NORSK POLARINSTITUTT
SKRIFTER NR. 138

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Geology of the Adventdalen map area

With a geological map, Svalbard C9G 1:100 000
by
HARALD MAJOR

NORSK POLARINSTITUTT
OSLO 1972

DET KONGELIGE DEPARTEMENT FOR INDUSTRI OG HÅNDVERK

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Contents

Abstract

The map area, covering 2,250 km², lies in the central part of Spitsbergen, south of Isfjorden. Geological investigations were started by Swedish expeditions in the last half of the 19th century, and the work was continued in the present century mainly by Norwegian expeditions. The region is mountainous, moderately glaciated, but shows a juvenile glacial morphology. The climate is polar.

The rock sequence exposed in the area is c. 3,400 m thick and consists of two Permian, six Mesozoic, and six Tertiary formations. The Permian deposits are mainly cherts, cherty limestones, limestones, and sandstones deposited under marine conditions. The Mesozoic-Tertiary sequence is composed generally of shales, siltstones, and sandstones deposited mainly in marine environments, and to a lesser extent under terrestrial conditions. Surficial deposits of Quaternary age are largely of glacial, colluvial, alluvial, and marine origin.

Diabases exposed in the northern part of the area were apparently intruded at the close of the Jurassic period. Thin beds of clay-like material occurring in the Tertiary are considered to be weathered volcanic ash.

The post-Silurian rock sequence has been only slightly deformed by crustal movements, the most important of which occurred in the Tertiary. The main structural features are elongated swells and depressions in the south-west and the Billefjorden fault zone in the east.

Coal seams occur at several horizons in the Tertiary, the Mesozoic, and possibly also in the Palaeozoic, but only the Tertiary coals have been mined commercially. The region is potentially favourable for petroleum, but no drilling has yet been carried out. Deposits of phosphate, gypsum, and bentonite are of doubtful economic value.

Sammendrag

Kartbladet Adventdalens område ligger i den sentrale del av Spitsbergen, på sørsiden av Isfjorden, og har et flateinnhold på 2 250 km². Den geologiske utforskning av området startet i siste halvdel av forrige århundre, dominert av svenske ekspedisjoner. Den norske aktivitet begynte for alvor i 1908 og hadde en særlig intens periode fram til 1925. Innsatsen deretter besto hovedsakelig i kullgeologiske undersøkelser. Den foreliggende beskrivelse er basert på publiserte og upubliserte observasjoner, mens kartet er utarbeidet ved hjelp av foto-geologi kombinert med upubliserte feltkart.

Området har en variert topografi som bærer preg av sterk landhevning samt

av ung, glasial og fluvial erosjon. I dag er området forholdsvis lite bredekket og dreneres overveiende gjennom fire hoveddaler. Klimaet er polart med forholdsvis lite nedbør, og vegetasjonen er høy-arktisk. Longyearbyen er det eneste sted med permanent bosetning.

Geologisk sett ligger kartområdet i Spitsbergentrauet som er en regional depresjon hvor øvre paleozoiske, mesozoiske og kenozoiske sedimenter ligger over det kaledonske metamorfe underlag. De to eldste formasjoner som opptrer i dagen er av Permisk alder, avsatt i marint miljø. Den nederste, Gipshukformasjonen (Gipsdalgruppen), er representert hovedsakelig ved kalksteiner, mens den øverste, Kapp Starostinformasjonen (Tempelfjordgruppen), består overveiende av flint, flintholdig kalkstein og sandstein. Den samlede mektighet av disse to enheter er ca. 476 m.

Lagrekken fra trias har en mektighet på ca. 645–660 m og omfatter tre formasjoner. De to nederste, Vardebukt- og Kongressfjellformasjonen, er marine og består hovedsakelig av skifer og siltstein, mens den øverste, Kapp Toscanaformasjonen, inneholder i det vesentlige marin skifer og siltstein, samt kontinental sandstein.

Det aller meste av under- og mellomjura er ikke representert ved sedimenter, mens overjura og nederste del av underkritt er bygget opp av marin skifer, siltstein og noe sandstein tilhørende Janusfjellformasjonen. Midtre del av underkritt er representert ved kontinentale sandsteiner og siltsteiner som danner Helvetiafjellformasjonen. Denne overleires av marine lag fra øvre del av underkritt, hovedsakelig skifer, siltstein og sandstein, som sammenfattes under Carolinefjellformasjonen. Deretter følger en hiatus som i det vesentlige omfatter overkritt. Den samlede mektighet av jura-krittlagrekken er ca. 860–880 m.

De tertiære sedimenter danner en nærmest kontinuerlig lagrekke bestående av de følgende seks formasjoner (etter avtagende alder): Firkantformasjonen – avsatt under vekslende marine og kontinentale forhold – består av sandstein med siltstein, skifer og noe kull nederst. Basilikaformasjonen, marin skifer med siltstein. Sarkofagformasjonen, marin sandstein med et kortvarig kontinentalt innslag øverst. Gilsonryggformasjonen, marin skifer. Battfjellformasjonen, vekslende lag av skifer, siltstein og sandstein, hovedsakelig marine. Aspelintoppformasjonen, kontinental sandstein og siltstein med skifer og kull. Den samlede mektighet av tertiær er ca. 1175–1540 m.

Kvartærtiden er i det vesentlige representert ved glasiale, colluviale, alluviale og marine sedimenter. De er hovedsakelig begrenset til dalene hvor de danner et løst dekke av sterkt varierende mektighet over fjellgrunnen.

Eruptive bergarter er det forholdsvis lite av. Diabasgangene i den nordlige del av kartområdet ble intrudert sannsynligvis på overgangen jura–kritt. Tynne lag av leirlignende bergart i tertiær er blitt tolket som forvitret vulkansk aske.

Tektonisk sett har området en enkel bygning. Lagene viser et svakt regionalt fall mot sør-vest (mot aksen av Spitsbergentrauet), og derfor passerer man stadig yngre formasjoner hvis man går fra nord-øst mot sør-vest. Den sør-vestlige del av området inneholder to slake og lite distinkte antiklinorier, samt tre tilsvarende grunne synklinorier. Disse strukturer har regionalt sett en sydøstlig strøkretning som synes generelt å følge Spitsbergentrauets akseretning. Et annet viktig strukturkompleks er Billefjordforkastningssonen med dens varierende lokale utformning. Sonen kommer til syne syd for Sassenfjorden og deler seg i to grener før den krysser Adventdalen.

Områdets geologiske historie faller i tre hovedavsnitt: 1) Geosynklinalperioden, som ble avsluttet av den kaledonske orogenese mellom midtre ordovicium og devon. 2) Senorogenperioden, begrenset hovedsakelig til devon. 3) Mobil-plattformperioden, som strekker seg fra karbon til i dag. Innen området er det bare plattformperioden som er representert med sedimenter på dagoverflaten, og er kjent i større detalj. Denne periode er karakterisert ved langsom senkning med sedimentasjon under marine, littorale, estuarine, eller terrigene forhold. Senkningen ble avbrutt av flere episoder med hevning og erosjon, hvorav de mest markerte forekom i under- til mellomjura og i overkritt. Billefjordforkastningssonen hadde en markert aktivitetsperiode på overgangen mellom jura og kritt, muligens i forbindelse med intrusjon av diabaser. I yngre tertiær ble Svalbard utsatt for sterke jordskorpebevegelser som bl. a. har utformet Spitsbergentrauet. Innen kartområdet har disse bevegelser resultert i: svak regional skråstilling av lagrekken med fall mot sør-vest; nye, markerte bevegelser langs Billefjordforkastningssonen; dannelse av noen få isolerte forkastninger; utforming av antiklinoriene i sør-vest, men dannelsen av disse strukturer var muligens innledet ved mesozoiske eller eldre bevegelser.

Lag av kull forekommer i flere horisonter i tertiær, mesozoicum og muligens også i paleozoicum, men bare tertiære lag har vist seg drivverdige. Kull har vært produsert i Advent City, Moskushamn, Grumantbyen og i Longyearbyen. Bare Longyearbyens gruver er i drift i dag. Kartområdet er potensielt gunstig for forekomst av petroleum, men mulighetene kan være begrenset av forholdsvis høy diagenesegrad i sedimentene. Prospektering for petroleum har vært i gang siden 1960 uten at man har foretatt boring. Avsetninger med fosfat, gips og bentonitt er kjent, deres potensielle verdi er imidlertid vanskelig å fastslå i dag.

I. Introduction

Location

The map area occupies about 2,250 km^2 and is situated in the central part of Spitsbergen. More precisely, it lies in the north-eastern part of Nordenskiöld Land (the peninsula between Isfjorden and Van Mijenfjorden). The region is mountainous and moderately glaciated. Around 2,000 km^2 of the map area is dry land, while the remaining 250 km^2 is covered by the waters of Isfjorden and its tributary bays Colesbukta, Adventfjorden, and Sassenfjorden.

Previous work

A considerable amount of geological work has previously been carried out in the map area. Valuable geological observations were made predominantly by

Swedish expeditions in the last half of the 19th century, and in the early 20th century. The results of these early field activities are described in BLOMSTRAND 1864; NORDENSKIÖLD 1863, 1866, and 1875; HEER 1876; NATHORST 1884, 1888, and 1910; DE GEER 1896, 1910, 1912, and 1919; STOLLEY 1911; SPATH 1921; and GREGORY 1921.

Extensive topographical and geological mapping was carried out in Nordenskiöld Land in the years 1908–1925 by members of The Norwegian State-supported Spitsbergen Expeditions. Geologists participating in the work (A. HOEL, G. AASGAARD, J. BRAASTAD, G. HOLMSEN, G. HORN, and A. K. ORVIN) completed field maps on a scale of 1:50 000. These maps were then synthesized by A. K. ORVIN, who presented the results at a meeting of the Norwegian Geological Association in 1925. One of the present authors, H. MAJOR, has used this map material in a continued study of the coal-field between Adventdalen and the inner part of Van Mijenfjorden, begun in 1949. In connection with the coal geology, he has made additional stratigraphical and structural observations as well as some adjustments to the previous field maps.

The present report

In 1961 and 1962 the map area was covered by vertical aerial photographs (scale 1:45 000), and this material has greatly increased the value of the available geological observations. Consequently, the map is based on photo-geological, as well as on previous work and, where necessary, additional field observations. The map has been compiled by H. MAJOR and drafted by M. GALÅEN, and was printed in 1964.

The topographical base map is sheet C9 Adventdalen, scale 1:100 000, published in 1950. This was originally produced in two sheets, E9 and F9, on a scale of 1:50 000, constructed by means of oblique aerial photographs and topographical field work.

The preparation of the present memoir was started by H. MAJOR and he was later joined by J. NAGY. Much of the study is compiled from published or unpublished reports of previous workers; the sources of this information are given in the text.

Norsk Polarinstitutt owns the copyright of the photographs reproduced in this memoir. Fig. 1 is a vertical aerial photograph taken in 1961, Figs. 2–9, 11, and 12 are oblique aerial photographs taken in 1936, while Fig. 13 is taken from the ground.

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II. Geography

Relief and drainage

The map area has a high, but moderately dissected topography with evenly distributed peaks, ridges, and plateaux. More than a dozen of the summits exceed 1,000 m in altitude. The highest altitude, 1,147 m, is on the ridge Møysalen, near the centre of the map. The landscape shows a morphologically juvenile character with abundant features of recent and older glacial and fluvial erosion. It is probably developed from a peneplane which was elevated to an altitude of more than 1,000 m. On the present rugged surface no or only trifling remains of this original feature have been preserved.

Four major valleys cut through this landscape. Three of them (Colesdalen, Adventdalen, and Sassendalen) run from south-east to north-west and open into tributary bays of Isfjorden. The fourth (Reindalen) runs from north-east to south-west and opens into Van Mijenfjorden outside the map area. All of the major, and many of the smaller valleys are typically U-shaped as a result of glacial erosion. A great number of the smaller valleys are still (partly or entirely) occupied by glaciers. The flat bottoms of the major valleys amount to about 1/12 of the total land area, and they are generally covered by unconsolidated glacial, alluvial, or marine deposits.

Streams draining the northern three-quarters of the land area discharge into Isfjorden, while those draining the southern quarter flow into Van Mijenfjorden. The principal rivers (Coleselva, Adventelva, Sassenelva, and Reindalselva) consist of a complicated system of channels in the bottoms of the four main valleys. Numerous tributary streams cut the mountain slopes and build extensive alluvial cones along the valley sides. The erosion and transport activities of the streams are restricted mainly to the intensive snow-melting periods in summer time.

A few more or less brackish lakes occur near the mouths of the large valleys,

Fig. 1. *Vertical view of Reindalen showing the broad valley bottom and the flanking mountains. On the northern side of the braided stream, Reindalselva, four pingos are developed: three of them with craters, and the fourth with distinct cracks. The recent retreat of the glaciers is marked by extensive terminal and lateral moraines.*

and they have proved to be valuable water resources for the population of the mining towns. Lakes dammed by moraines or temporary ice-dammed lakes are rare.

About one-sixth of the land area is covered by glaciers. These are essentially of valley and cirque types, but subordinate, thin plateau glaciers are also present. Prominent terminal and lateral moraines and other glacial and glacifluvial deposits are common (see Fig. 1).

Climate and vegetation

The temperature in the warmest month (July) is about $+6^{\circ}$C, and in the coldest month (February) about -16°C; the yearly precipitation is about 200 mm (measurements in Longyearbyen). Permafrost prevails in the ground down to a depth of 250–400 m.

Vegetation is very scarce and has a typical high-arctic tundra nature. Areas with continuous plant cover, consisting mainly of mosses, grasses and lichens, are restricted to valleys and other sheltered places. The mountains are generally bare, except for small patches of lichens, mosses, and some vascular plants.

Population

At present the area has a permanent population only in Longyearbyen where about 800 people are living. This is a mining town with the office of Sysselmannen (the governor of Svalbard), church, school, telegraph, and mail office. Until 1962 there also lived c. 1,000 people in the mining town Grumantbyen at Colesbukta.

III. Stratigraphy

The pre-Quaternary sedimentary succession exposed in the map area has an aggregate thickness of around 3,400 m and is composed of marine and non-marine strata. The age of the succession ranges from Permian to Tertiary. On the map altogether 12 stratigraphic units are differentiated, and a summary of their thickness, lithology, and further subdivision is given in Table 1.

In spite of the great thickness of sediments, deposition was not continuous in the map area. This is shown by unconformities at the base of: the Tempelfjorden Group (disconformity ?); the Vardebukta Formation (disconformity ?); the Janusfjellet Formation (disconformity); the Firkanten Formation (disconformity or slight angular unconformity); the Quaternary (angular unconformity). A local angular unconformity was recognised at the base of the Cretaceous by PARKER (1967) along the eastern side of the Billefjorden fault zone.

