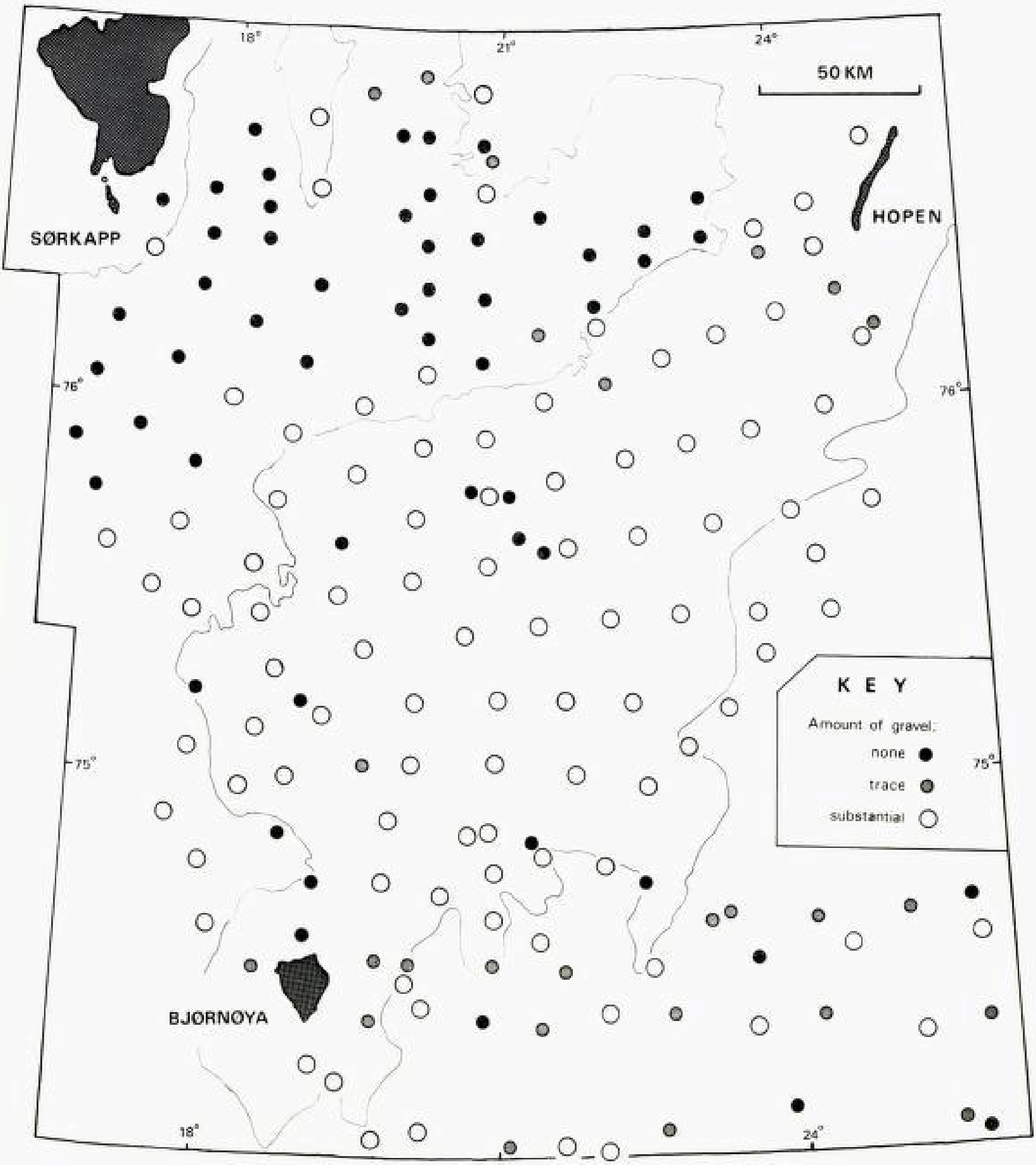

Fig. 2. Location of sampling stations, with relative abundance of gravel. Hundred metre contour shown.

to ice-rafted, glacial material, Dibner et al. concluded that the Spitsbergen Bank is underlain mostly by Carboniferous to Permian bedrock, with Mesozioc rock in the E and SE part of the Bank.

Spjeldnæs (1971), in a short note, described a siltstone slab collected from the central part of the Barents Sea, which he interpreted as Triassic and of local origin.

In response to the growing need for scientific information with regard to locating areas of oil potential, the Continental Shelf Division of the Royal Norwegian Council for Scientific and Industrial Research (NTNFK) initiated the Barents Sea Project, based on a proposal by the Norwegian Polar Institute in 1969.

