Outline of the Geology of Svalbard

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Short geological review and guidebook

Introduction

Svalbard is located in the northwestern corner of the Barents Shelf (Figures 1 and 2). The archipelago represents an uplifted part of this otherwise submerged shelf. The uplift was most extensive in the north and west, leaving progressively older rocks in these directions. A pronounced synclinal feature, the Central Spitsbergen Basin, occupies most of central Spitsbergen. The basin is bounded to the west by the West Spitsbergen fold- and thrust belt, which die out towards the eastern part of Spitsbergen. The basin boundaries parallel a dominant NNW- SSE structural grain on Spitsbergen comprised through four similarly aligned episodes of tectonic deformation. Regionally Svalbard may be divided into five geological provinces (Figure 2):

1. The Hecla Hoek complex comprising metamorphic rocks of Precambrian to early Silurian age. These rocks crop out along the west coast and on the north-eastern part of Spitsbergen, and on Nordaustlandet (Pre-Old Red basement in Figure 2)
2. The Devonian Grabens on northern Spitsbergen (Devonian cover rocks in Figure 2)
3. The central basin in the central parts of Spitsbergen
4. The platform areas on the eastern parts of Spitsbergen and on Barentsøya and Edgeøya
5. The Tertiary fold-belt along the west coast of Spitsbergen

The Caledonian Orogeny including faulting, folding, thrusting, and metamorphism of Precambrian to middle Ordovician sediments and igneous complexes was particularly intense, and formed the Hecla Hoek basement. The total stratigraphic thickness is in the order of 15-20 km and the degree of metamorphism and structural complexity varies considerably, particularly in the older part of the succession.
Following the Caledonian Orogeny, Devonian extensional shearing took place, with rift basin deposition of a thick pile of mostly continental red-beds. A stratigraphic thickness of up to 8 km has been reported in two major, N-S trending grabens in north Spitsbergen. The lower parts are found along the present north-western margins of the grabens and rest directly upon deformed Hecla Hoek. These lower beds consist of coarse clastics, mainly of alluvial fan and fluvial origin. The middle and upper parts comprise a succession of fluvial and possible deltaic sediments.

Around the early/middle Devonian boundary there is a change from red to grey facies. It probably reflects a transition from semi-arid climatic regimes (typically of Old Red sedimentation) towards more humid conditions. The fluvial systems are represented by the lower red bed facies of braided streams flowing from the west towards the axial portions of the graben. The basinal axis was characterised by a general northwards tilt and flow of high sinuosity fluvial systems towards a coast to the north. The shift from red to grey sediments is accompanied by a general development towards an upward fining trend. Facies patterns and fossils in the grey sandstones and shales of northernmost Svalbard may suggest deposition in deltaic environments. Channel sands are interbedded with shales representing humid coastal plains and brackish water interdistributary bays. Comparable beds in the main graben further south consists of coarser clastics, coals and ironstones, clearly showing the humid nature of this hinterland area.

The so-called Svalbardian tectonic movements in late Devonian was the result of large scale left-lateral movements along the Billefjorden Fault Zone (Figure 2, marked BFZ). These movements caused folding of the Devonian sediments resulting in an angular unconformity towards the overlying Carboniferous succession (Figure 3).
Figure 2  Simplified geological map of Svalbard (from Dallmann 1999)
The early to middle Carboniferous comprise a period of extension, with a small component of left-lateral shear in the middle Carboniferous. The middle Carboniferous extension concentrated along a few major lineaments like the Billefjorden Fault Zone, which caused the formation of the Billefjorden Graben east of it (Figures 2 and 4). Areas of major faulting and pronounced graben formation shifted across Spitsbergen during this period with non-marine to marginal marine infill of up to 2 kilometre in thickness.

The Billefjorden Group (Figures 2 and 3) consists of conglomerates, sandstones, and coals. The group represent palaeoenvironments dominated by large humid alluvial fans which built out from active fault scarps into adjacent swamps lakes and fluvial plains (Figure 4).
The uppermost parts of the Billefjorden Group show decreasing subsidence rates and retreating fan systems being replaced by fine-grained marsh and floodplain deposits. These include the youngest coal-bearing Carboniferous strata, which were mined by Russians at Pyramiden in the innermost part of Billefjorden up to 1997 (See the excursion map in Figure 10). This early Carboniferous succession is followed by up to 1 km of alluvial redbeds, marine carbonates and evaporites of the Gipsdalen Group continuing into the middle Carboniferous.

