

# Stratigraphic subdivision of the Devonian deposits of Spitsbergen

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## Abstract

Devonian deposits of the north-western part of the island of Spitsbergen are dealt with in the paper. A new stratigraphic scheme is proposed, based on a formational division of earlier recognized successions and formations. A brief lithological and palaeontological characterization of the formations is presented, and their interaction and area distribution is given.

## Introduction

Devonian grey-red continental and partly marine deposits totalling 8000 m occur within an extensive graben in northern Spitsbergen. Local outcrops of Devonian rocks are also known in the Hornsund area. The Devonian of northern Spitsbergen is subdivided into six groups: Siktetjellet (GEE and MOODY-STUART 1966), Red Bay, Wood Bay, Grey Hoek, Wijde Bay, and Mimerdalen (HOLTEDAHL 1914; VOGT 1938). Four of these groups were subdivided into formations.

At present, due to studies carried out by geologists from different countries, the Devonian section in Spitsbergen is rather well known.

Soviet geologists JU. P. BUROV, L. G. MURAŠOV, JU. I. MOKIN, A. I. PANOV) began to study the Devonian deposits of Spitsbergen during 1964. The studies and surveys carried out provided rich material allowing refinement of the existing stratigraphic section, and the recognition of a number of new formations. Fossils collected also enable more accurate dating of stratigraphic units.

On the basis of the material collected and the data available, a standard stratigraphic section of the Devonian deposits for northern Spitsbergen was compiled and is presented below.

## Lower Devonian

### GEDINNIAN

The Gedinnian continental, red-grey deposits are subdivided into two groups — Siktefjellet and Red Bay — occurring only in north-western Spitsbergen and in a narrow horst parallel to the main basin, adding complexity to the Devonian graben in the west.

#### *Siktefjellet Group*

The Siktefjellet Group was recognized in 1966 by GEE and MOODY-STUART in the Raudfjorden and Liefdefjorden areas and subdivided into the Lilljeborgfjellet and Siktefjellet Formations.

*Lilljeborgfjellet Formation.* These deposits extend in a narrow band from Rabotdalen in Raudfjorden to Siktefjellet in Liefdefjorden. They rest with a sharp angular unconformity on metamorphosed Upper Proterozoic rocks. This contact is evident on Siktefjellet, Högeloftet, Fränkelryggen, Lilljeborgfjellet, and in Rabotdalen. The conglomerates are overlain by the Siktefjellet sandstone.

The Formation consists of grey fine to medium pebble conglomerates with well rounded pebbles of schist, granites, gneiss, migmatite, quartzite and less common metamorphosed limestones. The matrix is grey coarse-grained polymict sandstone and gritstone containing calcareous material.

The greatest thickness (400 m) was measured on Lilljeborgfjellet. Northward and southward the thickness decreases to 100 m and less.

*Siktefjellet Formation.* The deposits on Siktefjellet in northern Liefdefjorden also extend in a narrow band southward to Bockfjorden. They rest without evident angular unconformity on conglomerates of the underlying formation and are overlain erosively by the Red Bay conglomerates.

The formation is represented mainly by fine- and coarse-grained polymict sandstones with gritstone lenses, and thin bands and lenses of siltstone and mudstone. The grain size decreases up the section.

Plant remains such as *Taeniocrada decheniana* (GOEPP) KR. et WEYL, *Prototaxites psigmophilloides* KR. et WEYL, *P.sp.* and *Hostimella* sp. were collected from three localities on Siktefjellet (north-eastern, north-western, and southern slopes). They indicate, in N. M. PETROSJAN's opinion, a Lower Devonian age.

Table 1

System	Series	STAGE	Group	After FRIEND 1961 and GEE & MOODY-STUART 1966		After L.G. MURASOV 1975					
				FORMATION		FORMATION MEMBER					
D E V O N I A N	U P P E R	Famennian	M I M E R D A L E N			Plantekløfta 100					
						Frasnian	Planteryggen 180-400				
		Givetian					Plantekløfta 100		Fiskekløfta 145		
						Planteryggen 400		Esteriahaugen 110			
						Fiskekløfta 400					
						Esteriahaugen 90-130					
		M I D D L E				Eifelian	W I J D E B A Y		5 0 0	Tage Nilsson 600	
										Forkdalen 630	
						Tavlefjellet 300					
						GREY HOEK				1 0 0 0	Gjels- vikfjel- let 250
	Verdalen 100										
	Emsian	W O O D B A Y				Stjørdalen 500					
						Keltiefjellet 600-900					
						Kapp Kjeldsen 1000 - 1500					
	Siegenian					Kapp Kjeldsen 1500					
	L O W E R	G E D I N N I A N	RED BAY	S I K T E F J E L L E T			Ben Nevis 900				
							Fränkelryggen 600		Fränkelryggen 600-750		
							Andréebreen 100-200		Andréebreen 200		
							Red Bay conglomerate 600	Princesse Alice 300			
			Rabotdalen 200								
Wulfberget 200											
Siktefjellet 1400			Siktefjellet 350								
Lilljeborgfjellet 100-400			Lilljeborgfjellet up to 400								