In 1971, bottom samples were recovered by the use of large and small grabs, dredges, gravity cores, and diving. Bottom photographs were taken and continuous seismic profiling was carried out. The gravel fraction was picked out of the sample, and described lithologically within arbitrary size classes. In a few cases, only some of the pebbles were retained from the sample. About 90 of the 177 sampling stations contain some gravel (Fig. 2).

Methods

In a preliminary study, 10 sandstone pebbles were selected from each of eight stations over a wide area to determine the degree of variation in sandstones both within and between stations. Striated pebbles were also picked out. For the detailed study, 22 stations covering most of the area were selected (one subsequently discarded), each with relatively large quantities of gravel. The samples were treated in the following way: material smaller than 2 cm was removed and set aside. The remainder was divided into eight lithological classes, or 'types', of which all but one are sedimentary rocks. Each type was further subdivided into striated and non-striated components. Groups of pebbles were then weighed and converted to per cent of the type at a particular station. Taking all the stations together, sandstones make up 56% of the gravel fraction, shales 17%, siltstone and shale 11%, siltstone 9%, and the remaining four types 7%. Other lithologies, such as flint, compose less than one per cent at any given station, and so were not included in the study.

The characteristics of the eight lithological types are:

1) Sandstone: usually very fine-grained to coarse-grained, mostly well indurated, grey to greenish grey, with occasional brownish weathering rims. Green sandstones with abundant glauconite occur at some stations. Calcite cement is occasionally present; the amount of matrix is generally low.

2) Shale: dark grey to black, somewhat fissile mudstones with high clay content and occasionally fossiliferous. Small mica flakes may be present.

3) Siltstone and Shale: pebbles with thin alternations of dark grey shale and grey siltstone (sometimes grading into very fine sandstone) with marked contrast in grain size; bioturbation is abundant.

4) Siltstone: mainly grey to dark grey massive or faintly laminated siltstone, occasionally with a high clay content.

5) Clay Ironstone: dense claystones with a characteristic dark purple surface colour, and often with a brown-yellow weathering rim several millimetres thick. Unoxidized claystone is medium to dark grey.

6) Limestones: light coloured, massive, fine-grained limestones, oolitic limestones, and dark, coarse-grained fossiliferous limestones.

