Precambrian rock-stratigraphic units of the west coast of Spitsbergen

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Abstract

On the basis of a formation analysis a correlation of the sections of different parts of the west coast of Spitsbergen is given, and a new scheme of division of the Precambrian for this region is proposed. Three groups separated by regional unconformity, have been recognized. The lower group (Lower Riphean?) includes the most ancient stratified successions of the crystalline schists. The middle group (Middle to Upper Riphean?), the sedimentary-volcanogenic one, encloses to a different degree changed basic intrusions. The upper group (Vendian), the carbonate-fragmentary one, is characterized by a considerable diversity of the section and by lateral variability; it is overlaid by polymict conglomerates, locally lying with a washout on more ancient horizons.

The Precambrian succession of the west coast of Spitsbergen is noted for its peculiarity and complex structure due largely to dislocations during the Alpine orogeny. Despite the relative accessibility of the western coast, its geology is not well known and data available does not provide a reliable basis for correlation. In this paper a Precambrian stratigraphic standard section is proposed for the western coast (south of Kongsfjorden), based on geological observation and tectonic analysis of the non-fossiliferous ("barren") sequences. A review of the data on the Precambrian of Spitsbergen published by the Norwegian Polar Research Institute (Winsnes 1965) and an excellent geological map of Southern Svalbard (1:500 000) (Flood, Nagy and Winsnes 1971) have contributed greatly to this work.

Field work was carried out by Krasil'ščikov during the Spitsbergen Expedition of the Research Institute of the Geology of the Arctic in 1969–1972 in Brøggerhalvøya, north side of Aavatsmarkbreen, northern St. Jonsfjorden, north coast of Isfjorden, Nordenskiöld Land (a peninsula between Recherchefjorden and Dunderbukta) (the Wimsodden area), and the north and south coasts of Hornsund.

Prior to the present time, the stratigraphic standard compiled by Polish geologists for the Hornsund area was used (Birkenmajer 1959, 1960). However in many cases this does not reflect real stratigraphic relationships. First of all this concerns the widespread conglomerate sequences and metavolcanites.

A number of clear continuous and characteristic rock units were recognized through the analysis of geological data and detailed lithology and petrography.

The Precambrian rocks south of Kongsfjorden were divided into four groups each named after the type locality. They are from below: Isbjørnhamna Group (schists), Werenskioldbreen Group (sedimentary-volcanic), Sofiebogen Group (flysh-like-carbonates) and Bellsund Group (carbonate-clastic).

The Isbjørnhamna Group consists of a complex of crystalline schists, including marbles and quartzites, outcropping on the north coast of Hornsund (type locality) and on Brøggerhalvøya. In both areas the complex, 1500 to 2500 m thick, consists of two schist sequences separated by a sequence of carbonate rocks. Contacts with adjacent groups are tectonic. The whole complex was metamorphosed to amphibolite facies (almandine subfacies). This high grade of metamorphism provides the only grounds for its recognition as a single rock-stratigraphic unit. However, the petrography of these carbonates is comparable to that of the clastic dolomites and limestones of the Upper complex, and the Upper Isbjørnhamna schists (Revdalen Formation) are similar to distinctive graphitic schists of the Werenskioldbreen group.

The Werenskioldbreen Group, a sedimentary-volcanic complex, consists of volcanics and gabbros formed during a single episode and metamorphosed to greenschist facies and closely related sediments consisting mainly of homogenous argillaceous-carbonate deposits containing phosphates and organic matter.

The contact of the Werenskioldbreen Group with the underlying schists is tectonic. The predominantly volcanic lower part of the complex suggests the beginning of a new episode in the history of the region. The upper boundary is drawn at the abrupt lithologic change from a homogenous "black shale" sequence to almost unmetamorphosed flysh-like deposits. The Werenskioldbreen Group is best exposed north of Hornsund, between Hansbreen and Torellbreen. A new interpretation is proposed using the data available for the structure and stratigraphy of the different rock-units (Birkenmajer and Narebski 1960; Smulikowski 1965, 1968), field data, rock collections and thin-sections (by Krasil'ščikov 1969, 1972).

According to Polish geologists (Birkenmajer and Narebski 1960) the older Isbjørnhamna Group is thrust over the Eimfjellet Group amphibolite complex with the Gulliksenfjellet Quartzite at the base. Smulikowski's detailed structural maps (1965, 1968) show the Gulliksenfjellet Quartzite overlying the Eimfjellet Group in an asymmetric dome-like structure with an "amphibolite" core with which the so-called "Gangpasset granitization zone" is associated. This dome-like structure is complicated by intense folding on the flanks with alternations of quartzites and schists of different composition.