Permian System

GIPSDALEN GROUP — GIPSHUKEN FORMATION (P1)

The oldest rocks exposed in the area belong to the Gipshuken Formation which is the uppermost formation of the Gipsdalen Group. Both the Gipsdalen Group and the Gipshuken Formation were defined by CUTBILL & CHALLINOR (1965) in a revision of the Carboniferous and Permian stratigraphy of Spitsbergen. The type

Table 1. *Generalized stratigraphic section of sedimentary rocks exposed in the Adventdalen map area. Abbreviations used: Gr = group, Fm = formation, Mb = member, UNC. = unconformity.*

System	Series	Lithostratigraphic unit		Lithology	Thickness in m
Quaternary				Marine sand, silt, and clay; beach gravel and sand; Alluvial gravel and sand; till and glacial outwash; soil and talus.	
		UNC.			
Tertiary	Oligocene-Miocene(?)	Aspelintoppen Fm		Sandstone, grey and greenish, interbedded with grey siltstone and silty shale; many thin coal seams. Abundant plant fossils.	500–600
Tertiary	Eocene-Oligocene	Battfjellet Fm		Sandstone, polymict, alternating with shale and siltstone.	100–200
Tertiary	Eocene-Oligocene	Gilsonryggen Fm		Shale, black and dark-grey; contains thin clay beds, clay-ironstone, and chert nodules.	200–235
Tertiary	Eocene	Sarkofagen Fm		Sandstone, greenish grey; locally with shale and siltstone in the lower and upper part. Nodules of chert and quartzite.	276
Tertiary	Palaeocene	Basilika Fm		Shale, dark-grey, silty; with some siltstones. Silty sandstones in the upper part. Thin beds of clay; nodules of chert and quartzite.	20–85
Tertiary	Palaeocene	Firkanten Fm		Upper part: Light sandstones with some silty and conglomeratic beds. Lower part: Shales, siltstones, and sandstones with five coal seams. Conglomerate at base locally.	80–140
		UNC.			
Cretaceous	Lower	Carolinefjellet Fm	Langstakken Mb	Alternating sandstone, siltstone, and shale.	153
Cretaceous	Lower	Carolinefjellet Fm	Innkjegla Mb	Shale and siltstone with some thin interbeds of sandstone.	95
Cretaceous	Lower	Carolinefjellet Fm	Dalkjegla Mb	Sandstone with silty interbeds.	22
Cretaceous	Lower	Helvetiafjellet Fm	Glitrefjellet Mb	Sandstone, fine to coarse grained; with interbeds of shale and siltstone. Thin coal seams, plant fossils.	88–95
Cretaceous	Lower	Helvetiafjellet Fm	Festningen Mb	Sandstone, light-grey, fine to coarse grained, locally conglomeratic.	6–14
Jurassic	Upper / Middle / Lower	Janusfjellet Fm		Dark shale, with calcareous or sideritic nodules; sandstones and siltstones in the upper part; conglomerate with phosphatic nodules at base.	c. 500
		UNC.			
Triassic	Upper	Kapp Toscana Fm	De Geerdalen Mb	Sandstone, sandy shale, and siltstone.	190
Triassic	Upper	Kapp Toscana Fm	Tschermakfjellet Mb	Shale, dark grey, with clay-ironstone concretions in the lower part and siltstone interbeds in the upper part.	63
Triassic	Middle	Kongressfjellet Fm	Botneheia Mb	Shale, finely laminated, black and dark-grey, bituminous; with phosphatic nodules.	157
Triassic	Lower	Kongressfjellet Fm	Sticky Keep Mb	Shale and shaly siltstone, dark-grey; with calcareous concretions.	121
Triassic	Lower	Vardebukta Fm		Siltstone and silty shale with some sandstone.	115–129
		UNC ?			
Permian	Upper / Middle	Tempelfjorden Gr	Kapp Starostin Fm	Shale, siltstone, sandstone, and limestone; lower and middle part strongly silicified. Rich in brachiopods.	c. 396
		UNC ?			
Permian	Lower	Gipsdalen Gr	Gipshuken Fm	Limestone, alternating with some shaly and silty beds. Thin beds of gypsum occur. Base not exposed.	80+

Fig. 2. *Oblique aerial view (towards north-east) of the Coloradofjella area showing Permian and Triassic rocks: Gipshuken Formation of the Gipsdalen Group (P1), Kapp Starostin Formation of the Tempelfjorden Group (P2), Vardebukta Formation (TR1). Possible unconformity (u ?).*

section of the Gipshuken Formation is situated in Bünsow Land in the north-east of the map area.

The Gipshuken Formation is exposed at the mouth of Sassendalen in two small areas: at Storgjelet on the northern side of the valley (Fig. 2), and at Svelt-ihel on the coast of Sassenfjorden. The sequence exposed at Storgjelet represents the upper 60–80 m of the formation, and consists mainly of limestones alternating with some shaly and sandy beds containing some thin layers of gypsum.

According to CUTBILL & CHALLINOR (1965) the age of the Gipshuken Formation is probably Artinskian.

TEMPELFJORDEN GROUP — KAPP STAROSTIN FORMATION (P2)

The Tempelfjorden Group includes three formations, namely the Kapp Starostin and Tokrossøya Formations in Spitsbergen, and the Spirifer Limestone on Bjørnøya. Within the map area and in most of Spitsbergen the group is represented by the Kapp Starostin Formation, the type section of which is situated at Festningen. The Kapp Starostin Formation has three members (in ascending order): The Vøringen Member, the Svenskegga Member, and the Hovtinden Member. The Tempelfjorden Group and the Kapp Starostin Formation with its three members were named by CUTBILL & CHALLINOR (1965). The Kapp Starostin Formation is equivalent to the Brachiopod Cherts of GEE et al. (1953).

The Kapp Starostin Formation is exposed on the southern side of Sassendalen and in the region north of Sassendalen. The formation consists mainly of shales, siltstones, and sandstones with some limestones. Especially in the lower and middle part of the formation the rocks are strongly silicified and pass into bedded chert.

The middle and upper parts of the Kapp Starostin Formation are widely exposed in the area north of Sassendalen. The base of the formation, however, lies below the surface with the exception of the north-western part of Coloradofjella, where the formation is exposed in its whole thickness (Fig. 2). At this locality the formation is c. 396 m thick (WINSNES 1966).

On the southern side of Sassendalen the upper and middle parts of the Kapp Starostin Formation are exposed in the area between Flowerdalen and Sticky Keep. The most complete sections here occur on Skarvrypehøgda and on the northern slope of Marmierfjellet. At the latter locality the combined thickness of the upper two members of the formation is apparently c. 300 m (GOBBETT 1963, p. 22).

All three members of the Kapp Starostin Formation are recognisable within the map area (see Section 1, p. 47). The *Vøringen Member* is a coarse, cherty limestone containing a rich brachiopod fauna. Complete sections of this unit are exposed at Gjelhallet. The overlying *Svenskegga Member* is composed mainly of chert and cherty limestone with some shale and sandstone. The *Hovtinden Member* represents the upper part of the formation and consists mainly of green or grey sandstone with cherty beds; the sandstone is usually glauconitic.

The rich brachiopod faunas occurring in the Kapp Starostin Formation were revised by GOBBETT (1963). According to this author, the age of the fauna "may be equivalent to that of the Mid-Permian unconformity widespread in the U.S.S.R., or to the Lower Kazanian".

In a consideration of the rates of sedimentation during Carboniferous and Permian times in Spitsbergen, CUTBILL & CHALLINOR (1965) assumed that the Kapp Starostin Formation represents the Kungurian and the whole Upper Permian.

Triassic System

VARDEBUKTA FORMATION (TR1)

The Vardebukta Formation was described by BUCHAN et al. (1965); its type section is situated in Vardebukta (between Kapp Starostin and Vestre Tvillingodde) where it forms part of the comprehensive Festningen Section. The formation comprises the lower, sandy part of the Spitsbergen Triassic, and is largely equivalent to the "Ältere Eo-Trias" of FREBOLD (1939).

On the western flank of the Spitsbergen trough, the formation consists of a lower shale-siltstone unit, the Selmaneset Member, and an upper sandstone unit, the Siksaken Member. In the map area (as in other areas on the eastern flank of the trough) the formation is more uniform, and the two members are not recognised.

The Vardebukta Formation is exposed around Sassendalen, where it consists mainly of siltstone and silty shale with some interbedded sandstone. On the north-east side of Sassendalen it caps Coloradofjella, Brattlihøgda, Kolldalsnosa, and Flatkollen; overlying the glauconite-bearing upper part of the Tempelfjorden Group. The formation also outcrops on the south-west side of Sassendalen on the mountain slopes between Flowerdalen and Vendomdalen (Fig. 3). In this area the formation is mostly scree-covered and appears as a brownish-grey coloured band of moderately steep topography below the more or less cliff-forming Kongressfjellet shales and siltstones. The thickness of the formation is

Fig. 3. *Oblique aerial view of the Trehøgddalen area, looking south-west. Trehøgdene in the foreground consists mainly of the Triassic Vardebukta Formation (Ꞧ 1), Kongressfjellet Formation (Ꞧ 2), and Kapp Toscana Formation (Ꞧ 3). The Permian is represented by the uppermost part of the Tempelfjorden Group (P 2), with its upper boundary marked by a probable unconformity (u ?).*

115 m on Vikinghøgda and 129 m on Sticky Keep, according to BUCHAN et al. (1965).

Fossils are rather rare in the Vardebukta Formation. BUCHAN et al. (1965) mentioned the occurrence of *Gymnotoceras* sp. indet. and *Aviculipecten* sp. on Botneheia.

The age relationships within the Triassic sequence of Spitsbergen have recently been discussed by TOZER & PARKER (1968). According to these authors, the Vardebukta Formation belongs to the lower part of the Lower Triassic; the lower part of the formation is of Griesbachian age, whereas the upper part probably represents the Dienerian.

KONGRESSFJELLET FORMATION (Ꞧ2)

The Kongressfjellet Formation is defined as the shale and shaly siltstone sequence lying between the Vardebukta Formation (below) and the Kapp Toscana Formation (above). The type section of the unit lies on Kongressfjellet to the north of the map area and has been described by FREBOLD (1931, profile 2, Kongressfjellet). A more recent description of the Kongressfjellet section is given in BUCHAN et al. (1965, Fig. 10). These, latter authors designated the present unit as the Kongressfjellet Subgroup, and subdivided it into a lower Sticky Keep Formation and an upper Botneheia Formation. For use in the present area these units have been changed in rank: the Kongressfjellet Subgroup is classed as formation, while the Sticky Keep and Botneheia Formations are classed as members.

Within the map area the Kongressfjellet Formation is exposed on the mountains along the south-western side of Sassendalen. The most extensive outcrops are present on Botneheia, Marmierfjellet, Vikinghøgda, Sticky Keep, Trehøgdene (Fig. 3), and Breikampen. The formation consists generally of shale and shaly siltstone; its thickness is 277 m on Vikinghøgda, 242 m on Botneheia, and 266 m on Sticky Keep as it appears from the sections given by Buchan et al. (1965).

The Sticky Keep Member is composed of dark-grey shale and shaly siltstone containing calcareous concretions, which are particularly common in the lower part. The silt content shows a marked increase in the upper part of the unit. The fauna preserved in these rocks consists mainly of ammonites, bivalves, and bone fragments. The age of the unit was recently discussed by Tozer & Parker (1968) who allocated the member to the upper part of the Lower Triassic. More precisely, its lower part is of Smithian, and its upper part of Spathian age.

The Botneheia Member is composed of black and dark-grey shale with some siltstone interbeds. The shale is finely laminated and bituminous, particularly in the upper, cliff-forming part of the unit. Small phosphatic nodules are common and increase in abundance towards the base. The member contains a rich fauna, the most common fossils being ammonites, bivalves, and bone fragments. According to Tozer & Parker (1968) the Botneheia Member is of Middle Triassic age, belonging to the Anisian and Lower Ladinian stage.

Section 2 (p. 48) illustrates the lithology of the Kongressfjellet Formation in the north-eastern part of the map area.

KAPP TOSCANA FORMATION (TR3)

The name Kapp Toscana Formation was introduced by Buchan et al. (1965) for exposures at Kapp Toscana on the southern shore of Van Keulenfjorden. The unit consists of marine and non-marine deposits and represents the termination of the marine deposition which commenced in the early Triassic.

The Kapp Toscana Formation is exposed in great extent on the southern coast of Sassenfjorden, south-western side of Sassendalen, and at the head of Adventdalen (see Figs. 3 and 4). The formation consists mainly of sandstone and sandy or silty shale; its thickness is 253 m at Botneheia (Buchan et al. 1965).

On the eastern slope of Roulletegga and Gattytoppen, the Kapp Toscana Formation wedges out gradually westwards, towards the Flowerdalen fault. On Marmierfjellet, between the Flowerdalen fault and Lusitaniadalen, the Janusfjellet Formation (probably Rurikfjellet Member – Lower Cretaceous) rests directly on the Kongressfjellet Formation (Botneheia Member – Middle Triassic). The Kapp Toscana Formation here is totally absent except in a small area at Aucellaskardet where a remnant of the formation has been preserved. These relationships are explained by elevation and subsequent erosion along the Flowerdalen fault in late Jurassic – early Cretaceous time (for further discussion see p. 37).

Buchan et al. (1965) distinguished a lower Tschermakfjellet Member and an upper De Geerdalen Member within the Kapp Toscana Formation. These two units are easily recognisable in the map area.

The Tschermakfjellet Member consists of dark-grey shale with siltstone interbeds in its upper part. It contains red weathering clay-ironstone concretions,

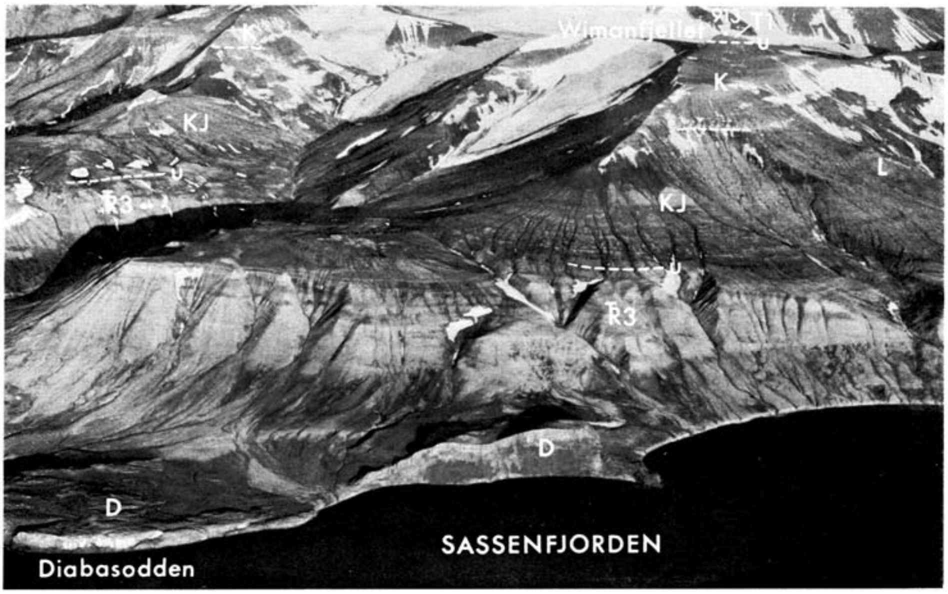

Fig. 4. *Oblique aerial view (towards south) of the Wimanfjellet area showing the following Triassic, Jurassic, and Cretaceous rock units: Kapp Toscana Formation (Ʀ 3), Janusfjellet Formation (KJ), Helvetiafjellet and Carolinefjellet Formations (K). The top of Wimanfjellet is an outlier of the Tertiary Firkanten Formation (T1). Unconformity (u), diabase (D), landslip (L).*

which are particularly common in the lower part, and give the unit a distinctive colour. The member contains a marine fauna of ammonites and bivalves; a common genus is *Nathorstites*. The age of the fauna has been discussed in several papers (e.g. FREBOLD 1929a and b; TOZER & PARKER 1968) from which it appears that both the Ladinian and Karnian stage are represented within the member.

The De Geerdalen Member in the map area consists of non-marine sandstones, sandy shales, and siltstones. This sequence is probably correlative with the upper part of the Kapp Toscana Formation at Reinodden and Kapp Toscana. The uppermost beds of the formation at these localities contain plant remains of Rhaetic age (NATHORST 1910, 1913, and BÖHM 1912).

The lithology of the Kapp Toscana Formation in the map area is illustrated by Section 3, p. 49.

Jurassic and Cretaceous Systems

JANUSFJELLET FORMATION (KJ)

The Janusfjellet Formation is the marine shale sequence occurring between the non-marine sandstones of the Kapp Toscana Formation (below), and the Helvetiafjellet Formation (above). The type section of the unit lies on Janusfjellet (north of Adventfjorden).

This unit was designated by PARKER (1967) as the Janusfjellet Subgroup which, on the basis of investigations made in the eastern part of Spitsbergen, he then

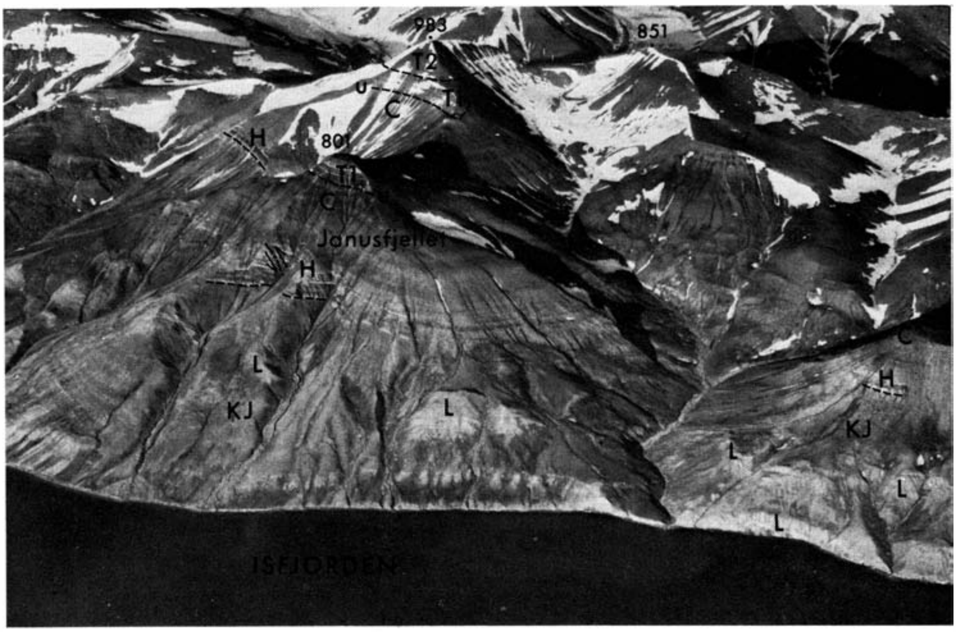

Fig. 5. *Oblique aerial view of the Janusfjellet area, looking south-east. The mountains consist of the following Jurassic, Cretaceous, and Tertiary rock units: Janusfjellet Formation (KJ), Helvetiafjellet Formation (H), Carolinefjellet Formation (C), Firkanten Formation (T1), Basilika and Sarkofagen Formations (T2). Numerous landslips (L) occur on the slopes below the Helvetiafjellet Formation. Unconformity (u).*

divided into a lower Rurikfjellet Formation and an upper Agardhfjellet Formation.