All these remains were reported in 1942 by HØEG from the Fränkelryggen Formation.

According to GEE and MOODY-STUART (1966), the thickness of the Formation is 1400 m, but the present authors consider it to be 350 m. This large disagreement is accounted for by different views on the geology of Siktefjellet.

### *Red Bay Group*

The Red Bay Group was recognized by HOLTEDAHL (1914) and subdivided into four formations: Red Bay Conglomerate, Andréebreen, Fränkelryggen, and Ben Nevis. In 1966 two lithologically different rock-units — Rabotdalen Sandstone and Princesse Alice Conglomerate — were reported from the Red Bay Conglomerates by GEE and MOODY-STUART. The present authors propose a tripartite subdivision for the Red Bay Conglomerate into the Wulfberget, Rabotdalen and Princesse Alice Formations because they differ in composition, have substantial thicknesses, distinct contacts, and a wide distribution.

*Wulfberget Formation.* These deposits are most widespread on Wulfberget as well as on Siktefjellet, Högeloftet, and Fränkelryggen. They rest unconformably on the Upper Proterozoic Signehamna and Generalfjellet formations and grey rocks of the Siktefjellet Formation. The upper boundary is drawn at the base of the overlying sandstones.

The Wulfberget Formation consists of red, large-pebble conglomerates with pebbles of metamorphosed limestone, quartzite, and metamorphosed microquartzite. Large blocks of angular, metamorphosed limestone occur in places at the base. The matrix is coarse-grained sandstone containing calcareous material. The thickness of the Formation is 200 m.

*Rabotdalen Formation.* These deposits occur mainly in the Raudfjorden area. They rest without an evident break on the underlying conglomerates and consist of coarse-grained polymict sandstones with lenses and bands of mudstone, siltstone, and silty calcareous rocks weathering (bright yellow). There are gritstone lenses in the sandstones.

In the Raudfjorden area plant remains such as *Taenioocrada? spitsbergensis* HØEG, characteristic of the Lower Devonian, were found for the first time, as were the ostracod *Clavofabelina? sp.*, A. ABUSČEK considers these also to be of Lower Devonian age. The thickness of the formation is 200 m.

*Princesse Alice Formation.* These deposits also occur mainly in the Raudfjorden area where they rest on the erosion surface of the underlying Rabotdalen Sandstones. The formation consists of red fine pebble conglomerates composed of quartz and quartzite. The conglomerates contain gritstones of the same composition and bands of coarse-grained sandstone. The thickness is 300 m.

*Andréebreen Formation.* This formation was named in 1961 by FRIEND (FRIEND 1961), but it was known as a rock unit earlier. It outcrops mainly in the Raudfjorden and Liefdefjorden areas and in particular on Wulfberget and Pteraspistoppen. The Andréebreen Formation rests without evident unconformity on the erosion surface of the Princesse Alice Formation. The upper boundary is drawn at the base of the Fränkelryggen redstones.

The Andréebreen Formation consists of coarse parallel bedded and large-

scale cross-bedded grey and greenish grey polymict sandstones with numerous siltstone and mudstone bands and lenses (up to 2.5 m thick). Mudstones contain carbonized detritus. The thickness is 200 m.

*Fränkelryggen Formation* was recognized by KLÆR in 1916 (KLÆR 1918). Until 1974 it was considered as the lowermost formation yielding fossils and plant remains. A narrow band of outcrops can be traced along the eastern coast of Raudfjorden up to Liefdefjorden, and may also be present on the southern coast of Liefdefjorden. The formation rests conformably on the Andréebreen sandstones and is overlain by micaceous grey sandstones of the Ben Nevis Formation.

The Fränkelryggen Formation consists mainly of red sandstones and mudstones with greenish grey sandstone and mudstone bands.