The Vimsodden Formation differs in composition, genesis, environment, and thermodynamic transformation, and occurs north of Werenskioldbreen, presumably obscuring a thrust fault system (Birkenmajer and Narebski 1960). In Birkenmajer's opinion the Vimsodden Formation is stratigraphically equivalent to the Eimfjellet Group while, according to Smulikowski (1968), it overlies the Eimfjellet Group as it is generally of lower metamorphic grade.

Most of the Eimfjellet rocks correspond in composition to actinolitized gabbro-diabases and albite-epidote-actinolite schists which cannot be termed "amphibolites". The amphibole of the schists is close in optical properties to glaucophane implying local fields of high pressure against a background of greenschist facies metamorphism.

The proposed subdivision of the Werenskioldbreen Group in the type locality is as follows:

1. Skålfjellet greenschist: (a) fine- to medium-grained actinolite schists with coarse-grained actinolite gabbro-diabase bodies, 550 m thick; (b) chlorite-muscovite schists with quartzite bands, 250 m thick.

2. Gulliksenfjellet quartzite: 250 to 300 m thick.

3. Kvislodden greenschists: chlorite and carbonate-mica schists with "rhyolitic conglomerate" beds, 100 m thick.

4. Pyttholmen arkose quartzites: 125 m thick.

5. Tonefjellet greenschists: carbonate-mica and chlorite schists with graphite-bearing schist bands and mica quartzites as well as lenticular and thick concordant bodies of actinolitized gabbro-diabases, 250 to 400 m thick.

6. Vimsodden "Black Shales": graphite-bearing schists with marble and quartzite beds, 200 to 250 m thick.

The Vimsodden quartzite-marble conglomerates and Tonedalen carbonate-clastic rocks are assigned to the younger Sofiebogen Group.

Further study of this region may prove that the Gulliksenfjellet quartzite, the Middle greenschists and the Skålfjellet greenschists are equivalent to the Pyttohlmen quartzite, the Upper greenschist and the Tonefjellet Formation, respectively. The subdivision of the Werenskioldbreen Group would thus be simplified, and the total thickness would be less.

Volcanics of the Werenskioldbreen Group are also widespread south of Recherchefjorden where they consist of a thick (up to 1500 m) sequence of green and black shales with thin amygdaloidal basalt sheets and metagabbros (Hjelle 1969) sediments. The black phosphate-carbonaceous shales and limestones of the Werenskioldbreen Group are better exposed farther north (Nordenskiöld Land, northern Isfjorden, St. Jonsfjorden), but greenschist units are subordinate in the north. Gabbro intrusions on higher structural-stratigraphic levels are as a rule less altered. The thickness of the black shale-carbonate sequence in these regions is between 300 and 800 m.

Thus, the Werenskioldbreen Group, about 2000 m thick, consists of three formations; volcanic, sedimentary-volcanic, and homogenous argillaceous-carbonates ("black shale"). These proposed formations are named after the regions of their widespread occurrence:

1. Skålfjellet Formation (more than 800 m thick), the Tonefjellet sequence is its possible equivalent;

2. Vimsdoden Formation (700 to 800 m thick) with the Gulliksen quartzites at the base, its equivalents are the Recherchefjorden and Nordenskiöld Land greenschists;