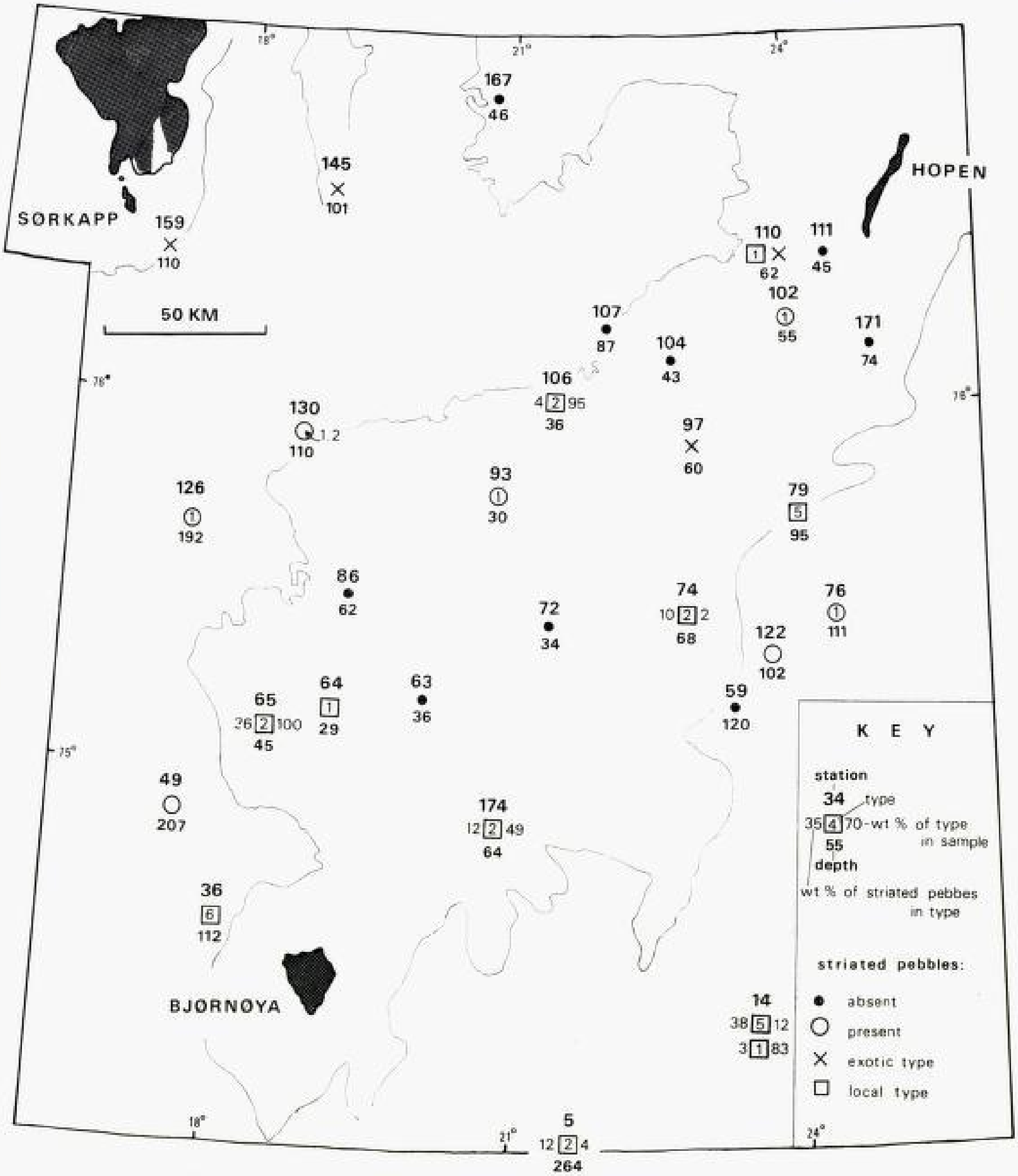

Fig. 3. Occurrence of striated pebbles. The lithologic type numbers are explained in the text. Hundred metre contour shown.

7) Crystalline Rocks: dark diabase, and coarse, reddish and grey granite and slightly foliated gneiss.

8) Marl: light grey, lime-rich claystone.