Abundant remains of fish, pelecypods, arthropods, and plants were collected from these deposits. Osteostraci (*Cephalaspis*), Heterostraci (*Cyathaspis*), and *Acanthodii* were identified. The thickness is 600 to 750 m.

*Ben Nevis Formation*. This Formation was recognized for the first time by KLÆR in 1916. The type section occurs on Ben Nevis, and outcrops are also present near Pteraspistoppen (northern Liefdefjorden) and on the northern side of Vonbreen. The lower boundary is drawn at the base of the first thick bed of grey-green micaceous sandstones. The upper boundary is drawn at the base of red beds of the Kapp Kjeldsen Formation.

The formation consists of greyish green, cross-bedded, fine- and coarse-grained polymict micaceous sandstones. A thick unit of violet-red sandstones and mudstones is present in the middle of the section. Abundant fossils of fish, ostracods and pelecypods occur throughout the sequence. Also the arthropod *Mesostomata* is found.

Fish include Osteostraci (*Cephalaspis*), Heterostraci (*Poraspis* and *Traquairaspis*), and *Acanthodii*. The thickness is 900 m.

## SIEGENIAN

### *Wood Bay Group*

The Wood Bay Group was recognized by HOLTEDAHL in 1914 and subdivided by FRIEND and HEINTZ in 1943 into three formations: Kapp Kjeldsen, Lykta (renamed Keltiefjellet in 1961 by FRIEND), and Stjørdalen. In 1966, FRIEND et al. proposed not to subdivide the group into formations because of the lack of good marker horizons and the uniform lithology. Instead of formations they proposed independent separate sequences differing in rock composition such as the Austfjorden Sandstone. However, geological works and surveys carried out by Soviet geologists showed that these deposits, despite some difficulties, may be subdivided into the earlier recognized formations which are even mappable.

*Kapp Kjeldsen Formation*. This formation is very widespread, extending from Liefdefjorden to Dicksonfjorden in the west and from Kartdalen (Andrée Land) to Nathorstalen (Dickson Land) in the east. The beds of the Kapp Kjeldsen Formation rest conformably on the grey-coloured rocks of the Ben

Nevis Formation. The contact was described by FØYN and HEINTZ (1943) and by BUROV and MURAŠOV (1967) in the Woodfjorden area on Kronprins-høgda and Sigurd fjellet. The top of the so-called “pale beds” was regarded as the upper boundary of the formation.

In the western areas of the Devonian graben the Kapp Kjeldsen Formation consists largely of a complex alternation of red siltstones, mudstones and fine-grained sandstones with rare thin layers of grey-green siltstones and sandstones yielding plant remains. The section is capped by the “pale beds” which consist of interbedded green, greenish-yellow, crimson and bright brown sandstones, siltstones, mudstones, and silty limestones. A gradual increase in sand content takes place south-eastward along the Bockfjorden–Austfjorden line, and in the Austfjorden area the Formation consists mainly of coarse-grained green, greenish-grey, and greenish-yellow cross-bedded and massive micaceous sandstones and sandy siltstones, with lenses and bands of gritstone and fine-pebble conglomerate beds along the boundaries. The red beds, very characteristic of western areas, occur only in the upper part of the formation to the east. The “pale beds” in this area consist of coarse-grained cross-bedded and massive green and yellowish-green sandstones with rare thin bands of crimson sandstone, siltstones and mudstones. A notable feature of the Kapp Kjeldsen Sandstones in the Austfjorden area is the presence of rounded clasts of quartz and orthoclase and numerous inclusions of black, very dense, coaly, sandy mudstones and siltstones.

The contrast in lithology and mineral composition of the rocks in the west and those in the east, implies different conditions of sedimentation. It is evident that the Austfjorden area was much closer to the source area, and the presence of quartz and orthoclase pebbles in the sandstones suggests that the deposition of the Kapp Kjeldsen Formation took place during the erosion of older crystalline rocks.

Osteostracii, Heterostraci, Arthrodira, Crossopterygii and Charophyta are the guide fossils. Pteraspids such as *Gigantaspis*, and Arthodires such as *Arctaspis* indicate a Siegenian age. Abundant ostracods and plant remains suggest a wider age range of Lower-Middle Devonian.