Within the map area the main exposures of the Janusfjellet Formation occur in a broad, more or less continuous belt which begins on the peninsula between Adventfjorden and Sassenfjorden, and extends to the south-eastern border of the map sheet. A narrow stripe of exposures is formed along the western line of the Billefjorden fault zone. The thickness of the formation is c. 500 m in the type section on Janusfjellet.

Only the upper part of the Janusfjellet Formation is present on Gattytoppen, Roulletegga, and the eastern side of Juvdalskampen. The lower part of the unit has presumably been removed by erosion following late Jurassic or early Cretaceous movements along the Wijdefjorden fault zone (further discussed on p. 37).

The Janusfjellet Formation consists predominantly of dark-grey shales and siltstones, with calcareous or sideritic concretions and some interbeds of lighter coloured sandstone (Figs. 4 and 5). The amount of siltstone and sandstone increases slightly upwards, and the upper silty to sandy part of the formation appears to be lithologically equivalent to the Ullaberget Series, which was originally described by Różycki (1959) from Midterhuken and Wedel Jarlsberg Land.

The base of the Janusfjellet Formation is formed by a thin conglomerate marking a break in sedimentation above the Kapp Toscana Formation. This conglomerate is the Brentskardhaugen Bed of Parker (1967) and the "Lias conglomerate" of earlier authors. In the map area this bed is usually 1—2 m thick; its pebble material is quartz, chert, and phosphorite. At some localities the bed is composed of several thin conglomeratic horizons separated by sandy intercalations.

The formation contains comparatively rich faunas of ammonites, belemnites and bivalves; some plesiosaur remains have also been found. The bivalve genus *Buchia* is particularly common throughout the unit.

The age of the Janusfjellet Formation has been discussed by several authors (e.g. FREBOLD 1930; SOKOLOV & BODYLEVSKIJ 1931; PARKER 1967) mainly on the basis of its well-preserved ammonite faunas. The formation belongs partly to the Jurassic and partly to the Lower Cretaceous. The oldest Jurassic fauna is recorded from the Brentskardhaugen Bed and indicates a Bajocian age. The overlying thick shale sequence contains several ammonite faunas which indicate that these deposits were formed during the time interval from the Lower Callovian to the Upper Hauterivian. According to PARKER (1967) this shale sequence is separated into two units by an Upper Valanginian hiatus which can be taken as the Jurassic-Cretaceous boundary.

Cretaceous System

HELVETIAFJELLET FORMATION (K)

The Helvetiafjellet Formation was deposited under continental conditions, and is characterized by light-grey quartzitic sandstones. It consists of a lower Festningen Member and an upper Glitrefjellet Member. A definition of the formation and its members was given by PARKER (1967), while a description of the type section on Helvetiafjellet is given in this paper (Section 4, p. 50).

The main exposures of the formation within the map area occur: around Lundströmdalen and Oppdalen, in the inner part of Adventdalen, between Adventdalen and Sassenfjorden, on the peninsula between Adventfjorden and the mouth of Sassenfjorden (Fig. 5). The sandstones of the Helvetiafjellet Formation form many large land-slips where the massive sandstones have slid down over the soft shales of the underlying Janusfjellet Formation.

The Festningen Member consists of light-grey, fine- to coarse-grained sandstone, and usually contains a thin conglomeratic bed near the base. Small conglomeratic intercalations may also occur higher in the sandstone. The member is cliff-forming; its thickness is 6 m on Helvetiafjellet, c. 10 m on Wimanfjellet, and 14 m on Carolinefjellet.

The Glitrefjellet Member is a thick sequence of medium- to coarse-grained sandstones with interbeds of shales and siltstones. The shales are usually carbonaceous, and the sandstones and siltstones contain carbonized plant detritus at several horizons; thin and impure coal-seams also occur locally. The thickness of the member is 90 m on Helvetiafjellet and c. 95 m on Wimanfjellet.

From the Helvetiafjellet Formation NATHORST (1897) described plant fossils collected from two localities situated north of the mouth of Adventfjorden. One of the localities lies in the lower part of Louisdalen, and contains a rich and well-preserved flora characterized by *Elatides curvifolia* (DUNKER) and *Pinites lind-*

Fig. 6. *Oblique aerial view (towards south-west) of the Endalen area showing Cretaceous and Tertiary rock units: Carolinefjellet Formation (C), Firkanten Formation (T1) with unconformity (u) at base, Basilika and Sarkofagen Formations (T2), Gilsonryggen Formation (T3), Battfjellet Formation (T4), Aspelintoppen Formation (T5). The stream of Endalen forms a large alluvial fan at the mouth of the valley.*

strömi NATHORST. The plants at this locality occur in a bed of carbonaceous shale which probably belongs to the lower part of the Glitrefjellet Member.

The age of the Helvetiafjellet Formation can be determined from the ammonite faunas occurring in the beds below and above the unit: the top of the Janusfjellet Formation contains the genus *Simbirskites* of Hauterivian age (PČELINA 1965a, PARKER 1967), whereas the lower part of the Carolinefjellet Formation contains the genus *Tropaeum* of Aptian age (FREBOLD & STOLL 1937). Consequently, the Helvetiafjellet Formation belongs mainly to the Barremian.

CAROLINEFJELLET FORMATION (K)

The Carolinefjellet Formation is a marine sequence of shales, siltstones, and sandstones. A definition of the unit was given by PARKER (1967). The formation is truncated by a disconformity, or slight angular unconformity, formed as a result of the pre-Tertiary uplift of the Spitsbergen area. This uplift was greatest in the north-western part of Spitsbergen and decreased towards the south-east. Therefore the Carolinefjellet Formation is most complete at Storfjorden where it is represented by five members (NAGY 1970), whereas in the Isfjorden region only its lower part is preserved.

Within the map area extensive exposures of the Carolinefjellet Formation occur around Lundströmdalen and Oppdalen, between Reindalen and Adventdalen, south of Adventfjorden, between Adventdalen and Sassenfjorden, and in the area north of Adventfjorden (see Figs. 5 and 6).

In the northern and central parts of the map area only the lower three members of the formation seem to be represented, they are (in ascending order) the Dalkjegla, Innkjegla, and Langstakken Member. These units were named by PARKER (1967), and are equivalents to HAGERMAN's (1925) Lower Lamina sandstone, Cretaceous shale, and Upper Lamina sandstone respectively. In the south-eastern part of the map area (Storknausen) perhaps an additional fourth member (the Zillerberget Member) is also present.

The Dalkjegla Member consists of alternating sandstones, siltstones and shales containing lenses of clay-ironstone. The thickness of the member is 153 m on Carolinefjellet.

The Innkjegla Member is a shale-siltstone sequence containing a few thin intercalations of sandstone. This unit is 95 m thick on Carolinefjellet.

The Langstakken Member is composed mainly of sandstone and silty sandstone. In the northern part of the map area only the lowermost part of the member is present below the pre-Tertiary disconformity, as the thickness of the member is only 22 m on Carolinefjellet. In this connection it is interesting to note that the total thickness of the member is 194 m on Trollstedet, to the south of the map area.

The most common fossils in the Carolinefjellet Formation are bivalves and *Ditrupa*, while ammonites occur more rarely. The unit also contains fossil wood and several types of trace fossils.

From Criocerasaksla and from the south-west coast of Adventfjorden STOLLEY (1912) has described *Tropaeum arcticum* collected from the Innkjegla Member. According to FREBOLD & STOLL (1937) this ammonite indicates an Upper Aptian age. Several ammonites have been recorded by SPATH (1921) from Breinosa in Adventdalen. The specimens at this locality were poorly preserved, and SPATH tentatively referred them to the Albian.

Tertiary System

The Tertiary succession of the Spitsbergen trough consists of alternating sandstone and shale formations showing marine, estuarine, or terrestrial facies. The succession was divided into six series by NATHORST (1910) on the basis of lithological observations mainly in the Isfjorden region. Some authors (e.g. ORVIN 1940, and ATKINSON 1963) have used NATHORST's lithostratigraphic scheme in its original form, whereas others (e.g. LJUTKEVIČ 1937, and LIVŠIC 1967) have slightly modified it by splitting NATHORST's Green Sandstone Series into two units. Recently, the Tertiary has been divided into four genetic units by VONDERBANK (1970) on the basis of major cyclic changes in the depositional conditions. The classification used in the present paper follows NATHORST's original scheme, but his series are renamed to formations (Table 2).

Until the last few years, the age of the Tertiary sequence of the Spitsbergen trough has generally been considered to be Palaeocene-Eocene. This age is based on RAVN's (1922) study of some molluscan faunas collected from the Firkanten, Sarkofagen and Battfjellet Formations. A more recent discussion of the age questions was given by LIVŠIC (1965b) who took into consideration both plant

Table 2

Age relationships and lithostratigraphic nomenclature proposed by different authors for the Tertiary sequence of the Spitsbergen trough. (**The map was printed in 1964.*)

Age		Lithostratigraphic classification				
RAVN 1922	LIVŠIC 1965 b	NATHORST 1910	LJUTKEVIČ 1937	LIVŠIC 1967	VONDERBANK 1970	This map* and memoir
Eocene	Oligocene – Miocene(?) (undifferentiated)	Upper plant-bearing sandstone series	Upper coal-bearing sandstone formation	Storvola Formation	Nordenskiöld-fjellet-Schichten	Aspelintoppen Formation
	Eocene – Oligocene (undifferentiated)	Flaggy sandstone series	Upper flaggy sandstone formation	Collinderodden Formation	Fardalen-Schichten	Battfjellet Formation
		Upper black shale series	Upper black shale form.	Frysjaodden Formation		Gilsonryggen Formation
Palaeocene	Eocene	Green sandstone series	Flaggy green sandst. form.	Hollendardalen Formation	Grumant-dalen-Schichten	Sarkofagen Formation
			Green sandst. formation	Grumant Formation		
	Palaeocene	Lower dark shale series	Lower black shale form.	Colesbukta Formation		Basilika Formation
		Lower light sandstone series	Lower coal-bearing sandstone formation	Barentsburg Formation	Adventfjorden-Schichten	Firkanten Formation

fossils, foraminifera, and molluscs. According to him, the Spitsbergen Tertiary comprises Palaeocene, Eocene, Oligocene, and probably Miocene deposits. VONDERBANK (1970), on the other hand, regarded the lower half of the Spitsbergen Tertiary (his Adventfjorden-Schichten and Grumantdalen-Schichten) as belonging to the Dano-Montian. The age conclusions drawn by RAVN and LIVŠIC are shown in relation to the different lithostratigraphical schemes in Table 2.

FIRKANTEN FORMATION (T 1)

General description. – The Tertiary System in Spitsbergen begins with the Firkanten Formation which is roughly bipartite. The lower coal-bearing part of the formation is composed mainly of shales, siltstones, and sandstones with local conglomerates. Many of these sediments weather easily, and the lower part of the formation is therefore mostly scree-covered, except for some more massive, protruding sandstone beds, which increase in dominance upwards. The upper part of the formation consists mainly of massive, light sandstones which weather reddish-grey and light brown. These sandstones are topographically well marked by steep slopes and rock walls.

The Firkanten Formation comprises both marine and non-marine deposits, and is comparatively rich in fossils. Bivalve faunas occur at several horizons, and are almost entirely of marine origin. Plant leaves are especially abundant in the lower part of the formation where root structures, indicating *in situ* growth of vegetation, are also observed.

The lower boundary of the Firkanten Formation is the disconformity which was formed by the pre-Tertiary uplift of the Spitsbergen area; the upper boundary is the contact between the cliff-forming sandstones of this formation and the slope-forming shales of the Basilika Formation. The type section of the Firkanten Formation is located on Firkanten, on the northern shore of Van Keulenfjorden, and is described in Section 5 (p. 51).

Development in the map area. – The Firkanten Formation is exposed on the mountains south of the upper part of Reindalen and in the area between the upper part of Reindalen and Adventdalen. Extensive outcrops are also present south of Adventfjorden, along the shore of Isfjorden from Platåberget to Kolberget, and furthermore in the area north of Adventfjorden and the lower part of Adventdalen (see Figs. 6, 7, and 8).

The formation is about 125 m thick, with a maximum of 140 m on Platåberget and a minimum of 80 m on Janusfjellet. Its lower part is of great economic interest because it contains five coal seams (from below): the Svea, Todalen, Longyear, Svarteper, and Askeladden seam. A more detailed stratigraphical description of the formation is given below, with the main stress laid on its lower coal-bearing part (see also Section 6, p. 52).

The disconformity at the base of the Firkanten Formation is locally marked by a conglomerate which is mostly less than 80 cm thick. The conglomerate is usually well developed in the eastern part of the outcrop area, while in the western part it is absent in all but a few localities. Where the conglomerate is not present, the basal beds of the Firkanten Formation are difficult to distinguish from the Lower Cretaceous rocks below, in spite of the considerable intervening hiatus.

The lowermost 5–10 m of the formation is composed of alternating shales and sandy siltstones, with horizons containing sideritic nodules, and with plant fossils occurring abundantly at some localities. These beds are overlain by the Svea seam which has a maximum thickness of 3.5 m in Lunckefjellet in the south-east, and becomes thinner towards north-west. The sediments immediately below the seam contain well developed root structures in places. One or two layers of soft clay occur closely above or interbedded within the coal seam.

These beds are followed by a 5–20 m thick sequence of shales and siltstones, with horizons containing sideritic nodules, and with the Todalen seam uppermost. The Todalen seam is usually less than 60 cm thick, but its thickness reaches 1 m in some limited areas.