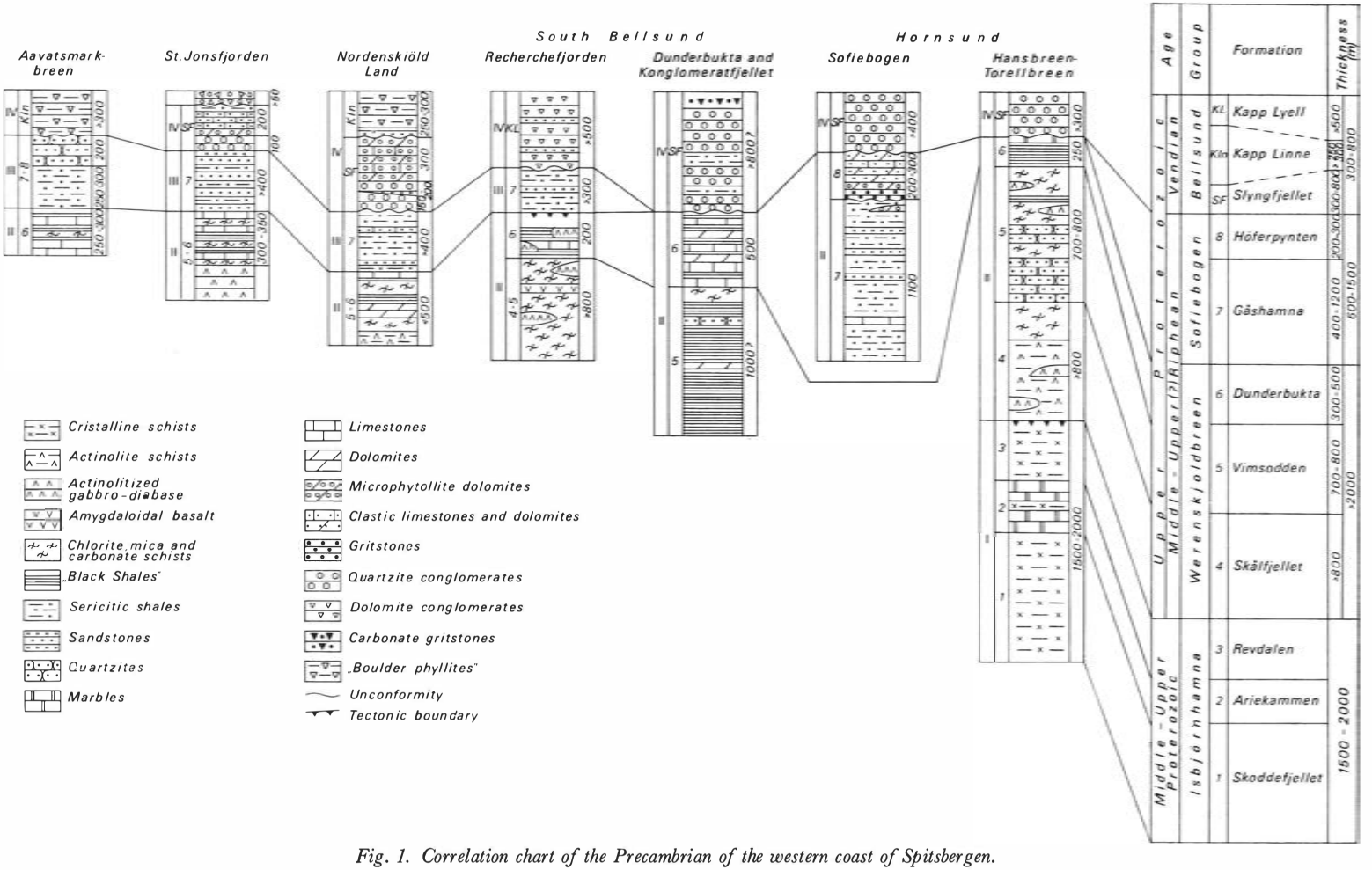

Fig. 1. Correlation chart of the Precambrian of the western coast of Spitsbergen.

3. Dunderbukta Formation (300 to 500 m thick), its equivalents are sequences of black shales and phosphate-carbonaceous limestones which can be traced from Vimsodden in the south to the Aavatsmarkbreen area to the north.

The Sofiebogen Group, a flysh-like carbonate complex, is widespread on either side of Hornsund where two lithologically different formations —the Gåshamna and the Höferpynten Formations can be recognized (MAJOR and WINSNES 1955, BIRKENMAJER 1960, KRASIL'ŠČIKOV 1970).

The Gåshamna Formation, up to 1200 m thick, is composed of sericitic shales (metamorphosed mudstones and siltstones) with sporadic bands of sandstone and carbonate. In the type section (Sofiebogen and Gåshamna), rocks of the formation form a steep west dipping monocline. In the east the monocline is thrust over a largely carbonate sequence assigned to the Cambrian; to the west the Gåshamna shales are overlain by a marker horizon of quartz gritstones with shale flakes. BIRKENMAJER (1959, 1960) considered this horizon to be the base of the Gåshamna Formation using the assumption that the beds in the Sofiebogen area are overturned. The equivalent of the Gåshamna Formation can be recognized in the Recherchefjorden area, on Nordenskiöld Land, and especially well on the northern coast of St. Jonsfjorden.

In the type locality the authors subdivide the Höferpynten Formation into three members: lower (40 to 60 m thick) — quartz gritstones, middle (50 to 150 m thick) — chiefly dolomites, and upper (about 100 m thick) — characterized by an alternation of metamorphozed limestones, dolomites, quartz-carbonate schists, and microquartzites.

North of Hornsund the lower member occurs in Nordbukta, in Nordenskiöld Land, and on the northern coast of Isfjorden. The middle member consisting of phytollite dolomites intercalated with limestones are widespread north of Kapp Martin.

Dolomites and rare limestones of the middle member contain numerous microphytollite nodules which help to distinguish this member as a good marker horizon. The microphytollites belong to a single Osagia group, *Osagia tenuilamellata*, characteristic of the Middle Riphean (RAABEN and ZABRODIN 1969, MILSTEIN 1971). However, the clastic nature of the enclosing beds indicates reworking of microphytollite nodules.