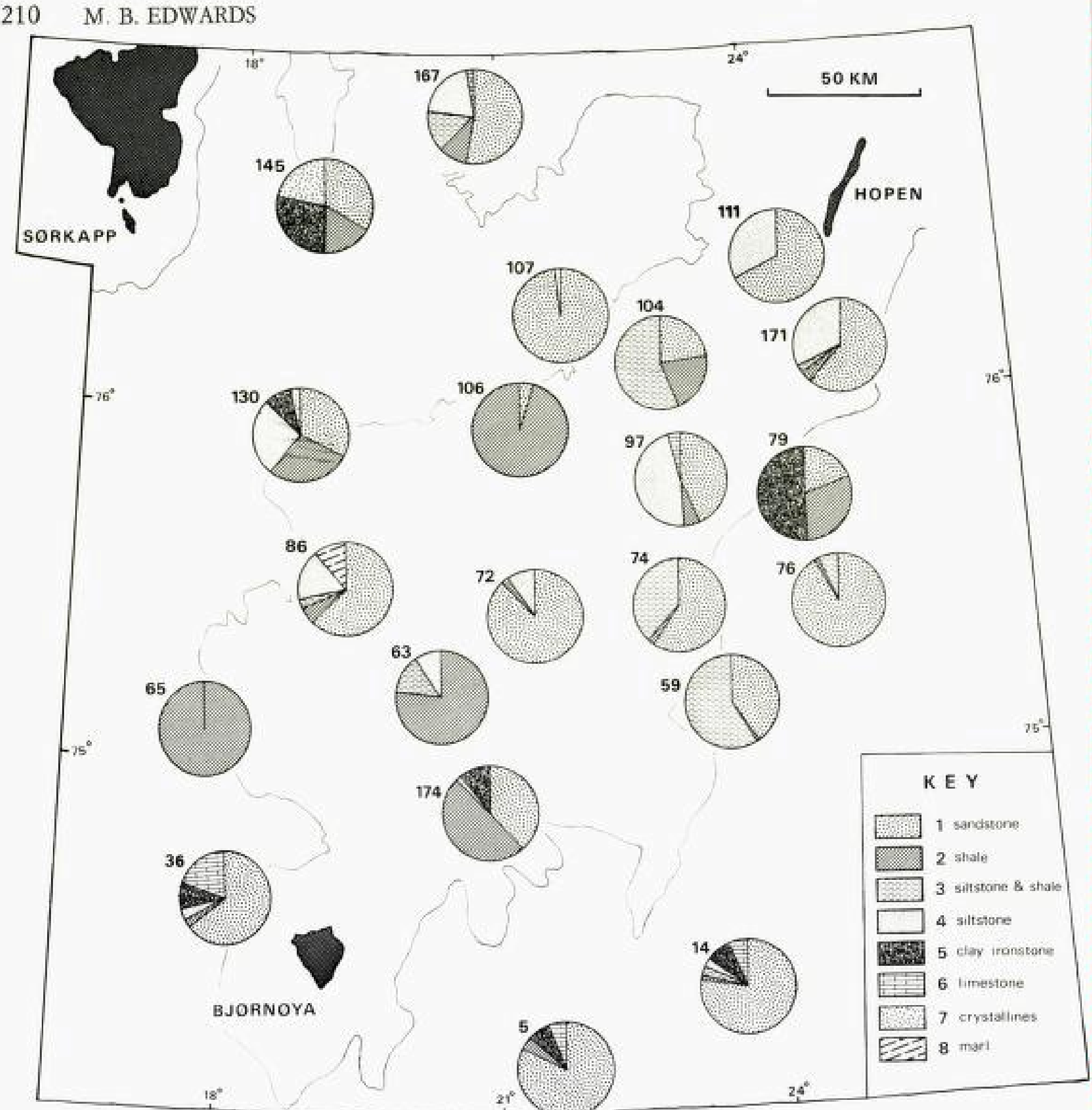

Fig. 4. Distribution and abundance of lithologic types. Pie diagrams show the weight per cent by lithologic type of non-striated pebbles at 21 stations (station number is given with each sample), as discussed in the text. Hundred metre contour shown.

Striated pebbles

Striated pebbles, found in 18 of 28 stations, are broadly distributed (Fig. 3). In 13 of the 22 stations in the detailed study, the striated pebbles are similar in composition to a substantial part of the non-striated pebbles in a given sample.

Lithological type

The distribution of the eight lithological types is shown in Fig. 4. The large differences in lithology between adjacent stations is striking. In general, either sandstone or shale is the predominant lithology at a given station, but siltstone and shale, and clay ironstone are locally abundant.

Sandstone petrography

Sandstones in the gravel material vary greatly in appearance, both in hand specimen and in thin-section. While some stations contain a homogeneous assemblage of sandstone pebbles, other stations may have several petrographic types mixed together. Rather than studying exclusively the gravel material, it was felt that more significant findings would result from a comparison between the sandstones in the gravel and those on the neighbouring land areas. A reconnaissance of the petrography of Upper Paleozoic and Mesozoic sandstones of Svalbard suggested that the sandstones in the gravel are similar to Mesozoic types. Accordingly, during field work in south Spitsbergen in 1973, close sampling of Mesozoic sandstones was carried out. Fig. 5 shows results of petrographic observations on these sandstones, which range from the base of the Sassendalen Group (Triassic) to the middle part of the Helvetiafjellet Formation (L. Cretaceous), and which are supplemented by material made available by other workers from other parts of Svalbard. These observations, discussed below, form the basis for study of the sandstones in the gravel.

The most easily distinguished sandstones in the sequence (Fig. 5) are those in the Kapp Toscana Group, particularly the upper, sandstone-rich De Geerdalen Formation. These sandstones always contain large quantities of feldspar and rock fragments, and the quartz content may be less than 50%. Volcanic rock fragments (an important indicator type), chert and polycrystalline quartz are abundant. The fine grain-size of the underlying Sassendalen Group (in the material collected from Sørkappland) prohibits the identification of rock fragments, but the feldspar content is similar to that of the Kapp Toscana Group. The overlying Wilhelmøya Formation (Worsley 1973) contains less feldspar and rock fragments than the Kapp Toscana Group, but the grain-size is comparable.

Following a thick sequence of shales, sandstones are again developed, locally, in the upper part of the Janusfjellet Sub-group and in the overlying sediments. The lower part of the Helvetiafjellet Formation, the Festningen Sandstone Member, consists predominantly of medium to coarse, sometimes very coarse and conglomeratic sandstone. Similar sandstones also occur locally, intercalated with other lithologies, in the upper part of the Janusfjellet Sub-group, and in the upper part of the Helvetiafjellet Formation. The somewhat coarser grain-size and lower feldspar content generally distinguished these sandstones from those of the Wilhelmøya Formation.

Fine-grained, feldspathic sandstones appear in the upper part of the Helvetiafjellet Formation, and are present throughout the Carolinefjellet Formation.