The next sequence, which leads up to the Longyear seam, is 10–20 m thick and consists mainly of thick-bedded sandstone. At one or two horizons the sandstone contains notched, tubular burrows which appear to be identical with *Ophiomorpha nodosa* Lundgren. In many places the uppermost coal-bearing part of the sequence

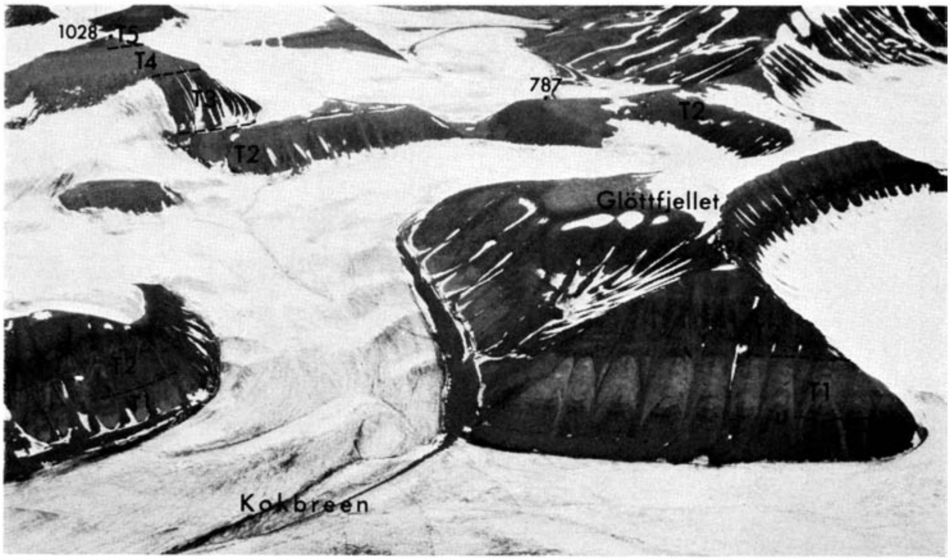

Fig. 7. *Oblique aerial view of the Kokbreen area, looking north-eastward. The mountains consist of the following Cretaceous and Tertiary rock units: Carolinefjellet Formation (C), Firkanten Formation (T1) with unconformity (u) at base, Basilika and Sarkofagen Formations (T2), Gilsonryggen Formation (T3), Battfjellet Formation (T4), Aspelintoppen Formation (T5).*

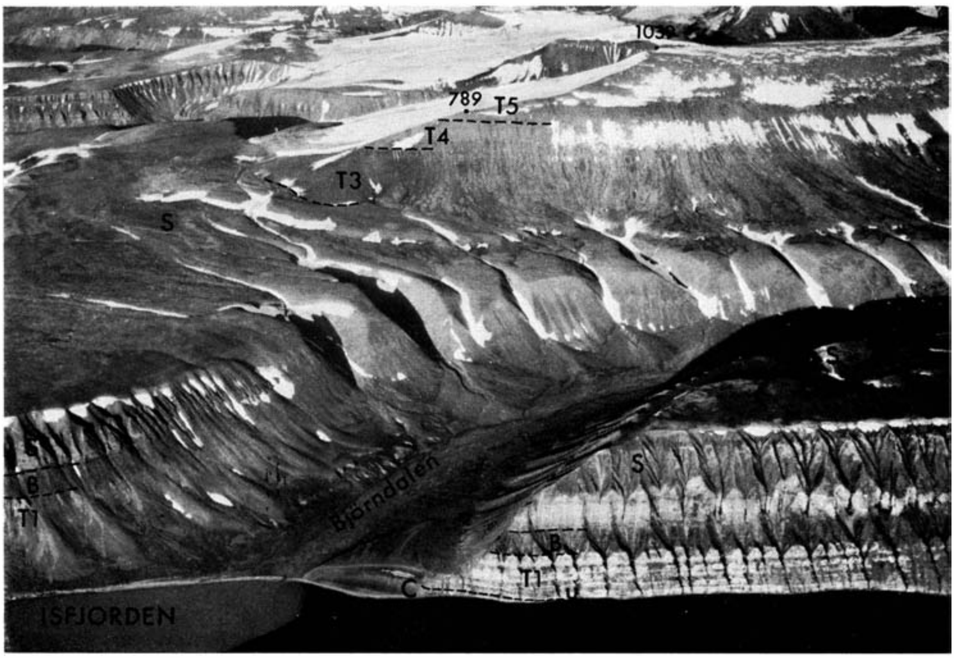

Fig. 8. *Oblique aerial view (towards south-east) of the Bjørndalen area showing Tertiary rock units: Firkanten Formation (T1) with unconformity at base, Basilika Formation (B), Sarkofagen Formation (S), Gilsonryggen Formation (T3), Battfjellet Formation (T4), Aspelintoppen Formation (T5). The top of the Carolinefjellet Formation (C) is exposed south-west of Bjørndalen. The sandstones of the Sarkofagen Formation form extensive plateaux.*

contains two minor coal layers below the main Longyear seam. The sediments below the coals are commonly penetrated by long, downward branched rootlets. The Longyear seam is locally more than 2 m thick on the northern side of Adventdalen, but shows a thinning to 1 m on the southern side of the valley. Clastic intercalations appear more and more commonly towards the south-west and the seam wedges out locally.

The Longyear seam is followed by a 10–18 m thick sequence of sandstone which is overlain by the Svarteper seam. In Foxdalen, near the southern side of Adventdalen, these sandstones are replaced by a much thinner shaly siltstone sequence. The Svarteper seam shows strong variation in thickness, and is usually split into several thin argillaceous coal beds with shaly intercalations.

The Svarteper seam is more or less distinctly separated from the fifth coal seam, Askeladden, by siltstones and silty shales the thickness of which may approach 10 m. The Askeladden seam is locally well developed, but its quality is impeded by a high sulphur content.

The upper part of the Firkanten Formation, from the Askeladden seam to the upper boundary, consists mainly of light sandstones with some silty and conglomeratic beds. Marine bivalves have been found at several horizons, e.g. about 5 m above the Askeladden seam and near the top of the formation. Some beds contain great number of siliceous tubes with diameter usually 2–3 mm. Plant remains occur in thin siltstone beds 20–25 m above the Askeladden seam, and some of these beds are probably equivalent to a minor coal seam observed locally on the northern side of Adventfjorden.

The top of the formation is marked by coarse-grained sandstones containing up to 30 cm thick beds of polymict conglomerate.

BASILIKA FORMATION (T2)

General description. – The Basilika Formation consists mainly of black and grey shales weathering into angular or prismatic fragments. These shales are most characteristic in the lower and middle part of the unit. In the upper part, the shales contain more coarse material, and pass gradually into grey siltstones and fine-grained, grey-green sandstones towards the upper contact. Scattered pebbles of quartzite and chert, rosettes of calcite, and thin beds of plastic clay (commonly with a yellow or reddish weathering colour) occur throughout the whole unit. In its north-eastern outcrop areas (eastern Nordenskiöld Land and northern Heer Land) the formation is thinner and contains generally more silty and sandy material than in the western and southern outcrop areas.

The Basilika Formation was deposited in a marine environment, but is generally poor in fossils; bivalves and foraminifera are recorded most commonly, but gastropods and crustaceans are also present.

The Basilika Formation consists of shales and its lower boundary is placed at the lithological change from the sandstones of the Firkanten Formation. The upper boundary of the Basilika Formation is gradational and is placed arbitrarily below the lowermost, laterally traceable sandstone bed of the Sarkofagen Formation. In the landscape this horizon is marked roughly by the topographical break between the rock-walls formed by the Sarkofagen sandstones (above) and the gentle slopes caused by the Basilika shales and siltstones (below).

The type section of the Basilika Formation is located on the mountain Basilika, on the southern side of Van Keulenfjorden, where the unit is c. 330 m thick.

Development in the map area. – On the map presented here the Basilika Formation is not differentiated from the overlying Sarkofagen Formation because of the comparatively small thickness of the Basilika Formation and the gradational nature of the contact between the two units. Outcrops of the Basilika Formation are confined to the following three areas: north of Adventfjorden and Adventdalen; the main Tertiary area delimited by Adventdalen, Adventfjorden, Isfjorden, the western and southern border of the map sheet, and the upper part of Reindalen; the area between the upper part of Reindalen and the southern border of the map sheet.

The formation is composed mainly of dark-grey silty shales and fissile siltstones, with silty sandstones in the upper part. The coarseness of the material increases from north-west towards south-east and the thickness of the formation decreases in the same direction as shown by the following measurements: along the shore of Isfjorden the formation is 65–85 m thick at Rusanovodden (LIVŠIC 1965b), 63 m thick on Pilarberget (Fig. 8), and 80 m thick on Carolinefjellet (A. K. ORVIN, field note); in the central part of the map area, on Hallwylfjellet, the thickness is reduced to 20–30 m and the formation consists of silty sandstone.

The sediments composing the Basilika Formation are easily eroded, with the exception of the sandy beds which are generally confined to the upper part of the unit. The bedrock is therefore commonly hidden below a thin cover of loose debris. Characteristic features of the formation are the above mentioned beds of plastic clay, which occur at different stratigraphical horizons throughout the whole unit (see Section 7, p. 53). These beds are more or less impermeable for water and are, therefore, commonly marked by thin bands of vegetation on otherwise unvegetated, scree-covered slopes.

SARKOFAGEN FORMATION (T2)

General description. – The Sarkofagen Formation is composed mainly of green and grey-green sandstones with a green, yellow, or rusty weathering colour. In the lower part of the unit, and locally also in its upper part, the sandstones are interbedded with siltstones and silty shales. Small siliceous tubes are present in great numbers throughout the whole unit. Scattered pebbles of chert and quartzite also occur, and locally form thin conglomeratic zones near the upper contact.

The formation is generally marine, but coal layers and plant fossils indicate that temporary, more continental conditions occurred in its upper part in Nordenskiöld Land. Bivalve faunas recorded from the upper part of the unit contain both marine and estuarine forms.

The lower boundary of the Sarkofagen Formation is gradational, and is placed at the base of the lowermost resistant sandstone bed. The upper boundary is well-defined by the sharp contact between the uppermost, more or less coarse-grained, sandstone of this formation and the dark shales of the Gilsonryggen Formation.

Topographically the Sarkofagen Formation is characterized by sharp ridges, steep slopes, and rockwalls which often lead up to extensive plateaux capped by the uppermost sandstone beds of this unit (Fig. 8). The type section is located on Sarkofagen at the head of Longyeardalen (Section 8, p. 54).

Development in the map area. – The Sarkofagen Formation is exposed in the region north of Adventfjorden and Adventdalen, between Adventdalen and Reindalen, and south of Reindalen. As mentioned above, the Sarkofagen Formation has not been differentiated from the underlying Basilika Formation on the present map sheet.

In the Colesbukta–Grumantbyen area the Sarkofagen Formation is markedly tripartite. Its lower and upper parts consist of sandstone with interbeds of shale and siltstone, while its middle part is a continuous sequence of massive green sandstone. Farther east the formation is more homogeneous as the shales and siltstones in its lower and upper part are partly or entirely replaced by sandstones. These sandstones contain beds of conglomerate around Adventdalen and in other eastern areas.

In the Fardalen area (Russekollen, Teltberget, Bingtoppen) the upper part of the formation contains a coal seam with a maximum thickess of 60 cm. Farther east and north-east, on Carl Lundhfjellet and Hiorthfjellet, the same horizon is developed as a conglomeratic sandstone containing some fossilized wood.

GILSONRYGGEN FORMATION (T3)

General description. – The Gilsonryggen Formation is a rather monotonous sequence of black and dark-grey, slightly silty shales weathering into angular fragments. The formation contains rounded pebbles of chert which generally occur scattered in the shale, but which occasionally are concentrated into thin conglomerate beds with small lateral extent. Isolated nodules and thin beds of clay-ironstone, and thin beds of plastic clay are also observed. The chert pebbles are of Permian age and were probably dropped from drifting kelp or trees (NATHORST 1910; BIRKENMAJER & NAREBSKI 1963). The clay beds are probably weathered tuffs.

The Gilsonryggen Formation was deposited under marine conditions, but seems to be poor in fossils. Some foraminifera and bivalves have been recorded.

The base of the Gilsonryggen Formation is defined at the sharp lithological boundary above the uppermost sandstone bed of the Sarkofagen Formation. According to LIVŠIC (1965b) a disconformity is developed at this boundary in the Van Mijenfjorden area. The upper boundary is less well defined and is placed at the base of the lowermost sandstone, or sandy siltstone bed of the Battfjellet Formation.

In the field the shattered Gilsonryggen shales form easily recognisable, smooth, dark-coloured slopes, which to a great extent are covered by weathering products (see Figs. 8 and 9). These slopes contrast well with the much steeper topography caused by the sandy formations above and below. The type section of the present unit is located on Gilsonryggen, at the head of Tverrdalen (see Section 9, p. 55).

Development in the map area. – The Gilsonryggen Formation is exposed in the

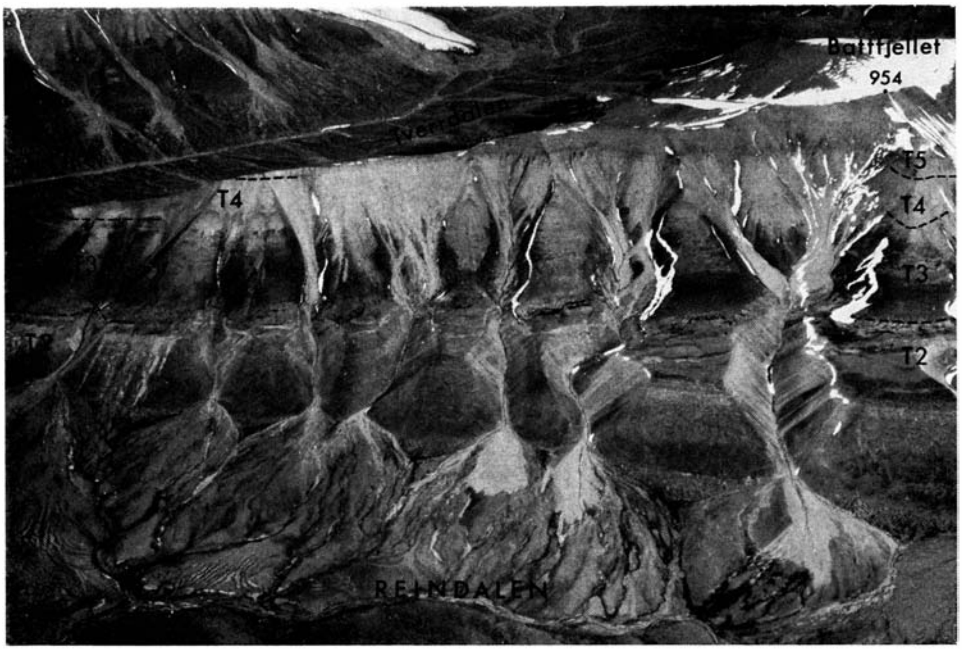

Fig. 9. *Oblique aerial view (towards north-west) of Battfjellet showing Tertiary rock units: Basilika and Sarkofagen Formations (T2), Gilsonryggen Formation (T3), Battfjellet Formation (T4), Aspelintoppen Formation (T5). Large alluvial cones built by intermittent streams are seen in the foreground.*

main Tertiary area bounded by Adventdalen, Adventfjorden, Isfjorden, the western and southern border of the map sheet, and Reindalen. Two small outliers are also present south of Reindalen. In its type section the formation is represented by a 235 m thick shale sequence, and this thickness seems to be a maximum in the map area. Thicknesses less than 200 m have been measured around Nordenskiöldfjellet and Håberget.

As mentioned above, the Gilsonryggen Formation contains scattered pebbles of chert. Occasionally, however, the pebbles also form thin conglomeratic beds of small lateral extent. Finds of loose blocks at two horizons suggest that the type section contains two beds of such chert conglomerate. Irregularly distributed thin beds and isolated nodules of clay-ironstone are most common in the upper part of the formation.

The mountain slopes composed of the Gilsonryggen shales are usually covered by loose debris, and good exposures are therefore difficult to obtain. These scree-covered slopes are almost devoid of vegetation except at a few stratigraphically well defined horizons where the impermeable clay beds (see above) collect the water and bring it out to the surface. In the type section three horizons with such clay layers are found. Similar horizons are observed also in other sections situated farther west in the map area.

BATTFJELLET FORMATION (T4)

General description. – The Battfjellet Formation is composed of polymict sandstones interbedded with shales or siltstones. These rocks contain scattered thin beds and isolated nodules of clay-ironstone and thin lenses of coal. The thickness of the unit increases towards the axis of the Spitsbergen trough where it reaches a maximum of 200–240 m (LIVŠIC, 1965b).

The Battfjellet Formation seems to have been deposited mainly in a shallow water marine environment with local and temporary incursions of lacustrine or estuarine conditions. Fossils are comparatively common; bivalves, calcareous foraminifera, worm tracks, leaf impressions, and other plant remains have been recorded.

The lower boundary of the Battfjellet Formation is placed at the base of the lowermost, usually shelf-forming sandstone bed which terminates the even slopes formed by the underlying Gilsonryggen shales. The upper boundary is defined as the base of a thick-bedded, cliff-forming sandstone which represents the lowermost part of the coal-bearing Aspelintoppen Formation. The type section of the present formation lies on Battfjellet where its thickness is 167 m (see Section 10, p. 55, and Fig. 9).

Development in the map area. – The Battfjellet Formation is restricted to the south-western quarter of the map area where it is widely exposed and usually forms the higher parts of the mountain slopes. Its thickness varies between 100 and 200 m; minimal thicknesses are found in the Lars Hierthafjellet–Teltberget area south of Longyearbyen, while maximal thicknesses occur around Nathorstfjellet, south of Colesdalen.

The basal strata of the formation are thin-bedded, fine-grained polymict sandstones. Irregular, convolute sedimentary structures, formed probably by slumping, occur about 2 m above the lower boundary in the type section. The dominant rock type in the lower half of the formation is dark-grey silty shale, which contains varying amounts of clay-ironstone nodules. The shale is interbedded with sandstone layers which show an increasing thickness upward from 2–4 cm to more than 10 cm. In the upper part of the formation the dark-coloured shale bands are replaced by greenish-grey, brittle siltstone beds which locally contain carbonized leave impressions and silicified stem fragments.

ASPELINTOPPEN FORMATION (T5)

General description. – The Aspelintoppen Formation is the youngest pre-Quaternary rock unit of the Spitsbergen trough. It consists of repeatedly alternating beds of light-grey and greenish sandstone, brownish or grey siltstone, and darker silty shale which is usually calcareous. Characteristic of the unit are numerous thin beds and lenses of coal. Nodules and lenses of clay-ironstone are also present.

