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Under Ledelse af Lauge Koch

THE GEOLOGY OF THE CAMBRO-ORDOVICIAN ROCKS OF CENTRAL EAST GREENLAND

PART I

STRATIGRAPHY AND STRUCTURE

BY

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WITH 78 FIGURES IN THE TEXT AND 13 PLATES

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PREFACE

The field work for this study, part of the programme of the Danish expeditions under the leadership of Lauge Koch, commenced in the July of 1950 on Ella Ø (see fig. 1 and Plate VIII). The major part of that summer was, however, spent at Kap Weber, mapping and collecting fossils from a highly disturbed and faulted Lower Palaeozoic sequence. From September onwards the geological mapping and fossil-collecting were continued on Ella Ø. By the end of October the gathering darkness of the polar night curtailed field work until the following March, when the principal tasks of section-measuring and fossil-collecting recommenced.

Autumn and winter reconnaissance had shown that the south coast of Ella Ø—where Cambro-Ordovician strata are admirably exposed in a continuous cliff-section—would provide the most suitable place for examination and measurement. This could best be achieved during early spring while the frozen surface of Narhvalsund allowed easy access to all parts of the lower cliff-sections, and a camp could be pitched on the fjord-ice in Antiklinalbugt; no suitable camp-site existed on the steep cliff-screes. Accordingly in 1951, between early March and the end of April, approximately 2000 metres of sediments of Pre-Cambrian to Devonian age were measured and described along the south coast of Ella Ø, searched for fossils and the lithological types sampled.

As plans required that a move be made to northern Hudson Land before the melting of fjord and river-ice made sledging impossible, further work on the section in Narhvalsund was suspended at the beginning of May: all but the younger strata had received adequate examination and description.

Field work in the Albert Heims Bjerge region of northern Hudson Land occupied the remainder of the 1951 summer from the latter part of May to the end of August. During these three months nearly 3000 metres of strata were examined, in a similar manner to the sequence in Ella Ø, and a geological map was produced (Plate IX). No single and continuous stratigraphical section could be measured in this region, owing to the nature of the topography and geological structure, but

well-defined marker-horizons allowed the erection of a complete section from smaller units. The measurement of these dispersed sections created transportation problems with respect to food and geological specimens. A large depot left at the western end of Promenadedal by a sledge party earlier in the year was supplemented in the third week of July by additional supplies flown in to Vibekes Sø. The final evacuation of the field party was similarly by air, at the end of August.

A complete stratigraphical succession of the Cambro-Ordovician rocks of Ella Ø was eventually established, to the standards achieved in northern Hudson Land, by further short periods of field work during the summers of 1952 and 1953.

One of us (J. W. C.) returned in the summer of 1954 and carried out further section-measuring, fossil-collecting and mapping in Ole Rømers Land. The area of investigation was Søryggen and Sødal, between Krumme Langsø and Vibekes Sø, and also on Randen (Plate VIII).

The authors are greatly indebted to Dr. Lauge Koch for the opportunity to carry out these studies in Greenland, for his invaluable guidance (drawing from a life-long experience of geology in the arctic), and for the deep interest he has shown in all aspects of our work. To Professor W. F. Whittard, who encouraged and supervised our researches, who gave of his time for consultation and instruction, and who has criticised this report, we give our special thanks. The financial assistance accorded to the authors by the Department of Scientific and Industrial Research during the tenure of research scholarships from 1950 to 1953 is gratefully acknowledged.

Cordial thanks are also due to all those whose efforts have furthered the research: friends on the expeditions, and others in Bristol. The following deserve special mention: Richard Nielsen, Copenhagen—for his introduction to the Cambro-Ordovician in 1950, his good companionship and experienced counsel; Axel Jensen, Copenhagen—our congenial winter companion of 1950—51 and mentor in arctic travel, whose tireless exertions on depot-laying sledge-journeys made possible our later field investigations; Erhardt Fränkl, Basel—our geological colleague and informal consultant on Pre-Cambrian and tectonic problems, with whom we enjoyed many helpful discussions; J. Jørgensen, Danish Army—station-leader at Ella Ø, whose co-operation and forbearance enabled much scientific work to be accomplished during the winter 'dark-time' of 1950—51, and to other members of the army sledge-patrol, Lützhøft, Sørensen, Carlsen and Andersen, for their comradeship and help. B. C. Betts and R. Goldring are thanked for their assistance in the summer of 1951. The Greenlander Edvard Kunak, Scoresby Sund, is also gratefully remembered for services rendered

in porterage and camp-duties during the spring and summer of the same year.

The aerial photographs were taken by E. HOFER and the late M. BRENNEISEN. The planning of field work and the production of the geological maps have been greatly expedited by their professional skill; we particularly wish to thank Hofer for his co-operative interest. E. W. SEAVILL, Geology Department, University of Bristol, is thanked for the photography of the lithological specimens, and for his assistance in the preparation of other illustrations.

University of Bristol, April, 1956.

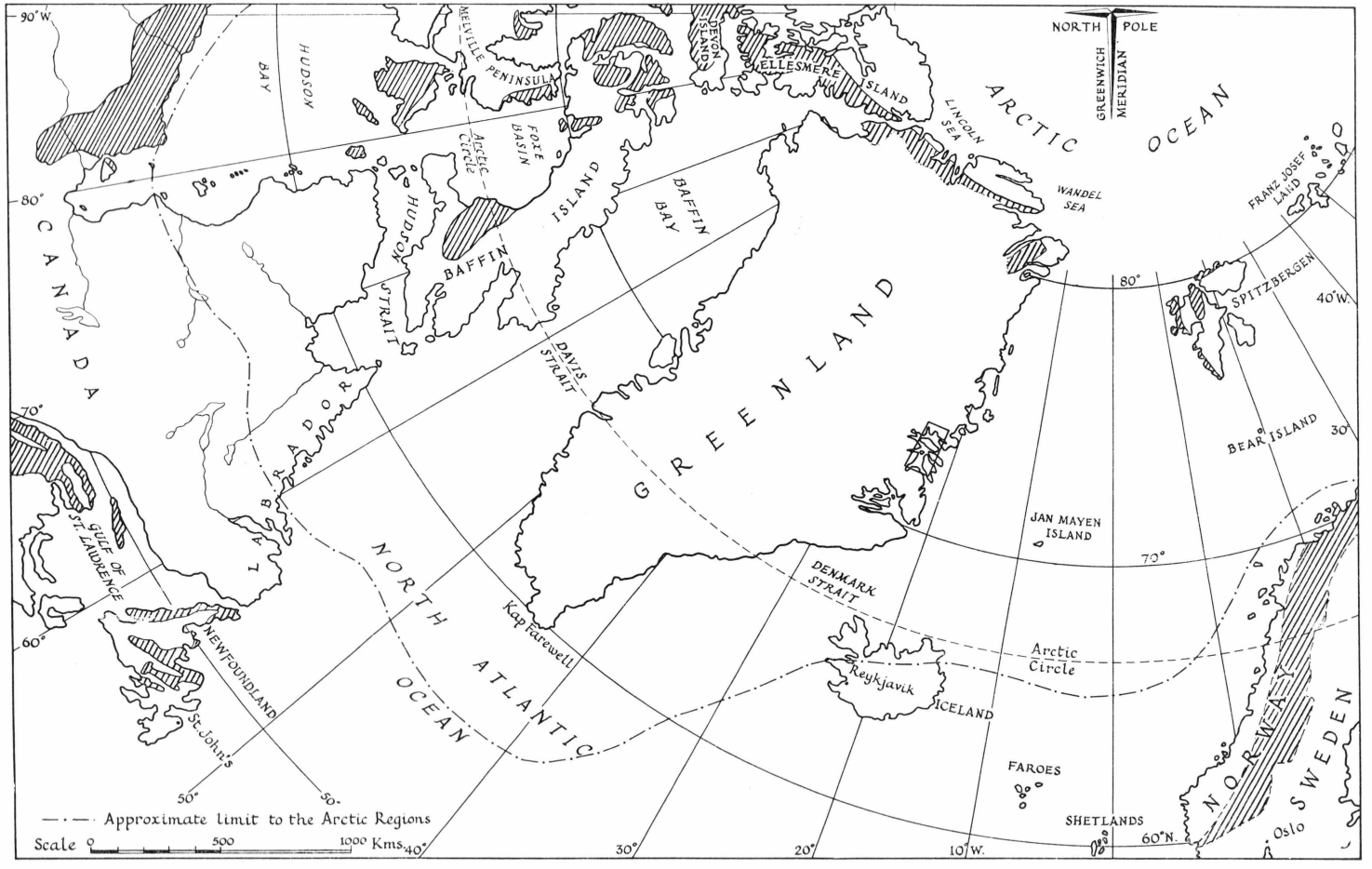

Fig. 1. A sketch map of part of the arctic regions with the area in Central East Greenland covered on Plate VIII outlined. The hatching indicates areas where Lower Palaeozoic strata occur; the outcrops in Central East Greenland are not shown due to their relatively small area. In Norway and Spitzbergen it has not been possible to differentiate some of the older rocks from the Lower Palaeozoic. The outcrops shown in Canadian Arctic and Peary Land are probably incomplete.

I. INTRODUCTION

a) Scope of the study.

This paper is the first result of a systematic investigation into the stratigraphy, palaeontology and structure of the Cambrian and Ordovician rocks of Central East Greenland. The main stratigraphical examination has been carried out, in conjunction with geological mapping, in northern Hudson Land and Ella Ø, two regions where considerable thicknesses of Lower Palaeozoic strata are encountered and which are only moderately disturbed by earth movements and metamorphism. In order to simplify the presentation of the data which have resulted from this investigation it has been considered advisable to defer the palaeontological descriptions, illustration of fossils, and discussion of faunal affinities for later publication.

Central East Greenland, as used in the title of this paper, is a term which has been adopted by the Danish authorities to cover the region lying approximately between latitude 70° and 77° North, extending from the settlement at Scoresby Sund as far north as the large radio and meteorological station at Danmarks Havn. The area north of this tract is now known as North-East Greenland; the stratigraphy and palaeontology of the Lower Palaeozoic rocks in this region, investigated by us in 1952 and 1953, are being treated separately (Adams & Cowie, 1953). While the field operations of the Danish expeditions led by Lauge Koch have covered much of Central East Greenland, the known outcrops of Cambro-Ordovician rocks are confined to a more limited area between latitudes 72°15′ and 74°15′ N., from Syltoppene to Wordies Gletscher, shown on Fig. 1 and Plate VIII[1]). The observations and the main discussion in this paper are therefore confined to that belt of latitude.

b) Topographical names.

The place-names originally given and subsequently used by explorers of diverse nationalities may have numerous forms in the literature. All localities are referred to in this publication by the officially approved Danish place-names found on the maps, scale of 1:250,000, issued by

[1]) See footnote on page 45.

the Geodetic Institute in Copenhagen, or subsequently approved by the official Danish Place-Names Committee. Anglicised place-names used adjectivally, in accordance with geological convention, may have become well established in literature and are therefore retained in their original form.

New topographical names approved by the Danish Place-Names Committee for this paper are:—

	translation
Antiklinalbugt	Anticline Bay
Ingridbugt	Ingrid Bay
Kap Margrethe	Cape Margrethe
Marabugt	Mara Bay
Pederpynt	Peder Point
Richardpynt	Richard Point
Septembersø	September Lake

Translations of Danish words for geographical features are:— Bjerge: mountain, hill. Bugt: bay, gulf. Dal: valley. Elv: river. Fjord: inlet, firth, frith. Gletscher: glacier. Halvø: peninsula. Havn: harbour, port. Kap: cape, promontory, headland. Nunatak: an isolated rock mass projecting like an island through the snow or ice of an ice-cap or glacier. Ö *or* Ø: island. Sund: sound, strait. Sö *or* Sø: lake.

c) History of research.

The principal researches on the Cambro-Ordovician rocks of Central East Greenland have been carried out by three groups of investigators: German and Swedish nineteenth-century pioneers, British expeditions from Cambridge University, and Danish expeditions under the leadership of Lauge Koch. Most of the advances in knowledge made during the present century have been due to the efforts of Lauge Koch and his collaborators.

Towards the end of the summer of 1870 a German expedition, under the leadership of Koldewey, first discovered and explored Kejser Franz Josephs Fjord (Koldewey, 1874, **1**, 662—679). Stratified rocks were found along the shores of the fjord, and were later described as "Palaeozoische Quarzite, Thonschiefer u. Kalke" and considered identical with Nordenskjöld's 'Hekla Hook Formation' of Spitsbergen in Svalbard (Toula, 1874, 479—480; Lenz, 1874, 481—482). No fossils were found in these rocks and it was not until later that the ages of the strata were established palaeontologically. During the summer of 1899 Nathorst led the Swedish expedition to North-East Greenland, re-examined Kejser Franz Josephs Fjord and extended his investigations into hitherto un-

discovered fjords. 'Silurian' and Devonian fossils were collected from strata previously assigned to the Palaeozoic by the Germans. NATHORST (1901) conceded the possibility that rocks older than the 'Silurian' might be present above his 'Archaean' division, and also noticed the similarity between the pre-Devonian sediments of the fjord region of Central East Greenland and those of Bear Island in Svalbard. The junction of the Devonian and underlying 'Silurian' strata was not clearly described, and on Ella Ø it was incorrectly interpreted as a fault.

The Cambridge Expedition, under the leadership of WORDIE, conducted extensive explorations in the fjord region of Central East Greenland during the summer of 1926. Fossils were collected at Kap Weber but, in the report published the following year, no new evidence was put forward for dating the Lower Palaeozoic rocks. Erratics "strongly resembling Cambrian quartzites from the North-West Highlands of Scotland" were reported near Kap Stosch, Hold with Hope (WORDIE, 1927, 252). Evidence suggesting folding movements of Caledonian age was discovered in Antarctics Sund (*op. cit.*, 252).

With his expedition to Scoresby Sund in 1926, LAUGE KOCH transferred his attentions from North-West to East Greenland. In the autumn of that year he sledged from Scoresby Sund to Mackenzie Bugt, and on the return journey examined the exposures at Kap Weber, where NATHORST had found Lower Palaeozoic fossils. It was not until the spring of 1927, however, when KOCH again visited the cape, that diagnostic Ordovician fossils were discovered (KOCH, 1929 a, 22—23). On Ella Ø Cambrian fossils were collected from the Bastion and Ella Island Formations, and Devonian rocks were observed to rest upon an erosion surface of Lower Palaeozoic beds (KOCH, 1929 a, 26—27, 32). In his 'Stratigraphy of Greenland' (1929 b, 83), KOCH affirmed the age of the folding as younger than Middle Ordovician and older than Upper Devonian.

The 1929 Cambridge Expedition to East Greenland, once again under the leadership of WORDIE, included PARKINSON and WHITTARD, whose joint paper published in 1931 contributed to the knowledge of many parts of the geological column. The expedition paid particular attention to tectonic problems in the Pre-Devonian rocks, and made the first ascent of Petermanns Bjerg. An examination of the Pre-Devonion inlier of Moskusoksefjord—first discovered by WORDIE in 1926 and investigated by KOCH in 1927 (Koch, 1929a, 71—75)—yielded a fossil which indicated the presence of Ordovician strata. A fossil of similar age was also found in rocks of comparable lithology on the western side of Duséns Fjord.

A Danish expedition, led by LAUGE KOCH, was also in the region during the summer of 1929. Among the seven geologists attached to the expedition, POULSEN was responsible for the investigations into the stratigraphy and palaeontology of the Cambro-Ordovician rocks. In a

preliminary report he split the subdivisions set up by Koch in 1929, and proposed a stratigraphical framework of seven formations which could be easily recognised in the field by reason of distinctive lithologies (Poulsen, 1930, 299). New Cambrian localities were discovered near Kap Weber and on the north-west coast of Ymers Ø but the outcrop of Cambrian rocks claimed to be present in south-east Lyells Land has not been confirmed by Sommer's recent work (verbal information). The fossil collections of the expedition, supplemented by material collected at other times by Wordie, Koch, Whittard and Teichert, were later described by Poulsen: the Cambrian faunas in 1932, and the Ordovician in 1937. One conclusion drawn from these studies was that the Cambrian fauna had North American affinities and was of an Arctic type. Poulsen also considered that "it does not seem absolutely improbable that the East Greenland geosyncline should be regarded as a continuation of the St. Lawrence geosyncline", and cited the absence of Silurian strata in support of this conclusion, suggesting that the main phase of folding corresponded with the Taconian orogeny (Poulsen, 1932, 64—66).

Danish expeditions led by Lauge Koch were active from 1930 until 1934, with some geologists remaining in Greenland during the winter months. Extensive topographical surveying was carried out by the Danish Geodetic Institute during this period, and when systematic geological investigations were continued in 1936 the scientists were able to use new maps of superior accuracy. The geological survey was interrupted in 1939; recommenced in 1947, it is still being continued. Except where otherwise stated all the following authors were members of these Lauge Koch expeditions at one time or another.

During 1930, while engaged in field-studies around Wordies Gletscher, Backlund had several views of Reservatet, Rødøen and Promenadedal. Seidenfaden describes (1931, 11—13) a canoe journey with Backlund, westwards up Vibekes Elv to a point south of Rødøen. On the basis of these observations the Reservatet—Rødøen—Promenadedal area was geologically mapped as Eleonore Bay Formation, although the possibility of Lower Palaeozoic outliers was also considered (Backlund, 1932, 113—114, pl. 1). During 1931—1932 Teichert was occupied by researches on the pre-Devonian sediments between Suess Land and a latitude approximately 76° N. He discovered Cambrian and Ordovician outcrops in Strindbergs Land, further elucidated the geology of the Muskox Fjord inlier, and also established the presence of Cambro-Ordovician strata in northern and western Ymers Ø (Teichert, 1933, 38—67, 73—76).

The preliminary results of Wegmann's investigations during the period from 1932 to 1934 included studies of the tectonics affecting Cambro-Ordovician outcrops (1935). Fossil gastropods were also reported

from moraines on Cecilia Nunatak (72°30′ N., 28° W.), far to the west of the known fossiliferous rocks of Central East Greenland (*op. cit.*, 14—15). The provenance of this morainic material is extremely vague, but the fossils in question could have originated from Lower Ordovician rocks.

CLEAVES and FOX, guests of the 1933 Howard Expedition from Boston, U.S.A., discovered fossils, ascribed to "? Middle Ordovician", around the western end of Duséns Fjord on Ymers Ø. Some strata were claimed to be "? Middle Cambrian" on the basis of extremely questionable evidence (1935). In the following year BÜTLER also observed Ordovician sediments in the area, on the south-western shore of Duséns Fjord (BÜTLER, 1935, 13, fig. 4).

T. HEINRICHSON commenced a field study of the Cambro-Ordovician sequence during 1936, remaining in Greenland until the latter part of 1938. No results of any scientific value can be expected from this study, due to circumstances connected with the last world war; some of HEINRICHSON's fossils are, however, being examined in conjunction with the authors' collection.

During the winter of 1936—37, SCHAUB worked on the late Pre-Cambrian and Cambrian rocks of the Kap Oswald peninsula, Ella Ø. Results published in 1950 and 1955 include a consideration of the stratigraphy and tectonics of this locality, and opinions were advanced regarding the appropriate stratigraphical position for the base of the Cambrian. Contributions to the knowledge of the geological structure of Ella Ø were published by BÜTLER in 1937.

The discovery of hitherto unknown Cambro-Ordovician outcrops in Hudson Land and Ole Rømers Land, was made by BÜTLER in 1938 (BÜTLER, 1940; BÜTLER *in* KOCH, 1950, pl. 7). He expressed the opinion that Albert Heims Bjerge was possibly formed in younger Lower Palaeozoic rocks than had been previously found in East Greenland—a prediction later proved correct by the authors' investigations. Another important result of this wide-ranging and fruitful reconnaissance was the discovery that, in the region of Hudson Land and Ole Rømers Land, the pre-Devonian sediments had been folded and faulted on a large scale during Devonian times (BÜTLER, 1940, 28).

POULSEN returned independently to Ella Ø in 1946, and has published additional stratigraphical details, expanded faunal lists, and a new geological map of the island (POULSEN, 1951). A summary of a lecture, concerning "The Position of the East Greenland Cambro-Ordovician in the Palaeogeography of the North-Atlantic Region", was also published in 1951, and gave more evidence for the correlation of East Greenland with the St. Lawrence geosyncline and north-west Scotland.

A series of regional geological surveys was initiated by LAUGE KOCH

in 1947. The Swiss geologists, Eha, Fränkl, Katz and Sommer, were primarily concerned with the Pre-Cambrian sediments in these regions, but also mapped Cambro-Ordovician rocks and made some contributions to their stratigraphy. Eha included Ella Ø on his geological map (1953, pl. 2), which is chiefly concerned with Ymers Ø and Suess Land where new Cambro-Ordovician outcrops were recorded: the Cambrian outcrop shown in northern Suess Land by Teichert (1933, 93, fig. 37) and Huber (1950, fig. 1), finds no place on this map. An 'excursion guide' was also provided for geologists visiting Ella Ø, the main base of the Lauge Koch Expeditions since 1947 (Eha, 1953, 62—71). Katz was occupied on Strindbergs Land and describes a full stratigraphical succession (1952); his fossil collections are being worked up with those of our own. Fränkl carried out a similar survey of eastern Andrées Land, and of particular interest is his remarkable geological map and sections of the Kap Weber neighbourhood (1953 a, pl. 4). In 1951 he also discovered Cambro-Ordovician strata forming part of the Syltoppene peaks in Scoresby Land; the interrelations here of formations below the lowest fossiliferous Cambrian are of considerable interest (Fränkl, 1953 b, 29—31, pls. 1—3). In 1952 and 1953 Haller continued his study of the Central Metamorphic Complex—which had commenced with the mapping of western Andrées Land and Fraenkels Land from 1949 to 1951—in Suess Land, Gletscherland and Goodenoughs Land. The first of a series of papers on the metamorphic complex (1955) includes, in the section on tectonics, description and discussion of structural features which occur in the Palaeozoic sedimentary rocks between latitudes 72° N. and 74°15′ N. Sommer commenced the latest regional survey of pre-Devonian sediments in 1952, on Lyells Land. This has now been completed, and a publication is in preparation (Koch, 1954, 10).

The discovery of Middle Devonian fish remains on Gauss Halvø in 1948 (Bütler, 1949) narrows the time interval during which the main folding of the Lower Palaeozoic strata took place there. Prior to this discovery only Upper Devonian fossils had been known in the region covered by Plate VIII, although a Middle Devonian fauna had been found in Canning Land (71°40′ N., 22°40′ W.) by Noe-Nygaard (1934, 16—25).

d) Geological mapping.

The field observations, from which Plates IX and X were made, were originally drawn on maps scaled to 1:50,000; these were constructed by a simple grid system of enlargement from the 1:250,000 topographical maps published by the Danish Geodetic Institute, but this degree of enlargement was beyond the accuracy of the official maps. The absence of accurate detail on the topographical maps has frequently caused

considerable difficulty in the drawing of geological boundaries; in order to improve the standard of geological mapping wherever possible, minor modifications have been made to coast-lines, contours and drainage by means of direct field observations and aerial photographs. In this manner the topographical map of Ella Ø has been extensively modified and improved. The scaling of Plate X at 1:40,000 is merely to represent the geology with as great an accuracy as possible: the geological detail is undoubtedly beyond the accuracy of the topographical survey, but any smaller scale maps would not permit the observed facts to be legibly recorded. The map of the Albert Heims Bjerge—Reservatet area, on a scale of 1:100,000, has an enlarged version of the Geodetic Survey map 'Clavering Ø, 74°ö.2' as its topographical basis, and no changes from the original have been considered necessary. The geological sketch map of the Lemmingdal window has been based on a topographical survey by A. J. STANDRING and F. W. SHERRELL. Only at Kap Weber was time taken for a plane-table survey of a limited area. There seems to be little doubt that if more detailed geological mapping is required in the future it will be necessary to have larger scale and more detailed topographical maps.

Oblique and vertical aerial photographs have proved extremely useful in drawing faults and boundaries between formations. The use of oblique aerial photographs, controlled by associated ground observations, has been found very effective in this arctic terrain where strata are frequently well-exposed (Plates I—VII). Inaccessible regions and precipitous cliffs can also be examined by this means (see Plate VI): the mapping of Reservatet (Plate IX), based on aerial photographs, was assisted by scrutiny with binoculars across the impassable glacial river which drains eastwards from the southern tip of Irisgletscher. Rødøen was mapped in a similar fashion. Boundaries or faults which were seen on the ground, through binoculars, from the air or from an aerial photograph, were recorded by a solid line. Inferred boundaries and faults, shown on the map by broken lines, indicate that the geology was obscured by superficial deposits, vegetation or snow, or in other ways has not been seen.

e) Descriptive methods in stratigraphy.

In the two main measured sections of Albert Heims Bjerge and Ella Ø individual formations have been examined metre by metre. Measurements have been made directly, by means of a graduated stick or steel tape. Descriptions are only given of rocks which were truly exposed. The search for fossils was maintained at all points in the sequence; at no time were fossils from loose boulders, screes, and rocks of doubtful provenance incorporated in the collections from measured sections or

important fossil localities. It is axiomatic, however, that equal attention cannot be given to all parts of a succession, and geology in relatively inaccessible regions is often handicapped by the impracticability of returning for a re-examination of any but the major points of doubt. The original field notes have been amplified and supplemented wherever possible by laboratory study of lithological samples from *in situ* rock outcrops.

The descriptive terminology may require some explanation, due to the considerable variation in usage, although too much importance should not be attached to its accuracy, as a full petrographical study of the sediments has not been attempted. The main rock classification adopted has the three components—silica, clay and carbonate—giving three pairs of end-members based on sandstone, shale, and limestone or dolomite. For example, an argillaceous sandstone under this classification is mainly composed of quartz grains, but contains more than 10 % by volume of clay minerals; the complete sequence of lithological types for this pair of end-members would be sandstone—argillaceous sandstone—arenaceous shale—shale. Adjectives such as arenaceous, argillaceous or glauconitic are only used when the quartz, clay minerals or glauconite amount to at least 10 % by volume of the rock. Where more than one adjective is used the relative abundance of the mineral group it refers to decreases with the distance of the adjective from the noun. For example, calcareous, glauconitic, arenaceous shales would have clay minerals in the majority and might contain 20 % of quartz, 15 % of glauconite and 12 % of calcite; small quantities of other minerals could also be present, each being less than 10 % and merely accessory. The word siltstone is used here to denote a quartz-rich rock in which the grains of quartz form the predominant constituent, but are of smaller size than in a sandstone. Shale, chiefly consisting of clay minerals, is highly fissile and possesses very thin laminae; mudstone, although containing a high percentage of clay minerals, is not so fissile.

The authors' field notes were expressed in terms of 'Beds', which were given consecutive numbers from the Pre-Cambrian to the Devonian. Many previous writers have published numerical systems for describing the stratigraphy of the Pre-Cambrian sediments. Schaub (1950) and Poulsen (1951) use systems of numbering which pass consecutively from the Pre-Cambrian through into the Cambro-Ordovician. Both authors commence numbering at what they consider to be the lowest horizon exposed on Ella Ø which, while being a useful course for purposes of description, is unsuitable for regional application. The numbering and lettering of stratigraphical units in parts of this paper, formation by formation, and locality by locality, are only for convenience in description. In order that no false comparisons should be made between

Albert Heims Bjerge and Ella Ø, the subdivisions in the former area are numbered, while in the latter a system of lettering is employed. A similar precaution has been taken with fossil horizons.

The stratigraphy of the Cambro-Ordovician set up by KOCH in 1929, and modified by POULSEN in 1930, incorporates the term 'Formation' for the major units. FRÄNKL published in 1953 a revised system, in English, devised in collaboration with KOCH, BÜTLER, WENK and HALLER, in which the Tillite Canyon Formation becomes the 'Canyon Series', the Spiral Creek Formation becomes the 'Spiral Creek Series', and the lower Bastion Formation of POULSEN is separated off as the 'Sandstone Series'. The present authors, while agreeing that the word Tillite in Tillite Canyon should be dropped, incline towards the use of Canyon and Spiral Creek Formations. To most geologists who write in English the term 'Series' is reserved for large stratigraphical units, of higher status than 'Formation' and is the primary subdivision of a System (HOLMES, 1944, 101; ASHLEY *et al*, 1933, 423—459; SCHAUB, 1950, 14). It is therefore quite unsatisfactory to have these 'Series', outlined by FRÄNKL and others, as part of a 'Tillite Formation', and presumably of inferior status to the well-established formations set up by KOCH and POULSEN. Kløftelv Formation is preferable to 'Sandstone Series', if only because the subdivision is largely composed of quartzites, and because a geographical place-name prefix, as used in the rest of the Cambro-Ordovician sequence, is considered more appropriate. Minor changes in formational names have been to bring the spelling of place-name prefixes into line with the Danish versions used on the official 1:250,000 Geodetic Survey maps of Greenland. Dolomite Point, Hyolithus Creek and Spiral Creek do not appear on these maps, and so the original versions are retained.

While the unconformable base of the Devonian defines the upper limit of the authors' studies a lower limit is not so obvious. The top of the Upper Tillite, readily seen in most areas under review, was eventually chosen. The unfossiliferous strata between this horizon and the first fossil-horizon in the Bastion Formation have been somewhat neglected by previous workers, who have concentrated chiefly on the tillites and the great thickness of underlying sediments. However, a complete section in the tillites of western Promenadedal was measured in 1951; details are included in an appendix. The same succession was examined in greater detail by FRÄNKL in 1952 but no results have yet been published.