The observations in the stratigraphic column (Fig. 5) show that 1) heterogeneous sandstone assemblages in the gravel can be explained by the

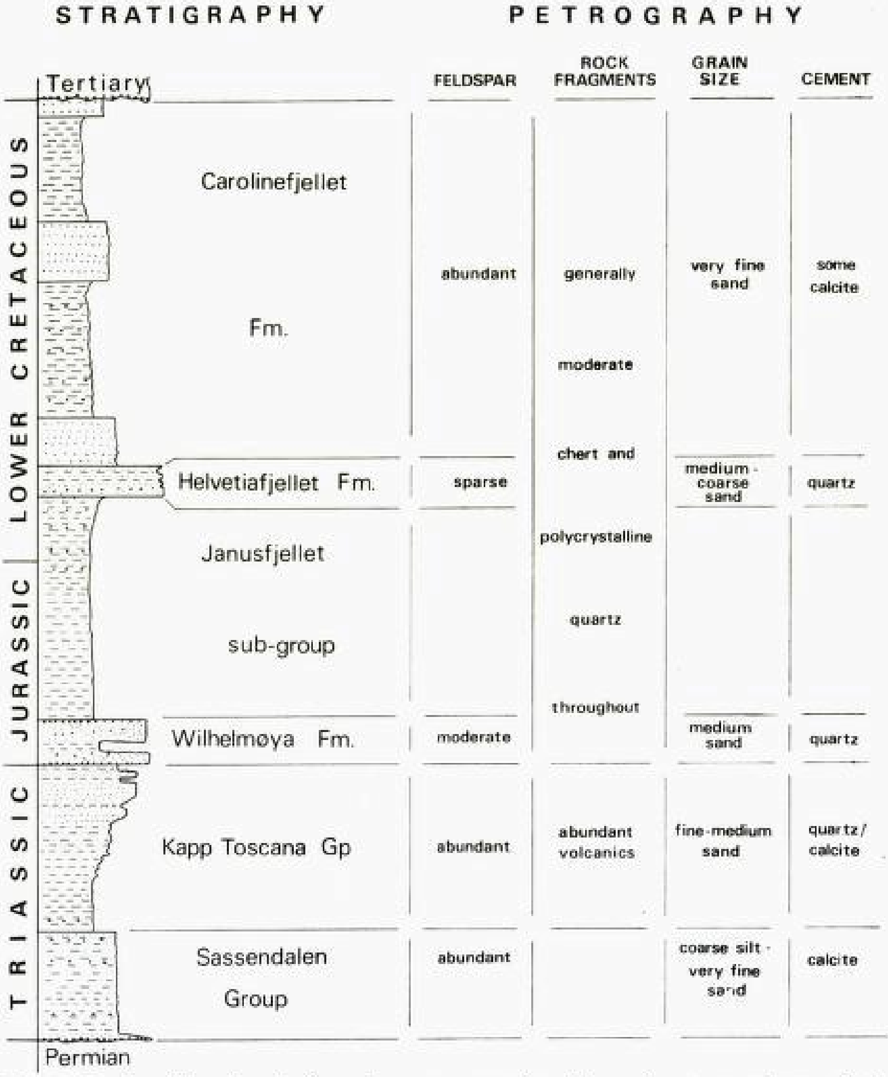

Fig. 5. Stratigraphic résumé of sandstone petrography. The sedimentary column, about 2,000 m thick, is generalised from parts of the Mesozoic in different areas of Svalbard. Descriptive terms indicate characteristic or typical features, and are not necessarily inclusive of all the sandstones in a given unit. Stratigraphic nomenclature is taken from Buchan et al. (1965), Flood et al. (1971a), and Parker (1967).

occurrence of contrasting types of sandstone in adjacent parts of the succession, and 2) the stratigraphic position of a large portion of the sandstone pebbles in the gravel can be determined. The two key indicator types are the sandstones in the Kapp Toscana Group and those in the Helvetiafjellet Formation. The occasionally low feldspar content of the sandstones in the Wilhelmøya Formation may allow confusion with those in the Helvetiafjellet Formation. Similarly, the very fine sandstones in the Sassendalen Group and the Carolinefjellet Formation may lead to confusion between these two units. More data, especially quantitative observations, could reveal significant differences