The lithology of the formation, together with the fossil content, suggest deposition under fluviatile, lacustrine, or partly estuarine conditions. Well-preserved plant remains occur in abundance at several levels. Coalified leaf imprints are most common, but petrified trunks and root structures are also known. North of Van

Keulenfjorden the basal beds of the formation contain small bivalves, which indicate pronounced reduction in salinity (Livšic 1965b).

The base of the Aspelintoppen Formation is marked by a thick, ledge-forming sandstone sequence; this is particularly prominent in the central and eastern parts of the Spitsbergen trough where its thickness is 30–60 m. The sandstone is commonly cross-bedded and contains coarse-grained or conglomeratic streaks and lenses. The top of the formation is truncated by the present erosional surface, and the largest preserved thickness of the unit is 500–600 m. Its type section is placed on Aspelintoppen on the southern side of Van Mijenfjorden.

Development in the map area. – The Aspelintoppen Formation is restricted to the south-western quarter of the map area, where it occurs above 500 m (above sea level) and forms the highest parts of the mountains and the higher summits (see Figs. 8 and 9). Its maximum thickness approaches 400 m on Sandsteinfjellet and Mefjellet, but fairly thick sections are present also on Ringdalsfjellet, Tillbergfjellet, Håberget, and Nordenskiöldfjellet. The basal, solid sandstone beds of the formation are generally well marked, and in several localities form steep crags on the mountain sides (e.g. Sandsteinfjellet) or flattened ridges (e.g. Battfjellet).

As in other regions, the formation in the map area is characterized by many thin coal seams and abundant plant fossils. Best known perhaps are the plant fossils from Nordenskiöldfjellet, which are steadily transported by the glacier Longyearbreen to its terminal moraine at the head of Longyeardalen.

Quaternary System – surficial deposits

More than one-sixth of the land area is covered by unconsolidated deposits of Quaternary age (thin covers of residual material, leaving no doubt as to the underlying bedrock, are not dealt with under this heading). In general, most of the deposits originated through the agencies of glaciers and mechanical weathering with subsequent modification by stream and tidal action. Very little is known about the thickness of these deposits. It is natural to suppose that the greatest thicknesses are present in the lower parts of the four principal valleys. All known surficial deposits of the map area belong to the Holocene; Pleistocene sediments, if they were present, must have been mainly removed during the latest period of glaciation. The following is a short account of the most important surficial deposits observed.

1. Glacial deposits. – Prominent features in the map area are the extensive lateral and terminal moraines bordering the present glaciers. These unaltered deposits were formed by oscillations and retreat of the ice margins in the recent past (Fig. 1).

Washed moraines occur at lower altitudes in the valleys and are remnants of older advances of the ice margin.

2. Colluvial deposits. – Talus cones are common at the base of nearly all mountain slopes. These features consist of rock detritus transported mainly by the action of gravity. But in many cases, running water is also of great importance in their formation during the short snow-melting periods.

Rock glaciers are present in many cirques and steep-sided valleys.

A multitude of smaller and larger landslips occur in areas where the Janusfjellet Formation and the overlying Helvetiafjellet Formation compose extensive mountain slopes (e.g. Arctowskifjellet and Forkastningsfjellet). These landslips consist of large blocks of massive Helvetiafjellet sandstone which have moved downslope over the soft Janusfjellet shales (see Fig. 5). Landslips formed of Triassic and Tertiary rocks are very rare (e.g. Breikampen, Sandsteinfjellet). It seems probable that landslips are preferentially formed on mountain slopes where the beds dip downhill as in Albert Bruntoppen, Arctowskifjellet, Storknausen, and Dalskuta.

Recent field work has proved that the large landslip shown on the geological map south of Hotellneset is nonexistent.

3. Alluvial deposits. – Extensive flood plains, consisting of stream gravel, sand, and silt are developed in the four principal valleys and in the larger tributary valleys.

Alluvial fans are common in the valleys. They are formed where tributary streams emerge onto the flood plains of larger streams, and dump great masses of loose rock material (Fig. 6).

Alluvial cones are confined to small, intermittent streams cutting into the steep mountain slopes (Fig. 9). There exist all possible transitions between these features and the typical talus cones.

Glacial outwash is mainly confined to areas immediately adjacent to the glaciers.

It is interesting to note that collovium and alluvium make up the bulk of the surficial deposits covering the valley bottoms. In some cases these deposits rest on older glacial material.

4. Marsh deposits. – Marshes occur essentially in the lower parts of the main valleys (e.g. Adventdalen). The sediments deposited here are proportionally rich in clay and silt.

5. Aeolian deposits. – Thin surficial layers of windblown sand and silt occur in certain dry localities exposed to prevailing strong winds.

6. Marine deposits. – Elevated marine features consisting of clay, silt, sand, and gravel occur in the coastal regions and in the larger valleys. Raised beaches and marine terraces to an altitude of 80 m are described by FEYLING-HANSSEN & JØRSTAD (1950) from the area between Vindodden and Sassendalen.

Very little is known about the stratigraphy of the marine sediments lying in the bottom of the larger valleys. The following section, measured by PORTMANN (1969) at the mouth of Todalen, gives an idea of these deposits (from above):

4. Outwash consisting of granules and pebbles; thickness 100 cm.
3. Marine clay, beige, with some granules; thickness 40 cm.
2. Marine clay, blue clay in the lower part; contains granules, pebbles, and shells; thickness 112 cm.
1. Moraine with striated pebbles, only the upper 40 cm exposed.

Patterned ground and pingos

Unconsolidated deposits covering flat surfaces tend to develop regular patterned ground by differential movements of fine-grained and coarser (often cobble) material. On tilted surfaces the regular pattern is deformed to ellipses and other less regular shapes, and finally to ribbonned sloping ground. Solifluction is common on slopes consisting of loose material.

Several, partly ice-filled, cone-shaped structures occur on the flat bottoms of the main valleys. Some of the structures in Adventdalen and Eskerdalen have been studied more closely by PIPER & PORRITT (1966) and SVENSSON (1970), who have described them as pingos. Four pingos from Reindalen are shown in Fig. 1.

Plaudal areas tend to develop ice lenses of considerable lateral extension with thicknesses of up to one metre.

IV. Igneous rocks

Diabase

Intrusions of diabase are exposed over a total area of about 6 square kilometres in the northern part of the map sheet. Here, the intrusions occur in two regions: 1) On the southern shore of Sassenfjorden (between Hatten and Marmierfjellet) the diabase is intruded into Triassic and Jurassic rocks where it forms sills, dykes, and more or less oblique veins of tabular or lenticular shapes. 2) On the north-eastern side of Sassendalen (in Brattlihøgda and Kolldalsnosa) the diabase occurs as dykes intruding Triassic and Permian sediments.

The intrusive character of the sills is indicated by their decreasing grain size toward the sediments above and below, as well as by thin zones of baked sediments on their overside. The term diabase is used here in accordance with "Glossary of geology and related sciences" (Amer. Geol. Inst., 1962). The name dolerite has been used alternatively for the rocks in question (e.g. BUROV & LIVŠIC 1965; PARKER 1966).

A petrographical study of the diabase intrusions of Barentsøya and of the De Geerdalen area (south of Sassenfjorden) has been made by BUROV & LIVŠIC (1965). According to these authors the intrusions occurring in both areas are composed of three main rock types: olivine-bearing diabase, porphyritic leucocratic gabbro-diabase, and porphyritic micro-diabase. The petrography of these rock types is described in Table 3. The distribution of the rock types in a vein on Grønsteinfjellet, west of De Geerdalen, is given by the following section (from base upwards):

1. Porphyritic micro-diabase	thickness	1 m
2. Olivine-bearing diabase and gabbro-diabase	»	20–25 »
3. Porphyritic leucocratic gabbro-diabase	»	30 »
4. Marginal porphyritic fine-grained diabase	»	$>$ 4 »

The total thickness of the vein is 55–60 m. The section is reproduced from BUROV & LIVŠIC (1965).

From the area south of Sassenfjorden two chemical analyses of diabase have been published (Table 4). The chemistry of these rocks may be related to the

Table 3

Petrography of the three main rock types composing the diabase intrusions of the De Geerdalen area and western Barentsøya. (*Excerpt from* BUROV & LIVŠIC *1965.*)

Rock type	Olivine-bearing diabase	Leucocratic gabbro-diabase	Porphyritic micro-diabase
Colour	dark-grey	greenish grey	dark-grey
Crystallinity	medium-grained, holocrystalline	coarse-grained	aphanitic, small phenocrysts
Texture	ophitic, porphyritic, or doleritic	porphyritic, groundmass ophitic	porphyritic, in some cases tholeiitic or hyalopelic
Plagioclase	46–56% phenocrysts 80–49% An, groundmass 56% An	60–75% phenocrysts zoned 75–65% An, groundmass 68% An	45–49% phenocrysts 70–74% An, groundmass 60–62% An
Monoclinic pyroxene	25–35% phenocrysts and groundmass brownish augite-ferroaugite	17–30% phenocrysts altered, groundmass less cryst-allized, augite-ferro-augite(?)	35–40% small unaltered grains, augite
Olivine	2–3%, hyalosiderite	not always present	not present
Quartz	Up to 6%, small grains commonly associated with apatite	2–6%, in mesostasis and interstices	0.5–1%, in mesostasis and interstices
Ore minerals	3–7%, magnetite, ilmenite, titano-magnetite, pyrite, and chalcopyrite	2–8%, titanomagnetite, ilmenite, magnetite, pyrite, and chalco-pyrite	2–4%, ilmenite, some titanomagnetite, pyrite, and chalcopyrite
Remainder	2–6%, chlorite, bowlingite, albite etc.	2–7%, chlorite, iddingsite, bowlingite, quartz, albite etc.	7–10%, up to 20–50% brown volcanic glass

large group of North-Atlantic tholeiites, as is probably the case with the greater part of intrusive rocks penetrating Mesozoic sediments in other parts of Svalbard.

Age of the intrusions. – Several attempts have been made to determine the relative age of the diabase intrusions of Spitsbergen by means of structural and stratigraphic evidence (e.g. TYRRELL & SANDFORD 1933; ORVIN 1940; HARLAND 1961). The ages estimated by these indirect methods vary from Late Jurassic to Early Tertiary. An estimate given by PARKER (1966) is of particular interest in this case, because it is based on observations made largely along the Billefjorden fault zone south of Sassenfjorden. The stratigraphic and structural relationships

Table 4

Two chemical analyses of diabase from the south shore of Sassenfjorden: No. 1, almost unweathered diabase from the north-west side of Diabasodden (BLANCK *et al. 1928*); *No. 2, medium-grained, olivine-bearing diabase from Grønsteinfjellet* (BUROV & LIVŠIC *1965*). *The extraordinary amount of MnO in analysis No. 1 is probably of postmagmatic nature* (TYRRELL & SANDFORD *1933*).

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	MnO	K_2O	Na_2O	P_2O_5	Ign. loss	H_2O 105–110°	Sum
No. 1	50,28	1,37	15,19	4,12	10,19	2,54	8,35	3,85	1,35	1,60	—	0,21	0,70	99,75
No. 2	49,28	1,13	16,31	3,61	9,51	5,65	8,76	0,17	1,05	2,94	0,27	1,81	0,80	100,49

recorded by PARKER indicate that the diabases of the Isfjorden area are of uppermost Jurassic – lowermost Cretaceous age.

Radiometric age determinations by the potassium-argon method have been made on several samples of diabase collected on the southern side of Sassenfjorden. Amongst the samples of Svalbard rocks determined by GAYER et al. (1966), there is one from Diabasodden for which an age of 149 $\pm$ 17 million years was found. Fifteen samples collected in the vicinity of De Geerdalen were determined by FIRSOV & LIVŠIC (1967); the ages varied from 71 to 130 m.y. Since the age variation did not show any relationship either with the distribution of the sample localities or with the position of samples within the intrusions, FIRSOV & LIVIŠC suggested only one intrusive period, calculating the mean age of the fifteen samples to 103 $\pm$ 15.5 m.y. The discrepancy between the ages given in these two papers may be explained by local post-magmatic alteration of the rocks, or by analytical errors larger than calculated, rather than by different periods of intrusion.

Volcanic tuff

Two Tertiary formations, the Basilika and the Gilsonryggen, contain thin beds of water impermeable, clay-like material with a grey, yellow or reddish weathering colour. The beds seem to have a large regional persistence and probably occur throughout the whole Spitsbergen trough in the two formations mentioned above. One of the beds in the Basilika Formation has been studied in detail on the west side of Colesbukta only c. 3 km west of the map area (GRIPP 1927). According to this work, the material of the beds has been formed by decomposition of volcanic ash with a probable basaltic composition.

V. Structure

Major structural elements

The map area is situated in the north-eastern part of the huge Spitsbergen trough, a position reflected both by the distribution of the formations and by the structure of the area. The thick sedimentary succession composing the area is only slightly deformed by crustal movements. It shows a regional dip towards the south-west, in the direction of the trough axis.

The south-western part of the map area, where the sedimentary succession is most complete, lies in the axial part of the Spitsbergen trough with a regional dip of only 1°. The most important structural features here are low, strongly elongated swells separated by shallow depressions. In a broad, central belt covering mainly the areas south of Sassenfjorden, Adventdalen, and Reindalen the regional dip is up to 3°. The most prominent feature in this belt is the Billefjorden fault zone which consists of several local structures. Along the eastern rim of the map sheet the slope of the Spitsbergen trough flattens out to an average dip of only 1°. Structural features of more local character are shown in Fig. 10.

According to LIVŠIC (1965a), faults of considerable length occur also below the bottom of the main valleys Reindalen, Colesdalen, and Adventdalen. The present authors, however, cannot find adequate evidence to support this opinion.

Swells and depressions

The swells are more or less continuous anticline-like features of considerable length and with gently sloping flanks. They tend to parallel the axis of the Spitsbergen trough, and plunge south-eastward, in the direction of the most depressed part of the trough which apparently lies in Nathorst Land. It is possible that the swells and depressions overlie horst- and graben-like structures, which were formed by faulting of the basement and the lower part of the sedimentary cover. The following account is partly based on a structural description given by LIVŠIC (1965a).

1. The Holmsenfjellet swell. – Only a short part of this structure is present in the south-western corner of the map area. Here, the swell is best seen on Semmelryggen and south of Passfjellbreen where the rocks dip toward south-east and south-west, respectively.

2. The Skiferdalen depression. – This significant feature begins at the mouth of Colesdalen, extends across Sandsteinfjellet, and leaves the map area at Skiferdalen. It is the eastern complementary structure to the Holmsenfjellet swell. The depression is asymmetrical, its west flank being steeper than its east flank, as it clearly appears on Semmelryggen and Mefjellet.

3. The Reindalen swell. – This structure lies east of the Skiferdalen depression and extends in a south-easterly direction from Grønberget to the mouth of Gangdalen where it leaves the map area. This swell is a less continuous feature, consisting of a row of smaller, more or less isolated, dome-shaped structures, three

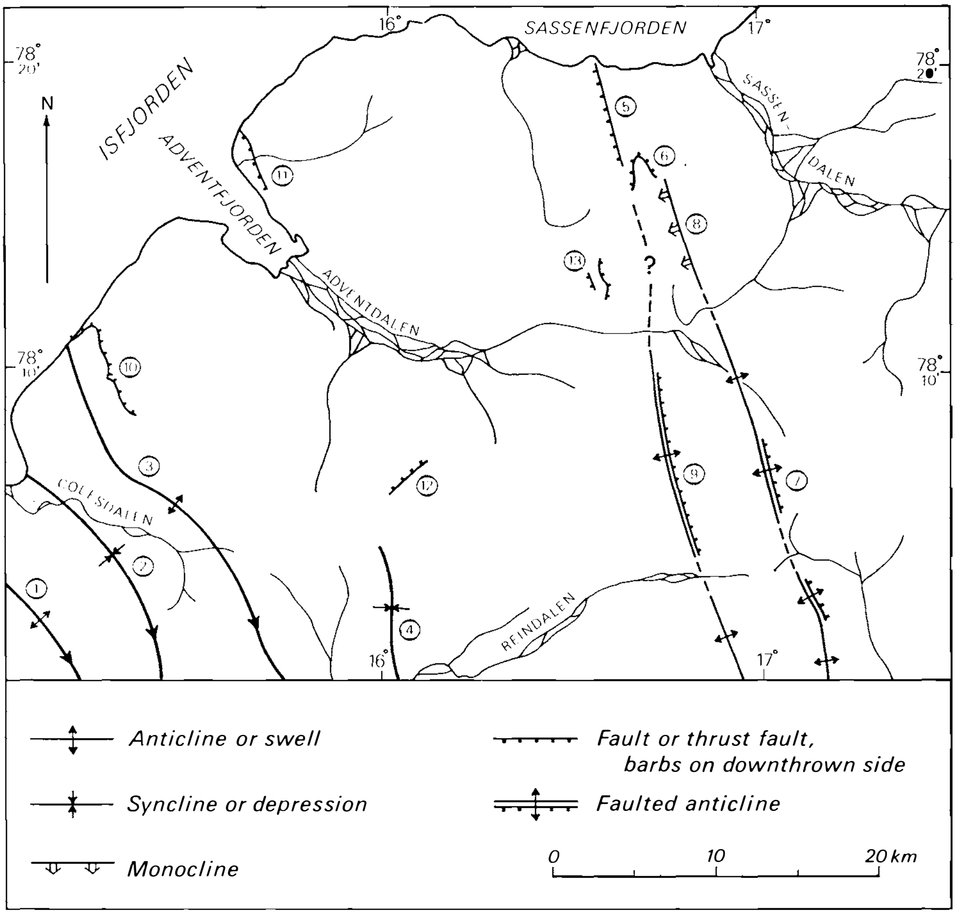

Fig. 10. *Structural features in the Adventdalen map area.*

Swells and depressions:
1. Holmsenfjellet swell
2. Skiferdalen depression
3. Reindalen swell
4. Tverrdalen depression

The Billefjorden fault zone:
5. Flowerdalen fault
6. Gattytoppen thrust
7. Eastern line
8. Roulletegga monocline
9. Western line

Other faults:
10. Grumantbyen fault
11. Louisdalen fault
12. Foxtoppen fault
13. Arctowskifjellet fault

of which are present within the map area (from north to south): the Grumantbyen dome, the Ringdalen anticline, and the Bromdalen dome.