SCHAUB, 1950.			POULSEN, 1951.		FRÄNKL, 1953; HALLER, 1954.			COWIE & ADAMS, 1957.	
			Devonian					Devonian	
	Upper Limestone Group	CAMBRIAN		LOWER ORDOVICIAN (CANADIAN)			CAMBRO-ORDOVICIAN	Heimbjerge Formation	Middle Ordovician
			Narwhale Sound Form.		Narhval-Sound Form.			Narhval Sund Form.	?
			Cape Weber Formation		Cape-Weber-Formation			Kap Weber Formation	LOWER ORDOVIC.
			Cass Fjord Formation		Cass-Fjord-Formation			Cass Fjord Formation	
Dolomite Point Form.			Dolomite Point Form.	? M. or U. CAMBRIAN	Dolomite-Point-Form.			Dolomite Point Form.	?
Hyolithus Creek Form.			Hyolithus Creek Form.		Hyolithus-Creek-Form.			Hyolithus Creek Form.	
Ella Island Formation			Ella Island Formation.	LOWER CAMBRIAN	Ella-Island-Formation			Ella Ö Formation	LOWER CAMBRIAN
Sandy Shale Member	Tömmer Bay Group		Bastion Formation		Bastion-Formation			Bastion Formation	
Quartzite Member		PRE-CAMBRIAN			Sandstone Series?	Tillite Formation	GREENLANDIAN	Klöftelv Formation	
Salt Cast Member			Spiral Creek Form.	PRE-CAMBRIAN (EOCAMBRIAN)	Spiral-Creek-Series			Spiral Creek Formation	LATE PRE-CAMBRIAN (GREENLANDIAN)
Sun-cracked Member			Tillite Canyon Form.		Canyon Series			Canyon Formation	
Varve Member									
Upper Tillite Member			Cape Oswald Formation		Tillite Series			Upper Tillite	
Intertillite Member								Inter Tillite Beds	
Lower Tillite Member								Lower Tillite	

Fig. 2. Proposed subdivisions of the Cambro-Ordovician of Central East Greenland compared with those of previous authors. The formations redescribed by Poulsen in 1951 were originally named by Koch (1929b) or Poulsen (1930).

II. GENERALISED SUCCESSION & REGIONAL STRUCTURE

A) Regional Stratigraphical Units.

The topmost Pre-Cambrian to Devonian divisions are shown in figure 2. More detailed subdivisions of the formations have been established, which are applicable in both northern Hudson Land and Ella Ø, and are probably valid throughout Central East Greenland (fig. 3).

Formation	*Subdivision*	*Age*
Heimbjerge	Grey Limestones Lower Limestones	Champlainian
Narhvalsund	Dolomitic Limestones Basal Dolomites	—
Kap Weber	—	Canadian
Cass Fjord	Upper Transition Limestones Limestone-Shales Lower Transition Limestones	,,
Dolomite Point	Upper Dolomites Calcareous Dolomite Lower Dolomites	—
Hyolithus Creek	—	—
Ella Ø	Upper Limestones Shaly Beds Lower Limestones	Lower Cambrian
Bastion Upper	Upper Shales Upper Shell-Limestones Upper Shales	,,
Bastion Lower	Lower Shell-Limestone Glauconitic Shales Glauconitic Sandstones	,,
Kløftelv	Upper Quartzites Upper Sandstones Middle Quartzites Lower Sandstones Lower Quartzites	,,

Fig. 3. Subdivisions and correlations of the Cambro-Ordovician Formations of Central East Greenland.

The Canyon Formation is absent in north Scoresby Land, according to Fränkl (1951); the overlying Spiral Creek Formation is also missing there and is, moreover, unrepresented in Ole Rømers Land and northern Hudson Land as well. These two formations are not, therefore, included in figure 3, but for completeness short descriptions and notes are given below.

Canyon Formation.

The lowest beds are characterised by shales interbedded with siltstones. In the middle of the formation a considerable thickness of dolomite is associated with dark shale, and towards the top dolomitic limestone and limestone are important with shale and dolomite contributing less to the thickness.

The Canyon Formation was first named by Poulsen (1930, 306—307) as the "Tillite Canyon Formation" from its occurrence near Tillite Canyon on the southern shore of Geolog Fjord, a few kilometres from Kap Weber. Later authors have preferred to drop the word "Tillite" as no tillites are to be found in the deposits. Poulsen interpreted the lower beds as varves and illustrated (*op. cit.*, fig. 20) a mudstone to corroborate his view. Although there are definite grounds for regarding some of the sediments as varves the occurrences examined by the authors could, it is considered, be interpreted as due to a rhythmical cycle of variation in sedimentation, which was not necessarily associated either with glacial conditions or with annual repetition. In 1950 a paper by Schaub gave a more detailed succession in the beds found on Ella Ø below the Kløftelv Formation. The position of the top of the "Tillite Canyon Formation" was left open to question (Schaub, 1950, 15) and there is a gap of approximately 60 metres in his succession. The present definition of the formation makes it equivalent to Schaub's "Varve Member", and part of his "Sun-cracked Member". The two descriptions of the succession cannot however be exactly matched. In his most recent paper on Ella Ø Poulsen did not add to his previous description but revised his opinion, now regarding the age as Eocambrian, and part of the Pre-Cambrian (1951, 11). A small-scale vertical section comparing Ella Ø and Ole Rømers Land (Plate XIII) shows that there is no detailed correlation between the two areas in this formation.

Spiral Creek Formation.

The basal dolomites of this thin but complex group of beds contain many intraformational conglomerates and are succeeded by ripple-marked dolomitic siltstones with well-preserved salt impressions. The upper beds are composed of dolomite containing a great quantity of chert in a diversity of forms.

The type-locality is near Spiral Creek, on the southern shore of Geologfjord, a few kilometres west of Kap Weber. Poulsen's first des-

cription (1930, 307) referred to "quartzite with ripple-marks, alternating with red and green, micaceous shale". The quartzite presumably corresponds with the dolomitic siltstone described above—a description based partly on examination of thin-sections which reveal that the rock consists of small angular quartz grains set in a matrix of carbonate, predominantly dolomite. We would disagree with the remark in the same paper that there "is a marked disconformity between the Spiral Creek formation and the subjacent formation" (*op. cit.*, 307), although this may be due to a difference in the usage of the word disconformity: there is a

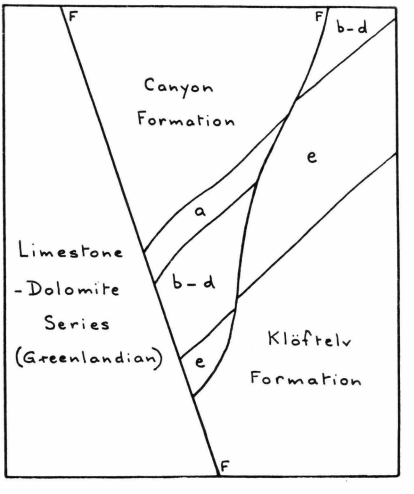

Fig. 4. Map of faulting near Klöftelv, Ella Ø. A portion of *e* is cut out by the subsidiary fault running NNE. *a*, *b*—*d*, and *e* are subdivisions of the Spiral Creek Formation. See Plate X for location.

small change of lithology from arenaceous dolomite to dolomitic siltstone but it is to a great extent a transitional boundary like most of the junctions between formations in the Cambro-Ordovician. It is largely for convenience that these beds are separated from the underlying Canyon Formation; the change of lithology to the overlying Kløftelv Formation is more sudden and, as suggested later (p. 148), is probably a true disconformity. In 1951 POULSEN included this formation in the Eocambrian, as part of the Pre-Cambrian.

SCHAUB published a somewhat more detailed account of this part of the Pre-Cambrian succession in 1950. As mentioned earlier his boundary between Canyon Formation and Spiral Creek Formation was not closely defined but it is evident that part of his Sun-cracked Member, and all his Salt Cast Member, correspond to the Spiral Creek Formation as we now apply the term. The cherty dolomite of subdivision e of our classification (fig. 4) appears to be represented by his Bed 44 which is only 4 metres thick, although a gap of observation is noted, of ± 5

metres, between Bed 44 and Bed 43—the bed with salt casts (Schaub, 1950, 40, fig. 10). Schaub evidently measured his section in the stream-cleft of Kløftelv under difficult winter conditions. We discovered a fault here which joins the main fault from the north-north-east (Plate X) which is not shown by Schaub on his geological map published in 1955 (Plates I & II). The fault follows the bedding-planes in the walls of the cleft and is difficult to detect there but can easily be traced on the ridge to the east (fig. 4). The cutting-out due to this fault probably explains the discrepancy between the two records and also perhaps for the fact that Schaub has little to say about the striking sedimentary features of these upper beds of the formation.

Kløftelv Formation.

The major part is composed of massive quartzite, which varies considerably in colour and frequently shows cross-bedding and ripple-marks. Two relatively thin bands of sandstone and arenaceous shale also occur and are often micaceous and glauconitic.

Poulsen (1930) grouped together this series of quartzites, sandstones and shales as the 'Bastion Formation' along with the overlying beds below the Ella Ø Formation. It is here separated into the Kløftelv Formation, named after the stream which enters the sea on the north coast of Ella Ø, near the delta of Storeelv. The name Bastion Formation is retained for the overlying shales and sandstones (fig. 2). Schaub's 'Quartzite member' (1950) is equivalent to the Kløftelv Formation: he divided it into two beds and gave a few more lithological details. Poulsen (1951), and Eha (1953) made no significant additions to the knowledge of the lithology.

Bastion Formation.

The Glauconitic Sandstones show at their base a glauconitic siliceous conglomerate containing phosphatic bodies composed of collophane, suggesting either a non-sequence or disconformity. Following in normal succession are sandstones, siltstones and arenaceous shales which are generally ferruginous, glauconitic, and sometimes micaceous; phosphatic bodies occur again. The occurrence of phosphates in the form of collophane may indicate the future possibility of discovering fossils in this part of the Bastion Formation. The Glauconitic Shales are micaceous at some horizons. The Lower Shell-Limestone is maroon, sometimes green or cream, massive, crystalline and glauconitic, and is composed almost entirely of fossil fragments, and at many outcrops it is conglomeratic and contains phosphatic pebbles. A disconformity, or non-sequence, presumably occurs at the base of the upper Bastion Formation. The Lower Shales are glauconitic and arenaceous, with occasional fine-grained massive bands which vary in lithology from limestone and arenaceous

limestone to siltstone. The Upper Shell-Limestones consist of bands rich in brachiopod fragments, together with shales which are often glauconitic and arenaceous. Arenaceous shale is the main lithological type in the Upper Shales where it is associated with massive bands, which constitute a higher proportion of the succession towards the base of the Ella Ø Formation.

The thickness of the Bastion Formation as determined in two localities, with the fossil horizons, is tabulated below.

Subdivision	Measured Sections	
	Albert Heims Bjerge	Ella Ø
Upper Shales	56 m Fossil Horizons 19—31	48 m Fossil Horizons F — J
Upper Shell-Limestone	10 m Fossil Horizons 13—18	2.5 m Fossil Horizon E
Lower Shales	32 m Fossil Horizons 2—12	35.5 Fossil Horizon B — D
Lower Shell-Limestone	0.5 m Fossil Horizon 1	0.5 m Fossil Horizon A
Glauconitic Shales	6 m	12.5 m
Glauconitic Sandstones	47 m	38 m
Total	151.5 m	137 m

Fossils of the Bastion Formation	Poulsen		Cowie & Adams		
	Andrées Land	Ella Ø	Ella Ø	Sødal, Ole Rømers Land	Albert Heims Bjerge
Fordilla troyensis Walcott	×				×
Brachiopoda ind.					×
Botsfordia caelata (Hall)		×			
B. cf. *caelata* (Hall)					×
B. sp.			×		×
Discinella bråstadi Poulsen					×
D. micans (Billings)	×				×
D. sp.			×	×	×
? *Dicellomus* sp.					×
Kutorgina sp.			×		×
Lingulella (Lingulepis) prisca Poulsen	×	×			
L. sp.					×

(continued)

Fossils of the Bastion Formation	Poulsen		Cowie & Adams		
	Andrées Land	Ella Ø	Ella Ø	Sødal, Ole Rømers Land	Albert Heims Bjerge
Lingulid ind.			×	×	×
Micromitra sp.				×	
? *Mickwitzia* sp.			×		×
Obolella congesta Poulsen	×	×			
O. sp.			×	×	×
Paterina sp.			×		
? *Prototreta* sp.					×
Rustella sp.					×
Gastropoda ind.			×		
? *Helcionella cingulata* Cobbold	×				
? *Dentalium* sp.					×
Helenia bella Walcott	×				
Hyolithellus micans (Billings)	×	×			
Hyolithes (Orthotheca) bayonet Matthew var. *groenlandicus* Poulsen	×	×			
H. (O.) bayonet Matthew var. *longus* Poulsen	×				
H. (O.?) communis Billings	×				
H. (O.) cf. *fistula* (Holl)	×				
H. (Hyolithes) americanus Billings	×	×			
H. (H.) billingsi Walcott	×				
H. (H.) mutatus Poulsen	×				
H. (H.) poulseni Resser		×			
H. (H.) similis Walcott	×				
H. (H.) sp.	×		×	×	×
Hyolithid ind.			×	×	×
Calodiscus lobatus (Hall)					×
C. sp. nov. A (cf. *lobatus* (Hall))					×
C. sp. nov. B (cf. *lobatus* (Hall))					×
C. sp. nov. C					×
Olenellus cf. *arcticus* (Hall)					×
O. cf. *thompsoni* (Hall)					×
O. cf. *truemani* Walcott			×	×	×
O. sp.	×		×	×	×
Olenellid ind.	×	×	×	×	×
? *Weymouthia* sp.					×
? Gen. nov. (cf. *Cobboldites*)					×
Bradoria sp.	×				

Ella Ø Formation.

This formation consists almost entirely of limestone, much of which is definitely arenaceous in character (fig. 5).

The presence of a thin group of shaly beds in the middle of the succession facilitates a threefold subdivision. The massive Lower Lime-



Fig. 5. The Lower Cambrian formations and the Hyolithus Creek Formation, south coast of Ella Ø. Height of cliff is approximately 600 metres (Plate V); photograph was taken from the fjord with the camera tilted. *K* – Klöftelv Formation; *B* – Bastion Formation; *E* – Ella Ø Formation; *H.C.* – Hyolithus Creek Formation; *D* – Devonian.

stones are chiefly composed of a fine-grained, hard, arenaceous limestone, which is often cross-bedded and is associated with bands of crystalline limestone. Slumping features are common, and intraformational conglomerates are present at a number of horizons. An abundance of broken-up trilobite tests is a minor but characteristic feature. The overlying Shaly Beds are still mainly composed of arenaeous limestone, but contain a high proportion of arenaceous shale. The lithology of the Lower Limestones is repeated in all its main features in the Upper Limestones, but the grey tint of the fresh rock gradually deepens towards the top.

The thicknessess of the subdivisions and the fossil horizons are tabulated overleaf:—

Subdivision	Measured Sections	
	Albert Heims Bjerge	Ella Ø
Upper Limestones	39.5 m Fossil Horizons 38—51	45.5 m Fossil Horizons Y — AG
Shaly Beds	7.5 m Fossil Horizons—none	3.5 m Fossil Horizons —none
Lower Limestones	55 m Fossil Horizons 32—37	31 m Fossil Horizons K — X
	Total 102 m	80 m

Fossils of the Ella Ø Formation	Poulsen		Cowie & Adams		
	Andrées Land	Ella Ø	Ella Ø	Sødal, Ole Rømers Land	Albert Heims Bjerge
Psammosphaera ? greenlandensis Howell & Dunn		×			
Archaeocyathus atlanticus Billings		×			
Scolithus linearis Haldeman	×				
Acrothele sp.			×		×
Discinella bråstadi Poulsen	×				
D. cf. *bråstadi* Poulsen					×
D. micans (Billings)	×		×		×
D. sp.			×	×	×
Kutorgina aff. *cingulata* Billings			×		
K. reticulata Poulsen		×			
K. sp. A					×
Lingulid ind.			×	×	×
Micromitra sp.			×		
Paterina mediocris Poulsen		×			
Hyolithellus micans (Billings)	×	×			
Hyolithid sp.			×		
Salterella rugosa Billings	×	×			
Stenothecoides poulseni Resser		×			
Alokistocarid ind. (cf. *Kochiella*)					×
Bonnia groenlandica Poulsen		×			
? *Bonnia* sp.					×
? *Bonniella* sp.			×		
Calodiscus agnostoides (Kobayashi)			×		
C. aff *lobatus* (Hall)			×		
C. sp. nov. C			×		

(continued)

Fossils of the Ella Ø Formation	Poulsen		Cowie & Adams		
	Andrées Land	Ella Ø	Ella Ø	Sødal, Ole Rømers Land	Albert Heims Bjerge
C. sp.				×	
Corynexochus (s. l.) sp. ind.	×				
Dorypygid ind.			×		×
Kootenia sp.			×		
Olenellus curvicornis Poulsen		×			
O. hanseni (Poulsen)		×			
O. simplex Poulsen		×			
O. tricarinatus (Poulsen)	×	×			
O. ? sp. I		×			
O. ? sp. II		×			
O. sp.			×	×	×
Olenellid ind.			×	×	×
Proliostracus liostracoides Poulsen		×			
P. noe-nygaardi Poulsen	×	×			×
P. rosenkrantzi Poulsen		×	×		
P. strenuelliformis Poulsen		×			×
? *Protypus* sp.			×		
Wanneria ellae Poulsen	×	×			
W. nathorsti	×	×			
W. ?nathorsti Poulsen			×		
? *W.* sp.					×

Hyolithus Creek Formation.

Massive, resistant, irregularly-bedded, dark-grey or black, hard dolomites, in which stylolites are very common, contain intraformational conglomerates at many horizons.

In the revised description of the formation published by POULSEN (1951, 18) he states that the "dolomite contains a great number of scattered, sharp-edged quartz grains" and that at certain horizons the rock has the appearance of a "fine-grained sandstone, although the greater part of it is formed by the dolomitic matrix; such horizons show cross-bedding". Laboratory studies by us have not revealed the presence of quartz in any appreciable quantity and the specimens were found to consist almost entirely of dolomite. It seems that POULSEN's description cannot be applied to the formation in many of its outcrops. EHA (1953, 34—35), and others, must surely be in error in considering the formation to be predominantly limestones.

FRÄNKL was the first to obtain fossils from the Hyolithus Creek Formation: *Salterella* from 55 metres above the base in the type-locality

near Kap Weber in Andrées Land. We have also collected species of the same genus in Albert Heims Bjerge (Fossil horizon 52) where the thickness of the formation is 215 metres, and in Ella Ø (Fossil horizon AH) where the formational thickness is 210 metres.

Dolomite Point Formation.

Massive, fine-grained dolomite predominates, but thinly-bedded, silty dolomite and dolomitic shales are encountered in the succession. The rocks show every gradation, from the rarely developed shales and thinly-bedded dolomitic siltstones, to the pure, medium and light-grey, finely crystalline dolomite which comprises the greater part of the thickness. Bands of massive grey dolomite, of a more coarsely crystalline character, also occur at intervals throughout the sequence. Disseminations of siliceous material in the form of chert and flint are widely distributed but are present more especially in the bottom and topmost parts of the succession. They occur as small ovoid bodies, lenticles and blebs of hard, black, splintery chert, which parallel the bedding direction of the strata or, more rarely, as grey to white flint showing a less regular form and distribution. These flint segregations occasionally assume the mushroom-shaped appearance of stromatolitic algal colonies; whether or not they represent the remains of such organic growths cannot be clearly established. At irregular intervals, thin and laterally impersistent intraformational breccias and conglomerates testify to the frequency of penecontemporaneous erosion during the accumulation of the strata.

The weathering of these essentially dolomitic rocks is most distinctive: well-exposed surfaces generally acquire a light-cream to buff coloration, which is sometimes tinted yellow or maroon red, and the more massive beds are often marked by irregular pitting of a 'carious' nature.

The absence of fossils has precluded the stratigraphical dating of the Dolomite Point Formation between those divisions recognized as Lower Cambrian and Lower Canadian in age. A threefold lithological subdivison has, however, been achieved on Ella Ø and in the Albert Heims Bjerge region of northern Hudson Land; all three divisions show features which permit correlation between the two areas.

Subdivisions	Measured Sections	
	Ella Ø	Albert Heims Bjerge
Upper Dolomites	327 m	290 m
Calcareous Dolomite	17 m	10 m
Lower Dolomites	77 m	71 m
Total...	421 m	371 m

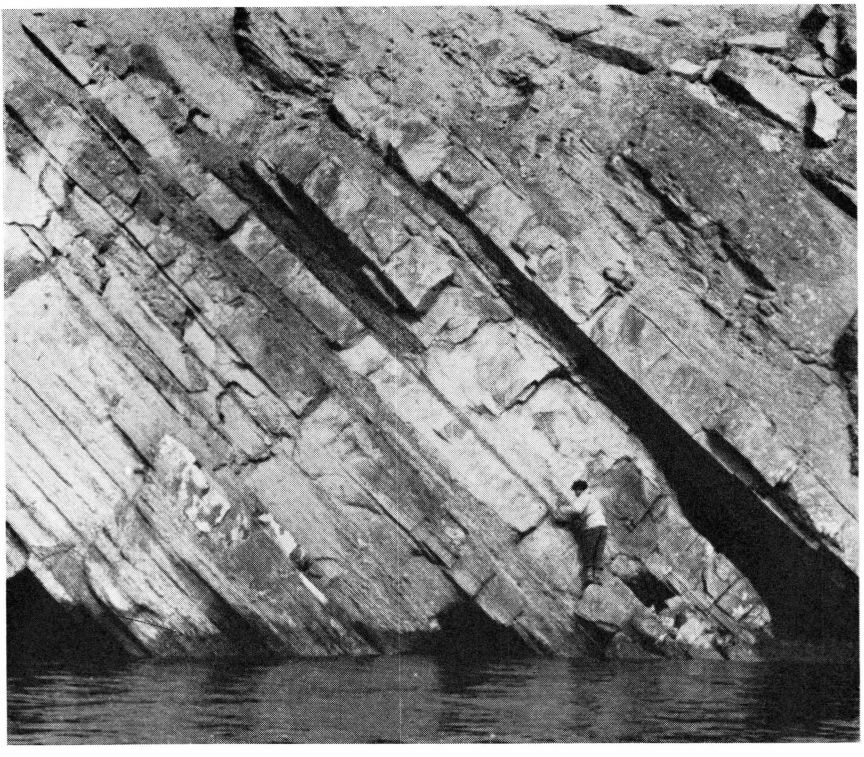

Fig. 6. A section in Limestone-Shales of Cass Fjord Formation, along the eastern limb of anticline on south coast of Ella Ø. The figure is standing on one of the massive limestone bands.

Cass Fjord Formation.

The typical lithology is formed by beds of thinly-stratified, nodular, muddy limestones and shaly partings, alternating with bands of a purer and more homogeneous limestone. Intraformational conglomerates comprise a considerable proportion of the limestone bands, but also occur within intervening limestone-shale beds as thin, impersistent lenses and pockets. The broader features of the relationship between massive limestone bands and limestone-shales are displayed in Fig. 6.

The thinly-bedded, muddy limestones with shale partings account for more than half the formation thickness, display a remarkable uniformity in lithology, and weather to a light greenish-grey colour, a feature which readily distinguishes the Cass Fjord Formation in the field. A close examination of these beds reveals the true nodular and lenticular nature of the limestones, and also shows that the individual lenticles are separated by soft, grey shales, with no sharp division between lithologies. The typical 'pebbly' appearance of weathered surfaces, illustrated by Fig. 7, is due to the differential erosion of limestone laminae and interleaving shales.

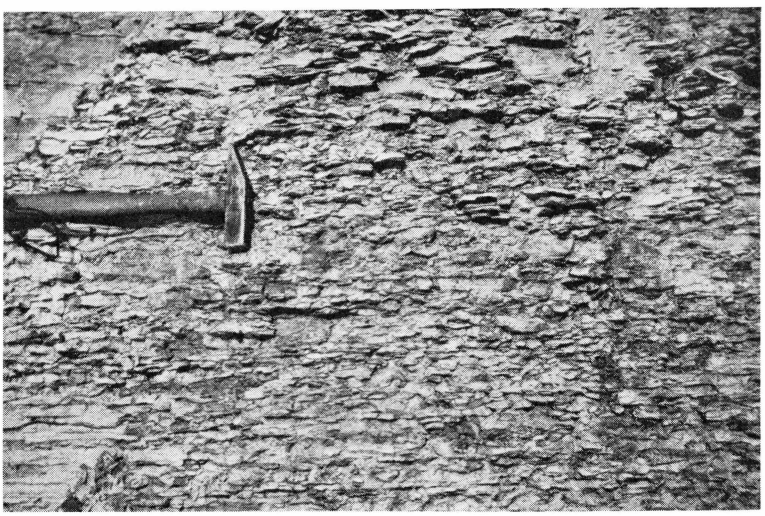

Fig. 7. A close-up view of a weathered 'strike' surface in Limestone-Shales of Cass Fjord Formation, eastern limb of anticline, south coast of Ella Ø.

Massive strata, which occur at frequent intervals, are composed of medium-grey, fine-grained limestone, and although usually well-defined, they sometimes show transition junctions with the beds of thinly-bedded lenticular limestones and shales. Many of the massive limestones consist almost entirely of intraformational conglomerates, the nature of which is often difficult to recognize owing to the lithologies of matrix and pebbles being closely comparable. Blebs and other small lenticular segregations of dolomitic material in the limestone generally weather to a yellowish-buff colour, in contrast to the medium-grey of the limestone itself. Disseminations of chert are confined to the lowest beds.

On Ella Ø, and in the Albert Heims Bjerge region of northern Hudson Land, a threefold division of the Cass Fjord Formation has been determined.

Subdivisions	Measured sections	
	Ella Ø	Albert Heims Bjerge
Upper Transition Limestones	39.2 m Fossil Horizons AS — AW	22.5 m Fossil Horizons 71—73
Limestone-Shales	199 m Fossil Horizons AJ — AR	154 m Fossil Horizons 55—70
Lower Transition Limestones	31.8 m Fossil Horizons AI	35.5 m Fossil Horizons 53—54
	Total 270 m	212 m

Fauna and age of the Cass Fjord Formation.

The fossils which have been obtained from the Cass Fjord Formation in Central East Greenland are considered to be of Lower Canadian age. POULSEN has published faunal lists, together with remarks concerning the age of the formation and its affinites in North America and Europe (1937, 1951). The authors' investigations have not necessitated any modifications to the conclusions propounded by POULSEN, as apart from one new species of the trilobite *Micragnostus*, and doubtful specimens of *Pseudohystricurus*, the other species hitherto unrecorded in Central East Greenland have all been previously recognised in the Cass Fjord and Cape Clay Formations of Northwest Greenland.

Fossils of the Cass Fjord Formation (Central East Greenland)	Poulsen		Cowie & Adams	
	Ella Ø	Kap Weber	Ella Ø	Albert Heims Bjerge
Bryograptus ? sp.	×			
Clonograptus sp. (cf. *tenellus* var. *callavei* Lapworth)	×			
Ophiograptus inexpectans Poulsen	×			
Dendroid ind.				×
Hydrophorida ind.	×	×		×
Eoorthis sp.	×			
Lingulella sp.			×	
Lingulepis tenuilineata Poulsen	×	×		
Orthid ind.			×	×
Schizambon nobilis Poulsen			×	×
Sinuopea whittardi Poulsen	×	×	×	×
Gastropoda ind.	×			×
Agnostid ind.			×	×
Hystricurus armatus Poulsen	×	×	×	×
H. cf. *ravni* Poulsen			×	
H. sulcatus Poulsen		×	×	×
H. sp. ind.			×	×
'*Hysticurus*' *nudus* Poulsen		×		×
Micragnostus sp. nov.				×
? *Pseudohystricurus* sp.			×	×
Symphysurina elegans Poulsen		×	×	
S. cf. *porifera* Poulsen			×	×
S. robusta Poulsen		×		×
S. cf. *woosteri* Ulrich	×	×		
S. sp. ind.		×		

It is significant that fossils closely resembling *Symphysurina porifera*, a trilobite originally reported from the Cape Clay Formation of North-

west Greenland (Poulsen, 1927), have been found in the highest beds of the Cass Fjord Formation in northern Hudson Land and in Ella Ø. These Upper Transition Limestones possibly represent the Cape Clay Formation and part of the Poulsen Cliff Formation which occur in Northwest Greenland.

The gastropod *Sinuopea whittardi*, considered by Poulsen (1937, 67) to be an index fossil for the Cass Fjord Formation, appears to be confined to the lower beds of the Limestone-Shales in the Albert Heims Bjerge region and on Ella Ø. The restricted stratigraphical range of this fossil would seem to justify the close correlation established in this part of the succession. However, Poulsen's tentative zonal division of the Cass Fjord Formation (Poulsen, 1937, 63) founded on two species of *Symphysurina* from a much faulted outcrop on Kap Weber, has not been substantiated by our own detailed investigations.

Kap Weber Formation.

The Kap Weber Formation, as developed on Ella Ø and in the Albert Heims Bjerge region, is an extremely thick sequence of massive limestones and dolomitic limestones, the lower part of which is occasionally intercalated by thinly-bedded and lenticular limestones with shaly partings. Intraformational conglomerates are common, but especially noteworthy as discrete bands amongst thinly-bedded limestones near the base. The colour, composition and texture of the limestones display certain variations through the succession but, in general, the lithology remains fairly constant, few of the minor changes being apparent on the weathered surfaces, which acquire an almost uniform light-grey colour and become deeply carious.

Segregations of brown to black weathering chert are frequently encountered, attaining a particularly dense distribution along the bedding planes of massive limestones in the middle part of the succession. When viewed from a distance these highly silicified limestones appear strongly banded, a feature which is due entirely to the differential weathering of the chert and limestone (see Fig. 57).

The surprisingly uniform lithology of the Kap Weber Formation has precluded the establishment of well-defined stratal subdivisions, although some broad variations through the sequence possibly suggest a threefold division into (i) a lower group of banded limestones (fig. 8) dolomitic in part, (ii), a middle group of massive and highly silicified limestones and (iii), an upper group of heavily dolomitised limestones. Such divisions would be difficult to define, owing to the gradual transition from one to the other and could not be applied in all areas where the

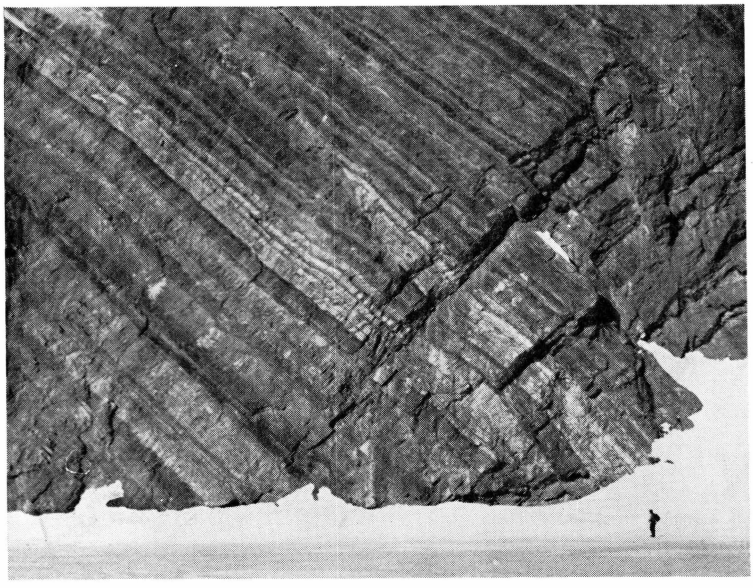

Fig. 8. The banded limestones of the lower Kap Weber Formation on the southwest coast of Ella Ø. A small fault displaces strata to left of figure standing on frozen fjord.

formation occurs. Although no generalized succession is suggested for the Kap Weber Formation, regional variations allow localized subdivisions; these are described in the detailed accounts of the stratigraphy.