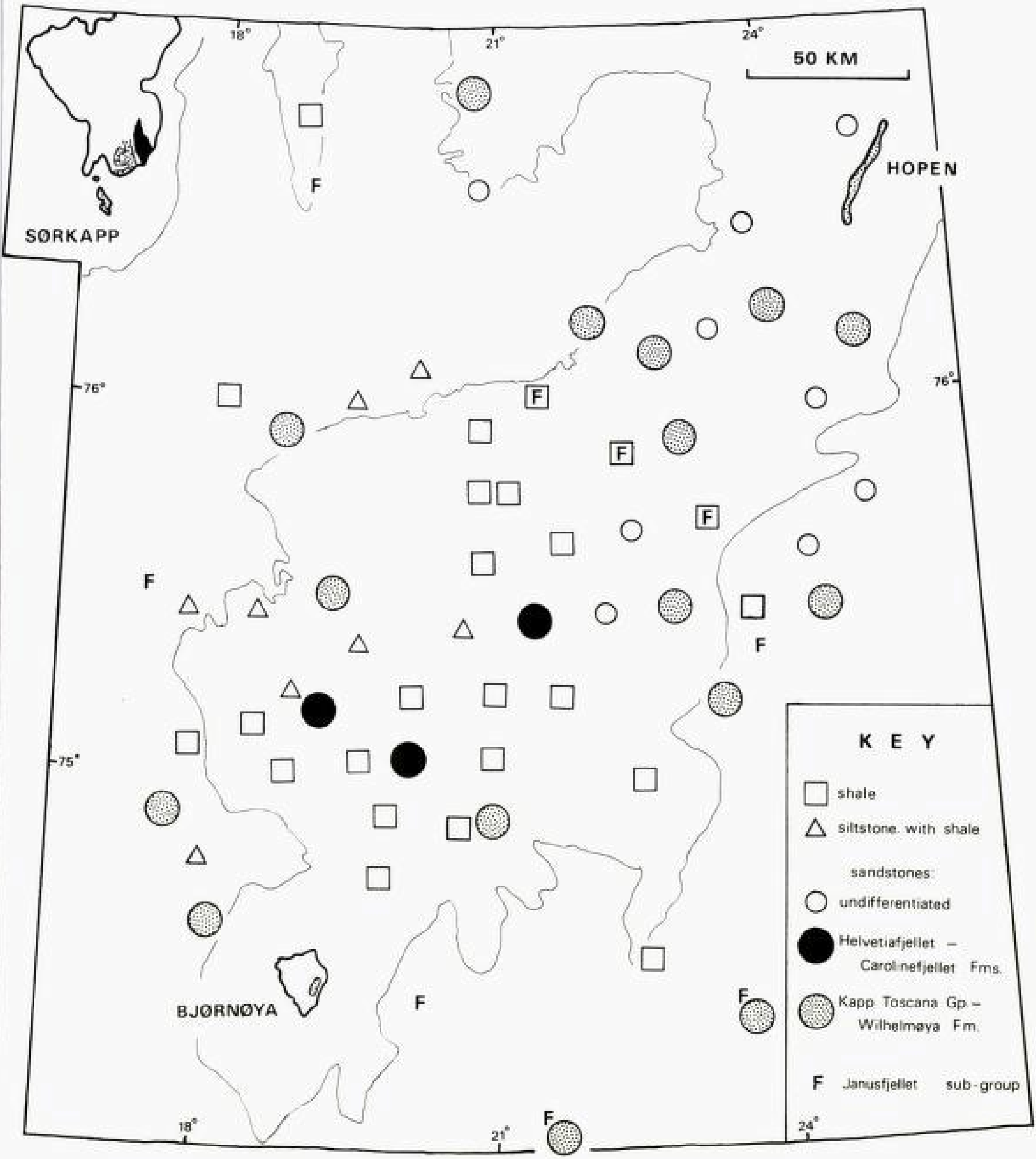

Fig. 6. Distribution of significant lithologies. Compiled from Fig. 4, data on sandstone petrography, and from an early account of the gravel lithology prepared by NTNFK. Geology of adjacent land areas based on Flood et al. (1971b) and Pčelina (1972). Hundred metre contour shown.

between these major stratigraphic units. Because of these uncertainties, the sandstone units are divided stratigraphically into two groups: those underlying, and those overlying the shales of the Janusfjellet Sub-group.

Stations containing a large proportion of pebbles which can be attributed to either of the two groups of sandstones are designated in Fig. 6.

Discussion

The differences in gravel lithology between various stations (Fig. 4) indicate that the material has not been rafted into place by icebergs. This has also been noted by Soviet scientists (Klenova, cited in Dibner et al. 1970), and is supported by the rarity of pebbles of definitely exotic lithologies, such as Caledonian granites and gneisses. Icebergs containing debris could originate from glaciers on Franz Joseph Land (400 km east of Svalbard) and on eastern Svalbard. Drift ice movements are controlled by both currents and wind. The main currents affecting the Spitsbergen Bank are the East Spitsbergen Current and the Bear Island Current (U.S. Hydrographic Office 1958), both of which are cold streams from the NE, and the North Cape Current, an east-flowing warm stream situated along the southern margin of the Bank. Winds are highly variable, and may temporarily disturb the effects of the currents (Lunde 1965). A considerable portion of the drift ice is carried southwestwards along the east coast of Spitsbergen, driven by the East Spitsbergen Current. It can be expected that only a small proportion of the ice finds its way southwards over the Spitsbergen Bank, which is consistent with the meagre quantities of apparently drifted material in the gravel.