The Sofiebogen Group is transitional between the underlying group, and the overlying Bellsund Group. Within the Sofiebogen Group are rocks similar to the upper horizons of the Dunderbukta Formation. There is no reliable evidence about the contact between these sequences but spatially they are adjacent in many places suggesting a possible facies replacement of boundary beds. The upper mainly carbonate part of the Sofiebogen Group is similar to clastic dolomites and limestones occurring among the conglomerates of the overlying Bellsund complex. However the historical-geological distinction of the Sofiebogen Group is emphasized by its low grade metamorphism, the absence of basic magmatism and the occurrence of rocks of the Gåshamna and Höferpynten Formation type within the clastic material of the overlying conglomerates.

The Bellsund Group, a carbonate-clastic complex is characterized by strong lateral changes accounting for the recognition by earlier workers of a number of conglomerate horizons of different ages (BIRKENMAJER's three "pretillite" horizons). Analysis of geological setting and petrographic study proves that all the conglomerate sequences on the west coast of Spitsbergen belong to a single rock-stratigraphic complex formed during a single tectonic cycle.

In a number of scattered conglomerate outcrops the clastic material has a relatively constant composition and the matrix is similar in structure and mineralogy. The conglomerates largely consist of carbonate-mica-quartz shales which do not differ in composition from the numerous bands of calcareous-quartz sandstones and shales found within the conglomerate sequences. The psephitic material is comparable to the following rock-types:

(1) various quartzite and quartzite-sandstones including the Gulliksenfjellet quartzites;

(2) feldspar-quartz and calcareous-quartz sandstones and siltstones (including those of the Gåshamna Formation);

(3) sericite, chlorite-sericite and chlorite (after metabasites?) schists (e.g. Vimsodden schists);

(4) mica slates and mica-carbonate graphite-bearing shales (including those of the Vimsodden and Dunderbukta Formations);

(5) black phosphate-bearing limestones (the Dunderbukta Formation type);

(6) microphytollites and clastic dolomites (the Höferpynten Formation type);

(7) granites, plagiogranites, quartz diorites.

The almost complete absence of pebbles of schists and metabasites is notable.

Visual differences of conglomerate sequences are mainly accounted for by large changes in the relative abundance of petrographically different pebbles. Three sequences were recognized, the lateral and stratigraphic relationships of which are not always clear.

The presumably lower sequence — the Slyngfjellet Formation — reported by BIRKENMAJER (1959) as mainly quartzite conglomerates, is 500 m thick. Besides predominant quartzite boulders the sequence is characterized by an abundance of boulder-pebble material (over 50%). The chiefly quartzite content of the conglomerates of Dunderbukta, Konglomeratfjellet, Kapp Martin, and Ankerbreen (north coast of St. Jonsfjorden) are equivalent to the Slyngfjellet sequence. In different areas quartzite conglomerates rest on different beds of the Dunderbukta, Höferpynten, and Gåshamna Formations.

The second sequence, the Kapp Linné Formation, was described by HJELLE (1962) as a 300 m thick sequence of "phyllites with boulder beds". Dolomite, quartzite, and altered quartz diorite were reported among the boulders. A non-persistant and as a rule small amount of boulder-pebble material without predominant rock, is a peculiar feature of the sequence. Shales with boulders usually occur within tectonic blocks, in association with clastic dolomites and

limestones. Thick schistose Comfortlessbreen conglomerates (HARLAND 1961) may be equivalent to the Kapp Linné "boulder philites".

The upper sequence, the Kapp Lyell Formation, is most complete on the south coast of Bellsund. It consists of schistose conglomerates more than 500 m thick with 5 to 40 per cent dolomitic psephite material. These conglomerates are thought to rest unconformably on the underlying rocks.

The clastic nature of the deposits, the overall unsorted character and the rapid lateral changes suggests that the Bellsund Group is a molasse deposit. The occurrence of conglomerates at different stratigraphic levels, and the composition of clastic material indicate tectonic activity prior to the deposition of the Bellsund Group. Most of the psephitic material cannot be identified with directly underlying rocks. This suggests that adjacent uplifted zones of early consolidation undergoing erosion provided the source for the coarse clasts. The tectonism most probably occurred in Prevendian times as the Bellsund Group is thought by many to correlate with the "tillite-like" Vendian formations of eastern areas of Svalbard. Therefore, the Sofiebogen Group is Middle-Upper Riphean in age (more probably Middle Riphean). The sedimentary-volcanic Werenskioldbreen Group presumably formed in a relatively narrow trough, the initiation of which may be tentatively assigned to the lower Upper Proterozoic.

Thus, the rocks of the West coast of Spitsbergen are thought to have formed in an Early Baikalian (Grenville) orthogeosyncline of embryonic development. At the close of the Baikalian stage a geosynclinal trough was buried under molasse-like deposits of Vendian age, then Early Paleozoic predominantly carbonate deposits accumulated under subplatform environment prior to the Caledonian orogeny. The complete inversion of sedimentary troughs, and the formation of the West Spitsbergen fold system, are related to the Caledonian orogeny.

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