During the late Carboniferous, Permian and Mesozoic, a stable platform evolved, comprising Svalbard and large parts of the Barents Shelf. The lower Carboniferous-Permian succession consists of limestones, dolomites and evaporites grading upwards into cherty limestones and silicified shales/siltstones belonging to the Tempelfjorden Group (Figure 5).
The Permian - Triassic boundary is widely exposed on Svalbard and can also be traced throughout the Barents Sea Shelf as a pronounced reflector. During the late Permian and early Triassic the depositional centre was situated in the outer Isfjorden area. In this area continued sedimentation took place. Today cherty black shales are overlain by soft dark grey shale without any visible break. Further east on central Spitsbergen the upper Permian succession consists of well-cemented sandy carbonates, often glauconitic, which at the top has an erosional surface. Reworked Permian sediments often occur in the basal Triassic beds, which consist of sandstones grading to greenish grey shales. The break in sedimentation increases from the depocenter and both south- and eastwards, being most extensive at Edgeøya were the entire lower Lower Triassic is missing.
The Mesozoic succession consists of repeated cycles of siliciclastic coastal and deltaic progradations into a wide shelf basin. The passage from lower Permian carbonates and evaporites to upper Permian and Triassic clastics took place while the plate drifted towards higher palaeolatitudes. Numerous well developed upwards coarsening sequences from shales and siltstones to variable sandstones in the Triassic and early Jurassic (Sassendalen and Kapp Toscana groups, Figures 3 and 6), pass into more homogeneous shales in the late Jurassic-early Cretaceous (Janusfjellet Subgroup).

Griesbachian (Early Triassic)  Anisian/Ladinian (Middle Triassic)  Carnian/Norian (Late Triassic)

The Lower and Middle Triassic Sassendalen Group is exposed along the Tertiary fold belt, in central and eastern Spitsbergen and on Barentsoya and Edgeøya. It represents series of stacked transgressive – regressive sequences, each being initiated by a significant transgression. In western Spitsbergen the group comprises deltaic to shallow shelf deposits grading eastwards and southwards into shelf mudstones. The upper part is highly organic and phosphatic and consists of fine-grained sandstones, siltstones and shales, representing shallow shelf deposition in an epicontinental sea (Figure 6).
The Upper Triassic to middle Jurassic Kapp Toscana Group is exposed in the same areas as the Sassendalen Group. The lower parts is made up of grey shales upwards grading into immature sandstones. This sandy interval contains a number of coarsening-upward units showing increasing proportions of sandstone towards the south-west, north-east and east. The uppermost part forms a condensed clastic sedimentary succession containing some thin phosphatic nodule layers. The Kapp Toscana Group was on Svalbard deposited in a generally nearshore, deltaic environment and is characterised by shallow marine and coastal reworking of deltaic sediments (Figure 6).

Overlying the Kapp Toscana Group, the Brentskardhaugen Bed is a 1 to 2 m thick, phosphatic conglomerate. It was deposited during the extensive Bathonian transgression initiating the deposition of the Adventdalen Group. On top of this bed the oolithic Marhøgda Bed is developed in several localities.

The Middle Jurassic to Early Cretaceous Adventdalen Group is widely exposed along the margins of the Central Basin, as well as in eastern Spitsbergen. The group is dominated by dark, marine mudstones, but also includes deltaic and shelf sandstones as well as thin, condensed carbonate beds (Figure 7).

A hiatus occurs near the Jurassic – Cretaceous boundary. This hiatus is found a few meters below the Myklegardfjellet Bed, which consists of reddish-yellow to green plastic clays. It is an easily weathering marine deposit, rich in glauconite at some horizons.

In Early Cretaceous clays were deposited in a deeper shelf setting than before. These shales grade upwards into prodelta-deltafront siltstones and sandstones (Figure 8). These are overlain by a pronounced, prograding deltaic sandstone unit in the Barremian (Helvetiafjellet Fm.) which is succeeded by a series of transgressive, stacked shelf sandstones and siltstones (the Albian –Aptian Carolinefjellet Fm., Figure 3).

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The Late Cretaceous opening of the Arctic Basin caused a northerly uplift and progressive southerly development of the basal Tertiary unconformity. In central Spitsbergen, Aptian – Albian strata are succeeded by the Tertiary section, with an intervening angular unconformity. The Tertiary deformation of Svalbard was the result of right-lateral transtension in the Paleocene followed by right-lateral transpression in the Eocene as Greenland slid by Svalbard during the initial opening of the North Atlantic - Arctic basins.

The Tertiary Central Spitsbergen Basin may be regarded as a regional foreland depression with cyclic infill of mixed continental to marine clastics (Figure 9).

An overall transgressive package, from coal bearing deltaic deposits to marine sandstones and shales, characterises the transtensional phase. A large-scale regressive package, from marine shales to fluviodeltaic sandstones and shales is typical for the shift towards transpressional conditions. The change in tectonic regime is evidenced also by a mutual shift from easterly to westerly sediment input, reflecting the growing compression of the West Spitsbergen fold-and-thrustbelt.
Figure 9  Early Paleocene palaeogeography (from Worsley 1986)


Selected reading


This short introduction to the geology of Svalbard and field excursion guide is an informal compilation to be used by the participants of the 7th ESF IMPACT Workshop.

It has intentionally been written in a form so that it hopefully can be of use, not only to geoscientists, but also for others visiting Svalbard for the first time. The most important sources are listed in the selected reading list. The majority of the figures are taken form Dallmann (1999) and Worsley (1986).