Measured sections

Albert Heims Bjerge	.....	1165 metres
	Fossil Horizons	74—96
Ella Ø	.....	1040 metres
	Fossil Horizons	AX—BT

Fauna and age of the Kap Weber Formation.

The fossils collected from the Kap Weber Formation in Central East Greenland are of Upper Canadian age, and are listed in the accompanying synopsis. The Formation is only sparsely fossiliferous, and the greater part appears to be disappointingly destitute of organic remains. Many of the fossils from the measured sections are fragmentary and badly preserved, and do not provide sufficient features for more than tentative identifications to be carried out. Only the 'Black Limestones' of the Albert Heims Bjerge section—at a stratigraphical height of between 550 and 600 metres above the base of the formation—have yielded well preserved fossil fragments in any abundance. (See page 69).

Fossils of the Kap Weber Formation (Central East Greenland)	Poulsen			Cowie & Adams	
	Strindbergs Land	Kap Weber	Ella Ø	Ella Ø	Albert Heims Bjerge
Porifera ind.			×	×	×
Archaeorthis groenlandica Poulsen	×	×			
Lingulella sculptilis Ulrich & Cooper					×
Orthid ind.				×	
Pelecypoda ind.		×			
Polytoechia sp. ind.		×			
Ectomaria sp.			×		
Gyronema sp.			×		
Helicotoma similis Whitfield		×			
H. spp. ind.	×	×	×	×	×
Holopea sp.				×	
Hormotoma sp.			×	×	×
Lophospira sp.			×		×
Maclurites sp.		×	×	×	
Pagodispira sp.			×		
Raphistomina sp.			×		
Solenospira sp.			×		
Turritoma sp.			×		
'*Orthoceras*' sp.				×	×
Proterocameroceras sp.			×		
Protocycloceras			×		
Asaphid ind.					×
Bathyurellus teicherti Poulsen	×				
B. sp. A				×	×
B. sp.				×	
Bathyurina megalops Poulsen	×			×	
B. sp. A				×	×
Bathyurida ind.				×	
Benthamaspis ? *problematica* Poulsen				×	
Bolbocephalus groenlandicus Poulsen		×	×	×	
B. sp.				×	
Carolinites aff. *genacinaca* Ross					×
'*Gignopeltis*' sp.				×	×
Goniotelina cf. *brighti* (Hintze)				×	
G. sp. A					×
Ceratopeltis latilimbata Poulsen		×			
Hystricurus crassilimbatus Poulsen	×	×			
'*H*' sp.				×	
Illaenus sp. A				×	
Isoteloides sp. nov. A				×	×
Niobe brevicauda Poulsen	×	×			
N. groenlandica Poulsen	×				
? *N.* sp. A				×	×
? *Peltabellia* sp.				×	

(continued)

Fossils of the Kap Weber Formation (Central East Greenland)	Poulsen			Cowie & Adams	
	Strindbergs Land	Kap Weber	Ella Ø	Ella Ø	Albert Heims Bjerge
Petigurus groenlandicus Poulsen	×	×			
Pliomerops sp. A				×	
Pseudomera barrandei (Billings)					×
Raymondaspis spp. A & B				×	
Remopleurides sp. A				×	
Styginid ind.				×	
Uromystrum affinis (Poulsen)			×		
Isochilina cf. *perporosa* Poulsen				×	
I. sp. A				×	×
Leperditia sp.				×	×
? *Paenaequina* sp.				×	
Cryptozoon		×			

The most significant additions to POULSEN's faunal lists are undoubtedly *Lingulella sculptilis* ULRICH & COOPER, *Carolinites* aff. *genacinaca* ROSS, *Pseudomera barrandei* BILLINGS, *Isoteloides* sp., and *Goniotelina* sp., all of which have been recovered from the 'Black Limestones' of the Albert Heims Bjerge section. *Lingulella sculptilis* is known from the Upper Pogonip Limestone of Nevada, close to the junction between Lower and Middle Ordovician (ULRICH and COOPER, 1938, 51). *Carolinites genacinaca* is associated with species of *Isoteloides*, *Pseudomera* and *Goniotelina* in the 'zone J' faunules, considered to be uppermost Canadian in age, from the Pogonip Group in Nevada (HINTZE, 1953). Ross (1951, 28) has recorded *Carolinites genacinaca* in 'zone J' of the Garden City Formation of north-eastern Utah, and recognizes the value of this fossil as a guide to the uppermost divisions of the Canadian. He also reports the presence of *Pseudomera barrandei* in other parts of Utah, again from faunal zones equivalent in almost all respects to 'zone J' of the Garden City Formation. These few preliminary correlations would seem to indicate that the fossils of the Albert Heims Bjerge 'Black Limestones' (see page 69), having strong affinities with faunas from strata of uppermost Canadian age in the south-western states of U.S.A., are of a similar age. This conclusion, however, sets the question of dating the almost unfossiliferous beds in the upper part of the Kap Weber Formation, and in the overlying Narhvalsund Formation. Do these strata represent the close of Canadian times, or do they represent fairly continuous sedimentation well into the Champlainian? The question is left unanswered here.

The collections from the higher beds of the measured sections in the Kap Weber Formation have not yielded diagnostically Champlainian

fossils, but certain elements of the fauna from Kap Margrethe (Locality 22) on Ella Ø indicate a possible Chazyan age for the limestones in this area. Although lithologically identical with limestones of the Kap Weber Formation, the strata at Kap Margrethe are probably faulted, and may indeed be younger. The trilobite genera *Pliomerops*, *Remopleurides* and *Raymondaspis* in particular have strong affinites with the Chazyan.

Narhvalsund Formation.

The Formation consists essentially of a basal group of massive light-grey dolomites and calcareous dolomites, overlain by a series of more thinly-bedded dolomitic limestones and limestones, which vary in colour from light to dark-grey, with some maroon tinted horizons. In the type section, i. e., along the south coast of Ella Ø, the differential weathering and coarsely crystalline nature of the lower dolomites permit a clear demarcation to be made from the underlying dolomitic limestones of the Kap Weber Formation. This distinction is more difficult to detect in the Albert Heims Bjerge region, owing to a more uniform dolomitic lithology continuing up the succession from the higher beds of the Kap Weber Formation, but sufficient features remain to warrant the retention of the stratal group as a discrete formation.

In the measured sections of Albert Heims Bjerge and Ella Ø a simple dual division of the Narhvalsund Formation has been achieved.

Subdivision	Measured Sections	
	Ella Ø	Albert Heims Bjerge
Dolomitic Limestones	180 m[1]) Fossil Horizons BU—BV	350 m
Basal Dolomites	70 m	112 m Fossil Horizon 97
Total...	250 m	462 m

Fauna and age of the Narhvalsund Formation.

The dolomitic nature of the formation has precluded the preservation of any clearly diagnostic fossils. Poulsen (1951, 21) considers the age to be Upper Canadian, a conclusion based on the discovery of several different types of undescribed bathyurid trilobites in the higher beds of the sequence, which he examined on Ella Ø. Our collections of fossils,

[1]) Only the lowermost 180 metres of the Dolomitic Limestones could be examined and measured on Ella Ø, as the higher beds—which must exceed 200 metres in thickness—are probably inaccessible where exposed along the south coast of the island (see fig. 68 b).

from both measured sections, have unfortunately not provided any definite evidence to substantiate or disprove POULSEN's conclusions, but it is thought that a lower Champlainian age is quite possible. This deduction would certainly fit in with the uppermost Canadian age established for the Kap Weber Formation, and the Champlainian (post-Chazy) age of the overlying Heimbjerge Formation.

Fossils of the Narhvalsund Formation (Central East Greenland)	Poulsen	Cowie & Adams	
	Ella Ø	Ella Ø	Albert Heims Bjerge
Hormotoma sp.		×	
Lophospira sp.	×	×	
Pagodispira sp.	×	×	
Trochonema sp.	×		
Trocholitoceras sp.	×		
Bathyurellus sp.	×		
Bathyurid ind.	×		
Ceraurus sp.	×		
Heterochilina obliqua Poulsen	×		
Isochilina sp.		×	
Leperditia sp.			×
Eccyliopterus sp.	×		

Heimbjerge Formation.

During many flights over unexplored parts of northern Hudson Land, LAUGE KOCH had seen a considerable thickness of sediments lying conformably above the recognizable divisions of the Cambro-Ordovician sequence cropping out on the north side of Promenadedal, and suspected their post-Canadian, pre-Devonian age. BÜTLER (1940, 12), after his reconnaissance of Hudson Land south of Promenadedal in 1938, also expressed the opinion that Albert Heims Bjerge was possibly formed in younger Lower Palaeozoic rocks than had been found previously in East Greenland. It was not until our investigations in the late spring and summer of 1951 that the presence of Ordovician strata, younger than those of the Narhvalsund Formation, was finally established. In the Albert Heims Bjerge region of northern Hudson Land more than 300 metres of uniformly grey-weathering limestones rest conformably upon the dolomitic rocks of the Narhvalsund Formation, and are themselves unconformably overlain by Devonian conglomerates. The name 'Heimbjerge Formation' is here proposed for this limestone sequence.

East of Albert Heims Bjerge a section in the limestones totalling 320 metres was examined; this figure probably represents the maximum

thickness now present in the area (Plate III). However, apart from the known outcrops of the type-area and suspected outcrops in Strindbergs Land, it is quite certain that the present distribution of the Heimbjerge Formation in Central East Greenland is restricted and in any case it is unconformably succeeded by Devonian. No strata of comparable age are known on Ella Ø.

The limestones of the Heimbjerge Formation are remarkably uniform in lithology, being generally light-grey in colour, massive, well-bedded, and have a finely crystalline granular texture. The limestones weather to an even, light-grey colour, and may be compared with the rocks of the Kap Weber Formation in this respect, although they are distinguished by the almost complete absence of dolomitisation, by the comparative rarity of chert, and by their more uniform lithology.

The lowermost 13 metres of the Formation are composed of thinly-bedded, maroon-grey limestones, which are unlike the remainder of the overlying sequence. A simple twofold division of the Heimbjerge Formation has accordingly been made.

Subdivision	Thickness	Fossil Horizons
Grey Limestones.....	307 m	100—106
Lower Limestones	13 m	98— 99
Total....	320 m	

Fauna and age of the Heimbjerge Formation.

The fossils listed below were all collected by us from the limestones of the Heimbjerge Formation, either from the measured section, or from two fossiliferous localities on the plateau north of Albert Heims Bjerge. Although the fossils collected from these two localities cannot be related to any particular part of the sequence, there is little doubt that they have strong affinities with the fossils from the measured section.

? *Calapoecia* sp.
Receptaculites '*arcticus*' Etheridge
Orthoceratid ind. (? *Endoceras*)
Öpikina sp.
Leptaena sp. (cf. *richmondensis praecursor* Foerste)
L. sp. ind.
Orthid ind.
Rafinesquina cf. *alternata* Conrad
R. spp.
? *Strophomena* sp. ind.
? *Cyclospira* sp.
Hormotoma sp.

Liospira sp.
Maclurites sp.
? *Bathyurellus* sp.
Bumastus aff. *fronto* Troedsson
B. sp.
Calliops sp.
Illaenus cf. *groenlandicus* Troedsson
I. sp. ind.
Pliomerops sp. (cf. *parvus* Billings)
Remopleurides sp. B.
Sphaerexochus sp. (cf. *canadensis* Billings)
Trilobite ind. (bathyurid ?)
Trilobite ind.
Anisochilina punctulifera Teichert
Eurychilina sp.
Primitia sp.

The first impression gained by a general survey of the listed fossils is that, with certain exceptions, they are post-Canadian and pre-Silurian in age. However, some of the fossils have a more restricted range than others, and provide the means of dating the rocks of the Heimbjerge Formation more precisely.

The presence of the brachiopod *Rafinesquina* is most indicative: the genus appears to be limited to strata of Trentonian—Richmondian age in the north-eastern parts of the U.S.A. and in northern Canada (Salmon 1942, 573), *R. alternata* Conrad (= *trentonensis*) being the most primitive form and restricted to deposits of Trentonian age. According to Salmon (*op. cit.*) the species has not been found in formations younger than the Sherman Falls, but Wilson (1946, 66) reports the form from the uppermost Trentonian (equivalent to the Cobourg Formation) strata of the Ottawa Formation in the Ottawa—St. Lawrence Lowlands.

The rafinesquinoid *Öpikina*, associated with *Rafinesquina* (*s. s.*) at the same horizon in the Heimbjerge Formation, is also an important index fossil of the Champlainian in North America, where it ranges in age from uppermost Chazyan to upper Trentonian. The close association of these two fossils would seem to indicate a Trentonian age for the containing strata which are the topmost beds of the measured section.

Receptaculites arcticus Etheridge embraces a number of species, of scattered distribution in the Middle (and Upper?) Ordovician rocks of the North American Arctic regions, which Troedsson has grouped together under the one name (1929, 143). Roy (1941, 66, 197) records this species 'group' from Silliman's Fossil Mount, near Frobisher Bay, Baffin Land, and ascribes a Richmondian age to the faunal assemblage, whilst nevertheless admitting the strong Mohawkian affinities of certain elements. *R. arcticus* is also of common occurrence in the lower beds of the Cape Calhoun Formation, and in the underlying Gonioceras Bay

Formation, of Northwest Greenland. Troedsson (1929, 157) considered these *Receptaculites*-bearing beds as being Mohawkian (Black River or Trentonian) in age. Teichert, however, does not entirely agree with this opinion, and in a brief review of the faunas from Gonioceras Bay and Kap Calhoun (1937, 18, 22) expresses the belief that no deposits of an earlier age than "lowest Trenton" are represented at either of these places. A similar Trentonian age may be suggested for the Heimbjerge Formation by the presence of *Receptaculites arcticus*, although no direct correlation between the formations should be attempted on the basis of this one fossil.

Other elements of the Kap Calhoun fauna, such as *Bumastus fronto* Troedsson and *Illaenus groenlandicus* Troedsson, have affinities with fossils collected from the Heimbjerge Formation. Troedsson has stressed the close relationship between *I. groenlandicus* and the Trentonian species *I. americanus*—of widespread distribution in North America—and suggests a similar Mohawkian age for the Greenland species. The genus *Calliops* is also represented in the Cape Calhoun fauna by the species *C. callicephala* (Hall), to which the Heimbjerge specimen bears some resemblance. In America this particular species has been collected in the Trentonian beds of New York, Ontario, Manitoba, Kentucky and New Jersey. Other species of *Calliops* are commonly encountered in the Champlainian formations of the Appalachian Valley (Cooper, 1953, Table I).

Of the remaining trilobite genera which have been recovered from the Heimbjerge Formation, *Pliomerops* and *Sphaerexochus* are both found in the North American Champlainian, although the stratigraphical range of the latter extends up into the Silurian. The specimens from the Heimbjerge Formation, represented only by fragmentary cranidia, appear to have features in common with two species from Chazyan (?) strata in eastern U.S.A. and Newfoundland. The vertical ranges of *Pliomerops canadensis* (Billings) and *Sphaerexochus parvus* Billings are uncertain, and varietal forms more closely comparable with the East Greenland material may be present in younger Champlainian formations of North America.

The ostracod *Anisochilina punctulifera* Teichert was first reported from Ungerlodjan, on the east coast of the Melville Peninsula, together with a fauna which included *Rafinesquina*, *Primitia* and *Eurychilina*—all genera represented in the Heimbjerge Formation. From his analysis of the Ordovician faunas obtained on the Melville Peninsula, Teichert concludes that the age of the strata is comparable with upper Trentonian divisions in parts of eastern North America (1937, 34).

The collection of fossils from Locality 32 in the much faulted area near the glacier snout which lies between Rødøen and Albert Heims

Bjerge (Plate X & fig. 26)—suggest perhaps a late Trentonian or even Cincinnatian age for the strata there. The poor state of preservation shown by the fossils precludes the expression of any conclusive opinion.

Summarizing these preliminary age determinations and correlations it becomes quite clear that the fauna of the Heimbjerge Formation is of Champlainian age, and shows strong Trentonian affinities in many of its elements. Future study of the fossil collections may reveal more detailed information concerning the faunal affinities and age of the formation. Such a study may also throw more light on the opinion, voiced by Roy (1941, 97), of recurrent Mohawkian faunas in strata of Richmondian age, which is a possible explanation of the many faunistic problems affecting the middle and upper Ordovician of the arctic regions.

B. An outline of regional structures.

The new information made available in recent years by the publication of numerous papers which include consideration of the structure of the rocks of Central East Greenland is probably sufficient for a thorough reassessment of the regional structural pattern. A recent paper by Haller (1955), comprising the first part of a series of publications on the Central Metamorphic Complex, has as its subtitle 'Die Geologische Karte von Suess Land, Gletscherland und Goodenoughs Land'. In this contribution consideration is given to the general structural features in the older geological systems between latitudes 72° and 74° north, from Scoresby Land to Strindbergs Land. It is claimed that the folding of the Pre-Devonian sedimentary series reflects deformations of the crystalline basement, with large-scale disharmonic folding (*op. cit.*, 161; also see Wegmann, 1935, 32—36). The broader structural aspects have previously been discussed by Koch (1935), Wegmann (1935) and Teichert (1939). The forthcoming publication referred to by Fränkl (1953 a, Tafel 6), a co-operative study by Koch, Bütler, Wenk, Fränkl and Haller, will, no doubt, collate and interpret the known facts. The Cambro-Ordovician is structurally an integral part of the Pre-Devonian sediments, which are best considered as a unit in regional studies. Discussion at length of these larger structural conceptions is no part of the authors' present task. However, a brief outline may be useful, before proceeding to the results of the relatively detailed geological mapping carried out in the Albert Heims Bjerge—Reservatet area and on Ella Ø.

In the broadest and most generalised view Central East Greenland is characterised by outcrops of most of the geological Systems, striking approximately north-north-east, with the older rocks in the west and the younger in the east. North and south of the region covered by Plate VIII metamorphic rocks may be present on the outer, eastern coast

flanking the Greenland Sea. To the north this may be due in part to the line of the coast being slightly west of north, whereas the outcrop trend is to the east of north: it is possible that the Pre-Devonian sediments of Central East Greenland may continue out below the sea in this area. In the south, where the metamorphic rocks of Liverpool Land are to the east of the unmetamorphosed Mesozoic strata of Jameson Land, a more complex relationship is indicated.

During late Pre-Cambrian and Cambro-Ordovician times part, at least, of Central East Greenland was the site of a large sedimentary trough, which was later subjected to strong metamorphism and folding movements. The major folding, which was evidently post-Middle Ordovician and pre-Middle Devonian, was not intense and lateral forces played a minor role. As illustrated by Fränkl (1953 a, Tafel 5) the folding style from Ella Ø to Strindbergs Land is characterised by uplifts, including domes, and broad synclines. The Pre-Devonian sediments have been folded along axes which vary in direction between little east of north, as in Ella Ø, to approximately north-east in northern Hudson Land. Due to warping along east-west directions the plunge of these folds is variable giving a series of axial culminations and depressions. The outcrops of the Cambro-Ordovician strata occur chiefly in synclines where there is an axial depression. In Ella Ø, however, the axial depression is sufficiently great to cause outcrops in the anticlinal region, towards the south coast of the island. The oldest structural elements are thought by Haller to be the east-west warpings, which in the sedimentary suprastructure appear as axial culmination and depression zones of the north-south trending anticlines and synclines. Their genesis is ascribed to vertical forces in pre- to early Caledonian times (Haller, 1955, fig. 12, 44—47) and forces of a similar nature are invoked for the north-south folds. The formation of these later structures is thought by Haller to be closely associated with the "rise of migmatitic front" (*op. cit.*, 161); the *mise en place* of the Central Metamorphic Complex, and the folding along north-south trends, represent the main phase of the Caledonian orogeny.

The Cambro-Ordovician outcrops between latitudes 72°15′ and 74°15′ North can be considered in four regions (Plate VIII):—

1. Syltoppene in Scoresby Land (ca. 72°20′ N. lat.), probably owes its isolation from the main crop to a combination of folding and faulting in the area of Kong Oscars Fjord and Segelsällskapets Fjord.

2. The outcrops which can be followed northwards from Ella Ø to southern Strindbergs Land.

3. The Rævedal—Ole Rømers Land trough, striking from Rævedal in Strindbergs Land to the outcrops around the great lakes of Ole Rø-

mers Land and northern Hudson Land (Krumme Langsø and Vibekes Sø) which are mainly to the east of a graben of Devonian. The boundary fault on the western side of the graben runs from Geologfjord northwards across Strindbergs Land and Waltershausen Gletscher; the eastern is roughly parallel, striking northwards from the lower part of Johan Davidsens Dal. These faults bring Devonian strata against Cambro-Ordovician and Pre-Cambrian rocks which range down stratigraphically to the lower part of the Upper Eleonore Bay Formation.

The region of Ole Rømers Land and northern Hudson Land which includes Albert Heims Bjerge and Reservatet—the 'Ole Rømerland-mulde' of BÜTLER (1940, 18, Tafel 2)—is a trough or large syncline which plunges towards the north-east where exposures are terminated by Wordies Gletscher. North of the southern margin of this great mass of ice, sediments have been recorded in C. H. Ostenfelds Nunatak and in part of Payers Land (MITTELHOLZER, *in* KOCH, 1950, pl. 6); but from the apparent absence of Lower Palaeozoic rocks it must be assumed that Wordies Gletscher forms the northern boundary to the Cambro-Ordovician outcrop in Central East Greenland[1]). The plunging syncline is much broken by faulting, as shown by BÜTLER (*in* KOCH, 1950, pl 7). Plate VIII, on a smaller scale, closely follows BÜTLER's interpretation, except for the fault crossing Søryggen and few other details. The effect of the three major dislocations—the two north-south faults which form the Devonian graben, and also the one crossing Vibekes Sø—is to throw the rocks up on the east in a series of steps compensating the plunge of the fold. Nevertheless, it is in Albert Heims Bjerge that the youngest Pre-Devonian deposits were found by the authors (page 39). The effect of plunge on the fold, and the resistant lithology of the rocks, have preserved these Middle Ordovician strata from erosion before they were covered by Devonian clastics, and have also preserved them from the later denudation which produced the present landscape.

4. Isolated inliers, outliers, fault-slices and fault-blocks are found in Hudson Land, and on both sides of the outer part of Moskusoksefjord (the 'Muskox Fjord Inlier').

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[1]) In 1956 HALLER landed by helicopter on C. H. Ostenfelds Nunatak (ca. 74° 18′ N. lat., 22° 55′ W), and discovered Cambro-Ordovician sediments (verbal information). Fossils collected, and the formations which the lithology of their matrix suggests are:—*Salterella* sp. (Hyolithus Creek Formation), *Sinuopea whittardi* POULSEN & brachiopod ind. (Cass Fjord Formation).

III. ALBERT HEIMS BJERGE—RESERVATET AREA, NORTHERN HUDSON LAND

A. Stratigraphy.

The approximate thicknesses of the formations are, to the nearest 5 metres (see Plate XIII):—

Heimbjerge Formation		320	metres
Narhvalsund	–	460	–
Kap Weber	–	1165	–
Cass Fjord	–	210	–
Dolomite Point	–	370	–
Hyolithus Creek	–	215	–
Ella Ø	–	100	–
Bastion	–	150	–
Kløftelv	–	70	–
Canyon	–	300	–

The Lower Cambrian rocks are compared with strata of the same age in Ella Ø in figure 9; a similar comparison for the Ordovician is given in figure 22 on page 61. Supplementary, detailed, descriptions of measured sections will be found in the Appendix.

Canyon Formation.

The succession of shales, sandstones and dolomites, measured in the stream gorge immediately south-east of the fault-line f_7 (Plate IX), where the junctions with the Upper Tillite and the Kløftelv Formation are clearly seen, is illustrated by a small-scale vertical section in Plate XIII.

There is no sign of an unconformity at the junction with the overlying Kløftelv Formation quartzites. However, a variation in the lithology of that part of the Canyon Formation below the quartzites was seen in a section along the bank of Vibekes Elv, between the faults f_8 and f_9. At this locality the dolomite of the topmost subdivision (7) is absent, and black, highly fissile shales, weathering dark-grey to black, similar to those of the subdivision (6) below the dolomite near f_7, are found

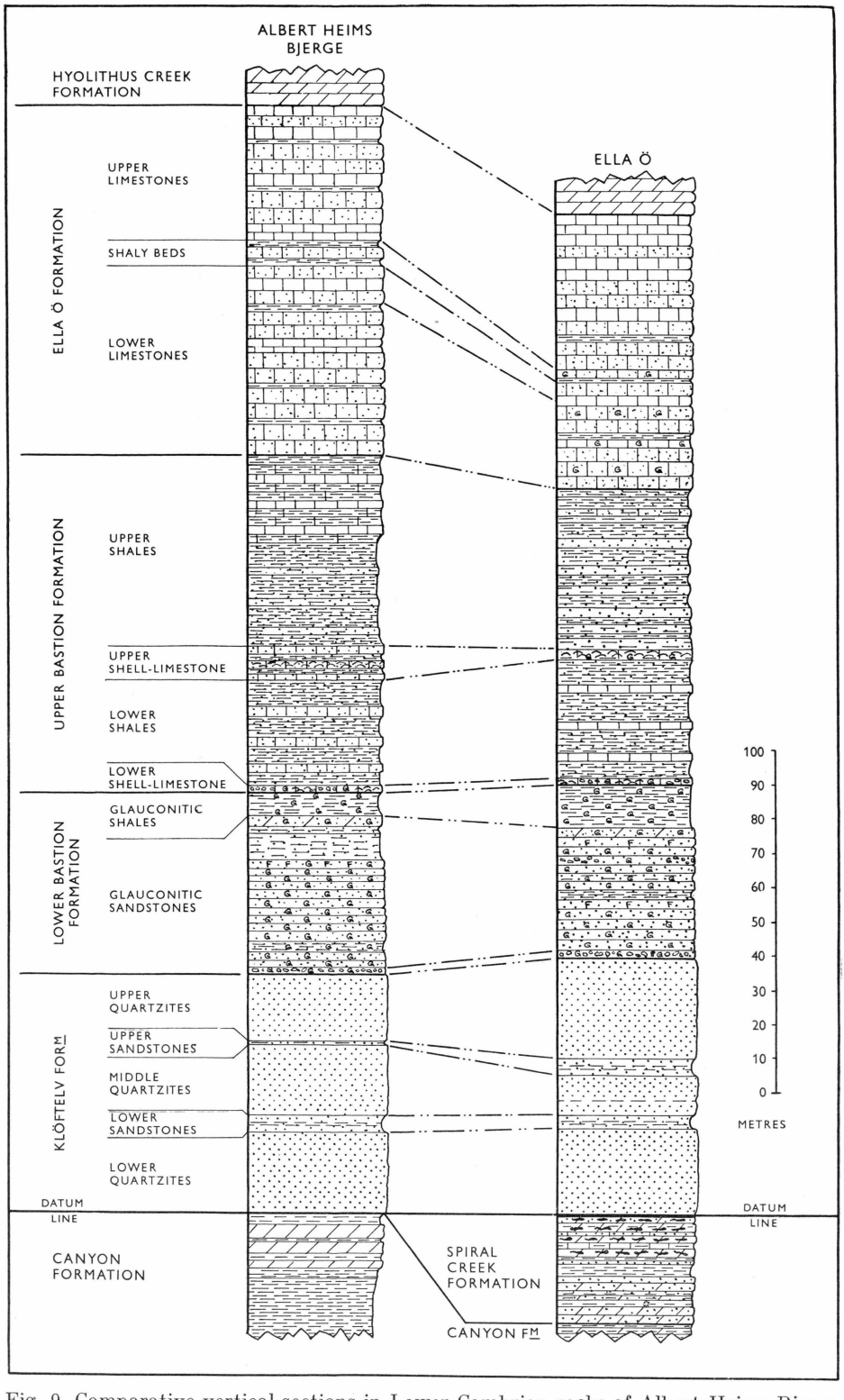


Fig. 9. Comparative vertical sections in Lower Cambrian rocks of Albert Heims Bjerge in northern Hudson Land, and Ella Ø.