The fact that striated pebbles are generally of the same lithology as non-striated pebbles in a sample suggests that both may be parts of the same glacial deposit. The distribution of this feature (Fig. 3) suggests that glacial deposition was widespread on the Spitsbergen Bank at an earlier time. Evidence supporting the glaciation of a large area of the Barents Shelf, probably during the Würm, has recently been put forward. A study of shorelines, with associated C^{14} datings, on Spitsbergen, Nordaustlandet, Kong Karls Land, Hopen and other areas in Svalbard indicates that the whole area of the NW Barents Shelf, possibly extending to the edge of the continental shelf, was covered by ice, with the greatest uplift (within the last 6500 years) in the southeast (Hoppe et al. 1970). These data, in conjunction with the inferred direction of ice movement from the NE on Hopen (Hoppe 1969), suggest that the ice sheet had its centre to the east of southern Svalbard, in the Barents Sea.

Although detailed work was not done on the roundness and sorting of the gravel, several observations are of interest. Most pebbles are sub-angular to sub-rounded, with other types relatively scarce. At some stations, rounded and well-rounded pebbles are dominant, suggesting extensive reworking. The gravel component appears rather poorly sorted. If the primary deposit was a subglacial till, then the presence of the gravel attests to some reworking. However, the preservation of striations on relatively soft lithologies, and the roundness of the pebbles suggests that this was not extended in time. Such reworking may have been due to glaciofluvial or marine currents. The effectiveness of the latter in winnowing the bottom at the present time is suggested by the current speeds of up to 2 knots (U.S. Hydrographic Office, 1958) and by observations made by divers during the sampling.

Thus, of the several mechanisms involved in the formation of the gravel, glaciers and icebergs, particularly the former, were probably responsible for transport, while glaciofluvial or marine currents resulted in reworking and some abrasion, with little significant lateral transport.

Applying the widely observed fact that subglacial tills tend to be composed mainly of local material (e.g. Flint 1971, p. 174), the composition of the gravel can be used to reconstruct the bedrock geology of the Spitsbergen Bank. The overall Mesozoic character of the bedrock is indicated by the predominance of sandstones with strong Mesozoic affinities, as well as by the occurrence of fossiliferous dark shales which have been assigned to the Janusfjellet Sub-group (Nagy, in prep). Omitted is material which, although datable, is a minor lithological constituent at a station. This applies, for example, to the limestones at stations 5 and 14 (and scattered pebbles at other stations) some of which closely resemble limestones on Bjørnøya, particularly the Permian Spirifer Limestone, but which are overshadowed by the large quantities of Mesozoic pebbles at those stations. The exotic pebbles found on the southern part of the Spitsbergen Bank may have been rafted into place by icebergs derived from calving glaciers on Bjørnøya during the last glaciation.

The resulting distribution of stratigraphic units does not form a simple pattern (Fig. 6). However, the occurrence of the older sandstone group on the NE and SW parts of the Bank, and the restriction of the younger sandstone group to a central area suggests a gentle synclinal structure to the Spitsbergen Bank, consistent with the regional structural pattern of southern Spitsbergen (Fig. 7). The concentration of limestone at station 36 may indicate the proximity of the station to the Permian–Triassic boundary. The anomalous central occurrences of the lower sandstone group in the central area could represent remnants of an end moraine complex or, on the other hand, reflect structural complications in the bedrock.

The inferred broad distribution of the Mesozoic formations, and the flat-lying aspect of the Triassic strata exposed on Bjørnøya and Hopen suggest that the strata underlying the greater part of the Spitsbergen Bank are, similarly, nearly flat-lying and largely undeformed. Additional evidence supporting these conclusions is provided by unpublished reports of NTNFK based on the continuous seismic profiling carried out in 1971.

Conclusions

1) Gravel material on the Spitsbergen Bank is essentially locally derived, transported into place largely by glaciers.
2) Petrographic observations can distinguish some of the sandsone units in the Mesozoic of Svalbard, and can be used to stratigraphically locate sandstones in the gravel from the Spitsbergen Bank.
3) Sandstones of the Kapp Toscana Group and the Wilhelmøya Formation have a wide distribution on the bank. Sandstones from the Helvetiafjellet and Carolinefjellet Formations have a limited distribution. The occurrences