The fossil content of the formation varies between the western and the eastern areas. The western sections contain numerous bands with remains of fish and ostracods, while plant remains are much less common. However, the eastern sections contain a high percentage of bands with plant remains; fish and ostracods are less common, implying contrasting environments of sedimentation. The thickness of the formation is 1500 m.

*Keltiefjellet Formation.* This was first described by FØYN and HEINTZ (1943) as the Lykta Formation, later renamed by FRIEND in 1961. Deposits are widespread in Andrée Land and Dickson Land where they rest on the “pale beds” of the Kapp Kjeldsen Formation. The first thick (25–30 m) bed of green sandstone above the “pale beds” is considered as the lower boundary. This sandstone bed is ubiquitous and forms a good marker horizon. The upper boundary is marked by the change from the grey-green and brown beds of the Keltiefjellet Formation to the crimson-red siltstones of the Stjørdalen

Formation. The last thick (up to 15 m) bed of green cross-bedded sandstone of uniform occurrence is regarded as the upper boundary. Both contacts are readily traced in Andrée Land.

Sections of the formation in north-western Andrée Land and in Dickson Land are different. They are characterized by the south-eastward increase of sand grain size. In Andrée Land the formation consists generally of brick-red siltstones and fine-grained sandstones alternating with rare bands of coarser brown-green and grey-green sandstones, sandy siltstones, and less common calcareous gritstones. In Dickson Land coarse-grained sandstones and gritstones considerably increase in abundance.

The most common fish are *Doryaspis* and *Arctolepis*. Less common are *Homostius*, *Actinolepis*, *Porolepis* and *Arctolepis* suggesting a Lower Devonian age (Siegenian-Emsian). The flora is represented by *Hostimella*, *Psilophyton*, and *Aphylopteris*. The thickness of the formation is 600 to 900 m.

*Stjørdalen Formation.* This formation was first documented by FØYN and HEINTZ (1943). The deposits occur both in Andrée Land and in northern Dickson Land. The lower boundary is marked by the change from the Keltiefjellet Formation rocks to the more argillaceous cherry-red and crimson-red deposits of the Stjørdalen Formation. The contact is conformable. The upper boundary is drawn at the base of the calcareous rocks known as the Verdalen Member.

The Stjørdalen Formation consists mainly of mudstones and cherry-red and calcareous siltstones with pelletoid structure. Thin (0.5 to 2.5 m) red-yellowish-grey, micaceous, flaggy, fine-grained sandstones occur at intervals over the entire section. Individual bands (up to 0.5 m) of violet-brown, fine-grained sandstone and light grey, quartzitic sandstone occur in the lower part of the section. The middle part is characterized by a slight increase in number of bands of greenish-grey, fine-grained sandstone, and the appearance of calcareous gritstones, greenish-grey in colour. In the upper part the number of greenish-grey bands abruptly decreases. Cherry-red pelletoid siltstones and mudstones predominate.

The most common forms of fossil fish remains include Nectaspids, Monaspids, Osteostraci, Arthorodira and Crossopterygii. In V. N. TALIMAA's opinion (personal communication) the most probable age of these deposits is Emsian. The thickness of the Formation in northern Andrée Land is 400 m, gradually decreasing southward; in northern Dickson Land (Lancasterryggen) the thickness does not exceed 200 m, on Bulmanfjellet it is 70 to 100 m, on Watsonfjellet 50 m, and farther south the Stjørdalen Formation dies out entirely.

## Middle Devonian

### EIFELIAN

Grey and partly Eifelian deposits occurring largely in Andrée Land and in places in Dickson Land and the Hornsund areas, are subdivided by the present authors into three formations: Gjelsvikfjellet, Tavlefjellet, and Forkdalen.

The *Gjelsvikfjellet Formation* is subdivided into two members: Verdalen and Skamdalen.

The Verdalen Member has been recognized from the Upper part of the Stjørdalen Formation. It occurs in central Andrée Land resting conformably on the Stjørdalen redstones. The lower boundary is drawn at the base of the first bed of violet-grey, yellow-weathering, silty limestone. The upper boundary is characterized by an abrupt transition from red to grey rocks.

This member is made up largely of violet-grey and grey silty limestones, alternating with violet-red calcareous siltstones, with bands and lenses of fine-grained violet-grey and greenish-grey polymict sandstones in the upper part.

Fish remains include *Homostius arcticus*, *Herasmius granulatus*, *Heimenia ensis*, *Amaltheolepis winsnesi*, characteristic in ØRVIG's opinion of the Lower Eifelian (1969).