4. The Tverrdalen depression. – This is a less prominent structure which passes from the head of Tverrdalen southward across Van Mijenfjorden.

Faults

1. The Billefjorden fault zone. – This fault zone is traceable for c. 200 km from Wijdefjorden in the north to Kjellströmdalen in the south, and was intermittently active from Devonian to Tertiary time (ORVIN 1940; MCWHAE 1953). In the northernmost part of the map area this zone is represented by the high-angle Flowerdalen fault which is exposed on the western slope of Marmierfjellet. On Gattytoppen the fault disappears below Jurassic and Cretaceous deposits, but probably continues southward below the surface. On Marmierfjellet the Flowerdalen fault cuts Permian and Triassic rocks, and has a downthrow to the west of up to 600 m. On the east side of the fault the upper part of the Janusfjellet Formation (Lower Cretaceous) rests unconformably on the Kongressfjellet Formation (Middle Triassic). This unconformity was caused by late Jurassic–early Cretaceous earth movements and subsequent erosion which was most intense along the fault zone. On Marmierfjellet the following rock-units have been removed by this erosion: the lower part of the Janusfjellet Formation, the entire Kapp Toscana Formation, and probably the topmost part of the Kongressfjellet Formation.

It is difficult to trace any single continuation of the hidden Flowerdalen fault between Gattytoppen and Adventdalen. A section through Valmuetoppen and Roulletegga shows no visible fault, but the lowermost competent Helvetiafjellet sandstones form an acute, south-westward dipping monocline. This structure continues northward until it forms part of a marked thrust fault truncating Gattytoppen and Ile de Francekollen. The thrust fault has a south-westward dipping plane, and a vertical throw as large as c. 150 m. It is here called the Gattytoppen thrust.

The Arnicadalen fracture of LIVŠIC (1965a) is essentially hidden beneath rock slides and other unconsolidated material. It is therefore not marked on the present map.

A section from Arnicadalen to Juvdalen shows a syncline which continues to the south of Adventdalen as a 4 km broad graben between two fault lines. Movements along the deep-seated, continuous faults hidden below these lines have formed anticlines, flexures, and faulted anticlines in the Mesozoic rocks exposed on the present surface: On the western line a faulted anticline is developed from Skolten through Rudieaksla and Drøntoppen to Aasgaardfjellet (Fig. 11). From

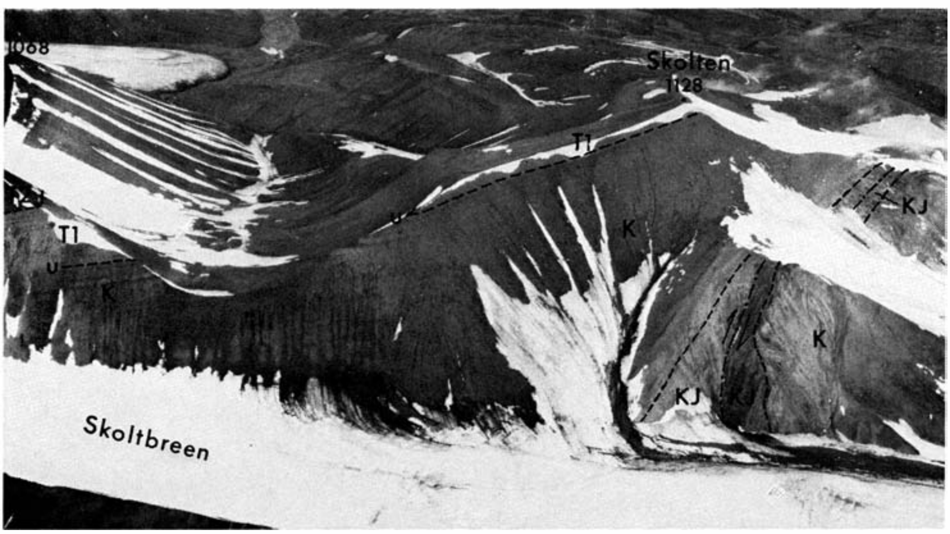

Fig. 11. *Oblique aerial view (towards north-west) of Skolten showing the western line of the Billefjorden fault zone. The structure developed here is a faulted anticline with the Janusfjellet Formation (KJ) exposed in its crest. Other rock units exposed are: Helvetiafjellet and Carolinefjellet Formations (K), Firkanten Formation (T1) with unconformity (u) at base, Basilika and Sarkofagen Formations (T2).*

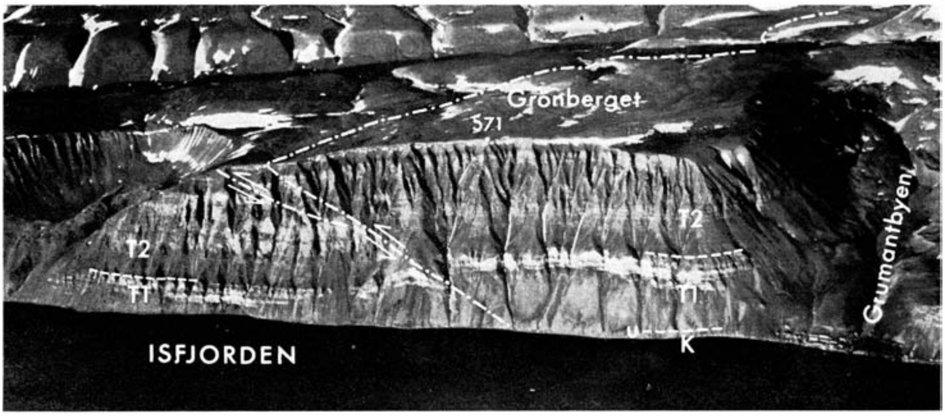

Fig. 12. *Oblique aerial view of the Grumantbyen fault, looking south-eastward. The sea cliff cut by the fault consists of the following rock units: Carolinefjellet Formation (K), Firkanten Formation (T1) with unconformity (u) at base, Basilika and Sarkofagen Formations (T2).*

here it continues as an anticline which fades out south of Lunckefjellet. The eastern line is marked by an anticline on Brentskardhaugen, which continues as a flexure on Fleksurfjellet. Farther south, on Tronfjellet and Glitrefjellet, this line forms an elevated thrust fault with overthrusted west side. The next structure on this line is an anticline.

2. The Grumantbyen fault. – This is a conspicuous thrust fault visible on the south coast of Isfjorden, east of Grumantbyen (Fig. 12). It has recently been described by LIVŠIC (1965a). The thrust plane dips south-westward, truncating Grønberget at an angle of 30–35°, but farther south the dip becomes steeper. The rocks along the thrust plane are locally folded and strongly shattered. The formations cut by the thrust are of Lower Cretaceous and Palaeogene age. The vertical throw amounts to 150 m; the western block being thrust above the eastern.

3. Minor faults. – Two faults traceable for a short distance are present on Arctowskifjellet; the western has a nearly vertical plane, while the eastern is a thrust fault similar to that on Gattytoppen. Small thrust faults with vertical displacements of up to 10 m are also known from the coal mines. The Foxtoppen and Louisdalen faults are of the high-angle type (Fig. 13). Some of the minor faults may be related to major hidden fracture zones, e.g. the Arctowskifjellet faults and the Louisdalen fault.

VI. Geologic history

The map area is part of the Spitsbergen trough, the history of which has been described by several authors, e.g. ORVIN (1940), HARLAND (1961), and SOKOLOV et al. (1968). The rocks composing this large structure were formed during three main periods: 1) a geosynclinal period completed between Middle Ordovician and

Fig. 13. *The Louisdalen fault exposed on the south-eastern bank of the river in Louisdalen. The rocks cut by the fault belong to the Carolinefjellet Formation.*

Devonian; 2) a late orogenic period confined mainly to the Devonian; 3) a mobile platform period ranging from the Carboniferous to the present time.

The rock sequence exposed in the map area was deposited from the Permian up to the present time and represents the geological history of the area during most of the platform period. Rocks older than the Permian are hidden below the surface, but the pre-Permian history of the region can be deduced from relationships known from other parts of the Spitsbergen trough.

Palaeozoic events

In late Precambrian and early Palaeozoic times the map area was part of a north-south trending geosyncline where great thicknesses of terrigenous and carbonate rocks accumulated. During the Caledonian orogeny, between Middle Ordovician and Devonian time, the rocks of the geosyncline were folded and metamorphosed. These Caledonian rocks form the basement below the younger, unmetamorphosed sediments deposited under late orogenic and platform conditions.

In Devonian time the Caledonian orogen was subjected to strong erosion producing great masses of clastic material. This material accumulated in late orogenic basins under continental-lagoonal conditions, and formed thick deposits of varying coarseness. Sediments of this type are preserved in the Devonian graben formed by subsidence between the Liefdefjorden and Billefjorden fault zones. A segment of the graben probably underlies the whole map area west of the Billefjorden fault zone.

Platform conditions were introduced in Early Carboniferous time by slight subsidence of the Spitsbergen area. The subsidence was followed by deposition of coal-bearing lacustrine and littoral sandstones over large areas. Much of these deposits were, however, removed by erosion caused by Middle Carboniferous block movements along the Devonian fault zones. Early Carboniferous sandstones are exposed around Billefjorden, and probably continue in the subsurface southward into the present map area in connection with the Billefjorden fault zone.

In Middle Carboniferous and Permian times the area underwent a new shallow subsidence which led to sedimentation under marine conditions. Deposition was, however, interrupted several times and many greater and lesser disconformities were formed, particularly in the Carboniferous. The rocks deposited first were coarse clastics, carbonates, and local evaporites formed in a mobile tectonic environment. These are overlain by silicified carbonates, shales, and glauconitic sandstones deposited under more stable conditions. It seems probable that toward the close of the Permian a regional disconformity was formed by slight uplift and erosion.

Mesozoic events

In early Lower Triassic time the map area was covered by a shallow, but extensive shelf sea. The first sediments accumulating in these waters were siltstones, shales, and sandstones which constitute the Vardebukta Formation. In late Lower Triassic time black shale facies was introduced into the shelf area, probably by the development of a large, shallow, poorly ventilated basin. The rocks deposited in the basin were mainly black and grey bituminous shales with some siltstones. These rocks are most typical in the Middle Triassic Botneheia Member of the Kongressfjellet Formation. During the Late Triassic the marine facies gave way to continental conditions, probably by filling up of the shelf sea, or by epeirogenic uplift of the sea bottom. The rocks deposited after this change are plant-bearing sandstones, siltstones, and shales, which form the upper part of the Kapp Toscana Formation.

In the Middle Triassic there was minor renewed activity along the Billefjorden fault zone (PARKER 1966). This movement, with downthrow east of the fault, is suggested by slightly increasing thicknesses in the middle part of the Triassic sequence across the fault zone from Botneheia in the west to Vikinghøgda in the east.

The sea again advanced over the map area in Early Jurassic time, but retreated again after a short period of marine deposition. A thin blanket of conglomerate (the Brentskardhaugen bed) with a Toarcian fauna was left behind to record this invasion of the sea.

A prolonged period of subsidence accompanied by deposition of a thick marine succession began near the close of Middle Jurassic time, and continued during the Late Jurassic into the Hauterivian stage of the Early Cretaceous. The rocks formed are the dark-grey shales and siltstones of the Janusfjellet Formation.

Deposition of the Janusfjellet Formation was interrupted along the Billefjorden fault zone by tectonic activity and subsequent erosion; this took place between the Uppermost Jurassic and Lowermost Cretaceous. The diabases exposed in the northern part of the map area were apparently intruded at this time.

At the end of the Hauterivian stage the shelf area was uplifted above sea level. Accumulation of sediments continued under continental conditions during the Barremian stage and the rocks formed are coal-bearing sandstones and siltstones which make up the Helvetiafjellet Formation. A new transgression began near the close of the Barremian, or early in the Aptian stage, and the platform probably continued to subside during the rest of the Early Cretaceous. Deposition took place mainly in shallow water during this period of marine subsidence and the rocks formed are sandstones, siltstones, and shales that compose the Carolinefjellet Formation.

The Mesozoic era terminated with an extensive uplift and denudation in Late Cretaceous time. A considerable part of the Carolinefjellet Formation within the map area has been removed by this erosion, which was most intense in the north-west.

Cenozoic events

The Palaeogene was a time of rapid accumulation of terrigenous sediments in a large, subsiding basin. Deposition started early in the Palaeocene under alternating terrestrial and shallow marine conditions, and the rocks deposited are sandstones with some shales, coals, and conglomerates composing the Firkanten Formation. Thereafter, the area underwent a more marked subsidence and deposition continued first in comparatively deep marine waters, then in shallower sea, and lastly in estuaries or on land. This gradual shoaling of the basin is recorded in the rock sequence by the Basilika shales which grade upwards into the Sarkofagen sandstones and siltstones. A new extensive subsidence led again to deposition in deeper marine waters which gradually became shallower and finally were replaced by estuaries and lakes. The rocks formed during the last shoaling period are (from below): dark shales of the Gilsonryggen Formation; shales, siltstones, and subordinate sandstones of the Battfjellet Formation; and coal-bearing sandstones, shales, and siltstones of the Aspelintoppen Formation which is the youngest rock unit of the Tertiary.

In post Eocene or post Oligocene time Spitsbergen was subjected to strong crustal movements which produced the Tertiary folding zone along the west coast, and the Spitsbergen trough farther east. Within the map area these movements have tilted the basement with its sedimentary cover regionally towards south-west at about 1 to 3°. In the south-western part of the map area the Tertiary tectonism produced swells and depressions, but these features were probably initiated by late Palaeozoic or Mesozoic block faulting. The diastrophism also activated the Billefjorden fault zone where the Tertiary structures were apparently formed by an east-west compression of strata. In addition to these features, the Tertiary movements produced several greater or smaller dislocations of different types scattered throughout the area, e.g. the Grumantbyen and Louisdalen faults.

After the Tertiary diastrophism the area was more or less peneplaned, and probably before the close of the Neogene the whole region was strongly uplifted and subjected to erosion. The present pattern of the fjord and valley system was possibly initiated already in this time. Nevertheless, the present landform of the region is mainly the product of glacial and fluvial action during the Quaternary.

The area must have been covered by ice during the Pleistocene glacial stages. By the start of Holocene time the ice of the Würm stage began to retreat, and the lower, deglaciated parts of the valleys became covered by sea where intensive sedimentation took place. The various marine deposits were then raised above sea level by isostatic elevation which is still in progress today.

VII. Economic geology

Coal is the only material that is produced commercially within the map area at the present time. The thick sedimentary sequence of the region is, however, favourable for the occurrence of petroleum and this possibility has led to considerable field activity during the last decade. Other industrial deposits of lesser or greater commercial value include phosphate, bentonite, gypsum, and anhydrite.