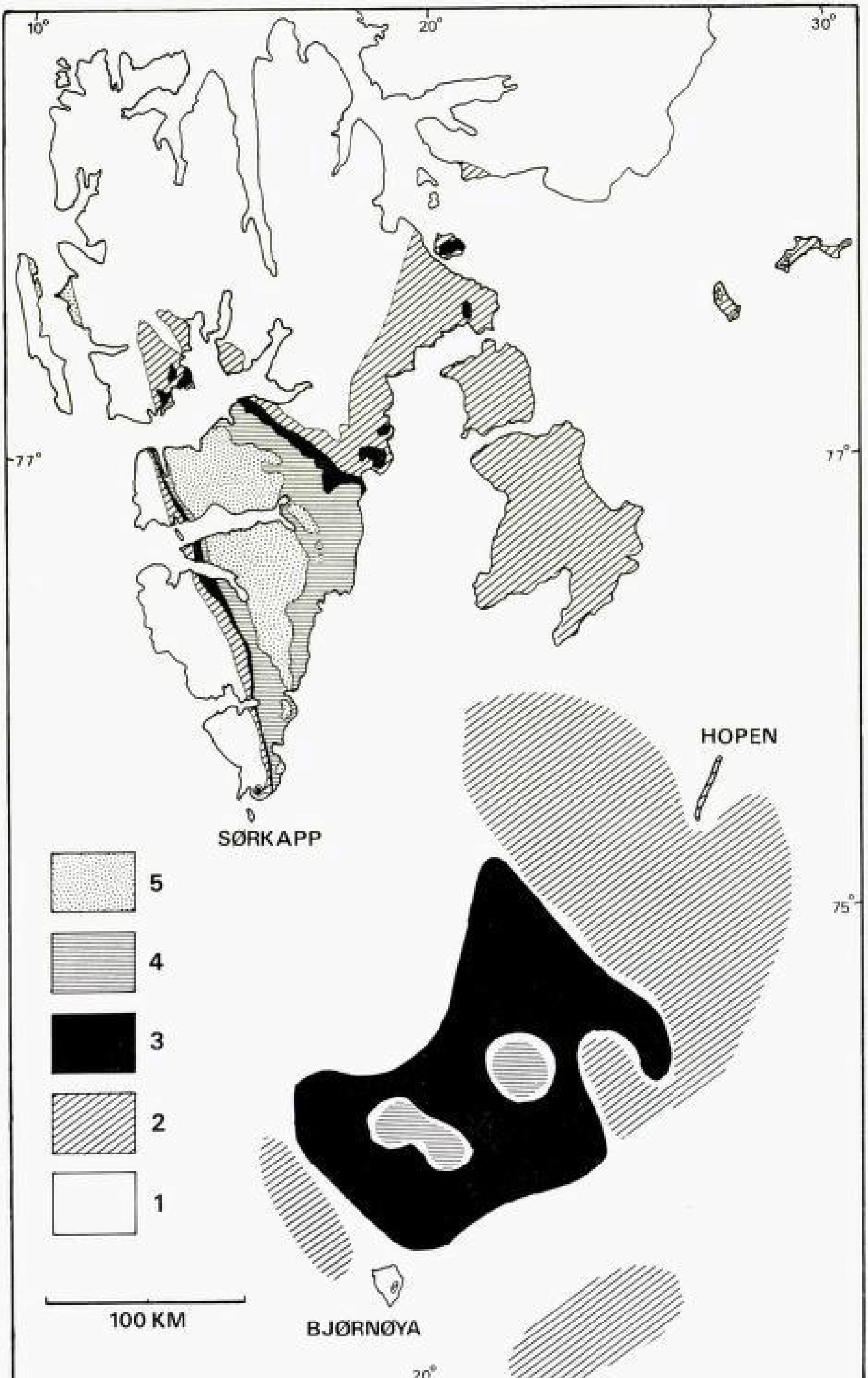

Fig. 7. Geological sketch map of the Spitsbergen Bank and Svalbard: 1) on land, pre-Triassic; on the Spitsbergen Bank, uncertain, 2) Triassic Sassendalen and Kapp Toscana Groups, and Liassic Wilhelmøya Formation, 3) Janusfjellet sub-group, 4) Lower Cretaceous (Barremian to Albian) Helvetiafjellet and Carolinefjellet Formations, 5) Tertiary. Based on Buchan et al. 1965); Flood et al. (1971b) and Orvin (1940).

show that these formations may continue for a considerable distance (at least 200 km) to the south of Spitsbergen.

4) The basic structure of Spitsbergen Bank appears to be a gentle syncline, a southward continuation of the dominant structure of Spitsbergen.
5) Shallow drilling at selected sites could test the hypothesis of the local nature of the gravel. Support for this hypothesis would render gravel a valuable aid in the investigation of the bedrock of the Barents Sea.

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