The thickness of this member at the type locality (Woodfjorden) is about 100 m, in the Vestfjorden area up to 60 m, and on Dickson Land it is absent.

The Skamdalen Member has been recognized from the lower Grey Hoek Group. The type section lies on the left of Skamdalen in Andrée Land. The member is widespread in Andrée Land (south of Jakobsenbukta latitude) and can be traced southward at least to Nathorstdalen (Dickson Land). It rests unconformably on the Verdalen deposits in Andrée Land and on the Stjørdalen red beds in northern Dickson Land. The lower boundary is marked by an abrupt change from red to grey rocks.

The upper boundary in Andrée Land is drawn at the change from calcareous rocks to almost black mudstones. It is impossible to trace it in Dickson Land.

The deposits of the Skamdalen Member are represented by dark grey and grey micaceous calcareous siltstones with bands and lenses of dense parallel-bedded siltstones. In the lower part there is a 27 m thick unit of almost black highly calcareous mudstone. South of Skamdalen the grain size of the sandy material increases and thin sandstone bands appear. In the Nathorstdalen area the deposits generally consist of grey-green siltstones and quartz sandstones with very scarce thin bands of grey arenaceous limestone.

Fish remains include *Heimenia ensis*, *Homostius arcticus*, *Amaltheolepis winsnesi* and *Herasmius granulatus*. In V. N. TALIMAA's opinion (personal communication) this assemblage is nearly identical to the fish fauna described by ØRVIG (1969) from the Verdalen Member and is Lower Eifelian in age. The Verdalen and Skamdalen Members may therefore be considered to be approximately coeval and similar in lithology. This, and their recognition over long distances enables them to be united into the Gjelsvikfjellet Formation totalling 250 m thick.

*Tavleffjellet Formation*. This formation was first recognized from the lower part of the Grey Hoek. The type section lies on the southern slope of Tavleffjellet west of Wijdefjorden.

This Formation may be traced in central Andrée Land from Mushamna in the north to Kartdalen in the south. A thick sequence of mudstones cropping out on the northern side of Hornsund probably belongs to the same formation.



The boundary with the underlying deposits is conformable and is marked by the change from the Skamdalen calcareous siltstones into mudstones. The upper boundary is drawn at the top of the mudstones which are conformably overlain by massive siltstones. Both contacts can be traced in several places on the southern coast of Andrée Land from Forkdalen to Kartdalen.

Within the type section these deposits are represented by two sequences. The lower sequence is composed of dark grey to black fragmentary mudstones, with bands of lighter calcareous siltstones forming scarps up to 2–3 m distinctly reflected in the topography. Individual siltstone beds are highly calcareous and sometimes are replaced by silty limestones. Carbonate nodules up to 10 m in diameter with fragments of fish and pelecypods occur throughout. The thickness of the sequence is 170 m.

The upper sequence is composed mainly of dark-grey to black calcareous mudstones with bands of mats and loaf-like silty carbonaceous nodules (up to 0.5 m in diameter) with fissures filled with brown calcite. The thickness of the sequence is 130 m.

Fish fossils include *Wijdeaspis arctica* HEINTZ, *Heimenia ensis*, *Porolepididae* gen idn., *Crossopterigii* fam. et gen., *Arthrodira* fam et gen. The following pelecypods were found: *Chenodonta* ex gr. *maureri*; BEUSH, *Prosocoelus* (?) sp., and *Nucula* sp.

V. N. TALIMAA and O. V. LOBANOVA concluded that the fossils found suggest a Middle Devonian (Eifelian) age. The thickness is 300 m.

*Forkdalen Formation.* This Formation is separated by the authors from the upper Grey Hoek Group. The type section lies on Tavlefjellet and a complete section was found on the northern flank of Forkdalen.

The Forkdalen Formation occurs mainly in northern Andrée Land where it composes the eastern and part of the western flank of the Forkdalen syncline and its periclinal zone.

The lower boundary is drawn at the first siltstone band conformably overlying the Tavlefjellet mudstones.

The upper boundary is drawn at the base of the first bed of light grey quartzitic sandstone of the Wijde Bay Group.

The Formation consists mainly of interbedded grey and dark-grey siltstones, black fragmentary mudstones and polymict sandstones. An increase in the number and thickness of sandstone units as well as in sand grain size is observed up section. "Loaf" carbonate nodules 1.0×0.4 m occur throughout the section. In the upper part large pelecypods of genus *Myalina* were found.