Coal

The rock sequence exposed in the map area contains coal seams of Triassic, Cretaceous, and Tertiary age. In addition to these, the occurrence of Devonian and Carboniferous coals may be expected locally in the subsurface. Commercially profitable mining is confined to the Tertiary coal seams developed in the Firkanten Formation.

1. Devonian and Carboniferous. – Coal seams of Middle Devonian and Lower Carboniferous age are developed in other parts of Svalbard and locally attain mineable thicknesses. It seems possible that coal seams of similar age occur within the map area below the surface, but their commercial potential is strongly reduced by the great thicknesses of overburden.

2. Triassic. – Coal beds have been reported from the upper part of the Kapp Toscana Formation. They are, however, thin, impure, and economically insignificant.

3. Cretaceous. – The Helvetiafjellet Formation usually contains one or more coal seams which are locally developed in mineable thicknesses.

4. Tertiary – Firkanten Formation. – The most important coal resources of the map area are limited to the lower 30 or 60 m of the Firkanten Formation. This part of the Tertiary contains five coal seams which are discussed in the following (in ascending order).

The Svea seam has been mined c. 12 km south of the map area, in Sveagruva at the head of Van Mijenfjorden, where seam thicknesses of up to 5 m are found locally. Within the map area a single pit on the south side of Reindalen showed a coal thickness of 3.5 m, but scattered pits in the vicinity had minor thicknesses and intercalations of clastic material. Farther north the seam is less well developed, and locally split into thin, hardly recognizable coal layers. It reappears, however, more well developed west of Longyeardalen and north of Adventdalen. The coal of the Svea seam is characterized by a comparatively high content of inert macerals (especially fusinite) and a correspondingly lower content of volatile matter.

The Todalen seam has been mined in Sveagruva, in the Svea west mine. Within the map area this seam is exposed on both sides of Reindalen where its thickness is commonly less than 60 cm. Farther north, the seam is found on both sides of Adventdalen, and in this area mineable coal thicknesses of up to 1 m are found in some places. The quality of the Todalen seam is similar to that of the overlying Longyear seam, and it can possibly be mined with profit in limited areas. It shows, however, a tendency to splitting and other irregularities.

The Longyear seam has yielded almost the entire coal quantity produced in the map area. Its thickness exceeds 2 m on the north side of Adventdalen, but decreases to 1–1.5 m on the south side of the valley. Further south and south-west the seam is split into two beds by a fairly uniform siltstone bed. In the same direction the coal shows thinning and increasing pyritic sulphur content.

The quality of the Longyear seam coal is well exemplified by the following values presented by HOFFMANN & HOEHNE (1959): volatile matter (waf) 42.5%, ash 7.9%, sulphur 1.4%, and P_2O_5 0.05%. A coal petrographic analysis of macerals, published by the same authors, showed: vitrite 27.5%, clarite 71.2%, and material rich in inert substance 1.8%. This coal type, characterized by a very high content of bitumen-rich clarite and low content of inert substance, accords well with the very high plasticity values obtained by laboratory tests. The coal of the Longyear seam has proved suitable as a major ingredient of coking coal blends, and is also appropriate for other metallurgical purposes.

The Svarteper and Askeladden coal seams occur fairly persistently over a large area. However, they consist usually of impure, very sulphur-rich coal which is commonly split by thin layers of carbonaceous shale and siltstone. For this reason the seams have not been developed commercially.

5. Tertiary – Sarkofagen Formation. – In the Fardalen area an up to 60 cm thick coal seam occurs near to the top of the Sarkofagen Formation. The seam is apparently of small regional extent and has little or no commercial importance.

6. Tertiary – Aspelintoppen Formation. – This unit forms the highest parts of the mountains in the south-western part of the map area and, consequently, its distribution area is strongly dissected by the valleys. It contains numerous thin coal seams, but none of them is considered commercially exploitable.

Coal mining

Coal has been mined in the map area throughout almost the whole of the present century. Mining operations have been confined to the following three areas: the north side of Adventfjorden with the mining camps Advent City and

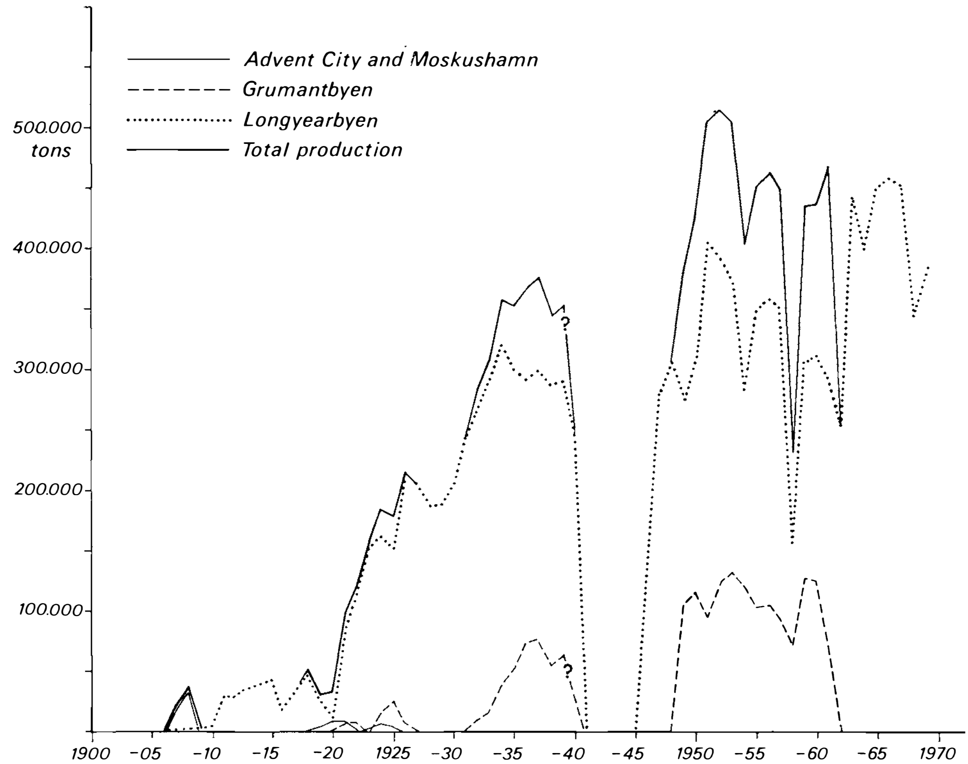

Fig. 14. *Coal production in the Adventdalen map area until 1970.*

Moskushamn; the south side of Adventfjorden and Adventdalen centred on the mining town Longyearbyen; and the Grumantdalen area with the mining town Grumantbyen. The total amount of coal produced in the map area until 1970 is about 14 million tons; the production of the different districts is shown in Fig. 14.

Small scale mining operations were started on both sides of Advenfjorden in 1900 and 1901. Exploratory mining on the north side of the fjord was first confined to a Lower Cretaceous coal seam, which later proved too thin and of too low quality for industrial mining. Continued attempts at mining the Tertiary Longyear seam, about 400 m higher on the same mountain, disclosed good seam thicknesses but the coal had a lignitic character with low heating value. Because of this disadvantage, mining was interrupted several times and finally stopped in 1946. The two mining camps in the area, Advent City and Moskushamn, are abandoned. The coal production of the area totals c. 100,000 tons.

On the south side of Adventfjorden and Adventdalen mining was started around Longyearbyen and later extended mainly towards the south-east. Production has been confined to the Longyear seam, which in this area consists of a bituminous semi-coking coal of a far better quality than that north of Adventfjorden. The Longyear seam has warranted a generally slowly increasing production interrupted only by World War II. The total production of the Longyear mines was about 12 million tons until 1970.

Exploratory work began at Colesbukta in 1910 and production was started in

Grumantbyen in 1920. The coal seam mined in Grumantbyen is probably identical with the Longyear seam. In any case, it has about the same type of coal, but in many places it is split in two by a thick stone band. Mining operations in Grumantbyen were interrupted during the economic crisis of 1927–1930, and by World War II. Production was stopped in 1961 because of reduced seam thicknesses and tectonic hindrances. The total amount of coal mined in Grumantbyen is 1.75 million tons.

Petroleum

Oil and gas possibilities in the map area are generally confined to the upper Palaeozoic and Mesozoic sequence. The Tertiary is less favourable because it is deeply eroded except in the south-eastern corner of the map area.

Rocks containing abundant organic material which can therefore be regarded as possible sources for oil or gas are: shales and siltstones of Middle Devonian age, probably present west of the Billefjorden fault zone; micritic carbonaceous beds in the Carboniferous and Permian; fossil-bearing dark shales and siltstones of the Lower and Middle Triassic; dark shales and siltstones of the Jurassic and lowermost Cretaceous.

It might be natural to expect that the following deposits have good reservoir properties: sandstones and limestones of the Carboniferous and Permian; non-marine sandstones of the Upper Triassic; non-marine sandstones of the Lower Cretaceous. The reservoir qualities of these rocks seem, however, to be reduced by a comparatively high grade of diagenesis which is also indicated by the high values of fixed carbon ratio in the coals. Potentially productive reservoirs are probably developed secondarily by fracturing of beds along the faults.

The map area contains several more or less well-defined anticlines and domes, which can be considered as favourable for accumulation of petroleum. Suitable oil structures seem to be present also along the Billefjorden fault zone. Possible cap rocks for the structures are shales of Triassic, Jurassic and Cretaceous age, as well as thin beds of plastic clay in the Tertiary.

Prospecting for petroleum in the map area started in 1960, and has since then continued with varying intensity. Although large parts of the area have been claimed during this period by different companies, no test well for oil has been drilled to date. It must be mentioned, however, that 17 km south of the map area a test well was drilled on the Ishøgda anticline which is a culmination of the Reindalen swell. The rock sequence penetrated by the drill ranges from the lower part of the Tertiary down to the Permian or Carboniferous. No commercial accumulation of petroleum was discovered by the project.

Other industrial deposits

1. Phosphate. – The Botneheia Member of the Kongressfjellet Formation contains phosphatic material which occurs mainly as blue-black to dark-grey pellets in silty shales and bituminous, calcareous siltstones. No representative analysis of this material is known from the map area. It is of interest to note that on Tschermakfjellet, 17 km north of the map area, there was some prospecting for phosphate in 1918. Hand-sorted products from the Botneheia Member at this locality contained only 11–16.5 percent P_2O_5.

2. Sulphate rocks. – Gypsum and anhydrite occur extensively in the Lower Permian sequence throughout central Spitsbergen in a basin centred in Isfjorden. Within the map area only the uppermost part of the sequence is exposed north of Sassendalen, where it contains some thin beds of gypsum and anhydrite. No attempt has been made to exploit the deposits.

3. Bentonite. – A few bentonitic beds occur in the Tertiary Firkanten Formation in connection with the Svea and Todalen coal seams. The thickness of the beds is usually 10–20 cm and rarely more than 50 cm, while their clay substance is mixed with rather much silt. Thin beds of plastic clay are present also in the Basilika and Gilsonryggen Formations. None of the beds have any commercial application.

4. Gravel and sand. – Gravel and sand occur abundantly along the courses of braided streams, as well as in raised marine terraces. Material from these deposits is suitable for local road construction and other ground work, but is less applicable as foundry sand.

Stratigraphic sections

Section 1

KAPP STAROSTIN FORMATION

Age: Permian
Location: Gjelhallet on the northern side of Sassendalen, 4 km from the sea.
Remarks: Reproduced after WINSNES *(1966); subdivision into members is made by the present authors.*

Vardebukta Formation (Triassic):
Sandstones and siltstones with shales and shaly siltstones.

Kapp Starostin Formation;	*Thicknes in m*
Hovtinden Member:	
15. Covered	12±
14. Sandstone, green and glauconitic	30
13. Chert, blue-grey and dark with some sandy layers	24
12. Sandstone, glauconitic	4
11. Covered	16
10. Sandstone, grey; the lower part contains many worm tracks and borings	26
9. Sandy chert, light	38
8. Covered	10
Total Thickness of the Hovtinden Member	160±
Svenskegga Member:	
7. Chert, in part covered	48
6. Limy sandstone, yellow weathering, containing brachiopods and bryozoans	3
5. Covered	60
4. Cherty limestone; some brachiopods present	1
3. Chert, light	10
2. Chert, dark, with bands of light chert 20 and 60 m above the base	80
Total thickness of the Svenskegga Member	202
Vøringen Member:	
1. Cherty limestone; rich in brachiopods	34
Total thickness of the Vøringen Member	34
Total thickness of the Kapp Starostin Formation	396±

Gipshuken Formation (Permian):
Limestones with shaly and sandy beds and some layers of anhydrite and gypsum.

Section 2

KONGRESSFJELLET FORMATION

Age: Triassic
Location: Vikinghøgda, on the south-eastern side of Sassendalen
Remarks: Reproduced after BUCHAN *et al. (1965); rank of units is changed by the present authors.*

Kapp Toscana Formation (Triassic);
Tschermakfjellet Member:
Dark-grey shale with clay-ironstone concretions. Siltstone interbeds are particularly common in the upper part.

	Thickness in m
Kongressfjellet Formation;	
Botneheia Member:	
6. Shale, dark grey, similar weathering, often slightly silty, papery to top, with interbeds of harder grey siltstone, flaggy, laminated, usually slightly calcareous, weathering yellow and orange-yellow. Two horizons of large grey limestone concretions occur at the top, hard, silty, weathering pale yellow and orange........	55
5. Shale, with siltstone interbeds similar to above, weathering light grey, with two fine-grained grey-green sandstone horizons at top, and small phosphatic nodules at base	33
4. Siltstone, dark-grey, shaly, weathering light grey	20
3. Shale, dark-grey and blue-grey, rarely silty, with common small spherical dark-grey phosphatic nodules, and two interbeds of hard grey-green siltstone, sandy, irregularly parted, weathering light yellow	49
Total thickness of the Botneheia Member	157
Sticky Keep Member:	
2. Siltstone, shaly, dark-grey, weathering light grey and yellowish with common interbeds of siltstone, grey, hard, flaggy and shaly, laminated, occasionally calcareous, weathering light yellow and orange. Also near the base, with large grey septarian limestone concretions, weathering grey-brown and yellow............	61
1. Shale, dark-grey, weathering light-grey, occasionally silty, passing down into dark-green shaly siltstone. Frequent thin interbeds of dark-grey hard siltstone occur, usually calcareous, laminated, weathering very light grey and yellow. Horizons of grey silty limestone concretions are common, weathering pale yellow and orange	60
Total thickness of the Sticky Keep Member	121
Total thickness of the Kongressfjellet Formation	278

Vardebukta Formation (Triassic):
The section is covered by scree of siltstone, shaly siltstone, and fine-grained silty sandstone.

Section 3

KAPP TOSCANA FORMATION

Age: Triassic
Location: Botneheia, on the southern coast of Sassenfjorden.
Remarks: Reproduced after BUCHAN *et al.* (*1965*).

Janusfjellet Formation (Jurassic and Cretaceous):
Brentskardhaugen Bed:
Grey conglomeratic siltstone, weathering yellow and reddish.

	Thickness in m
Kapp Toscana Formation;	
De Geerdalen Member:	
8. Sandstone, grey, grey-green, and grey-brown, flaggy and slabby, but largely shaly, laminated, rarely cross-laminated, becoming shaly lower, fine-grained, weathering rusty, grey-brown, occasionally yellow and orange-brown	45
7. Shale, silty, dark-grey, non-calcareous, weathering light-grey	16
6. Sandstone, light-grey, weathering dark-brown, finegrained, thin-bedded, blocky with flaggy and shaly interbeds, slightly calcareous in places, becoming buff and weathering whitish to base, partly covered to top, becoming laminated and shaly	44
5. Shale, sandy, dark-grey, weathering grey-brown with interbeds of sandstone, grey, weathering same, and slightly brownish, fine-grained, thin-bedded, blocky, some cross-bedding and ripple marks lower. One horizon of cone-in-cone marl occurs. Largely covered in the upper part	39
4. Shale, dark-grey weathering light-grey, slightly sandy, with flaggy grey sandstone interbeds	33
3. Sandstone, light-grey, fine-grained, weathering light-brown and orange-brown, calcareous to base, flaggy with shaly partings and interbeds, cross-laminated in places	13
Total thickness of the De Geerdalen Member	190
Tschermakfjellet Member:	
2. Shale, dark-grey, weathering same, occasionally rusty brown, with thin siltstone interbeds near top, grey, weathering orange-brown, sandy, flaggy, passing down into similar shales with many small rounded grey clay-ironstone concretions weathering red and orange	55
1. Shale, silty, dark-grey, with small grey-brown limestone concretions, one horizon of larger grey silty limestone concretions at base, weathering light yellow	8
Total thickness of the Tschermakfjellet Member	63
Total thickness of the Kapp Toscana Formation	253

Section 4

TYPE SECTION OF THE HELVETIAFJELLET FORMATION

Age: Lower Cretaceous
Location: Helvetiafjellet, on the northern side of Adventdalen; south of summit 834.
Remarks: Measured with tape and handlevel by H. MAJOR *in 1963.*

Carolinefjellet Formation (Lower Cretaceous):
Siltstone, carbonaceous, laminated, dark-grey; with thin interbeds of light-grey sandstone.