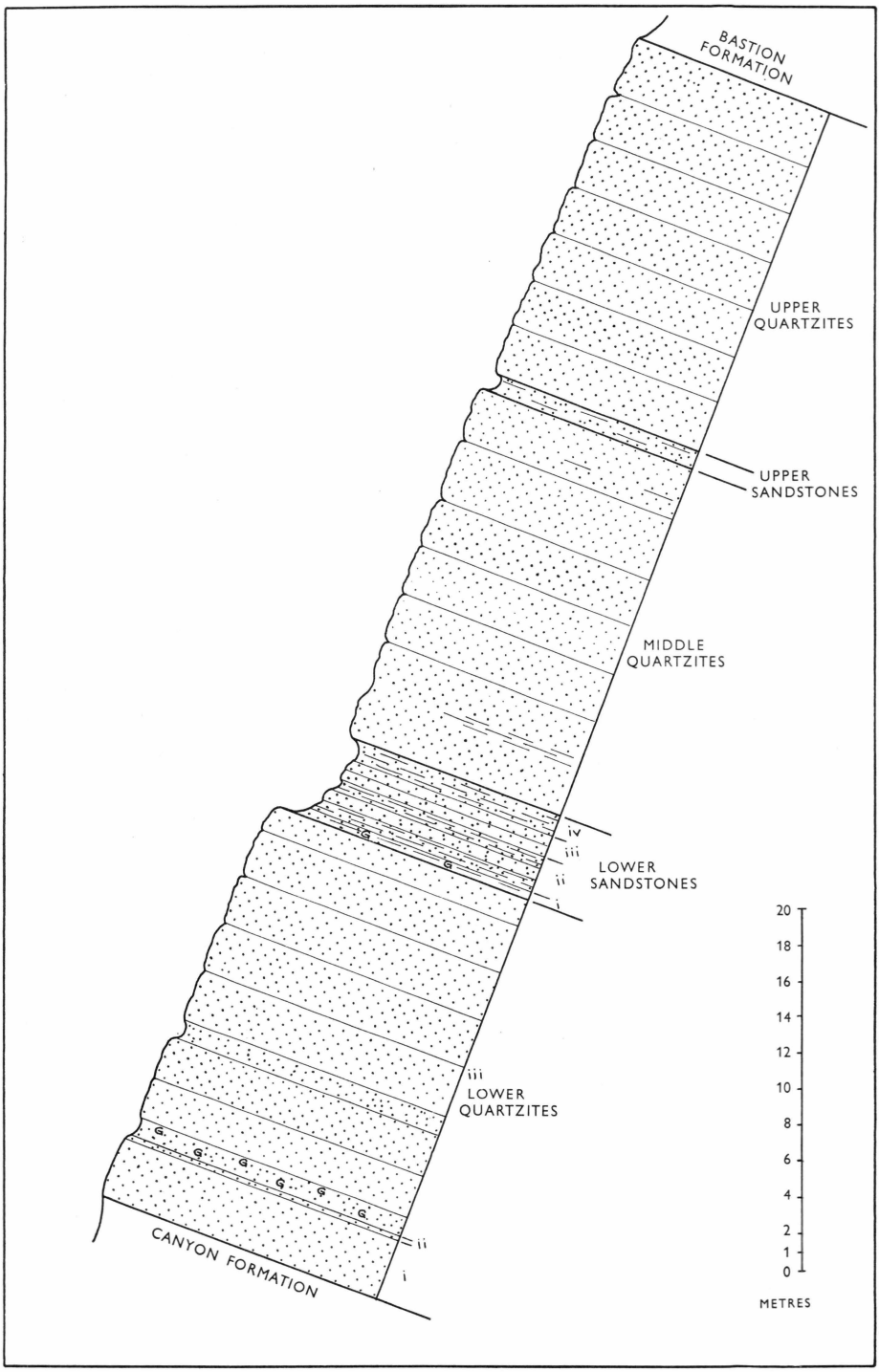


Fig. 10. Profile of Kløftelv Formation.

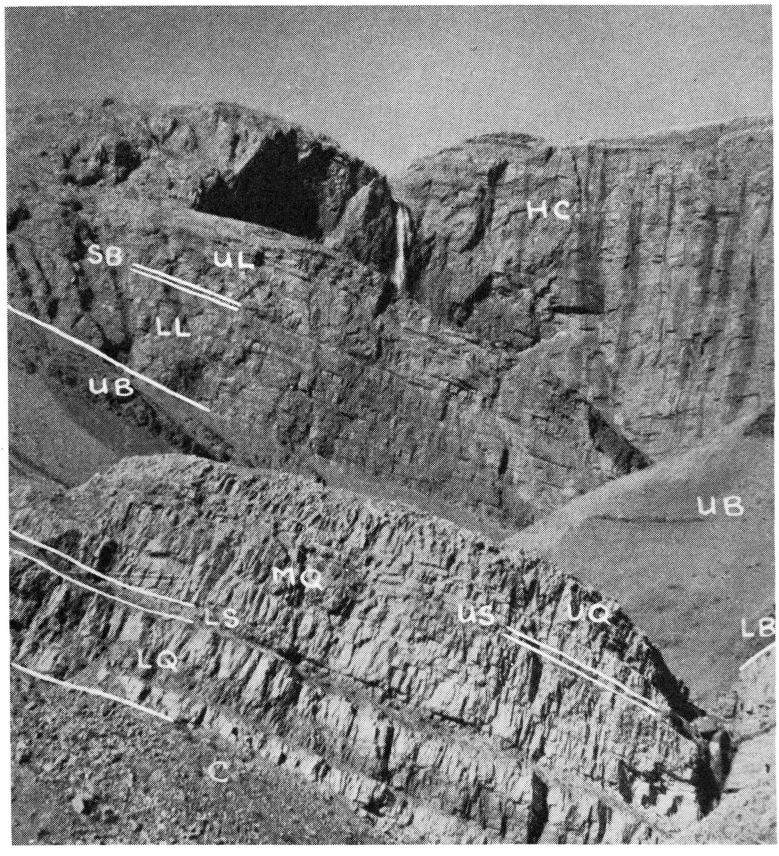


Fig. 11. The cliff exposures to the north-west of fault f_7, which can be seen in Plate II (also see the map – Plate IX). *C* – Canyon Formation; Klöftelv Formation: – *LQ* – Lower Quartzites, *LS* – Lower Sandstones, *MQ* – Middle Quartzites, *US* – Upper Sandstones, *UQ* – Upper Quartzites; *LB* – Lower Bastion Formation; *UB* – Upper Bastion Formation; Ella Ø Formation: – *LL* – Lower Limestones, *SB* – Shaly Beds, *UL* – Upper Limestones; *HC* – Hyolithus Creek Formation. (The photograph was taken with the camera tilted upwards.) Albert Heims Bjerge, northern Hudson Land.

below the quartzites of the Kløftelv Formation. The junction is apparently conformable and unfaulted. This considerable variation, involving the apparent absence of 19 metres of sediments, occurs within a distance of approximately six kilometres.

Kløftelv Formation.

The sequence of quartzites and sandstones was measured in a section exposed along the bank of Vibekes Elv, between the faults f_8 and f_9. A well-exposed alternative section, although not so accessible, was found immediately to the north-west of fault f_7 and is illustrated in fig. 11, and Plate II. The succession is illustrated by a profile in fig. 10.

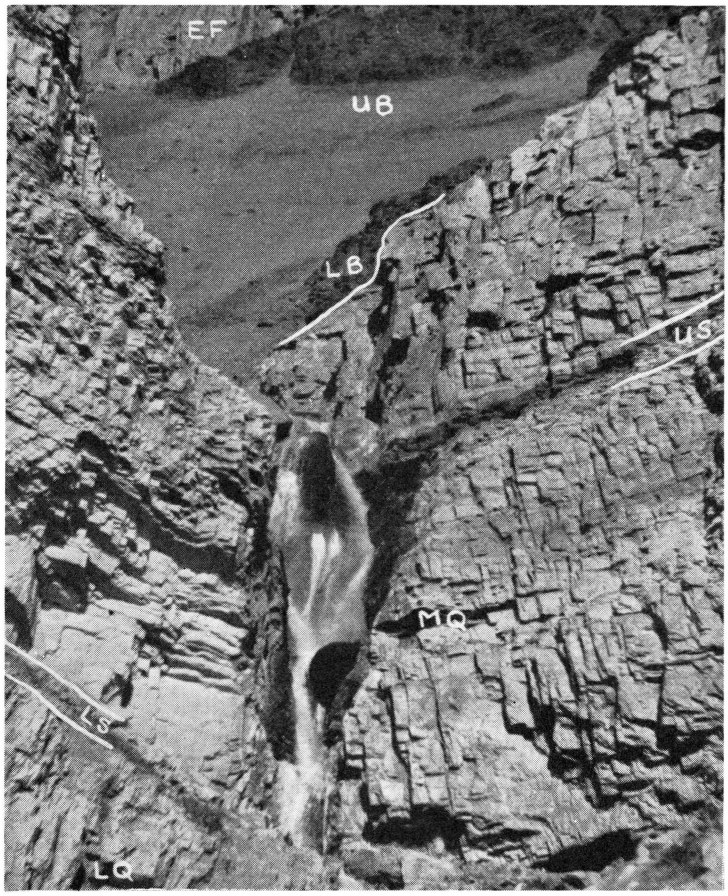


Fig. 12. The waterfall section north-west of fault f_7 (see fig. 9, Plates II & IX). The Middle Quartzites are 20 metres thick. Klöftelv Formation: – *LQ* – Lower Quartzites, *LS* – Lower Sandstones, *MQ* – Middle Quartzites, *US* – Upper Sandstones; *LB* – Lower Bastion Formation; *UB* – Upper Bastion Formation; *EF* – Ella Ø Formation. (The photograph was taken with the camera tilted upwards). Albert Heims Bjerge.

Bastion Formation.

A typical development of this easily eroded succession of shales and sandstones is seen in figure 11, and also in the aerial photograph of Plate II. The section measured is exposed immediately to the north-west of fault f_7 (Plate IX).

Lower Bastion Formation.

The succession is illustrated by a profile in figure 13.

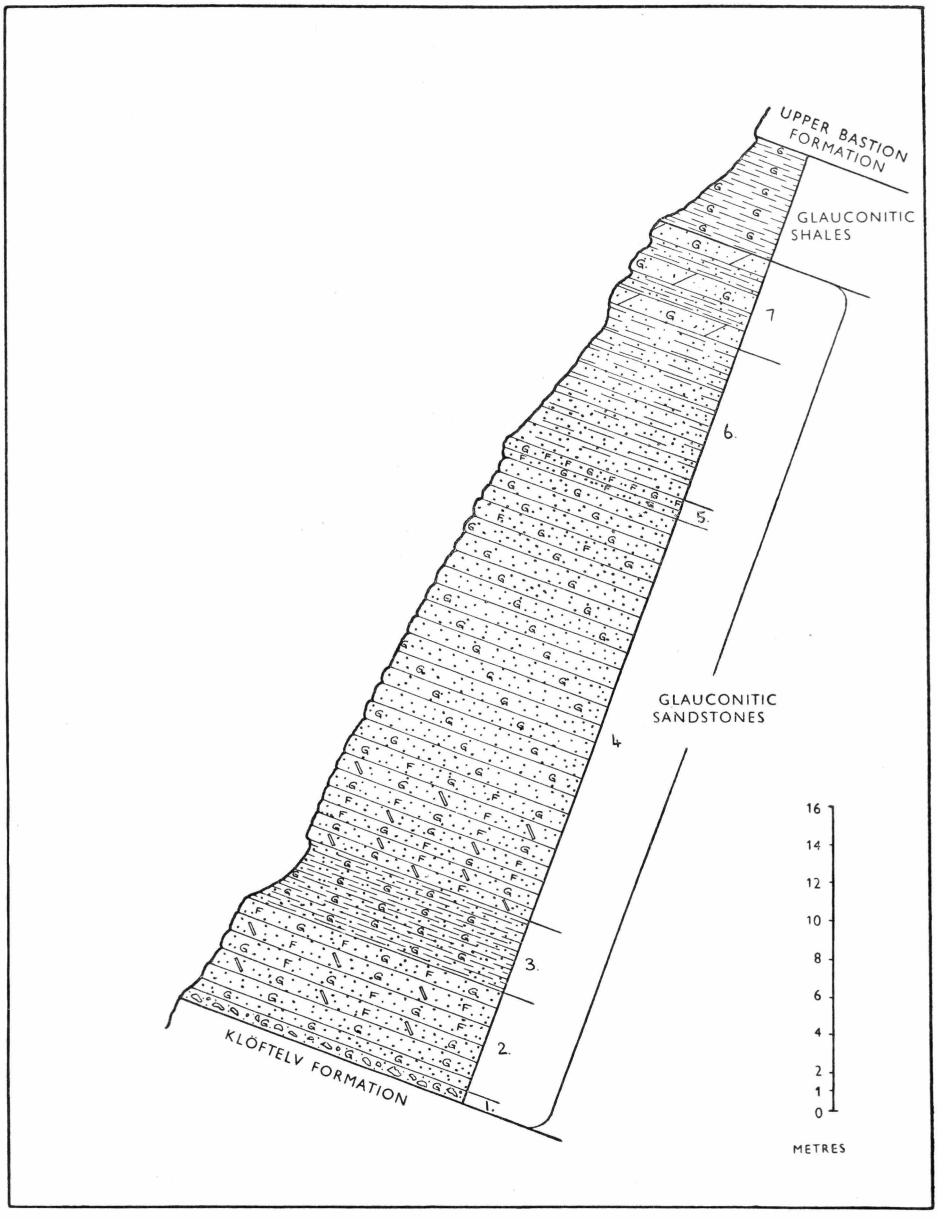


Fig. 13. Profile of lower Bastion Formation.

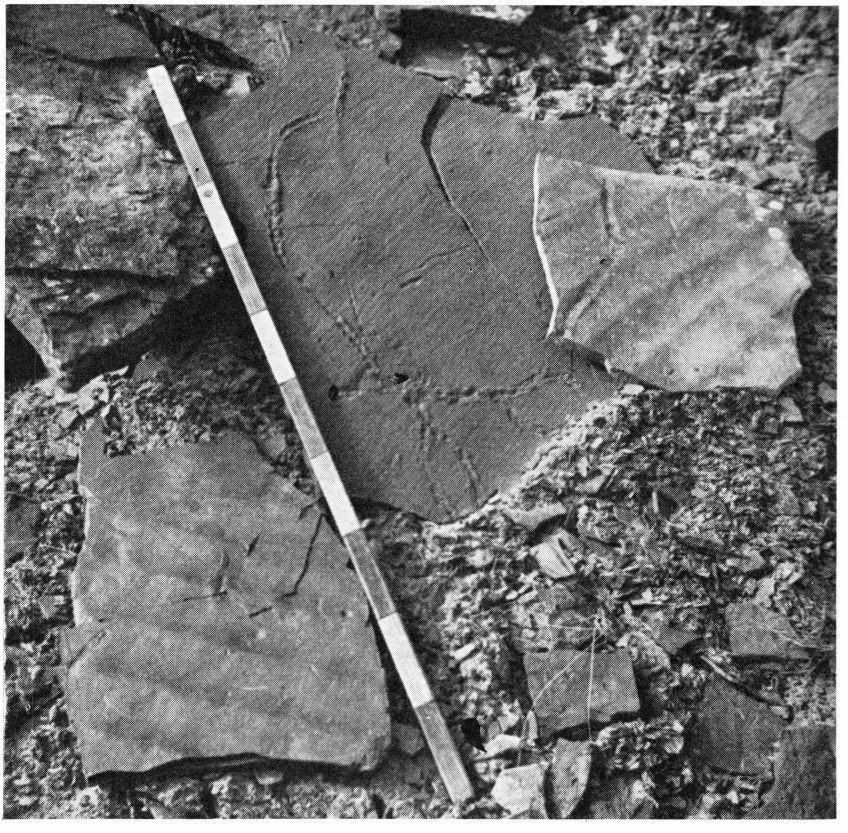


Fig. 14. Bedding-plane features, possibly caused by organisms, and ripple-marking, in the sandstone of subdivision 2, lower Bastion Formation, Albert Heims Bjerge. The measuring-stick is 1 metre long and is divided into 10 cm units.

Glauconitic Sandstones.

1. A glauconitic, siliceous conglomerate containing pebbles of quartz. Near the base are found grains and black, rounded irregular-shaped bodies of phosphatic material. The quartz pebbles range up to 7 mm across the longest dimension and are well-rounded. The black bodies are often larger, ranging up to 25 mm. Chemical tests show that these rounded black concretions, nodules, pebbles, pellets and grains are highly phosphatic. From thin-sections the mineral form of the phosphate was determined as crypto-crystalline or amorphous collophane. Krumbein (1942) suggests that phosphatic pellets or nodules are associated with unconformities of submarine origin and he considers glauconite zones to have similar associations. While there is no angular discordance at the base of the Bastion Formation there is good evidence of an interruption in sedimentation—a non-sequence, or possibly a disconformity.

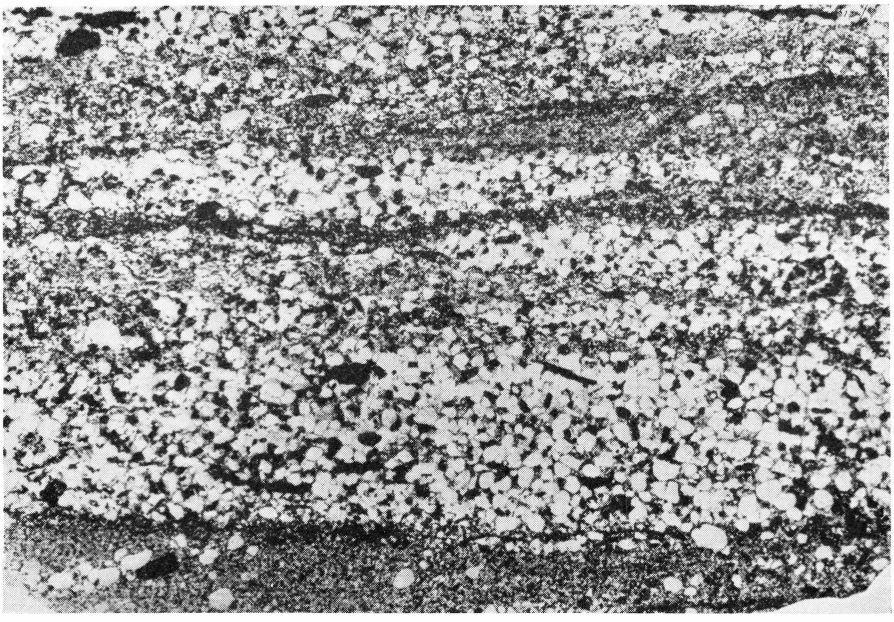


Fig. 15. Thin-section showing grains and pellets in the sandstone between 1.5 and 6 metres above the base of subdivision 4 of the lower Bastion Formation. This rock contains black ovoid nodules, pellets and grains of phosphatic material, sometimes elongated and tabular, with their long axes parallel to the bedding—the largest is 4 cm long. Albert Heims Bjerge. (× 2).

The presence of conglomerates, glauconite and phosphatic nodules supports this conclusion. The origin of the phosphatic material can only be surmised: it may be organic—either coprolitic, or accumulations of phosphatic hard parts of organisms during a period of non-deposition—or it might be inorganic. However, the phosphorus cycle generally involves the participation of the biosphere (PETTIJOHN, 1948, 349), and the phosphatic deposits at this level in the succession, well below the first undoubted fossil horizon at the base of the upper Bastion Formation, may therefore indicate the existence of organisms at that time.

2. Long narrow grooves or ridges are present on many bedding-planes of the sandstones of subdivision 2, the ridges on undersurfaces having counterpart grooves on the upper surfaces of beds beneath. These phenomena are very irregular and could well be due to inorganic sedimentary processes, but may be interpreted as tracks and trails of organisms. They are $^1/_2$ mm to 4 mm in width, their average height is 1 mm, and they are sometimes of considerable length (fig. 14).

Upper Bastion Formation.

The succession is illustrated by a profile in figure 16.

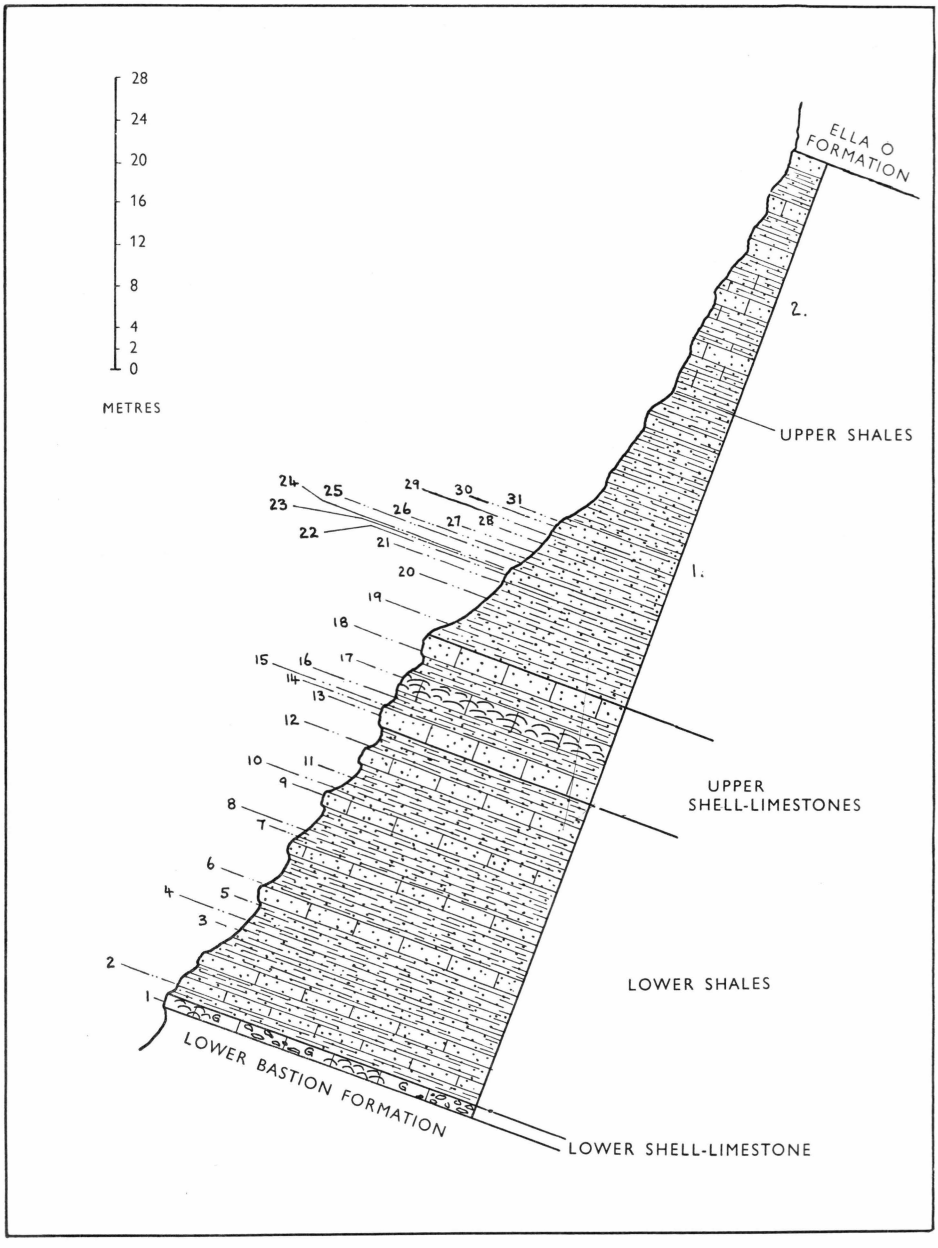


Fig. 16. Profile of upper Bastion Formation.

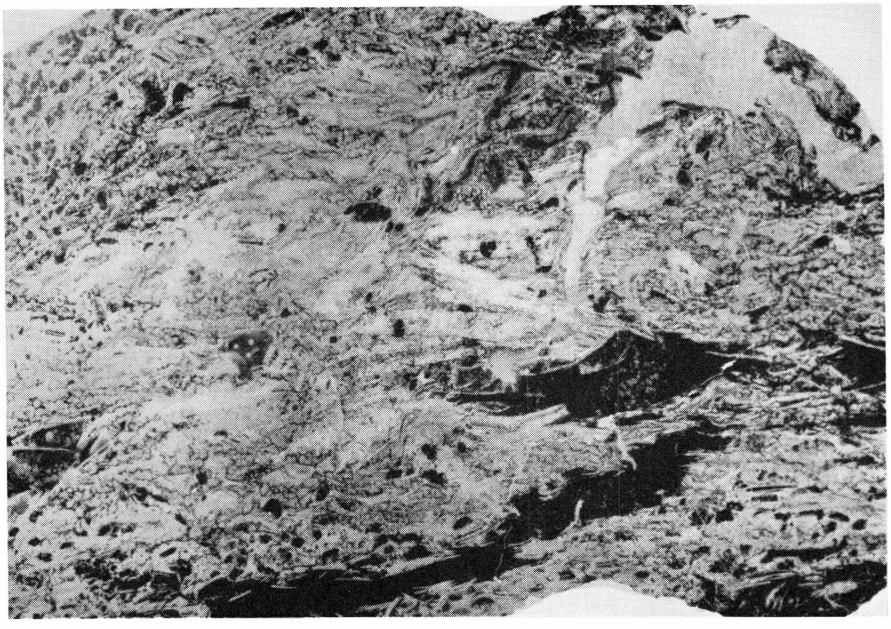


Fig. 17. Thin-section of glauconitic shell-limestone, Lower Shell-Limestone, upper Bastion Formation. Albert Heims Bjerge. (× 2).

Lower Shell-Limestone.

This massive, crystalline, glauconitic limestone is chiefly maroon in colour, but also green and cream, and consists largely of fossil fragments (fig. 17). There is little manifestation of bedding and the rock is characteristically laterally variable in colour and texture. It weathers to a ruddy-brown colour with a maroon tint. Thin-sections show the presence of small quantities of disseminated iron-ore which, coupled possibly with some manganese, presumably gives rise to the characteristic maroon colour. Small geodes containing crystals of calcite are also seen. Large patches of deep maroon-coloured shaly material with a lustrous sheen probably contain ferruginous and manganiferous concentrations. In many places the subdivision exhibits a conglomeratic character which, together with the shell-bank lithology, probably indicates a rapid change in the conditions of sedimentation at this level in the succession. Parts of the rock exhibit a greensand lithology in some exposures and comprise thin bands, up to 5 cm in thickness, composed almost entirely of glauconite, which are found obliquely traversing the regional bedding. The pebbles of the conglomerate, some of which are black and phosphatic with a rounded nodular character, range in size up to 5 cm across the long dimension.

The comments already made (page 52) on this type of deposit lead one to conclude that a non-sequence, or disconformity, is also present

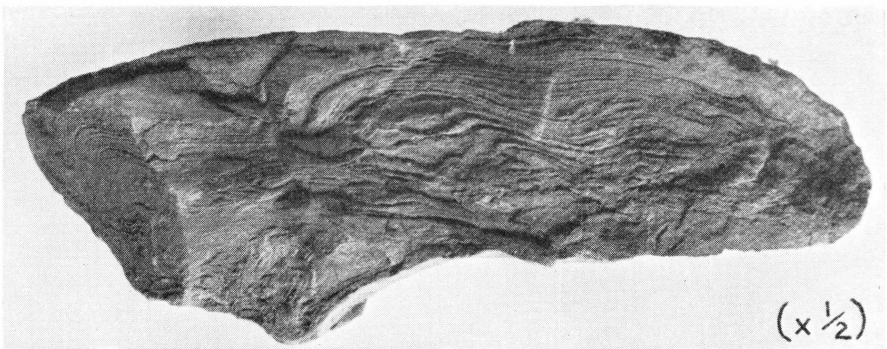


Fig. 18. Slump structure in arenaceous limestone of subdivision 2, Upper Shales, upper Bastion Formation. Albert Heims Bjerge.

at the base of the upper Bastion Formation. Four sedimentary features are present which support such a conclusion: 1) conglomerates, 2) glauconite, 3) phosphatic nodules, and 4) the shell-limestone consisting of broken-up fossil shells. These are the first definite fossils encountered in the succession, and from this Fossil Horizon 1 the following forms have been determined:— ? *Dicellomus* sp., *Discinella micans* (Billings), *D.* sp., Lingulid ind., ? *Mickwitzia* sp., *Obolella* sp., ? *Prototreta* sp., Olenellid ind., Hyolithid ind.

Thickness 50 cm.

Lower Shales.

Grey to green, fine-grained, glauconitic and arenaceous shales, weathering green and brown, interbedded with subordinate bands of fine-grained limestone. Fossils:— *Botsfordia* sp. (4, 8), *Obolella* sp. (10, 11, 12), Lingulid ind. (2, 5, 8, 9, 10, 12), Olenellid ind. (3, 6, 7, 8, 10), *Hyolithes princeps* Billings (5), *H.* ind. (5, 6, 8, 9, 10, 11). *Numbers in brackets indicate Fossil Horizons.*

Thickness 32 m.

Upper Shell-Limestones.

Grey, fine-grained, arenaceous limestone occurs in bands of irregular thickness and are nodular, irregularly bedded and weather brown and buff. There are also intercalations of greenish-grey, slightly glauconitic, arenaceous shale which weather green and brown. Brachiopod shell-limestones are found at a number of horizons. Fossils:— *Botsfordia* cf. *caelata* (Hall) (14), *Discinella bråstadi* Poulsen (18), D. sp. (13), *Kutorgina* sp. (17), *Lingulella* sp. (14, 15), Lingulid ind. (13, 16, 17), *Obolella* sp. (13, 16, 17), *Rustella* sp. (17), ?*Dentalium* sp. (17), *Fordilla* cf. *troyensis* Walcott (17), *Calodiscus* sp. nov. A (cf. *lobatus* (Hall)) (14), *C.* sp. nov. B (cf. *lobatus* (Hall)) (14), *C.* sp. nov. C (15), Olenellid ind. (16), ? *Weymouthia* sp. (14), ? Gen. nov. (cf. *Cobboldites*) (14).

Thickness 10 m.

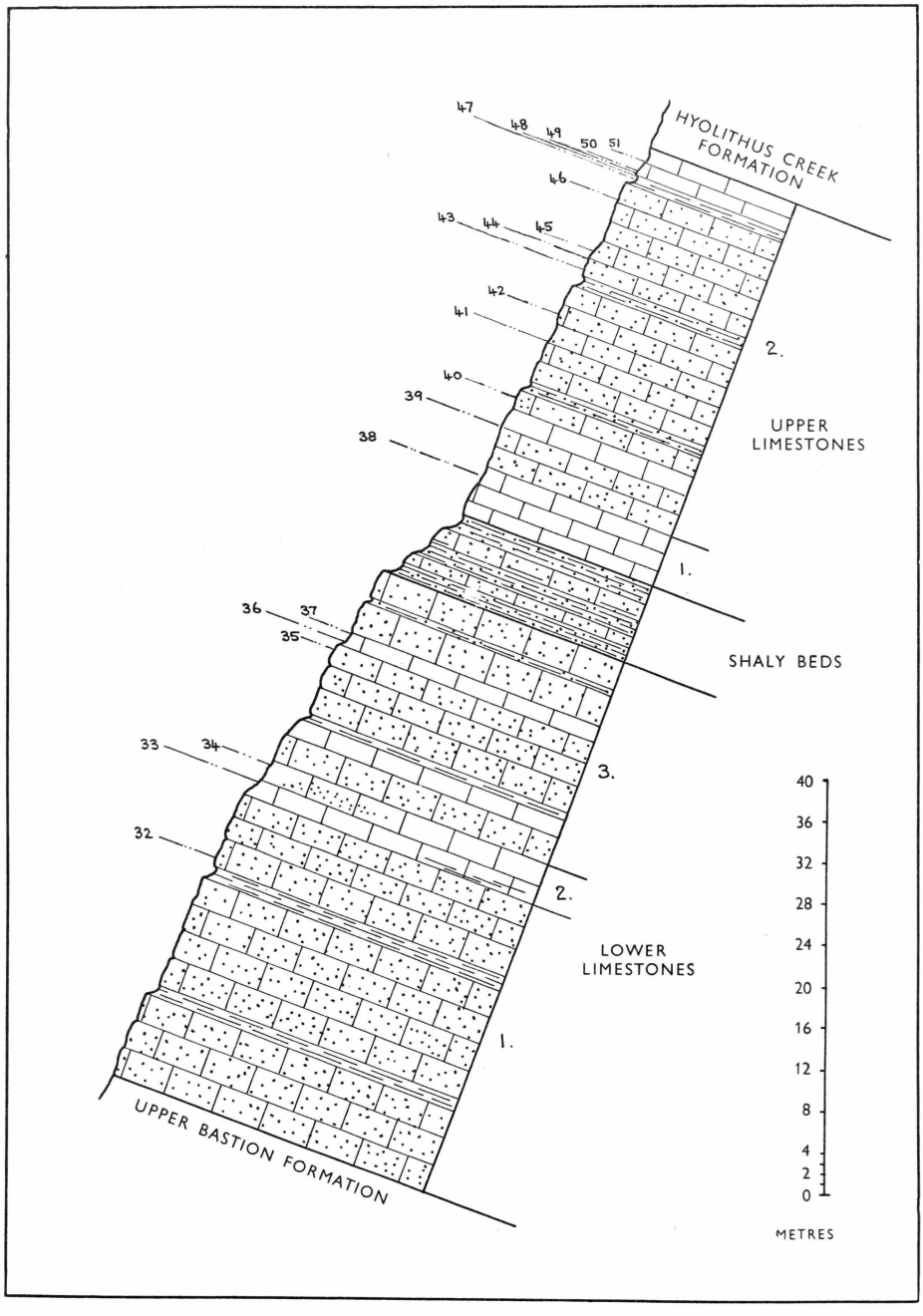


Fig. 19. Profile of Ella Ø Formation.