Within a fault zone in north-western Andrée Land the Forkdalen Formation is strongly folded and represented mostly by light-grey and grey quartzites and quartzite-like sandstones.

Fish fossils from the Forkdalen Formation include *Arthrodira*, *Heimenia*, *Arctonemia*, *Homostius*, *Antiarchi* and *Brachythoraci*. Pelecypods are represented by *Carditomantea* ex gr. *spinata* QUESNT., *Prosochama*, *Prosocoelus*, *Myalina*, *Myaphoria*, and *Montonaria*. The flora contains *Hostimella*, *Protocephalopteris*, *Psilophyton*, *Pseudouralia*, *Enigmophyton*, *Arctophyton* and *Taeniocrada*.

These fossils suggest a Middle Devonian (Eifelian) age for the Forkdalen Formation. The thickness of the Formation is 630 m.

#### GIVETIAN

Both the Wijde Bay Group, which the authors propose to consider as the Tage Nilsson Formation, and the Esteriahaugen Formation in the Billefjorden area, belong to the Givetian.

*Tage Nilsson Formation.* This formation occurs in the Tage Nilssonfjellet area in north-eastern André Land, at the locality of the type section. The lower boundary is drawn at the base of the first quartzitic sandstone. The upper contact is not exposed.

The Tage Nilsson Formation consists of closely intercalated quartzitic sandstones, massive siltstones, and mudstones. A notable feature is the intense jointing of the quartzitic sandstones usually accompanied by iron mineralization of magnetite-hematite type. Lenses of gritstone with abundant fish remains were observed at the base of sandstone bands. The siltstones yielded abundant fossils of strongly deformed pelecypods and floral remains.

Fish include *Arthrodira*, *Holomena*, *Homostius*, *Herasmius*, *Antiarchi* and *Asterolepis*. The following pelecypods were found: *Myalina*, *Avicula*, *Puella*, *Concoardium*, *Pterinea*, *Solenomorpha*, and *Laiopectinella*.

The flora is represented by *Protocephalopteris*, *Enigmophyton*, *Hostimella*, *Psilophyton*, *Taeniocrada*, and *Barrandeinopsis* allowing these deposits to be assigned in N. M. PETROSIAN's opinion, to the Late Eifelian-Givetian. The observed thickness is 600 m.

*Esteriahaugen Formation.* This unit is not very widespread. Outcrops extend in a narrow band in the interfluvium of Munindalen and Mimerdalen. The lower contact is tectonic. This formation is faulted against variegated Lower Devonian Reuterskiöldfjellet sandstones. However, VOGT (1938) has observed the Esteriahaugen deposits resting on the red-coloured Lower Devonian deposits with an unconformity representing a gap.

The upper boundary is drawn at the base of the 1.7 m thick unit of black fragmentary mudstones.

In the lower part of the formation fragmentary mudstones dominate, with less common bands and lenses of light-grey polymict quartzitic sandstones. A large number of rounded argillaceous nodules and thin bands of coals and coaly rocks occur in the mudstones. The upper part is composed mainly of quartz sandstone containing numerous rounded pyrite nodules which when oxidized show rusty patches.

The following fossils were collected from this Formation: Plants: *Platiphyllum*, *Protocephalopteris*, *Pseudoporochnus* and *Svalbardia* (determined by N. M. PETROSIAN); ostracods: *Hogmochilina* (identified by ABUSHEK); pelecypods: *Myalina* and *Pteria*.

Identified spores include *Camarozonotriletes*, *Archaeotriletes*, *Stenoronotriletes*, *Archaeoperisaccus*, and *Archaeozono* (determined by G. K. VAITEKUNENE).

Thus, these deposits may tentatively be assigned to the upper Givetian, but they may be Frasnian. The observed thickness is 100 m.

## Upper Devonian

### FRASNIAN

Frasnian rocks are represented by a single formation and were observed only in the Mimerdalen area (Billefjorden).

*Fiskekløfta Formation.* This formation occurs mainly in the upper and middle reaches of Mimerdalen. The type section lies in the Fiskekløfta gorge. The lower contact is conformable and is drawn at the top of a plant-bearing, grey-green sandstone.

Generally the deposits consist of interbedded black fragmentary mudstones, grey-green, fine-grained quartz sandstones with carbonized plant detritus, and dark-grey siltstones. Flattened carbonate-iron nodules (up to 5 cm in diameter) occur throughout the section.