	Thickness in m
Helvetiafjellet Formation;	
Glitrefjellet Member:	
23. Sandstone, coarse-grained, markedly cross-bedded, light-grey, weathering yellow	6
22. Shaly zone, covered. 75 cm thick shaly coal seam uppermost	3
21. Sandstone, irregularly bedded, light-grey, weathering brown	2.5
20. Shale, carbonaceous	1
19. Sandstone, with dark silty partings	1.5
18. Sandstone, yellow and grey, with some short lenses of coal	0.5
17. Sandstone, thin-bedded; with carbonaceous material on the bedding planes, and lenses of coal	4
16. Sandstone, cross-bedded, light-grey; with carbonaceous material on the bedding planes	2.5
15. Sandstone, thin-bedded; with carbonaceous material on the bedding planes, and lenses of coal	3
14. Sandstone, massive	5
13. Covered	5
12. Shale, partly covered	20
11. Sandstone, cross-laminated	2.1
10. Sandstone, dark, carbonaceous; with thin (20 cm) calcareous zone at base	5.2
9. Sandstone, thin-bedded	3
8. Sandstone, shaly, brown-grey	1
7. Sandstone, thin-bedded	1
6. Shale	2
5. Sandstone, light-grey, in 5–20 cm thick beds	10
4. Covered	10
3. Sandstone, shaly, partly covered	2
Total thickness of the Glitrefjellet Member	90
Festningen Member:	
2. Sandstone, coarse-grained, poorly bedded, light-grey; contains a thin coal seam	6
1. Conglomerate, polymict; consisting of well-rounded pebbles with diameter up to 10 cm	0.3
Total thickness of the Festningen Member	6.3
Total thickness of the Helvetiafjellet Formation	97

Janusfjellet Formation (Jurassic and Lower Cretaceous):
Dark-grey shale with some interbeds of siltstone and sandstone; partly covered.

Section 5

TYPE SECTION OF THE FIRKANTEN FORMATION

Age: Tertiary
Location: Firkanten, on the northern side of Van Keulenfjorden.
Remarks: Measured by E. NYSÆTHER *in 1963. The lower part of the section (unit 1–19) was measured with tape, while the upper part (unit 20–22) with aneroid barometer.*

Basilika Formation (Tertiary):
Shale, dark-grey; contains scattered pebbles of quartzite and chert, rosettes of calcite, and thin beds of plastic clay.

Firkanten Formation:	*Thickness in m*
22. Sandstone, fine- to medium-grained, argillaceous, massive, thick-bedded, grey to dark-grey, weathers brown-grey; contains scattered pebbles of chert and quartzite	18.2
21. Sandstone, fine- to medium-grained, argillaceous, massive, thick-bedded, dark-grey, weathers grey-brown; contains scattered pebbles of flint and quartzite. Thin bed of breccia (20 cm) in the lower part	80.8
20. Siltstone, coarse-grained, argillaceous, grey-black; with organic material	12.0
19. Sandstone, fine-grained, argillaceous, grey-black; with organic material	1.7
18. Siltstone, coarse-grained, argillaceous, grey-black; with organic material	5.4
17. Sandstone, fine-grained, argillaceous, grey-black; with organic material	2.3
16. Siltstone, coarse-grained, argillaceous, slabby, grey-black; with organic material. Thin bed of clay (9 cm) near the top	7.4
15. Sandstone, fine-grained, argillaceous, slabby, grey-black; with organic material	0.8
14. Siltstone, coarse-grained, argillaceous, slabby, grey-black; with organic material	5.0
13. Siltstone, medium-grained, argillaceous, shaly, with black organic material	1.6
12. Siltstone, coarse-grained, argillaceous, slabby, grey-black; with organic material	2.7
11. Sandstone, fine-grained, argillaceous, slabby, grey-black; with organic material	0.6
10. Siltstone, coarse-grained, argillaceous, slabby, grey-black; with organic material	3.7
9. Sandstone, medium-grained, thick-bedded, slabby, dark-grey, weathers grey; contains scattered pebbles of chert and quartzite	3.4
8. Clay-ironstone	0.2
7. Conglomerate, sandy	0.1
6. Clay-ironstone	0.1
5. Sandstone, medium-grained, massive, thick-bedded, grey-green, weathers light-green	9.3
4. Conglomerate, consists of quartz and chert pebbles (diameter 2–15 mm) in sandy matrix	0.2
3. Sandstone, medium-grained, thick-bedded, light-grey, weathers red-brown	9.5
2. Sandstone, medium- to coarse-grained, varying types, light-grey, weathers easily, weathering colour grey	3.1
1. Clay and dark shale	3.1
Total thickness of the Firkanten Formation	171

Carolinefjellet Formation (Cretaceous);
Zillerberget Member:
Shale and siltstone, grey; with intercalations of grey-green sandstone.

Section 6

FIRKANTEN FORMATION

Age: Tertiary
Location: Unit 1–24 were measured on the eastern side of the valley Endalen where the remaining part of the formation is covered. The section was continued on the western side of the valley where unit 25–31 were measured.
Remarks: Measured with tape by H. MAJOR *in 1951.*

Basilika Formation (Tertiary):
Beds of greenish-grey siltstone

Firkanten Formaton (composite section):	*Thickness in m*
31. Sandstone, coarse-grained, with scattered pebbles; 5 cm thick conglomerate layer at the base	1.45
30. Sandstone, fine-grained, light-grey, containing a basal and a middle band of clay-ironstone nodules	4.15
29. Sandstone, in unsolid 10–15 cm thick beds, light-grey; with one 10 cm thick clay-ironstone bed near the base. Numerous small bivalves in the middle part and larger ones near the base	6.10
28. Sandstone, in solid beds, weathering rusty and light-grey	10.05
27. Sandstone, greenish-grey; in uneven, medium and thin beds. Four to five clay-ironstone beds occur in the upper four metres and one near the base	16.00
26. Sandstone, light-grey, faintly layered except for its lower third which is regularly laminated	7.35
25. Sandstone, unevenly bedded, greenish-grey; with clay-ironstone nodules	4.25
24. Sandstone, unevenly bedded and flaggy in alternation	3.00
23. Sandstone, unevenly bedded, greenish-grey; with beds of clay-ironstone	4.60
22. Sandstone, fine- to medium-grained, thick-bedded, faintly reddish-grey; containing scarce and scattered pebbles of chert and quartzite, and lenses and beds of clay-ironstone	9.75
21. Sandstone, silty, more or less argillaceous, mostly thin-bedded. Contains a 1.2 m thick zone which is rich in root remains, and a 8 cm thick conglomerate	7.24
20. The Askeladden coal seam. Its upper 7 cm consists of carbargilite	0.62
19. Shale, silty, sandy uppermost; contains some clay-ironstone beds in its upper and lower part	2.65
18. The Svarteper coal seam. Consists of seven coal beds 5–32 cm in thickness, alternating with shale beds	2.45
17. Shale, dark-grey	0.15
16. Sandstone, dense, in 20–30 cm thick beds, grey, weathering greenish. Uppermost part shaly and contains plant fossils. Clay-ironstone bed in the lower and middle part	3.45
15. Sandstone, medium-grained, thick-bedded, partly cross-laminated, light-grey; contains clay-ironstone nodules and scattered quartz pebbles	3.15
14. Sandstone, in 5–10 cm thick beds, interlayered with dark shale	0.40
13. Clay-ironstone nodules in grey shale	0.20
12. The Longyear coal seam consisting of: an upper unclean coal bed which is 24 cm thick; a 70 cm thick interbed of silty shale, partly with plant fossils; a lower coal bed which is 90 cm thick and productive	1.84
11. Siltstone, shaly, grey to dark-grey	1.58
10. Coal and carbargilite	0.05
9. Sandstone, silty, grey. Lower 5 cm contains thin root remains and other plant fossils	1.70
8. Siltstone and shale, dark-grey	1.97
7. Coal with a thin siltstone layer	0.13

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Section 6 continued	*Thickness in m*
6. Sandstone, mainly thick-bedded. Plant fossils and small root remains occur in the upper part. Below a 15 cm thick middle bed of bituminous shale with clay-ironstone nodules, the sandstone contains notched tubular burrowings similar to *Ophiomorpha nodosa*. The lower part is fine-grained, argillaceous, with clay-ironstone layers and some plant fossils	11.05
5. The Todalen coal seam	0.35
4. Sandstone and shale, silty: with thin clay beds and clay-ironstone. Lower and upper part contains tiny root remains and other plant fossils	9.25
3. The Svea coal seam	0.35
2. Clay (unconsolidated) sandy, greenish-grey	2.00
1. Sandstone, fine-grained; with a clay-ironstone bed in the upper part, and a 25 cm thick bed of dark-green glauconitic, silty clay near the base	3.00
Total thickness of the Firkanten Formation	120

Carolinefjellet Formation (Cretaceous):
Fossiliferous dark-grey shale and siltstone.

Section 7

BASILIKA FORMATION

Age: Tertiary
Location: Pilarberget, north-east slope.
Remarks: Measured with tape, handlevel, and aneroid barometer by H. MAJOR *in 1964.*

Sarkofagen Formation (Tertiary):
Thick-bedded, precipice-forming, greenish-grey sandstone.

Basilika Formation:	*Thickness in m*
28. Siltstone, sandy, dark-grey	0.20
27. Sandstone, medium-grained, in 4–10 cm beds	0.95
26. Sandstone, fine-grained, grey; with some 5–15 cm thick, unsolid, silt-pelite interbeds	4.35
25. Clay; upper half is fairly consolidated and silty, lower half is brown-grey, unconsolidated	0.12
24. Siltstone, grey, in 15–20 cm beds	1.03
23. Clay	0.03
22. Silty sandstone, grey; with a 3 cm thick dark band of unsolid siltstone 25 cm from the top. The lower 25 cm contains carbonaceous, rusty-red layers	1.43
21. Clay: the upper 1 cm is silty and dark brown-grey; the middle 3 cm is plastic and yellow; the lower 1 cm is silty, dark brown-grey, and less plastic	0.05
20. Silty sandstone, grey; the lower part is inhomogenous and reddish brown-grey. A 50 cm thick bed in the middle part is abundant in small, white, siliceous tubes	2.50
19. Covered	15.00
18. Silty clay-pelite, dark-grey, irregularly fissured	0.35
17. Clay: the upper 16 cm is silty, grey coloured; the lower 23 cm is orange-brown, with greenish and grey lenses and streaks	0.39
16. Silty clay-pelite, irregularly fissured	0.20
15. Covered	7.00
14. Silt-pelite, dark-grey and rusty	0.04

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Section 7 continued	*Thickness in m*
13. Clay: the upper 3 cm is silty and brownish grey; the middle 1 cm is ochre-brown, clean, but weathered; the lower 6 cm is silty, dark-grey, and somewhat consolidated	0.10
12. Sandy siltstone, dark-grey, with clay-ironstone nodules	0.20
11. Covered	10.00
10. Silty shale, dark-grey, thin-bedded	2.00
9. Sandy siltstone, dark-grey	0.08
8. Clayey silt, brown-grey, unconsolidated	0.05
7. Clay, ochre-brown	0.04
6. Covered	4.00
5. Silty shale, grey, fissile	0.15
4. Clayey silt, brownish-grey, unconsolidated	0.08
3. Silty shale	0.02
2. Covered	10.00
1. Sandy siltstone, abundant in plant remains	1.50
Total thickness of the Basilika Formation	62

Firkanten Formation (Tertiary):
Coarse-grained sandstone with layer and lenses of conglomerate.

Section 8

TYPE SECTION OF THE SARKOFAGEN FORMATION

Age: Tertiary
Location: Sarkofagen, at the head of Longyeardalen.
Remarks: Measured with aneroid barometer by H. MAJOR *in 1964.*

Gilsonryggen Formation (Tertiary):
Shale, dark-grey, fissile and brittle.

Sarkofagen Formation:	*Thickness in m*
12. Sandstone, medium- to thin-bedded, fossil-bearing	13
11. Shale, silty, fissile and brittle, dark-grey	13
10. Sandstone, medium- to thin-bedded	10
9. Shale, silty, dark-grey	10
8. Sandstone, thick-bedded	40
7. Sandstone alternating with thinner siltstone beds; carbonized plant debris in the lower part	50
6. Sandstone, dark greenish-grey; weathers rusty; rich in pyritic concretions	25
5. Sandstone, silty, pale greenish-grey	15
4. Sandstone, well-bedded, dark-grey; weathers in part rusty; rich in sand-filled cylindric burrowings	10
3. Sandstone, silty, olive grey; with some plant fossils	30
2. Siltstone, thin-bedded, dark-grey	30
1. Sandstone, thick-bedded, greenish-grey	30
Total thickness of the Sarkofagen Formation	276

Basilika Formation (Tertiary):
Siltstone, grey

Section 9

TYPE SECTION OF THE GILSONRYGGEN FORMATION

Age: Tertiary
Location: Gilsonryggen, at the head of Tverrdalen.
Remarks: Measured with aneroid barometer by H. MAJOR *in 1963.*

Battfjellet Formation (Tertiary):
Sandstone, silty, thin-bedded, grey; weathering light-brown.

Gilsonryggen Formation:	*Thickness in m*
15. Shale, silty, dark-grey; forms an even, scree-covered slope	50
14. Shale, weathering rusty; contains six thin layers of clay	2.15
13. Shale, fissile, dark, disintegrated	15
12. Shale, dark-grey	1
11. Shale, fissile, dark-grey, disintegrated	35
10. Shale, disintegrated; with a band of chert-conglomerate (indicated by loose blocks and pebbles)	1
9. Shale, fissile, dark-grey, disintegrated	50
8. Thin layer of clay, marked by a vegetation band	0.04
7. Shale, fissile, dark-grey, disintegrated	5
6. Very thin layer of clay; weathering brown	?
5. Shale, fissile, dark-grey, disintegrated	10
4. Shale, disintegrated; with a band of chert-conglomerate (indicated by loose blocks)	1
3. Shale, fissile, dark-grey, disintegrated	35
2. Layer of grey clay, marked by a broad vegetation band	0.27
1. Shale, fissile, dark-grey, disintegrated	30
Total thickness of the Gilsonryggen Formation	235

Sarkofagen Formation (Tertiary):
Sandstone, coarse-grained, irregularly bedded, light-grey.

Section 10

TYPE SECTION OF THE BATTFJELLET FORMATION

Age: Tertiary
Location: Battfjellet, west side, on the northern side of Reindalen.
Remarks: Measured with aneroid barometer by H. MAJOR *in 1964.*

Aspelintoppen Formation (Tertiary):
Sandstone, coarse-grained, carbonaceous.

Battfjellet Formation:	*Thickness in m*
8. Sandstone, thin-bedded; alternating with siltstone, sandy, laminated, and carbonaceous. Thickness of individual beds up to 15–20 cm	37
7. Sandstone, silty, in 3–4 cm thick beds; separated by thin (1–2 mm), shaly, carbonaceous partings	7
6. Covered by silty shale material, and slabs of sandstone and siltstone	43
5. Sandstone with ripple marks and foreset-lamination; thickness of beds 4–7 cm, increasing upward to 15 cm. Interbeds of shale with clay-ironstone nodules	10
4. Silty shale in alternation with silty sandstone; thickness of beds 3 cm, increasing upward to 4–7 cm, two beds are 30 cm thick	30
3. Partly covered by soft silty shale and sandstone. Consists of silty shale with thin beds of flaggy sandstone	37
2. Sandstone with irregular structures formed probably by slumping	2
1. Sandstone, fine-grained, yellowish grey	0.7
Total thickness of the Battfjellet Formation	167

Gilsonryggen Formation (Tertiary):
Shale, silty, dark-grey, friable.

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ERRATA

P. 18, line 1.	For:	a lower Rurikfjellet Formation
	read:	an upper Rurikfjellet Formation
» 18, » 1.	For:	an upper Agardhfjellet Formation
	read:	a lower Agardhfjellet Formation
» 19, » 10.	For:	a Bajocian age
	read:	a Toarcian age
» 19, » 14.	For:	an Upper Valanginian hiatus
	read:	an Upper Volgian hiatus

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