Upper Shales.

Arenaceous shales with bands of mudstone or arenaceous limestone. Fossils:— Brachiopoda ind. (26), *Calodiscus lobatus* (Hall) (23), *Olenellus* cf. *arcticus* (Hall) (26), *O.* cf. *thompsoni* (Hall) (22), *O.* cf. *truemani* Walcott (23, 25, 26, 31), *O.* sp. (20, 21, 24, 27, 28, 29, 30, 31), Gen. nov. (cf. *Cobboldites*) (19).

Thickness 56 m.

Ella Ø Formation.

Figure 11 shows an exposure immediately to the north-west of fault f_7 (Plates II & IX): a section was measured nearby, and is illustrated by a profile in figure 19.

Lower Limestones.

Fossils:— *Discinella* cf. *bråstadi* Poulsen (36), *D. micans* (Billings) (32, 34, 35), *D.* sp. (33), Dorypygid ind. (36), *Olenellus* sp. (35, 36, 37), Olenellid ind. (32, 33, 34, 35).

Thickness 55 m.

Upper Limestones.

Fossils:— *Acrothele* sp. (47), *Discinella micans* (Billings) (38), *Kutorgina* aff. *cingulata* Billings (43), *K.* cf. *reticulata* Poulsen (47), *K.* sp. A (47), *Dentalium* sp. (47), Alokistocarid ind. (cf. *Kochiella*) (47), ?*Bonnia* sp. (46), Dorypygid ind. (43), *Olenellus* sp. (45, 46, 48, 51), Olenellid ind. (39, 40, 41, 42, 44, 46, 47, 48, 49, 50), *Proliostracus strenuelliformis* Poulsen (51), *P. noe-nygaardi* Poulsen (51), ?*Wanneria* sp. (51).

Thickness 39.5 m.

Hyolithus Creek Formation.

Measurement and examination of this thickness of dolomites was carried out less than one kilometre south of fault f_7 (Plate IX); part can be seen forming the higher cliff in figure 11. Detailed profiles of the rather uniform series of sediments of this, and following, formations have not been drawn, but reference may be made to Plate XIII for a small-scale vertical section. Fossils:— *Salterella* sp. (52).

Dolomite Point Formation.

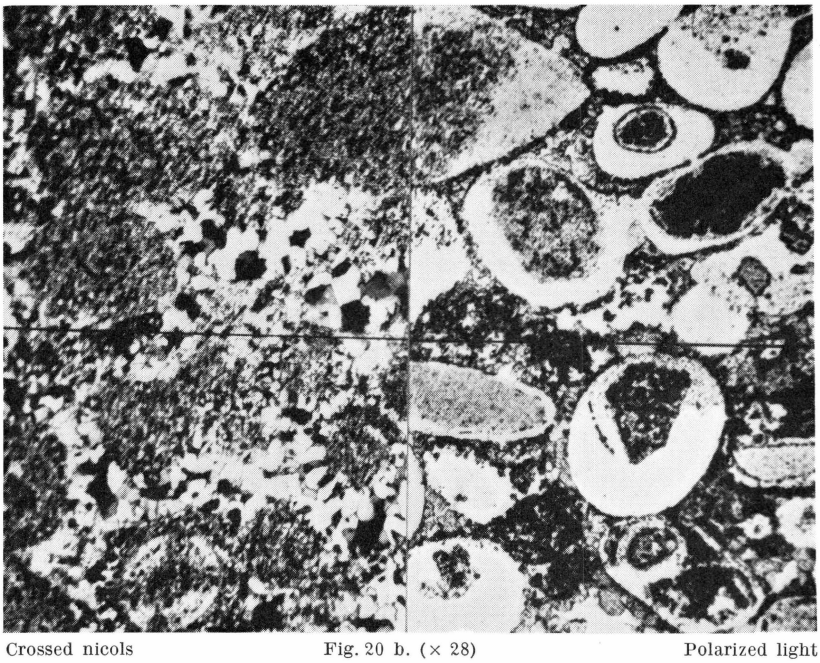
The Dolomite Point Formation, measured and described east of fault f_7 (Plate IX), has been subdivided into three units.

Lower Dolomites.

Predominantly light-grey, finely crystalline dolomites, weathering cream to yellowish-buff, interbedded with subordinate bands of darker grey, coarsely crystalline calcareous dolomite, weathering brownish-buff.



Fig. 20 a. (× 2)



Crossed nicols Fig. 20 b. (× 28) Polarized light

Fig. 20. a) Oolitic nature of the silicified dolomite on weathered surfaces. b) Photomicrograph showing replacement of dolomite by silica in individual ooliths. Both from 41 metres above base of Lower Dolomites, Dolomite Point Formation. Albert Heims Bjerge.

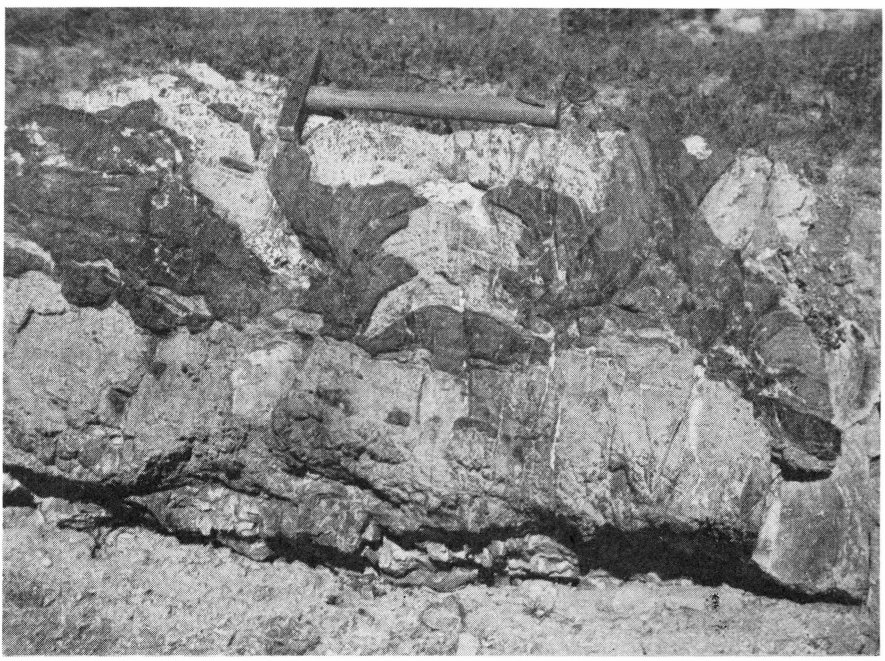


Fig. 21. Silicified stromatolitic structures near base of Upper Dolomites, Dolomite Point Formation. Albert Heims Bjerge.

Blebs and lenticles of dark-grey to black chert occur at intervals, and thin, inconstant intraformational breccias are occasionally present.

Thickness: 71 metres.

Calcareous Dolomite.

A massive bed, ten metres in thickness, of medium to dark-grey calcareous dolomite, uniformly fine-grained and weathering brown with carious surfaces. Small segregations of pinkish-white carbonate are distributed along the bedding planes in some parts of the bed.

Thickness: 10 metres.

Upper Dolomites.

Well-bedded, light-grey, fine-grained dolomite, weathering light buff to cream, forms the dominant rock type. Within the group there is a frequently repeated 'cycle' of thinly-bedded, almost shaly, dolomite, followed by a series of more massive dolomite bands, passing up into a coarsely crystalline dolomite which only shows indistinct and irregular bedding. Thin bands of dark-grey, finely crystalline dolomite are occasionally present. Chert is rarely encountered and is chiefly concentrated near the top of the succession. Intraformational breccias and conglomerates are present, although usually of only impersistent lateral extent.

Thickness: 290 metres.

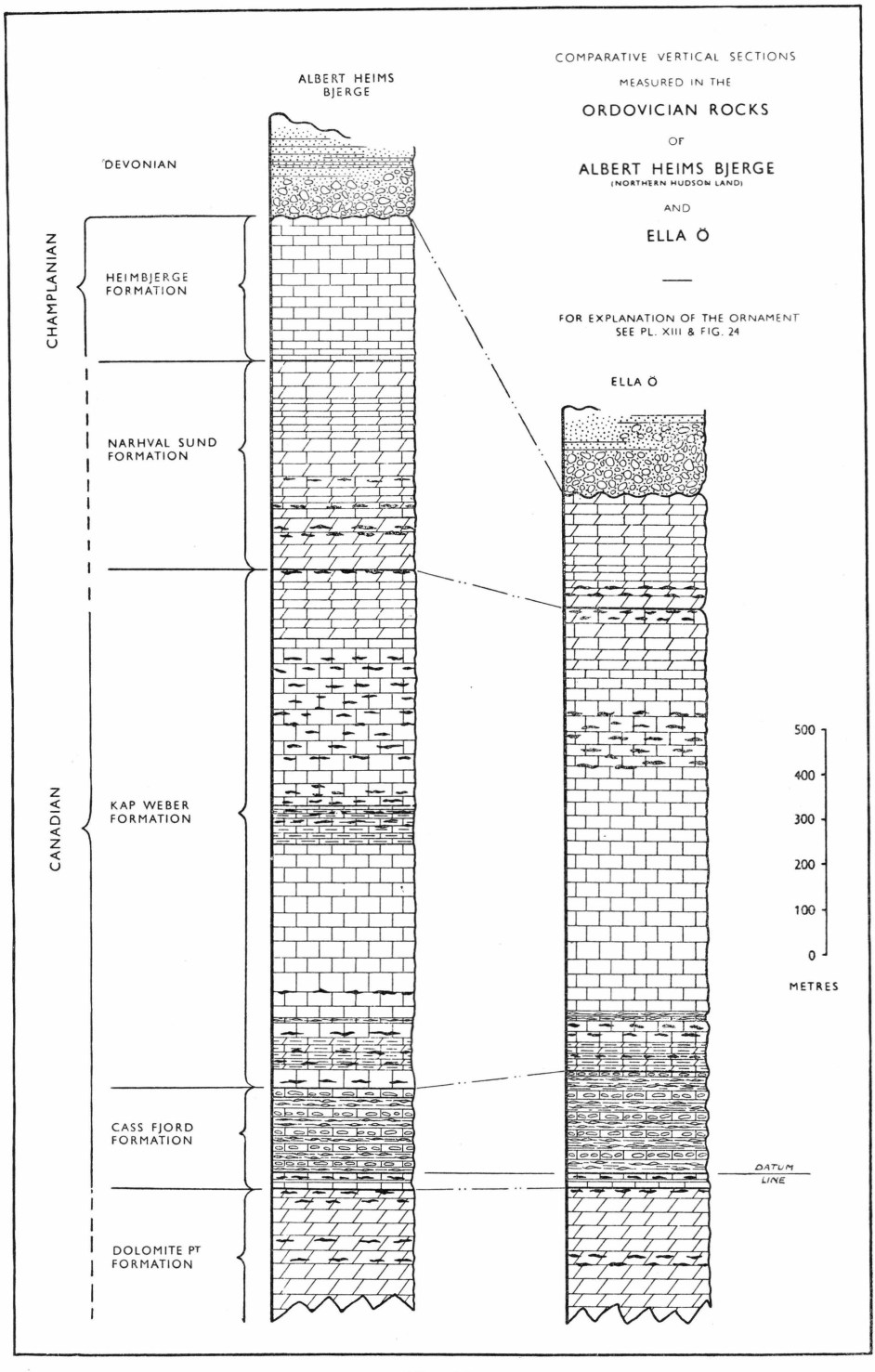
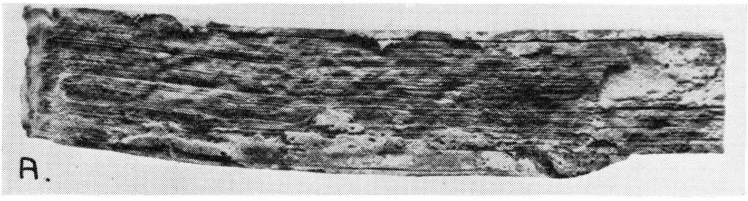

COMPARATIVE VERTICAL SECTIONS
MEASURED IN THE
ORDOVICIAN ROCKS
OF
ALBERT HEIMS BJERGE
(NORTHERN HUDSON LAND)
AND
ELLA Ö
FOR EXPLANATION OF THE ORNAMENT
SEE PL. XIII & FIG. 24
ALBERT HEIMS BJERGE
ELLA Ö
DEVONIAN
CHAMPLANIAN
CANADIAN
HEIMBJERGE FORMATION
NARHVAL SUND FORMATION
KAP WEBER FORMATION
CASS FJORD FORMATION
DOLOMITE PT FORMATION
DATUM LINE
500
400
300
200
100
0
METRES

Fig. 22.



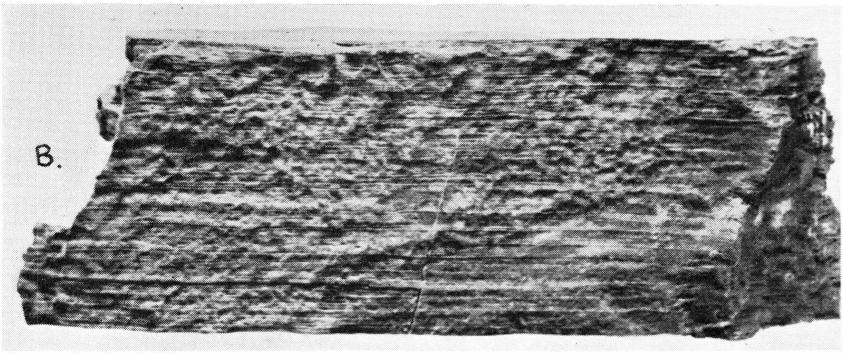


Fig. 23. A comparison of the weathered surfaces of the thinly-bedded limestones in Lower Transition Limestones, Cass Fjord Formation, of Albert Heims Bjerge and Ella Ø. A) Albert Heims Bjerge, about 23 metres above base, B) Ella Ø, about 21 metres above base. (×1).

Higher in the sequence the characteristic lithology of the Dolomite Point Formation is replaced by the dominantly calcareous rocks of the transition Beds in the lower part of the Cass Fjord Formation. Although unsupported by palaeontological evidence, the junction between the two formations has been tentatively drawn above the Upper Dolomites, for the reason that the abrupt change in sedimentation must indicate a stratigraphical break of some magnitude. It must be remembered, however, that no angular discordance has been detected between the strata of the two formations.

Cass Fjord Formation.

The Cass Fjord Formation measured and described along Promenadedal, south of fault f_7 (Plate IX), has been divided into three units.

Lower Transition Limestones.

Lying between lithologies typical of the Dolomite Point and Cass Fjord Formations, this transition group of rocks is composed essentially

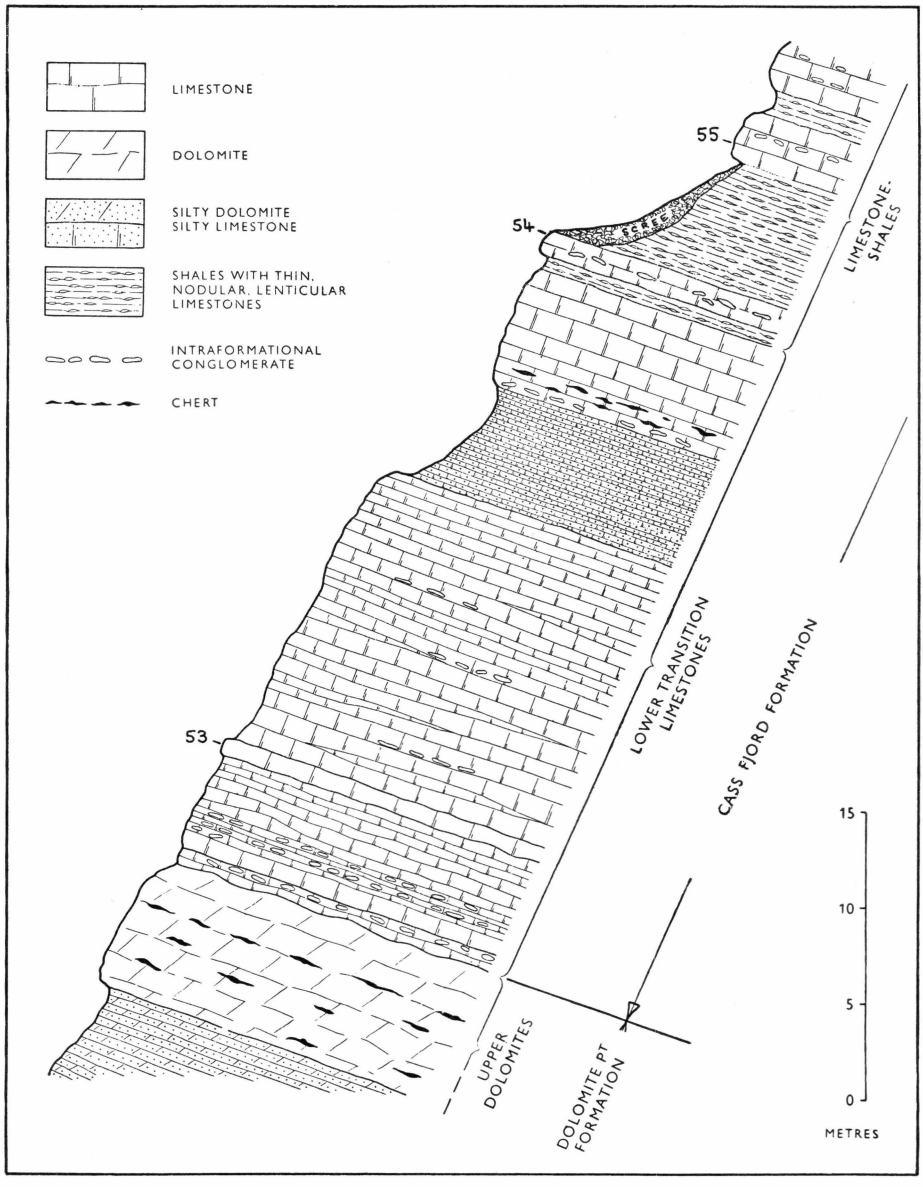


Fig. 24. Profile in Lower Transition Limestones, Cass Fjord Formation.

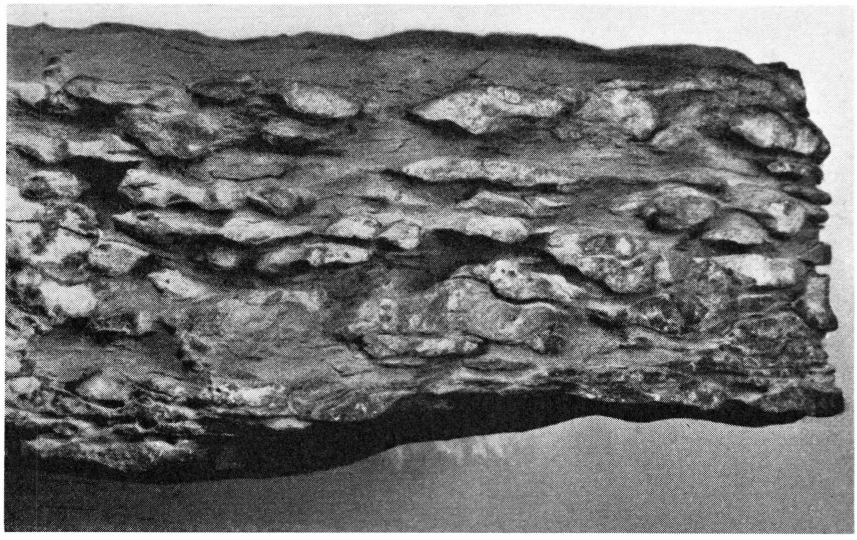


Fig. 25. A natural-scale photograph showing the typical differential weathering of thinly-bedded, nodular limestones and shale partings, as developed in the Limestone-Shales of the Cass Fjord Formation, Ella Ø.

of massive, irregularly-bedded limestones weathering dark-buff to grey in colour. Some of the more thinly-bedded limestones contain a small proportion of argillaceous material together with minute grains of quartz. Intraformational conglomerates are present in many parts of the sequence, but disseminations of chert appear to be confined to a single horizon.

No identifiable fossils have been recovered from the Lower Transition Limestones. Badly preserved orthid brachiopods, and a few gastropod fragments, do not permit any definite conclusions to be drawn regarding their stratigraphic age, although they are considered to have Ordovician affinities.

Thickness: 35.5 metres.

Limestone-Shales.

Forming the greater part of the Cass Fjord Formation, the Limestone-Shales consist of thinly-stratified, nodular, muddy limestones and shale partings, alternating with discrete bands of a more homogeneous limestone. The impure limestones and shales present a remarkably uniform lithology throughout the succession; the limestone strata are thin and are composed of lenticular nodules, with extremely wavy bedding planes marking the vertical gradation into shaly partings. Unweathered

cross-sections through the strata also show a gradation in colour from the medium-grey of the limestone nodules to the darker grey of the shale interleavings, but weathering gives rise to a uniform greenish-grey colour. Weathered surfaces generally display a distinctive 'pebbly' appearance, due to the limestone nodules standing out in relief against the more easily and deeply eroded shales.

The bands of massive grey limestone rarely attain any considerable thickness, and usually remain subordinate to the nodular limestones and shales with which they are interbedded. Normally quite distinct, these bands of massive limestone occasionally grade vertically into the adjacent lithology through zones characterized by increasing argillaceous material and by more irregular bedding. Intraformational conglomerates form a high proportion of the limestone bands, but their true nature is often difficult to detect owing to the similarity of lithology between matrix and contained pebbles. The majority of the fossils from the Cass Fjord Formation have been found as fragmentary remains in the massive limestone bands of the Limestone-Shales. Fossils:— Hydrophorid ind. (63), Orthid ind. (68), *Schizambon nobilis* POULSEN (55), *Sinuopea whittardi* POULSEN (59, 61, 62), Agnostid ind. (63), *Hystricurus armatus* POULSEN (58, 63, 65, 66, 68), *H. sulcatus* POULSEN (65), '*H*'. *nudus* POULSEN (56, 63), *H.* sp. (68, 70), *Micragnostus* sp. nov. (65), ?*Pseudohystricurus* sp. (65), *Symphysurina* cf. *robusta* POULSEN (57, 65, 66), *S.* sp. A (65), *S.* sp. B (65, 66, 68), *S.* sp. (67, 69), *S.* sp. ind. (60, 64).

Thickness: 154 m.

The exact position of the fossil horizons in the succession is given in the Appendix.

Upper Transition Limestones.

A series of massive limestone bands, separated by beds of thinly-stratified, lenticular and nodular limestones with shale partings. These Upper Transition Limestones form the 'passage beds' into the overlying Kap Weber Formation by a gradually increasing proportion of more uniformly bedded limestone, at the expense of the thinly-bedded nodular limestone and shales. The junction with the basal beds of the Kap Weber Formation cannot be clearly defined lithologically or palaeontologically, but must be almost arbitrarily drawn where dolomitisation of the limestones becomes significant, and where the thinly-bedded limestones and shales, so characteristic of the Cass Fjord Formation, become relatively unimportant. Fossils:— Dendroid graptolithina ind. (73), *Hystricurus* sp. ind. (71), '*H.*' sp. ind. (73), *Symphysurina* cf. *porifera* POULSEN (72, 73), *S.* sp. (71. 73).

Thickness: 22.5 m.

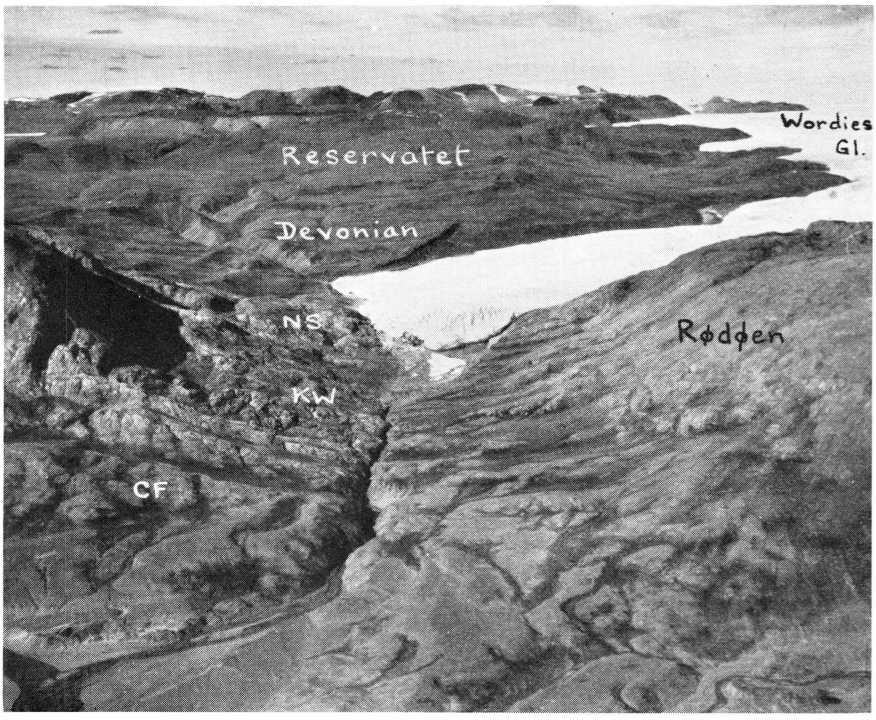


Fig. 26. Aerial view of eastern end of Promenadedal looking north towards Reservatet. Section measured in Kap Weber Formation lies to left of foreground river. *C.F.* – Cass Fjord Formation; *K.W.* – Kap Weber Formation; *N.S.* – Narhvalsund Formation.

Kap Weber Formation.

The section was measured at the eastern end of Promenadedal, on the western side of the river dividing Rødøen from the 'mainland' of Albert Heims Bjerge (see fig. 26). In this area the Kap Weber Formation comprises a great thickness of limestones, dolomitic limestones and dolomites, which may be broadly subdivided as follows:—

Subdivision	Thickness	Fossil horizons
Dolomites and Dolomitic Limestones	170 m	96
Upper Limestones	372 m	90—95
Black Limestones	85 m	79—89
Lower Limestones	538 m	74—78
Total.....	1165 m	

The lithological subdivisions cannot be shown on a map as discrete units owing to their boundaries being transitional and not well defined.



Fig. 27. Banded nature of Lower Limestones, Kap Weber Formation, in the Albert Heims Bjerge measured section. An impression of scale is gained from figure standing in lower-left-centre. (Compare fig. 8.)

In fact, detailed examination has shown that with the exception of the distinctive group of Black Limestones and the uppermost group of Dolomites and Dolomitic Limestones, the Kap Weber Formation displays—with no apparent major disconformity—a tediously homogeneous sequence of massive grey-banded limestones, some of which are dolomitised to a varying degree. Such dolomitisation is not only confined to certain horizons, but often appears in lateral continuity with the calcareous lithology. Chert is widely disseminated in many parts of the succession, being particularly concentrated in the higher beds of the Black Limestones, and also in the Upper Limestones.

Lower Limestones.

Formed mainly by alternating beds of light, medium and dark-grey massive limestone, the Lower Limestones of the Kap Weber Formation in the Albert Heims Bjerge region display a strongly banded appearance on well-weathered surfaces (see fig. 27). Such banding is further accentuated by the horizons of yellow-buff weathering dolomitic limestones and dolomites which appear at frequent intervals.

Although finely laminated at certain levels in the lower part of the succession, individual bands usually show a thickness which ranges from a little less than one metre to between two and three metres, and display slightly wavy irregular bedding. Many of the limestone bands possess

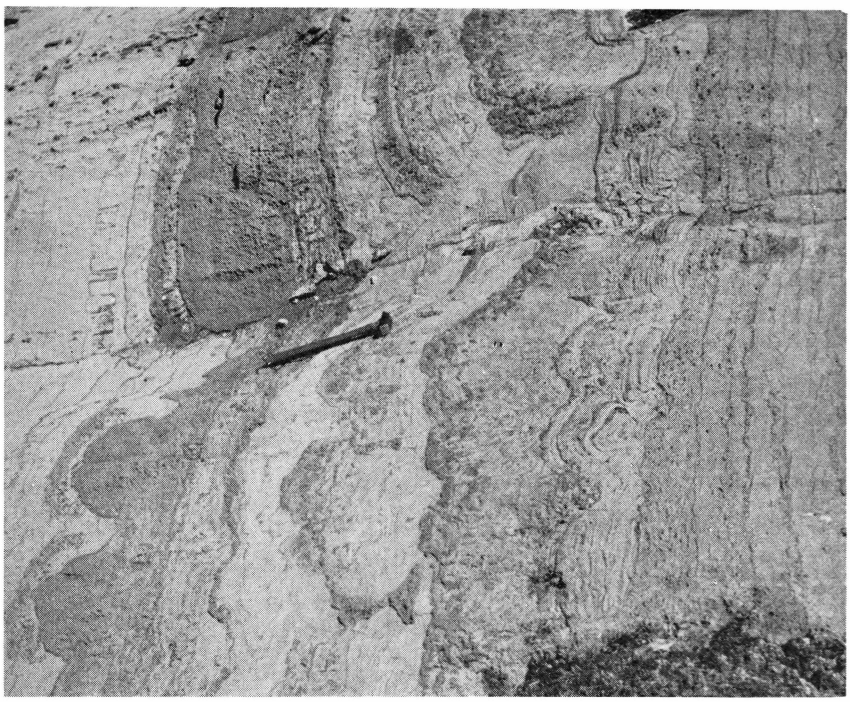


Fig. 28. Algal-like structures in basal beds of Lower Limestones, Kap Weber Formation, Albert Heims Bjerge. Photograph shows a weathered strike surface with younger beds on left. Dark-weathering streaks are dolomitic. (Compare with fig. 8.)

markedly convex and hummocky bedding planes (see fig. 28), sometimes picked out by streaky dolomitisation, which strongly suggest an origin due to algal activity.