Fish and plant remains as well as spores were collected from the deposits.

Fish: *Asterolepis scabra* (WOOD), *A.sp.ind.*, characteristic in V. N. TALIMAA'S opinion of the lower Upper Devonian (Frasnian).

Flora: *Aulacopteris vulgaris* GRAND EURU., *A. vulgaris* HØEG, *Anarthrocanna gopperti* NATH., *Heteraugium sp.*, *Leptofloeum rhombicum* DAMS. (*Bergenia spitsbergensis sp. nov.*, and *Rhizomopteris nordenskiöldi* NATH.). N. M. PETROSIAN considers these to be indicative of an Upper Devonian age.

Spores: *Archaeozonotriletes cf. notatus var. asper* TSCHIBR., *A.sp.*, *Acinosporites sp.*, *Densosporites lyssi var. spinatus* TAUG-LANTZ, *Calamospora cf. microrugosa* (IBR.) BALME, *Hystricosporites porcatus* (WINSON) ALLEN, *Geminospora sp.*, *Lophotriletes unguatus* NAUM., *Punctatisporites sp.*, and *Retusotriletes greggsii* MCGREGOR. suggest an Upper Devonian (Frasnian) age. The thickness of the formation is 145 m.

### FAMENNIAN

*Planteryggen Formation.* The formation is assigned by the present authors to the Famennian stage.

The Planteryggen Formation was first named by FRIEND in 1961. Deposits occur in the upper Munindalen and Mimerdalen. The lower boundary is drawn at the base of a bed of sugary sandstones containing large fragments of tree trunks.

The lower part of the formation consists of grey-coloured sandstones with bands of mudstones and siltstone. The upper part comprises sandstones, siltstones and mudstones. The section is capped by a unit (40 m thick) of red conglomerate with pebbles of quartzite, microquartzite, sandstone and siltstone.

Floral impressions include *Bothrodendron sp.*, *Leptophlecum rhombicum* DAMS., *Cyclostigma Kilterkense* (HAUGHTON) NATH., *Knorria sp.*, *Lepiodendron spitsbergensis* NATH. and *Lepiodendrops sp.* In N. M. PETROSIAN'S opinion this assemblage suggests an Upper Devonian age.

In the upper reaches of Odindalen a large fragment of a vertebra was found. E. VOROBEVA believes it to belong to the crossopterygians, however it may also have belonged to the oldest stegocephalians. The thickness of the formation is 180 to 400 m.

## CARBONIFEROUS

These deposits are discussed because they have previously been considered to be Upper Devonian. These rocks belong to the Mimerdalen Group and are represented by the Plantekløfta Formation developed in the area of Plantekløfta creek and along the west side of Munindalen. These deposits rest with an angular unconformity on different horizons of the Planteryggen Formation. The upper contact is not exposed. In Munindalen the upper beds of the formation are faulted against the Lower Devonian Reuterskiöldfjellet sandstone (Wood Bay Group).

The Formation consists of interbedded fine- to medium pebble conglomerates, dark-green sandstones and siltstones. The pebbles consist of 95% violet and greenish-greyish sandstones and 5% grey siltstones. Gritstones cementing the pebbles contain 60% quartzite and 40% sandstone and siltstone.

PETROSIAN determined the flora to be *Cyclostigma kilterkense* (HAUGHTON) NATH., *Bothrodendron* sp., *Leptophlocum rhombicum* DAWSON, *Bergenia mimerensis* HØEG and *Lepidodendropsis theodoty* (ZAL.) JOGUM.

In addition remains of lycopods were found with fine cushions similar to lycopods of the lower Carboniferous. However, poor preservation does not allow accurate identification. PETROSIAN claims that they may be younger than Upper Devonian, namely lower Lower Carboniferous. The thickness of the formation is 100 m.

## Conclusions

The study of the Devonian deposits of Spitsbergen by Soviet geologists resulted in the further subdivision and dating of the Devonian section:

1. Three formations, i.e. Wulfberget, Rabotdalen, and Prinsesse Alice, earlier known as lithological horizons, were recognized within the Red Bay Group.
2. The Grey Hoek Group was subdivided for the first time into three formations: Gjelsvikfjellet, Tavlelfjellet, and Forkdalen.
3. On the basis of plant remains the ages of the formations of the Mimerdalen Group were refined.
4. New paleontological data became available which enabled more accurate determination of the age of the Devonian deposits in Spitsbergen.

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