Thin and laterally impersistent intraformational conglomerates are often encountered in the limestones of the group, especially in the lower parts of the succession where they are associated with occasional beds of thinly-stratified, lenticular limestones and intercalated shales. Some of these intraformational conglomerates are most difficult to detect, owing to the small size of the pebbles and their close lithological identification with the limestone matrix.

Calcite veining is widely distributed in most parts of the succession, but disseminations of chert are of only minor importance and are inconspicuous. Carious weathering of rock surfaces is almost ubiquitous. Fossils:— *Bathyurellus* sp. A (75, 77), '*Hystricurus*' sp. ind. (74), *Niobe* sp. A (78), *Leperditia* sp. (76, 77). Thickness: 538 m.

Black Limestones.

The Black Limestones form a distinctive subdivision in the Kap Weber Formation of the Albert Heims Bjerge region, consisting predo-

minantly of thinly-bedded, dark-grey to black limestones, weathering brownish-grey. Although generally fine-grained in texture, individual limestone bands often show patches of a more coarsely crystalline nature, in which fossil fragments are frequently both abundant and well-preserved. Shaly intercalations are present between the limestone bands in higher parts of the sequence, where brownish-weathering chert is also more heavily concentrated. Dolomitisation and carbonate veining are evident in places. Fossils:— *Lingulella sculptilis* Ulrich & Cooper (89), Asaphid ind. (80, 87), *Bathyurina* sp. A (87), *Carolinites* aff. *genacinaca* Ross (80, 81, 87), '*Gignopeltis*' sp. (87), *Goniotelina* sp. A (79, 82), *Isoteloides* sp. nov. A (83, 84, 85, 86, 87), *I.* sp. (80), *Pseudomera barrandei*? (Billings) (88).

Thickness: 85 m.

Upper Limestones.

The group consists of well-bedded, massive limestones, in bands ranging in colour from light to dark-grey, but which generally weather uniformly light-grey and carious. The limestone lithology is usually finely crystalline, with more coarsely crystalline varieties present at some horizons. Dolomitisation is not so extensive as in the overlying beds, but occurs in the form of yellow-buff streaks and patches, which weather more resistantly to a dark-grey colour on exposed surfaces. Brown-weathering chert is abundantly distributed throughout the group, as thin bands and lenticles along bedding planes, but is more heavily concentrated in the lower 50 metres of the sequence. Veins and segregations of calcite are occasionally encountered. Fossils:— ?*Bathyurellus* sp. (95), *Isochilina* cf. *perporosa* Poulsen (94), *Isochilina* sp. A (92, 93).

Thickness: 372 m.

Dolomites and Dolomitic Limestones.

Forming a transition group of strata into the dolomites of the overlying Narhvalsund Formation are dolomites and dolomitised limestones, amongst which bands of pure limestone are occasionally interbedded. The dolomitisation is usually manifested as streaks, bands and irregular-shaped masses, which weather more resistantly and to a darker grey colour than the dominantly light-grey weathering limestones. Thin bands and lenticles of chert are more abundant in the lower beds. No fossils of diagnostic value in the determination of stratigraphic age have been discovered in this group of strata. Fossils:— *Helicotoma* sp. (96), ?*Hormotoma* sp. (96), ?*Lophospira* sp. (96).

Thickness: 170 m.

Narhvalsund Formation.

Owing to the nature of its outcrop the measured sequence of the Narhvalsund Formation has been compiled from two separate sections,

linked by horizons common to both. The lower beds were examined in a steeply dipping succession below the unconformable Devonian rocks south-west of the glacier offshoot between Rødøen and Albert Heims Bjerge, whereas the greater part of the sequence was measured in the main cliffs of northern Promenadedal, on the western side of the fault f_{11} (Plate IX).

Basal Dolomites.

The subdivision consists essentially of massive, light-grey, coarsely crystalline, saccharoidal dolomite, weathering light-grey to buff, interbedded with subordinate bands of medium-grey, finely crystalline, dolomitised limestone. The extent of the dolomitisation varies in an irregular manner, giving rise to patches of more or less dolomitic limestone which weather light-grey or buff in colour. Some of the dolomite beds are pink-tinted, or mottled maroon-grey in colour. Thin bands of chert appear at irregular intervals in the upper part of the succession. Fossils:— ?*Leperditia* sp. (97).

Thickness: 112 m.

Dolomitic Limestones.

Showing a transition downwards into the Basal Dolomites, this upper division of the Narhvalsund Formation is formed by a thick sequence of interbedded limestones, dolomitic limestones and occasional dolomite bands. The sequence presents a strongly banded appearance, due to the alternation of beds which differ slightly in lithology and vary in colour from medium-grey to a dark maroon-grey. Although evenly bedded on the whole, individual bands show variations in texture from coarsely crystalline and saccharoidal to finely crystalline or almost porcellanous. Chert is only sparsely distributed, and is confined to the lower half of the subdivision.

Thickness: 350 metres.

Heimbjerge Formation.

A stratigraphical section through the Heimbjerge Formation was measured on a limestone bluff lying to the north-east of the minor fault f_{10}, about four and a half kilometres east of the main peak of Albert Heims Bjerge (Plates III & IX).

Lower Limestones.

Thinly-stratified, lenticular and irregularly-bedded, fine-grained limestones distinguished from the overlying beds by a distinctive maroon-grey coloration and a comparatively thinly-bedded aspect. Fossils:—



Fig. 29. Partly silicified, streaky algal growths in massive limestone from about 232 metres above the base of the Grey Limestones, Heimbjerge Formation. Albert Heims Bjerge.

Rafinesquina sp. (99), *Liospira* sp. (98, 99), ?Bathyurid ind. (98, 99), *Bumastus* sp. ind. (99), *Illaenus* sp. ind. (99), *Primitia* sp. (99).

Thickness: 13 m.

Grey Limestones.

A thick group of massive, medium-grey, finely crystalline limestones, weathering cariously to a light-grey colour on exposed surfaces. Bedding is generally obscure within the group, except where revealed by more thinly stratified horizons. Many of the limestones show a true 'calcarenitic' texture, being composed of fine-scale intraformational conglomerates, in which minute rounded fragments (2 mms maximum diameter) of limestone are embedded in a calcite matrix. The strata are only sparsely fossiliferous. Fossils:— ?*Calapoecia* sp. (106), *Receptaculites* '*arcticus*' Etheridge (103, 104), ?*Cyclospira* sp. (100), *Leptaena* sp. ind. (106), *Öpikina* sp. (106), *Rafinesquina* sp. (cf. *alternata* Conrad) (100, 106), *R.* sp. (106), *Maclurites* sp. (106), *Endoceras*? (105), ?*Bathyurellus* sp. (106), *Bumastus* aff. *fronto* Troedsson (106), B. sp. (106), *Remopleurides* sp. B (106), *Eurychilina* sp. (102).

Thickness: 307 m.

Locality 30.

A few fossils of considerable stratigraphical value were obtained from some limestone crags about $3^1/_2$ kilometres north of the main peak of Albert Heims Bjerge. As the outcrop is surrounded on all sides by deposits of glacial debris, no certainty exists as to the true relationship of the limestones at this locality with the measured sequence. However, lithological and faunal similarities provide convincing evidence to show that the limestones belong to the Grey Limestones of the Heimbjerge Formation.

The dominant lithology of the outcrop is constituted by a hard, massive, medium-grey and crystalline limestone, which is penetrated by abundant segregations and veins of secondary calcite. The bedding of the limestone is obscured by the uniformly light-grey and carious appearance of all weathered surfaces. Fossils:— Orthid ind., ?*Strophomena* sp. ind., *Maclurites* sp., *Bumastus* sp., *Calliops* sp., *Illaenus* cf. *groenlandicus* Troedsson, *Pliomerops* sp. (cf. *parvus* Billings), *Remopleurides* sp. B, *Sphaerexochus* sp. (cf. *canadensis* Billings), *Anisochilina punctulifera* Teichert, *Eurychilina* sp.

Locality 32.

Situated in a much faulted and sheared area on the western side of the river which emanates from the snout of the glacial offshoot to the west of Rødøen, this locality is ascribed with less certainty to the Heimbjerge Formation but the rocks nevertheless show a number of comparable features. The dominant lithology is massive, grey, finely crystalline limestone, traversed by numerous veins of red-stained calcite. Fossils:— *Receptaculites* '*arcticus*' Etheridge, ?*Eofletcheria* sp., *Leptaena* sp. (cf. *richmondensis praecursor* Foerste), *Hormotoma* sp., Trilobite ind.

B. Structure.

i. Folding.

The main fold in the Albert Heims Bjerge—Reservatet area is a steeply plunging syncline with a somewhat indeterminate axial-plane direction of approximately SW—NE. From variations in dip directions it might be considered that the area is part of a slightly elongated basin, which has its north-eastern half obscured by Wordies Gletscher. The regional structure makes the concept of a plunging syncline more acceptable, however, and the values of dip in the eastern part of Promenadedal on the southern flank of the syncline are greater than near the fault f_7 where the dip can be ascribed to the plunge of the principal fold. Dip values in Reservatet are certainly not large and can only be estimated

from the outcrops mapped by means of aerial photographs, and also where the strata can be seen across the river emanating from Irisgletscher. Near fault f_1, along the southern bank of the river, dips of about 27° were obtained, and this value was subsequently used as a guide in drawing horizontal section AA_1. If the estimated value is correct the syncline is asymmetrical, greater dips (50°—60°) being common in the south-eastern limb.

The plunge is evidently variable; the axial plane must be near the position of, and in the same direction as, f_5 and f_7 where they cross Vibekes Elv. There the true angle of dip of the strata, which is presumably equal to the angle of plunge of the fold, averages approximately 27°. On the plateau of Albert Heims Bjerge, north of f_6 and near the Devonian unconformity, the plunge is apparently between 10° and 20°. This may be taken as indicating that the point of maximum axial depression is beneath the Devonian towards the north-east.

The Devonian sandstones and conglomerates lying unconformably upon the Cambro-Ordovician rocks overstep from Heimbjerge Formation on to the Kap Weber Formation: the surface of unconformity is considerably irregular (Plate III). The angular discordance, as shown by dips taken above and below the surface of erosion, is in many cases not great. At the river near Rødøen the Kap Weber Formation has a dip of 50°, while just over a kilometre to the north-west the Devonian is inclined in roughly the same direction at 30°. Between f_{10} and f_{11} the Narhvalsund Formation has a dip of 35°, while that of the Devonian is probably about 25°, but in much the same direction. At the fault between f_4 and f_6 the inclination of the Devonian is in a similar direction to that shown by the Heimbjerge Formation. In the area around f_4 the direction of tilt in the Devonian strata has swung around to a direction slightly south of east, in common with the Ordovician beds below the unconformity, there being little difference between the strata of the two systems in values of dip.

ii. Faulting.

Faults are, in general, roughly parallel to dip and directed towards the centre of the synclinal trough. The faulting cannot be fully explained and has not been adequately mapped as the geological mapping always yielded priority to the stratigraphical measurements and fossil-collecting. Some areas were inaccessible at the time of year, from May to August, when the work was proceeding: at this season melting proceeds apace and rivers are in flood.

The fault f_1 has a considerable movement and brings Lower Tillite against Bastion Formation. The dip of the fault-plane is unknown: the strong curvature shown on the map does not necessarily indicate a low

angle but could be due to a change in strike of the fault surface. f_1 and f_2 can both be definitely traced as far as the river, but beyond there is no evidence available. f_2 is the most powerful dislocation in the area and probably meets the fault which crosses the eastern end of Vibekes Sø (p. 45), although Bütler (*in* Koch, 1950, Pl. 7) gives a different interpretation. The dip of the fault-plane is fairly steep to the south-east. If the slip is assumed to be chiefly dip-slip it is a normal fault with considerable throw, juxtaposing Lower Tillite and Dolomite Point Formation which are stratigraphically separated by 1120 metres of sediments. The fault f_3 is inferred largely from the disappearance of outcrops, which could only be observed with binoculars from the south side of the river. It is not necessarily continuous with f_1, and is possibly related in some way to f_2 and f_4. This small area with f_1, f_2, f_3 and f_4 is not properly understood, nor are the reasons for the curvature of f_1 and f_3.

The fault f_4 is inferred from the disappearance of the Narhvalsund and Heimbjerge Formations, and their replacement northwards by the Kap Weber Formation. Due to movements associated with f_1, f_2, f_3 and f_4 the Heimbjerge Formation seems to be absent in Reservatet, and does not appear in the north-western limb of the syncline, as shown in the section AA_1. The Narhvalsund Formation is also absent in that part of the section, but a limited outcrop of it is presumed to be present elsewhere in Reservatet.

Between f_2 and f_7 dip-faults occur which are probably normal and downthrow uniformly to the south-east. The fault f_7 is a major one, throwing down to the south-east and bringing Bastion Formation against Hyolithus Creek Formation, a movement in the region of 200 to 300 metres. The striking nature of the fault-cleft and the displaced formations can be seen in Plate II; the unnumbered fault between f_5 and f_7 can also be seen in the left of the photograph. The whole of this step-faulted valley-side is illustrated in Plate I. The two faults immediately to the south of f_7 probably throw down to the south also, and seem to join with one another and f_7 on Søryggen to the south-west of Vibekes Elv. Between f_7 and f_8 the dip swings from north-east to north, and the faults f_8 and f_9 follow this change to a great extent, remaining dip-faults. In contrast, however, the throw of these eastern faults (assuming, as seems likely, that they are true dip-slip faults) is down to the west by considerable amounts. Fault f_{10} has only a small movement, but probably throws down to the west, as does f_{11} and the fault to the east. It is of importance that direct evidence was obtained for the continuation of f_{11} for some distance into the Devonian conglomerates and sandstones. The throw of the fault is considerably greater in the Lower Palaezoic rocks, but the displacement of the unconformable Devonian was quite definite, along a clearly and easily traced fault-line.

The limestone plateau of Albert Heims Bjerge (Plates II and III), formed largely in Kap Weber Formation which has been abraded into *roches moutonées*, partly covered by scree and glacial debris, is a very difficult area for geological mapping. Recognition of horizons in the Kap Weber Formation, either by lithology or fossil fauna, is practically impossible. Faults can only be recognised by brecciation, red staining and other features. The Narhvalsund Formation forms a useful "marker horizon" in this area, and enables f_4, f_6, the eastern end of f_7 and the northern end of f_9 to be mapped.

There is evidence for the existence of thrusting in cliff exposures between f_{11} and the stream issuing from the glacier snout west of Rødøen. Thrust-planes can be seen close to the glacier itself although the ice-cliffs of the snout, glacial rivers and ice-polishing make their study difficult: it was not possible to mark them on the map. Aerial photographs of the Rødøen cliffs suggest that the Kap Weber Formation is much faulted and disturbed in this area.

iii. Interpretation.

The asymmetrical plunging syncline in the late Pre-Cambrian and Cambro-Ordovician strata was formed after the Middle Ordovician sediments of the Heimbjerge Formation had been laid down, and before the deposition of the unconformably overlying Devonian clastics, the age of which is not definitely known, although considered to be possibly Middle Devonian. Judging by the disappearance of some faults at the junction with the Devonian, they also originated largely within the same time interval as the main fold. The faulting, mainly directed towards the NE-SW axis of the syncline may be due to adjustments penecontemporaneous with the principal folding. The reversal of throw as the axis is crossed, from an easterly downthrow, may also be significant in this respect.

From a consideration of the dips in the Devonian strata it is probable that additional folding occurred after their deposition. The possibility cannot be excluded that the changing directions of dip in the Devonian strata—from almost due north near Rødøen, to south of east near the fault f_4—could be due to a depositional or initial dip of the sediments. It seems likely, however, that posthumous folding has occurred; posthumous movement of a fault is certainly displayed by f_{11}.

The first and presumably most important period of movement was Caledonian *sensu lato*, and probably Taconian in age. The second period of detectable movement, either Devonian or post-Devonian, may have been Acadian, and contemporaneous (or pene-contemporaneous) with the movements described by Bütler (1954).

C. Physical Features.

i. Introduction.

Part of Hudson Land, Ole Rømers Land, Stenos Land and Bartholins Land, see Plate VIII, are surrounded on three sides by ice—Waltershausen Gletscher, the main inland ice-cap and Wordies Gletscher; smaller valley-glaciers and upland ice-caps also break up the region into a complex pattern of land and ice. The fourth side is formed on the south-east by Vrangelven, which flows from Krumme Langsø, through Johan Davidsens Dal and along the edge of Waltershausen Gletscher, into Nordfjord. A low watershed (454 metres in height) from the acute bend of Krumme Langsø to Vibekes Elv in Promenadedal (fig. 30) and the line of Vibekes Elv to the sea near Wordies Gletscher, completes the boundary with the remainder of Hudson Land.

The main part of northern Hudson Land south of Vibekes Elv, with the Tagbjergene rising on the southern side of Promenadedal, is an alpine area with sharp peaks and ridges, cirques and small valley-glaciers descending from mountain ice-caps. Numerous small rivers descend from the Tagbjergene into Vibekes Elv, but the stream issuing northwards from Stordal is small. The watershed in the great valley is close to Promenadedal, and the topographical misfit river drains southwards through a series of lakes into Moskusoksefjord.

Ole Rømers Land and the Albert Heims Bjerge—Reservatet area present a very different type of topography from that shown by the main part of northern Hudson Land, due to a number of reasons, one of which is their close proximity to the main inland ice-cap and greater distance from the sea, which results in reduced precipitation and a higher altitude for permanent snow and ice. Another reason for this difference is the nature of the rocks, which are mainly limestones, dolomites, shales and sandstones; there are no metamorphic and igneous types like those found to the south in Hudson Land and to the west in Bartholins Land and Stenos Land. Few peaks are more than 1000 metres in height, and the effect of relief is further reduced by the considerable elevation of valley-floors in this inland region. The gently undulating plateaus seen in Plates I and II, bear much glacial debris, although rock outcrops are never far to seek. The moderately steep valley walls descend to wide valleys often containing lakes, such as Vibekes Sø and Krumme Langsø. Some of these valleys, such as the lower part of Johan Davidsens Dal and Promenadedal have until recent times been the site of lakes.

There is abundant evidence to show that the present drainage system is the result of comparatively recent glacial retreat. The outlet of Vibekes Elv past Wordies Gletscher into Wordies Bugt, and of Vrang-

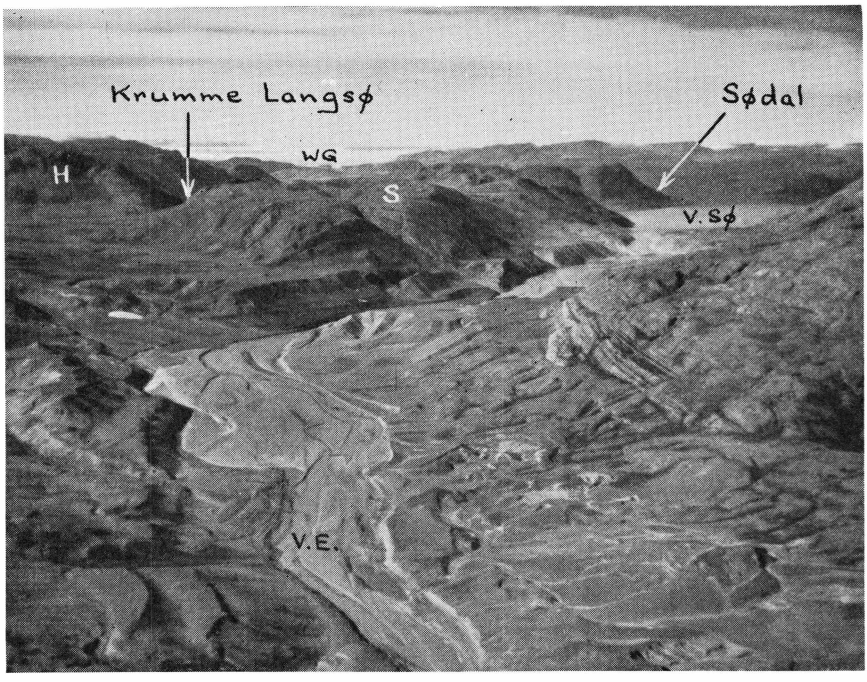


Fig. 30. Aerial photograph of the upper part of Promenadedal showing part of Ole Rømers Land, and the lower slopes of Albert Heims Bjerge. *H* – Hjørnebjerget, *W.G.* – Waltershausen Gletscher, *V. Sø* – Vibekes Sø, *V. E.* – Vibekes Elv, *S* – Søryggen.

elven past Waltershausen Gletscher into Nordfjord, must have been inoperative or restricted at some time during recent geological history. Even at the present day these outlets have a variable control on the level of the river waters, comparable with the sluice-gates of a dam, as revealed by the deposits along the river banks. The flat-topped deposits from which Promenadedal derives its name, and which are also found between that valley and Krumme Langsø (Plate I; Fig 30), are lacustrine in origin. The superficial deposits at the western end of Krumme Langsø and in Sødal, are of a similar nature and origin. The height of the water-shed in Stordal is such that a great lake flooding the valleys of Ole Rømers Land would most probably have drained southwards through that valley, if the outlets past Wordies Gletscher and Waltershausen Gletscher had been sealed off by ice. Such a hypothesis would explain the steep-sided, trench-like profile of Stordal, which could hardly be caused by the erosive power of a river of the present size. Both Vibekes Elv and Vrangelven show rejuvenation, with attendant cutting-down through the lacustrine deposits, which is considered to be largely due to the glacial retreat as described above. However, it may be partly ascribed to isostatic or eustatic adjustments (Plate I; Fig. 30).



Fig. 31. The lacustrine deposits (approximately 150 metres high) of Promenadedal, seen from the frozen surface of Vibekes Elv. In the background is Albert Heims Bjerge.

In addition to this evidence of glacial retreat, the valley-sides of Promenadedal and the cliffs above the shores of Vibekes Sø show many horizontal terraces, which occur up to several hundred metres above sea-level. Some of the 'steps'—which cut across geological features, and bear large quantities of morainic material, including erratic boulders of exotic lithological types—may be seen in Plate II, to the right of the fault f_7. The most striking relict erosion levels are seen on the slopes of the Tagbjergene, opposite Albert Heims Bjerge, and are comparable with the classic 'Parallel Roads' of Glen Roy in Scotland (Holmes, 1944, 236—267, Plate 56).

ii. The Albert Heims Bjerge—Reservatet area.

The orientation of Promenadedal is evidently governed by the regional strike of the rocks. Minor valleys and clefts, not shown by the contours on Plate IX, occur along or near the line of such faults as f_1, f_2 and f_7 (Plate II). The valley (fig. 26), the upper reaches of which are occupied by a branch of Wordies Gletscher west of Rødøen, probably owes its

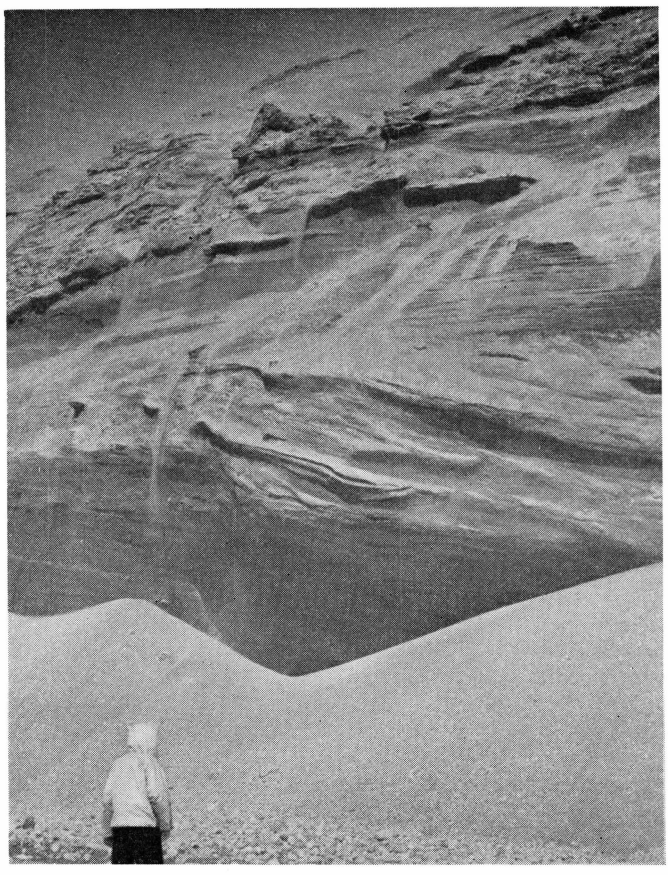


Fig. 32. Cross-bedding in lacustrine deposits, Promenadedal. The rivulets of sediment streaming down the cliff have been loosened by wind-action.

existence to the erosion of much faulted and shattered strata. The direction of Irisgletscher appears to be similarly related to the strike of the beds in Reservatet. In general, the uplands are formed in limestone or dolomite of the Limestone-Dolomite Series (late Pre-Cambrian), or of the sequence between the Hyolithus Creek and Heimbjerge Formations. The softer and more easily eroded Cass Fjord Formation often serves to undercut and steepen the cliffs of the Kap Weber Formation which lie above. A similar effect is caused by the shaly Bastion Formation which undercuts the Ella Ø and Hyolithus Creek Formations (Plate II); the same relationship appears to exist between the Narhvalsund and Heimbjerge Formations judging by the changes of slope seen in the cliffs (Plate III). The Devonian seems to be easily eroded, and generally gives rise to a gently undulating and monotonous terrain in Albert Heims Bjerge, Reservatet and Rødøen (Plate III).

The lacustrine deposits of Promenadedal were examined in some detail: their flat tops gave a route for easy travel (Plate I). Although they are between 150 and 200 metres thick, Vibekes Elv has cut down through them and often flows over solid rock, which is probably part of the original valley floor exposed before the superficial deposits were laid down. The deposits are essentially clastics which vary in grade from fine silt to boulders, but are predominantly composed of sand and silt (fig. 31). The larger heterogeneous cobbles and boulders are well-rounded and fairly well-sorted, and their deposition was almost certainly under water. Lithification and compaction have not proceeded far, varying with the grade, porosity and depth of burial—the finer grades are closer to rock than the coarser. Bedding is clearly seen and cross-bedding is common (fig. 31). The winds which blow down the valley from Vibekes Gletscher strongly erode these poorly compacted silts and sands. This is effected not only by drifting and dust storms, but the cliffs, which have been caused by the cutting down of the rivers and streams, are broken down by undercutting and fretting, releasing minor slides and rivulets of loosened material (fig. 32); this includes large boulders which, in the spring, can bowl at speed across the frozen river to the diversion of those who use it for sledging.

IV. ELLA Ø

A. Stratigraphy.

The approximate measured thicknesses of the formations in Ella Ø are, to the nearest 5 metres (see plate XIII):—

Narhvalsund Formation		250	metres
Kap Weber	–	1040	–
Cass Fjord	–	255	–
Dolomite Point	–	420	–
Hyolithus Creek	–	210	–
Ella Ø	–	80	–
Bastion	–	140	–
Kløftelv	–	75	–
Spiral Creek	–	25	–
Canyon	–	220	–

Canyon Formation.

This succession of shales, dolomites, limestones and siltstones was fully measured along the stream gorge of Storeelv to the west of Bjørnesø, near the eastern branch of the Tømmerbugt fault system (Plates IV & X). The lower part is described from this exposure, but the description of the upper part, which is more detailed, applies to a section studied in the faulted block of strata to the east of Antiklinalbugt on the south coast (Plate V). The descriptions of these measured sections, and those of younger formations, are to be found in the Appendix with those given for Albert Heims Bjerge.

Spiral Creek Formation.

The sequence of dolomites and siltstones was examined in the stream cleft of Kløftelv, in the gorge of Storeelv, and along the anticlinal core on the south coast. The descriptions and thicknesses (fig. 34) are based on exposures examined in the faulted block to the east of Antiklinalbugt on the south coast (Plate V).

b. On the lower surfaces of the siltstone bedding-planes are found casts of salt (NaCl) crystals, in the form of hopper cubes (fig. 37).

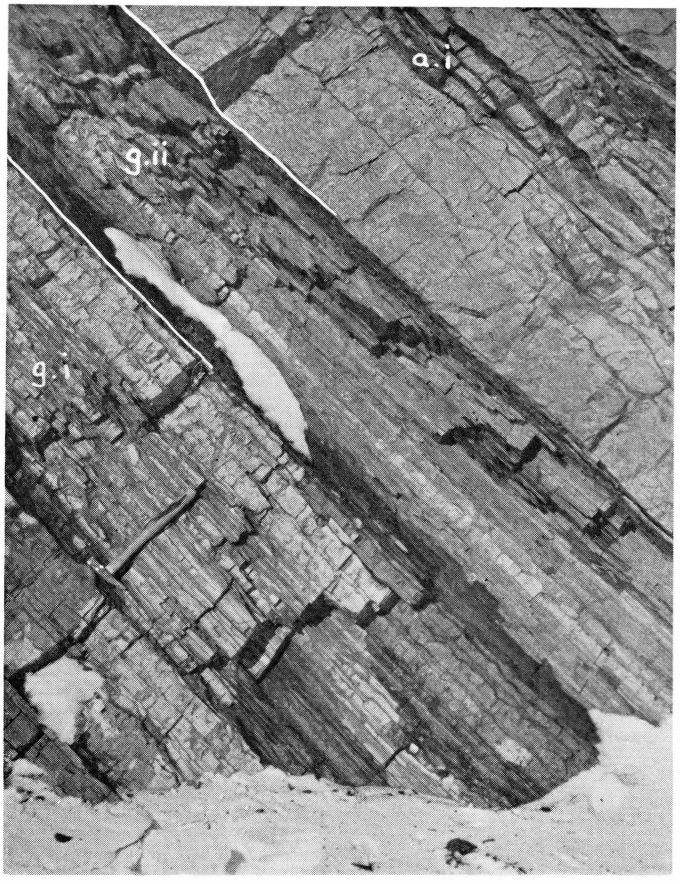


Fig. 33. Top of Canyon Formation and base of overlying Spiral Creek Formation shown in faulted block to the east of Antiklinal Bugt, south coast of Ella Ø. Canyon Formation: g.i & g.ii. Spiral Creek Formation: a.i. The length of the hammer is 34 cm.

There is no discontinuity between the dolomitic siltstone of the salt casts and that of the overlying bed. The cubes occur at the junctions between siltstone and shale horizons and their surfaces have a thin veneer of argillaceous material. The orientation of the cubes varies, they frequently occur with faces subparallel to the bedding.

The size of the cubes commonly ranges between 5 mm and 15 mm, but smaller and larger examples may be found—the largest collected was 32 mm square. These salt casts are found throughout the subdivision; limited to the lower surfaces of bedding-planes they form a useful criterion for the order of superposition (Shrock, 1948, 146—149, figs. 105—107).

e. The dolomite has prolific chert disseminations of all sizes and shapes, lenticles, bands, blebs, streaks, pisolites and oolites. Some of

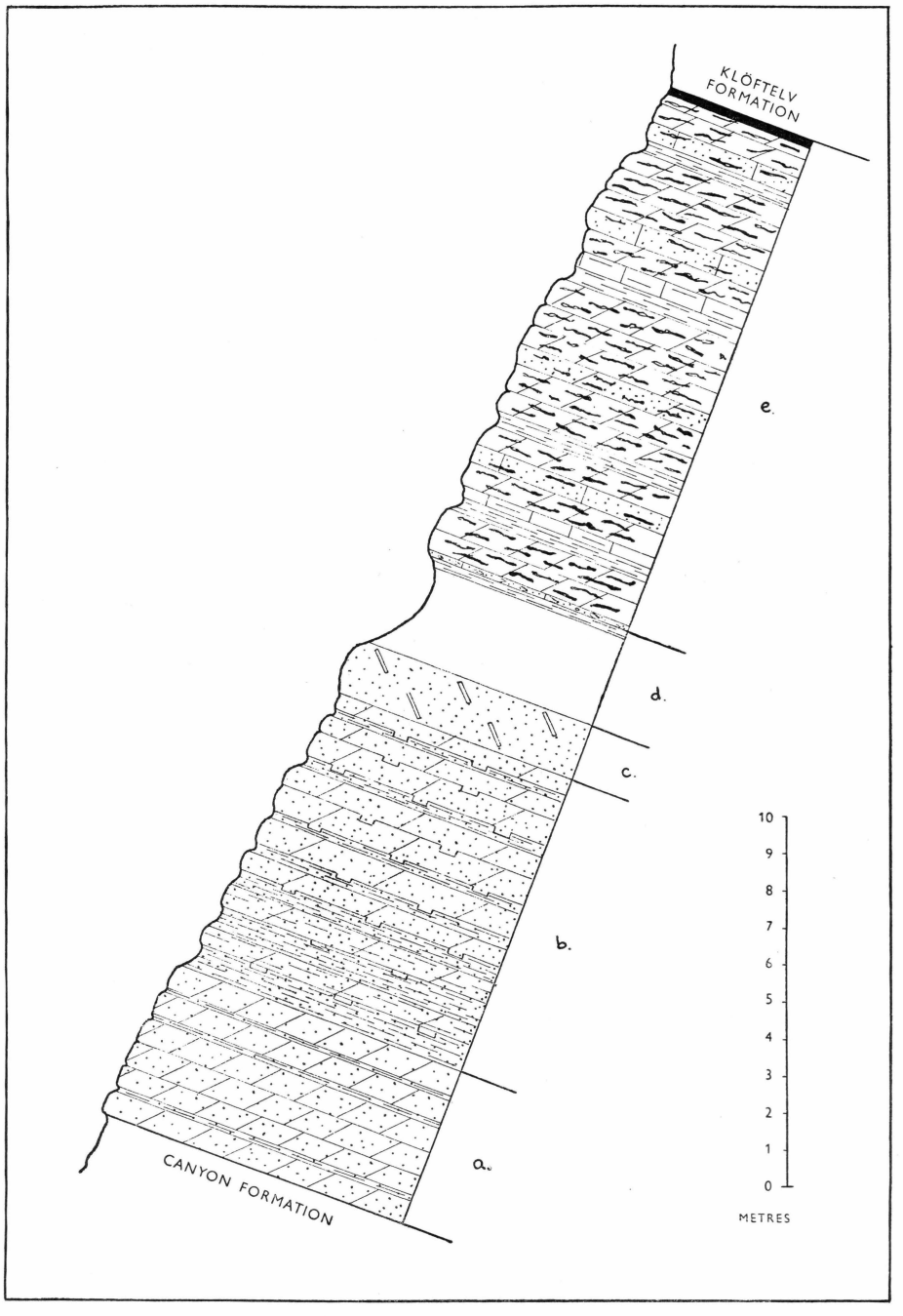


Fig. 34. Profile of Spiral Creek Formation.

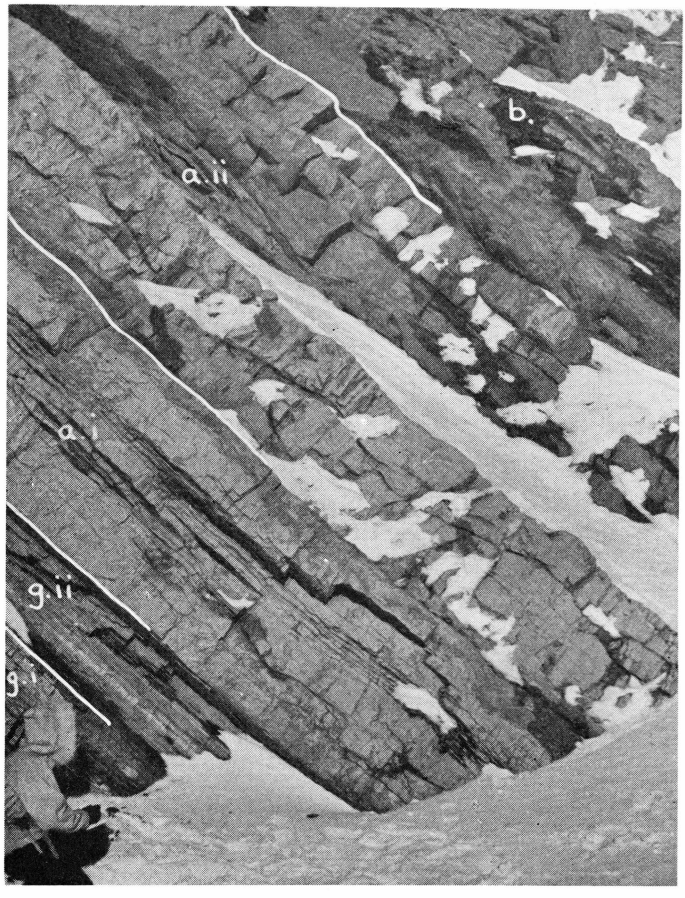


Fig. 35. Lower subdivisions of Spiral Creek Formation overlying Canyon Formation, south coast of Ella Ø, fault block to east of Antiklinalbugt. Canyon Formation: g.i. and g.ii. Spiral Creek Formation: a.i., a.ii and b.

these are very irregular in shape and appear to cut across the bedding, although the bedding is, in detail, most irregular. The drawn-out lenticles and streaks have an undulating character with great lateral variation in both lithology and thickness, the chert pisolites and plates sometimes forming impersistent beds. In some collected specimens the percentage of siliceous material was found to be greater than that of the mineral dolomite. The chert is predominantly dark-grey or black, with a black patina which can be seen in thin section to be due to a concentration of minute opaque mineral grains on the outside of the chert—probably iron oxide (fig. 39). Occasionally near the top pink-grey varieties of dolomite are found. Stylolites are well developed in the dolomite at some horizons.

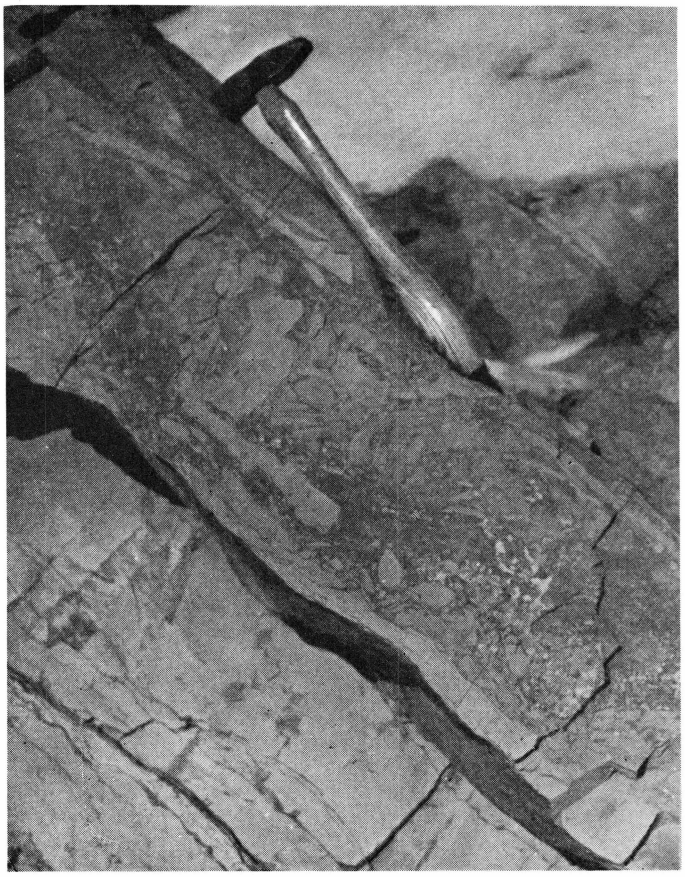


Fig. 36. Intraformational conglomerate at top of subdivision a.i of Spiral Creek Formation in the fault block east of Antiklinalbugt, south coast of Ella Ø. Length of hammer = 25 cm.

Kløftelv Formation.

This formation was measured in two places on the south coast: in the core of the anticline, and in the faulted block along its south-eastern limb. The latter supplies the main lithological description, but the former is taken in some parts of the succession to give more accurate thicknesses. The succession is illustrated by a profile in fig. 40. The correlation with Albert Heims Bjerge is shown in fig. 9.

Bastion Formation.

Being easily eroded, and having a stratigraphical position below the massive rocks of the Ella Ø and Hyolithus Creek Formations, this formation is frequently covered by scree or vegetation. Parts of the sequence can be examined east of the Kløftelv fault above Bjørnesø,

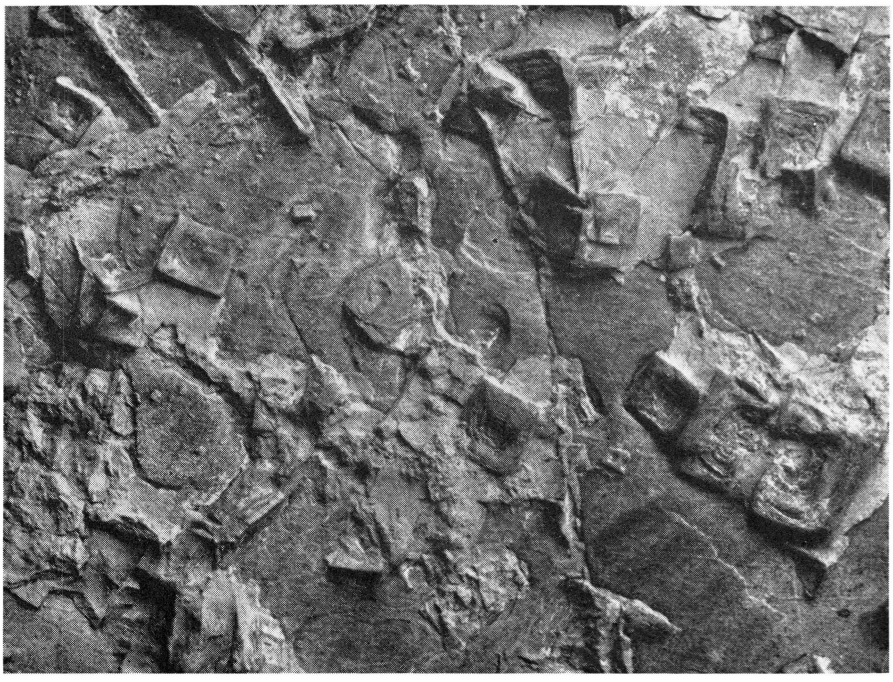


Fig. 37. Pseudomorphs of hopper-cube crystals of salt on the lower surface of a siltstone bedding-plane, Spiral Creek Formation. South coast of Ella Ø. (×1).

and in the cliffs above Bastionbugt. The exposures on the plateau between Kap Oswald and Antiklinalbugt are most restricted and the type occurrence at Bastionpynt, originally described by Koch, is incomplete and faulted (p. 114). The best section is found in the cliffs of the south coast above Antiklinalbugt: the succession illustrated by a profile in fig. 42 is take from the eastern limb of the anticline.

Lower Bastion Formation.

The succession is illustrated by a profile in fig. 42.

Glauconitic Sandstones.

a. A whitish-grey glauconitic and siliceous conglomerate is the basal subdivision, which laterally changes in composition to a coarse-grained quartzite and weathers to a rusty-brown. Black phosphatic nodules, pellets and grains occur (fig. 43) comparable with those already described in a similar stratigraphical position in Albert Heims Bjerge (p. 52). As previously stated they may indicate the existence of organisms, and, in conjunction with the conglomerate and glauconite suggest an interruption of sedimentation.

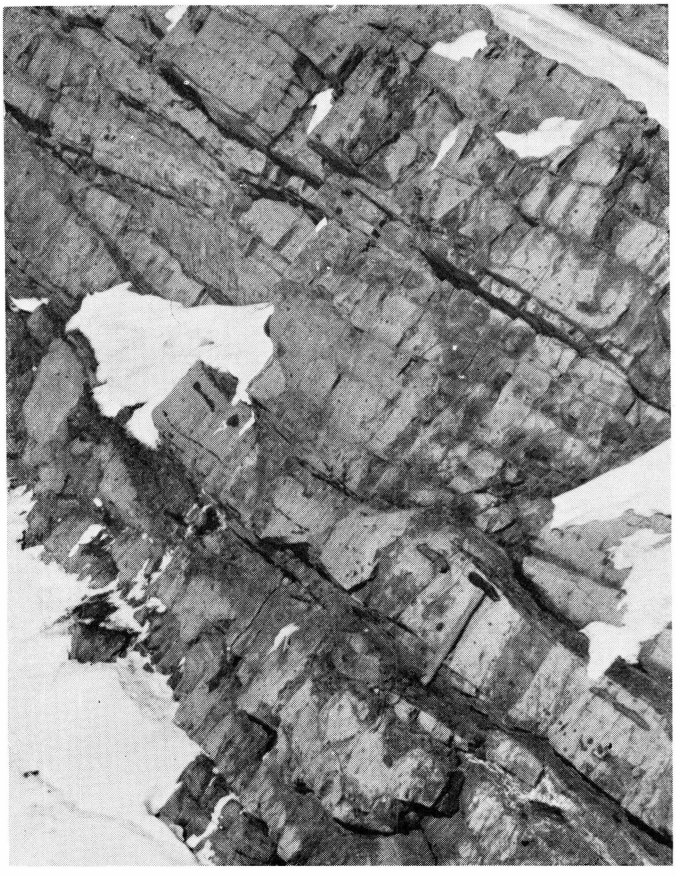


Fig. 38. Lower part of subdivision *e* of Spiral Creek Formation, south coast of Ella Ø. Length of hammer 34 cm.

Upper Bastion Formation.

The profile, fig. 44, illustrates the succession.

Lower Shell-Limestone.

The lithology of this basal subdivision is closely comparable with the corresponding unit at the base of the upper Bastion Formation in the Albert Heims Bjerge area, and the same lithological description (p. 55) will suffice. If a difference can be discovered it is that the Ella Ø samples contain a little more glauconite, but this is a conclusion based on study of thin sections and is unnoticeable in the lithological specimens and in the rock outcrops. The thickness of the southern outcrop varies between 35 and 90 cm.

As in Albert Heims Bjerge this is the first fossiliferous horizon encountered ascending the succession and the fauna comprises



Fig. 39. Chert in dolomite, subdivision *e* of Spiral Creek Formation, south coast of Ella Ø.

(Fossil Horizon A):— Lingulid ind., ?*Mickwitzia* sp., Hyolithid ind., Olenellid ind.

Lower Shales.

Glauconitic arenaceous shales yielding *Botsfordia* sp. (C), *Discinella* sp. (B, C), *Kutorgina* sp. (B), Lingulid ind. (B, C), *Paterina* sp. (B, C), Hyolithid ind. (B), Olenellid ind. (D).

Upper Shell-Limestones.

The shell-banks differ from those at a similar horizon in Albert Heims Bjerge, in being set in a calcareous mudstone. This subdivision, although without doubt soundly correlated with the corresponding part of the section in northern Hudson Land, is in general less massive, more argillaceous and less calcareous. The shales are highly glauconitic and in places are a true greensand weathering to a soft green powder. Fossils:— Gastropoda ind. (E).

Upper Shales.

Fossils:— Lingulid ind. (G), Olenellid ind. (F, G, H, J).

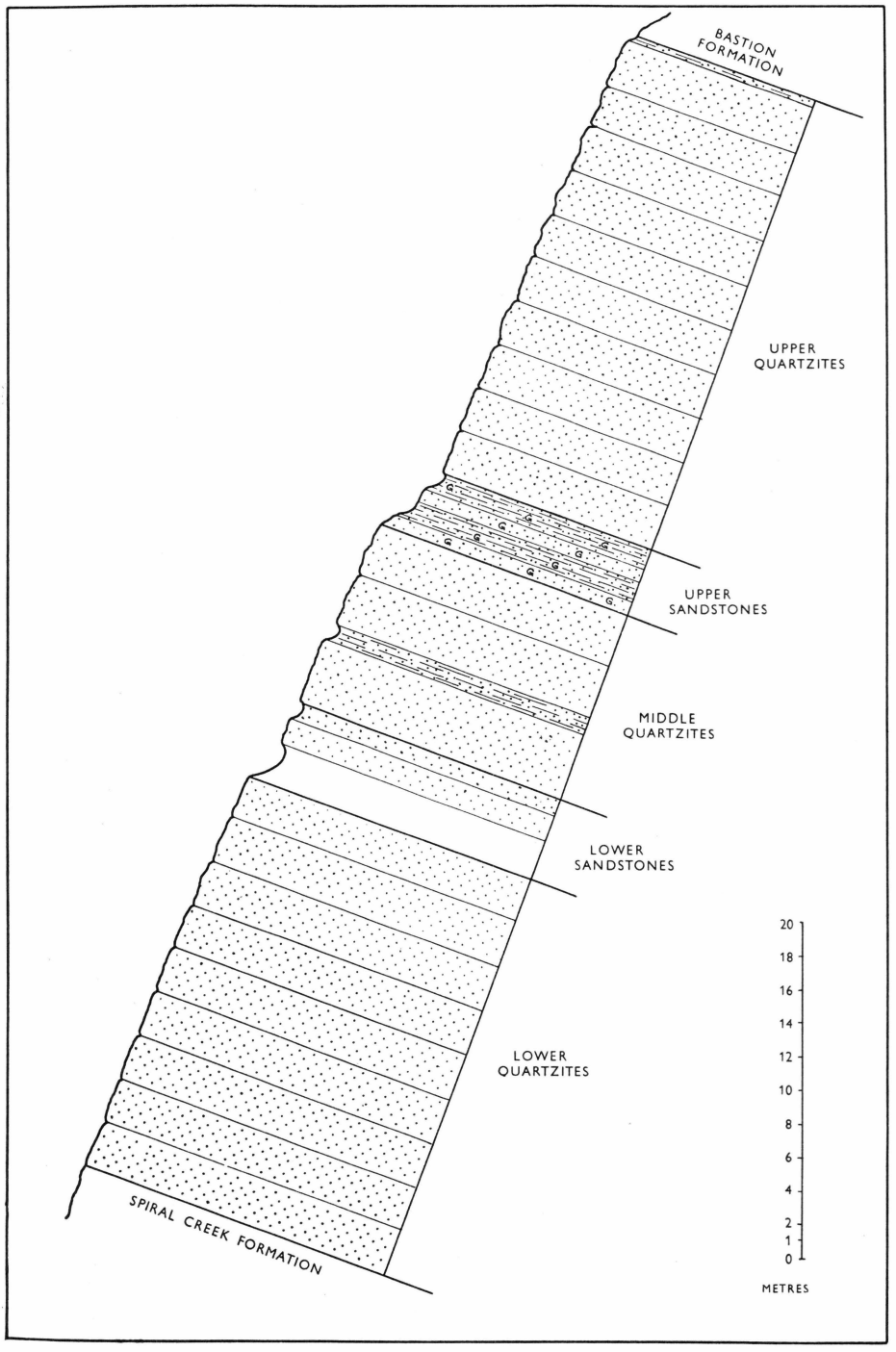


Fig. 40. Composite profile of Kløftelv Formation.

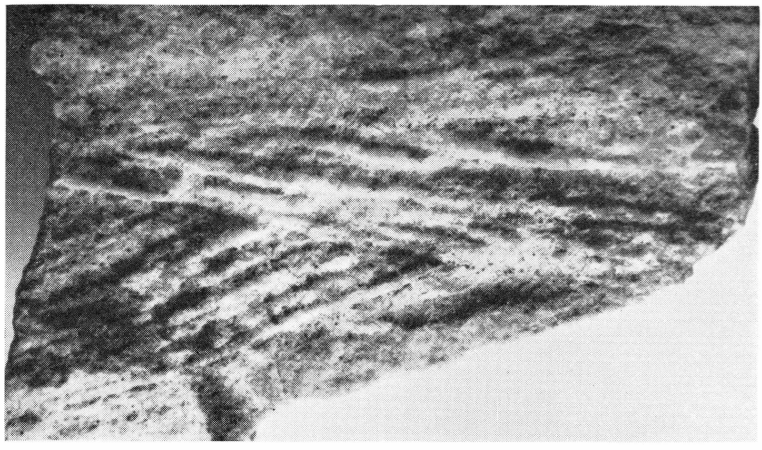


Fig. 41. Cross-bedding in quartzite, Lower Quartzites, Kløftelv Formation. South coast of Ella Ø. (× 1/2).

Ella Ø Formation.

All the major exposures of this formation were examined but the best section is on the south coast—in the eastern limb of the anticline (fig. 5). The succession is illustrated by a profile in fig. 45.

Lower Limestones.

Fossils:— *Discinella micans* (Billings) (X), Lingulid ind. (M), *Micromitra* sp. (N), ?*Bonniella* sp. (S), *Calodiscus agnostoides* (Kobayashi) (R), *C.* aff. *lobatus* (Hall) (P, R, V), *C.* sp. nov. C (R), *C.* sp. (P, R, V), *Olenellus* sp. (P, R, S), Olenellid ind. (K, L, M, N, O, Q, T, U, V, W, X).

Shaly Beds.

See Fig. 47.

Upper Limestones.

Fossils:— *Acrothele* sp. (Z), *Discinella micans* (Billings) (Y), *Discinella* ind. (Z), Hyolithid ind. (Z), ? *Bonniella* sp. (Y), *Calodiscus* aff. *lobatus* (Hall) (Y), Dorypygid ind. (Y), Olenellid ind. (Y, Z, AA, AB, AC, AD, AE, AG), *Proliostracus rosenkrantzi* Poulsen (AF), ?*Protypus* sp. (Y).

Hyolithus Creek Formation.

The section in the eastern limb of the anticline on the south coast was continued through this series of dolomites. This formation is usually very inaccessible and it is doubtful if the complete thickness can be

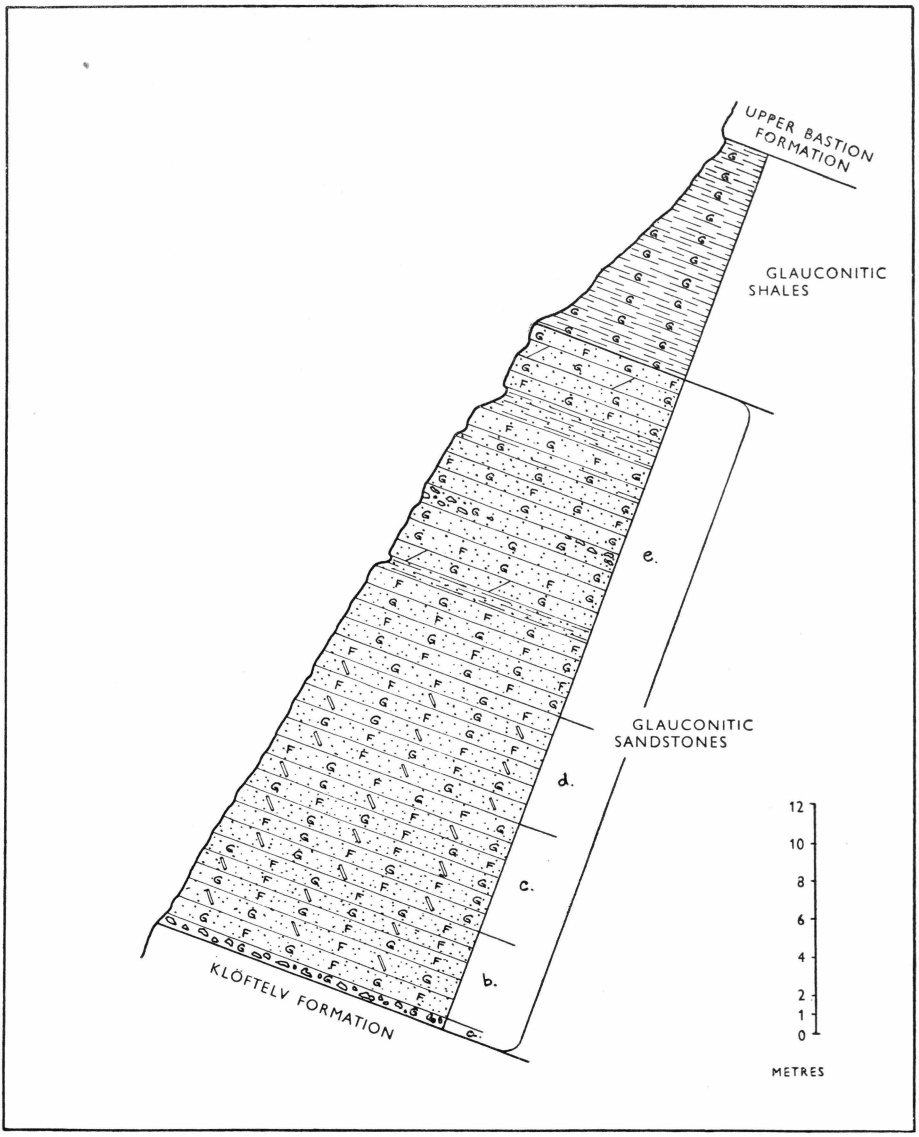


Fig. 42. Profile of lower Bastion Formation.

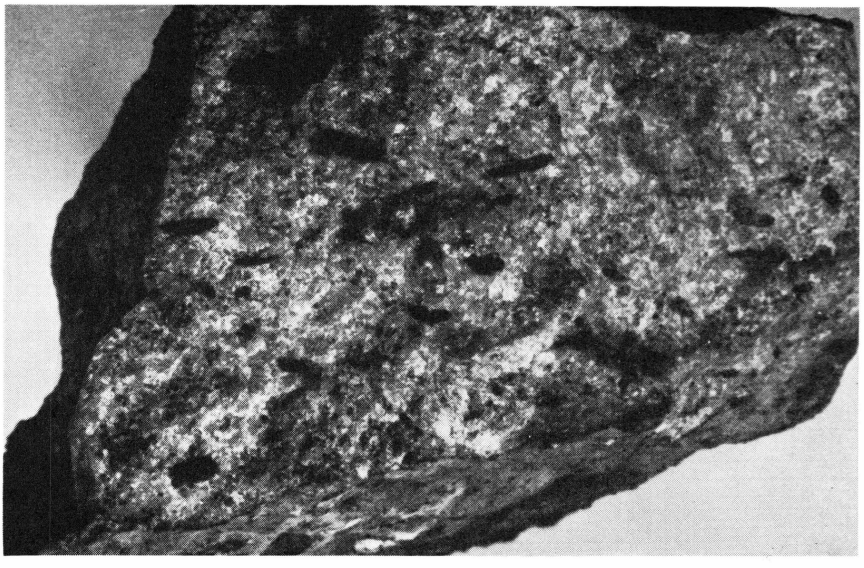


Fig. 43. Phosphatic nodules in quartzite of basal subdivision, Glauconitic Sandstones, lower Bastion Formation. South coast, Ella Ø. (×1).

examined in one continuous exposure at any other place on Ella Ø. The outcrops in Lemmingdal are chiefly in the valley-bottom and are largely obscured by superficial deposits and vegetation. The vertical section in Plate XIII illustrates the succession. On the north side of Lemmingdal below the window, fossils were collected at 60 metres above the base of the formation from a grey limestone weathering brown; they are specimens of *Salterella* (Fossil Horizon AH).

One difference between the Ella Ø section and that of Albert Heims Bjerge seems to be the absence of chert in the southern section. It is significant perhaps that in all examinations of the formation on Ella Ø, both casual and systematic, no chert has been observed. Eha (1953, 35) mentions the interesting occurrence of siliceous lenses with a diameter of up to 10 cm which "are often met with"—chert is perhaps present in Ymers Ø or Suess Land if not on Ella Ø.

Dolomite Point Formation.

The Dolomite Point Formation was measured and described along the eastern limb of the main anticline on the south coast of Ella Ø.

Lower Dolomites.

The lower part of the Dolomite Point Formation on Ella Ø is composed predominantly of massive-bedded, light-grey, fine-grained dolomite, generally weathering yellow to buff in colour, interbedded with bands of finely crystalline, dark-grey to black, calcareous dolomite, which

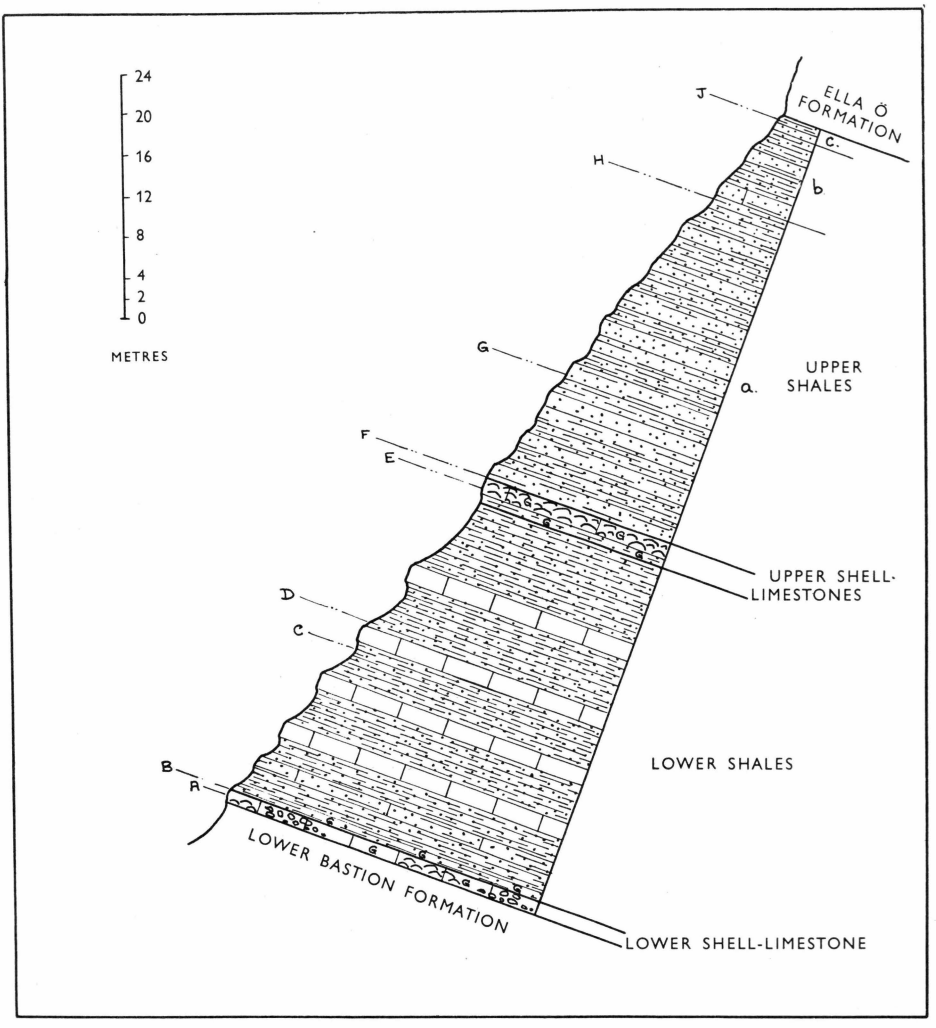


Fig. 44. Profile of upper Bastion Formation.

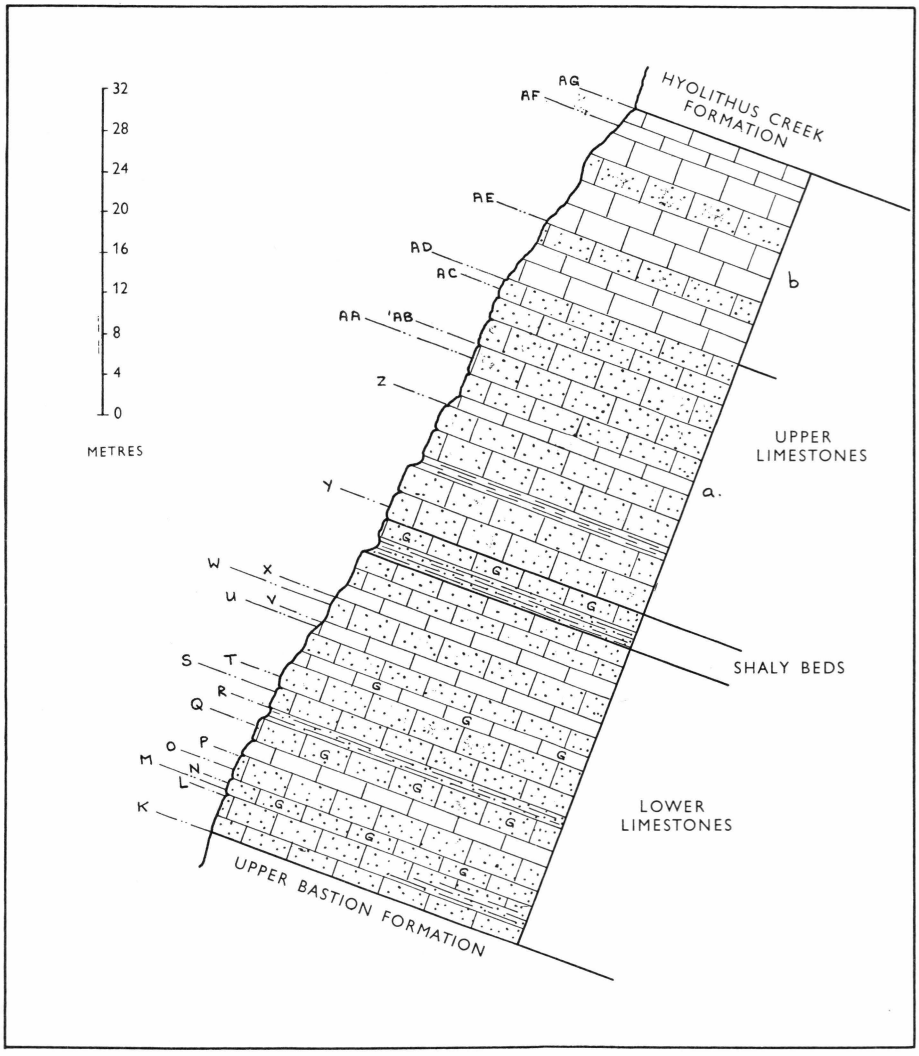


Fig. 45. Profile of Ella Ø Formation.

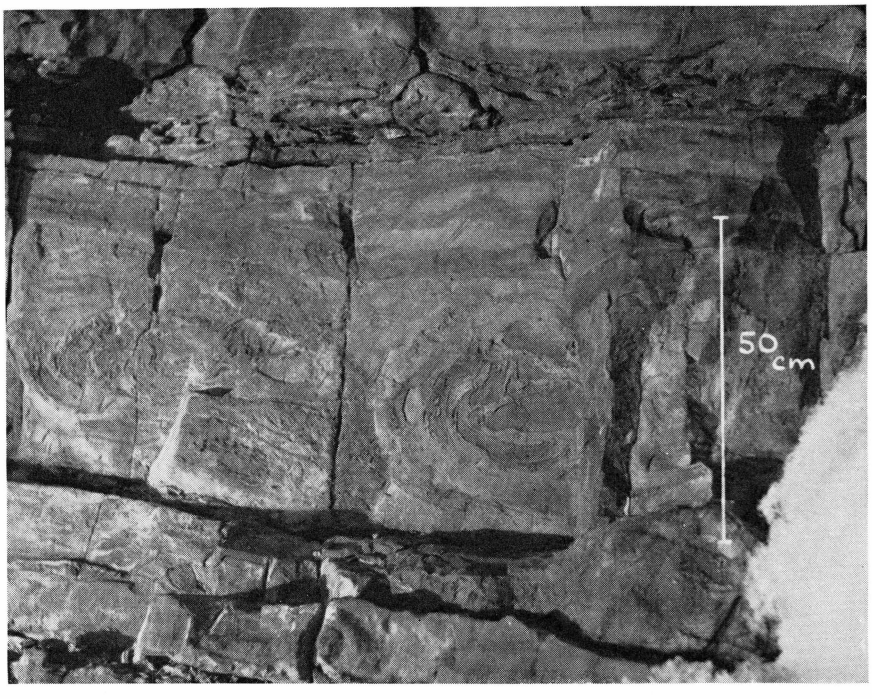


Fig. 46. Slump structure in Lower Limestones, Ella Ø Formation. Ella Ø. These highly contorted beds are found between relatively undisturbed strata, as seen in this figure. Although mainly found in arenaceous limestone, fossiliferous bands of purer limestone may be involved and laminae of comminuted fossil fragments are occasionally found 'wrapped' around the 'hassocky' bodies. Slumping was frequently observed at all levels in the Ella Ø Formation successions in Ella Ø, Albert Heims Bjerge and Ole Rømers Land: it evidently characterises the formation.

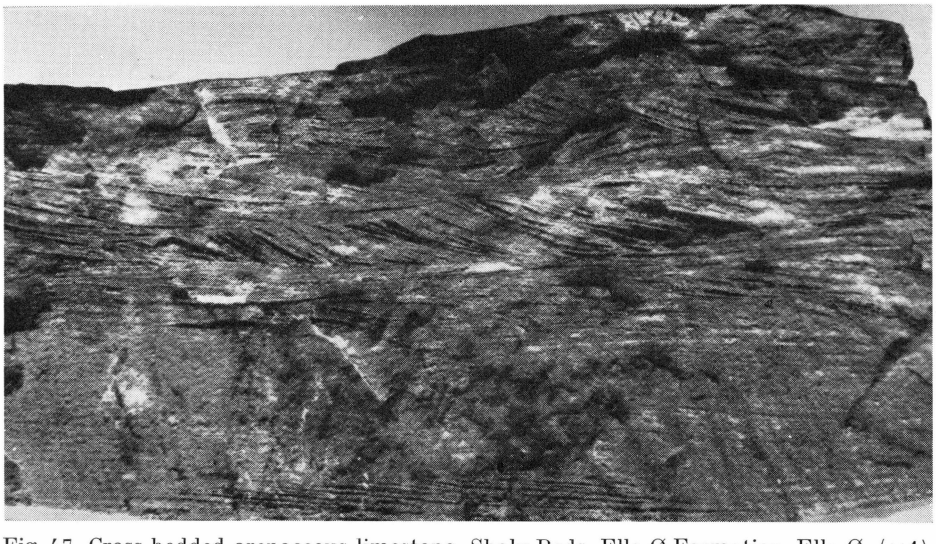


Fig. 47. Cross-bedded arenaceous limestone, Shaly Beds, Ella Ø Formation, Ella Ø. (×1).

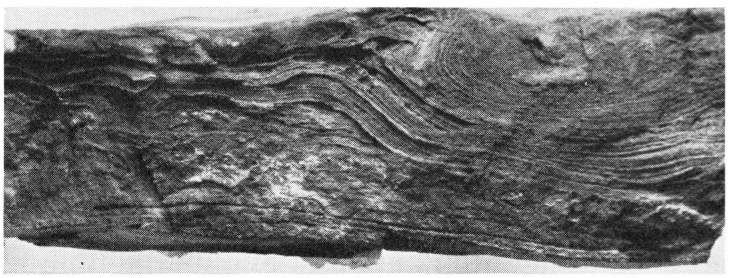


Fig. 48. Slumping in arenaceous limestone, Upper Limestones, Ella Ø Formation. Ella Ø. (× 1/2).

weather to a distinctive brownish-buff hue. Bedding planes are generally wavy and irregular, but become more even in the thinly-bedded strata. Intraformational breccias and conglomerates are present at some levels in the succession and indicate penecontemporaneous erosion. Dark-grey to black-weathering chert also occurs in many parts of the sequence, as nodules, blebs and lenticles along bedding planes.

Thickness: 77 m.

Calcareous Dolomite.

A well-bedded band of dark-grey to black, coarsely crystalline, calcareous dolomite, having a markedly irregular fracture. The rock shows numerous small drusy cavities lined with rhombohedral crystals of yellowish-white dolomite. Although more compact and massive in the uppermost eleven metres the band forms a distinctive brownish weathering marker horizon up the cliff-section. Small pockets of fine-scale brecciation are found in places, but no chert appears to be present.

Thickness: 17 m.

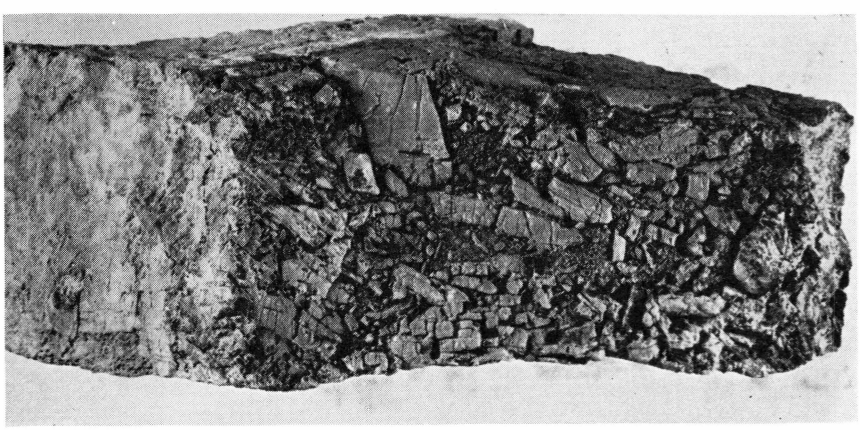


Fig. 49. An intraformational breccia in massive dolomite, 45 metres from base, Lower Dolomites, Dolomite Point Formation. South coast of Ella Ø. (× 1).



Fig. 50. Disturbed bedding in massive, finely crystalline dolomite with darker-weathering laminations of silty dolomite. Broken laminae give rise to an 'edgewise breccia', seen on weathered strike surfaces. 235 m from base of Upper Dolomites, Dolomite Point Formation. South coast of Ella Ø. (×1).

Upper Dolomites.

A thick group of strata which consists predominantly of massive dolomite, fine to coarsely crystalline in texture, and weathering yellowish-buff to grey, interbedded with more thinly-stratified, fine-grained dolomite, which is sometimes shaly in appearance. Bedding is generally slightly wavy, but becomes more regular and even in the thinly-stratified units. Intraformational conglomerates and breccias are present at frequent intervals in the succession, although rarely showing much lateral persistence. Siliceous disseminations, chiefly in the form of chert, are especially well developed in the higher parts of the subdivision.

Thickness: 327 m.

Correlations with the Albert Heims Bjerge sequence.

(1) Lower Dolomites. The subdivision is closely comparable with the Lower Dolomites of the Albert Heims Bjerge succession, but shows a higher proportion of the brownish-buff weathering bands ot calcareous dolomite.

(2) Calcareous Dolomite. The subdivision appears to be the lithological equivalent of the Calcareous Dolomite in Hudson Land, although it is of much greater thickness.



Fig. 51. Arenaceous dolomite showing intraformational conglomerate and current bedding. 302 m above base of Upper Dolomites, Dolomite Point Formation. South coast of Ella Ø. (×1).

(3) Upper Dolomites. There is a considerably greater thickness of strata in the Upper Dolomites of the Ella Ø sequence, and although the lithology throughout both measured sections is essentially the same, no direct correlation between any particular horizons can be attempted. The greater thickness on Ella Ø includes a higher proportion of thinly-bedded and shaly dolomite, a feature which may indicate more continuous deposition in a deeper-water environment, less disturbed by penecontemporaneous erosion.

Cass Fjord Formation.

A completely exposed and measurable section in the Cass Fjord Formation was examined along the eastern limb of the anticline on the south coast of the island.

Lower Transition Limestones.

These limestones were originally given the name 'Brown Beds' during early field investigations, on account of their distinctive brownish-



Fig. 52. Spherical structures on dolomite bedding planes due to peculiar form of chert accumulation. Darker areas represent chert. 317 m above base of Upper Dolomites, Dolomite Point Formation. South coast of Ella Ø.

hued weathering, when compared with the dominantly yellow-buff colour of the underlying Dolomite Point Formation and the greenish-grey colour of the overlying Limestone-Shales.

The greater part of the subdivision is composed of massive, irregularly-bedded limestone, which is appreciably silty at some horizons. The silty limestone often occurs as fine laminae, the less resistant nature of which serve to pick out the irregularities in the bedding. A most distinctive bed of thinly-stratified limestones is silty and argillaceous, and almost shaly in appearance on weathered surfaces. Intraformational conglomerates are present in the subdivision, but chert appears to be confined to the higher beds.

The first supposedly Ordovician fossil horizon occurs near the top of the Lower Transition Limestones, although yielding only unidentifiable orthid brachiopods.

Thickness: 31.8 m.

Limestone-Shales.

Comprising the greater part of the Cass Fjord Formation, the Limestone-Shales consist of thinly-bedded, nodular and lenticular muddy limestones and shaly partings, alternating with subordinate bands of more homogeneous limestone. The lithology of the Limestone-Shales is

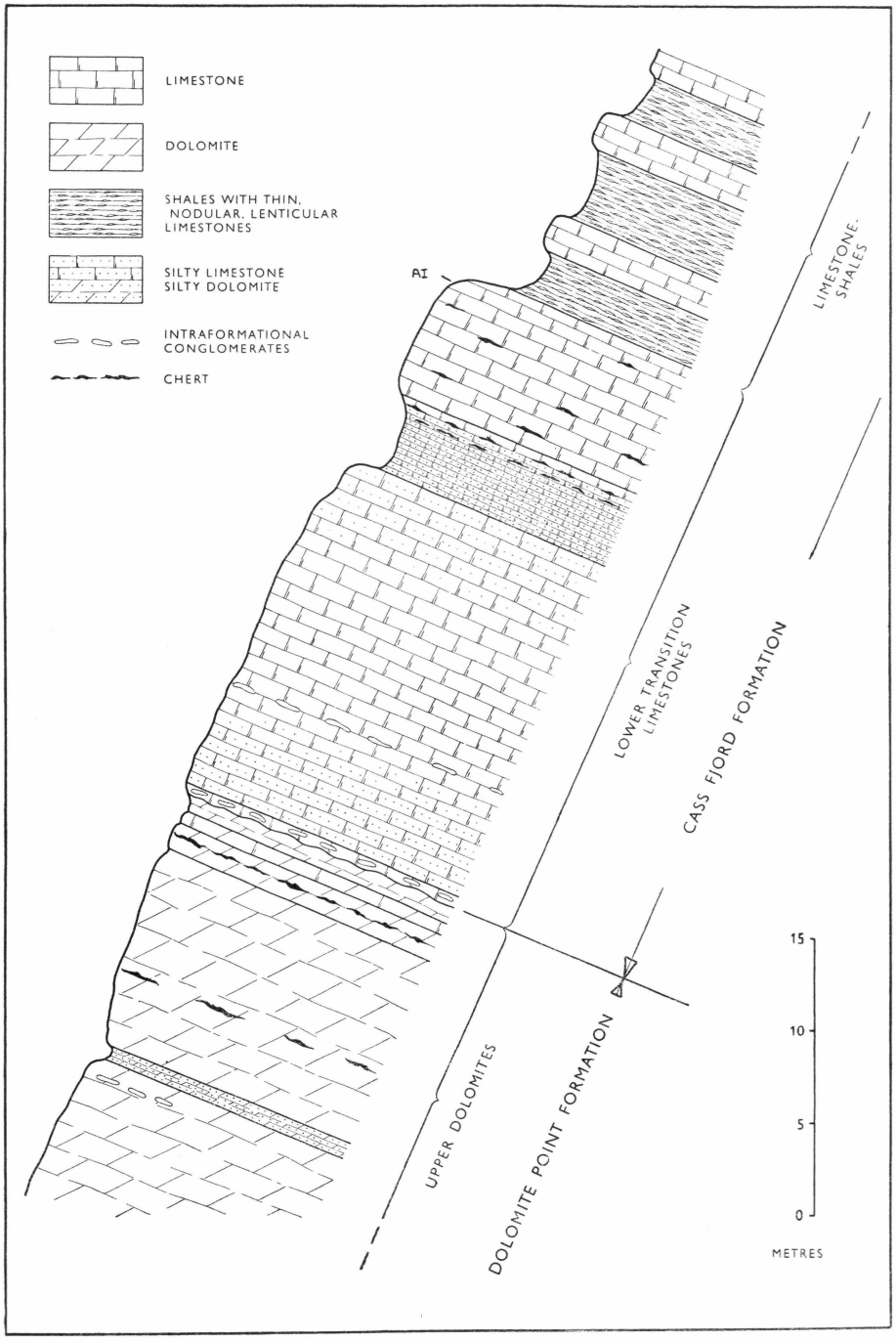
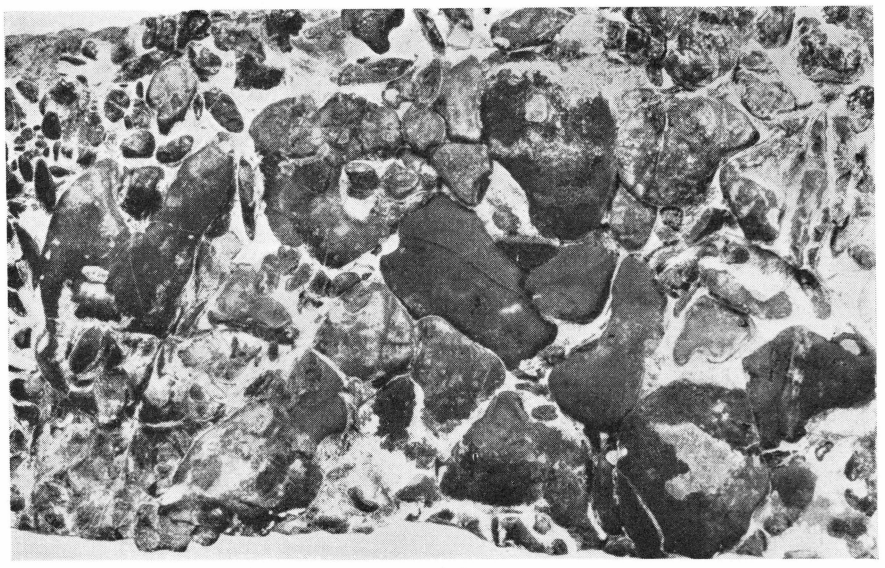
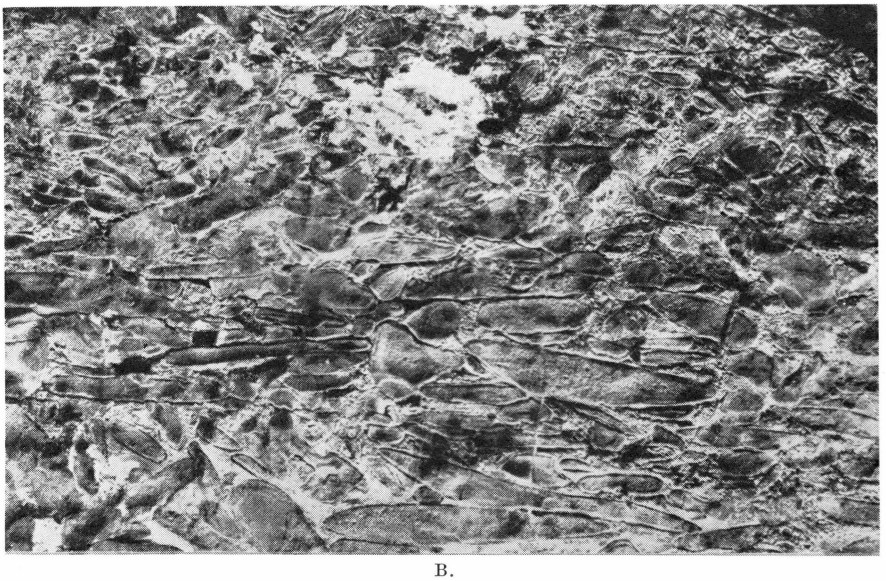


Fig. 53. Profile of Lower Transition Limestones, Cass Fjord Formation.



A.



B.

Fig. 54. A massive band consisting almost entirely of limestone intraformational conglomerates. 156.3 m above base, Limestone-Shales, Cass Fjord Formation. South coast of Ella Ø. A. Top bedding-plane, B. Weathered strike surface. (×1).

essentially the same as that displayed by the equivalent subdivision of the Albert Heims Bjerge measured section, described in general terms on page 64.

Thickness: 209 m.



Fig. 55. Thinly bedded limestones with argillaceous partings. When compared with the typical lithology of the Limestone-Shales (see fig. 25) the more regular bedding of the limestone laminae, and their greater average thickness becomes apparent. 30 m above base of Upper Transition Limestones, Cass Fjord Formation. South coast of Ella Ø.

Fossils:— *Lingulella* sp. (AQ), *Schizambon nobilis* Poulsen (AN), Hydrophorida ind. (AL, AM, AO), *Sinuopea whittardi* Poulsen (AK), *Hystricurus armatus* Poulsen (AO), *H. sulcatus* Poulsen (AJ), *H.* sp. (AL), *H.* sp. ind. (AN, AO), *H.* ? sp. (AJ), '*H.*' sp. ind. (AM), *Pseudohystricurus* ? sp. ind. (AO), *Symphysurina elegans* Poulsen (AR), *S.* sp. (AJ, AL, AO).

Upper Transition Limestones.

The subdivision consists essentially of a series of massive limestone bands, separated by beds of thinly-stratified, lenticular and nodular limestones with partings of greenish-grey shale. Passing up the sequence there is a gradual reduction in the proportion of nodular limestones and shales, and an increase in the proportion of more homogeneous and evenly-bedded limestone bands. Intraformational limestone conglomerates still make an important contribution to the lithology of the sequence.

Thickness: 39.2 m.

Fossils:— *Hystricurus ravni* POULSEN (AS), *H.* sp. ind. (AS, AT), *Pseudohystricurus* ? sp. ind. (AW), *Symphysurina* cf. *porifera* POULSEN (AS, AV), *S.* sp. (AU).

Correlations with the Albert Heims Bjerge sequence.

(1) Lower Transition Limestones. The group of strata is remarkably similar in lithology to the equivalent subdivision of the Cass Fjord Formation in the Albert Heims Bjerge region of northern Hudson Land. The subdivisions in both areas show a basal band of black limestone with a distinctive intraformational conglomerate, a bed of thinly-laminated, silty limestones, and a restriction of chert to the higher strata (compare figs. 24 and 53).

(2) Limestone-Shales. Many lithological comparisons may be made between the Limestone-Shales of the two areas, but detailed faunal correlations are lacking. The gastropod *Sinuopea whittardi* (fossil horizons AK, 59, 61 and 62) appears to be confined to the lower part of each subdivision, although the distribution of the brachiopod *Schizambon nobilis* (fossil horizons AN and 55) is not so limited.

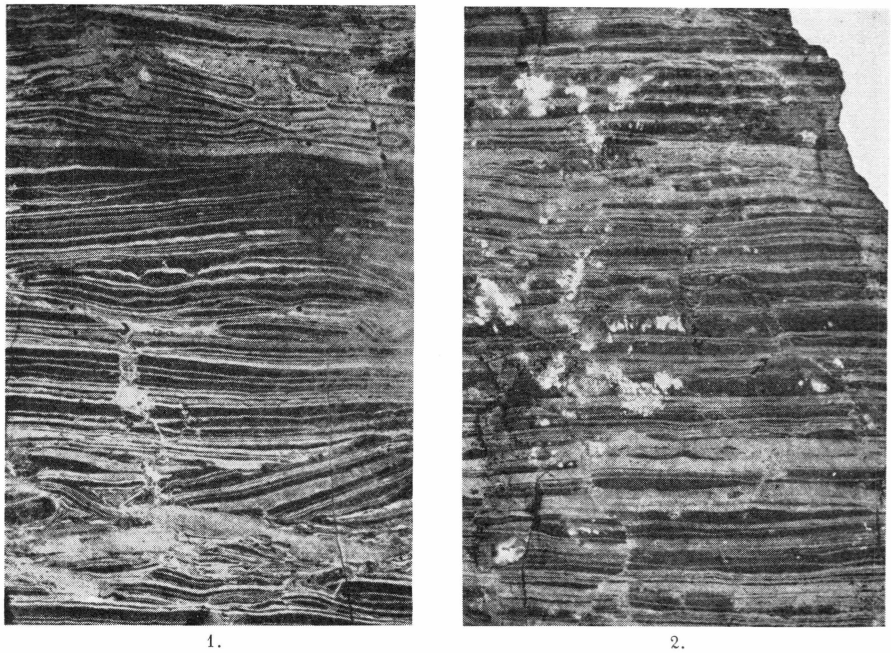
(3) Upper Transition Limestones. The transition from the lithology of the Limestone-Shales into the Kap Weber Formation takes place in a similar manner in both regions, without any disconformity being apparent. The trilobite *Symphysurina* cf. *porifera* is the characteristic fossil of both sections.

Kap Weber Formation.

The rocks of the Kap Weber Formation in Ella Ø have been broadly subdivided into the three lithological groups below:—

Subdivision	Thickness	Fossil Horizons
Dolomites and Dolomitic Limestones	140 m	BS, BT
Main Limestones	680 m	BH — BR
Banded Limestones	220 m	AX — BG
Total.....	1040 m	

The lowermost part of the Kap Weber Formation, the Banded Limestones, was examined and measured on the south coast of the island, along the eastern limb of the main anticline. The remainder of the formation in this section could not be given more than a brief scrutiny at the time, owing to the difficult and lengthy negotiation of steep, snow-covered screes at the cliff-base. The formation was re-measured at a later date, on the central plateau between the main Tømmerbugt and Kløftelv



1. 2.

Fig. 56. A comparison between the thinly-laminated dolomitic limestones near the base of the Kap Weber Formation on Ella Ø and in northern Hudson Land. 1. Lower Limestones, 60 metres above base, Hudson Land. 2. Banded Limestones, 20 metres above base, Ella Ø. (×1).

faults, north-west of the Devonian unconformity (see Plate X). The Main Limestones, together with the overlying Dolomites and Dolomitic Limestones, were fully examined and sampled over the continuous sequence exposed in the area, but the lower beds of the formation were merely checked in order to confirm lithology and thickness. As in northern Hudson Land, it has not been possible to map these subdivisions of the Kap Weber Formation because of their ill-defined boundaries.

Banded Limestones.

The banded appearance of the subdivision is due to alternating beds of limestone, the colour of which varies from dark to light-grey, and to the greyish-buff weathering dolomitisation along some bedding planes. Such banding is well displayed in the cliffs along the south-western coastal section of the Bastion syncline, and is illustrated in fig. 8. Many beds in the lower part of the sequence are finely-laminated, as shown by fig. 56, but individual bands generally range in thickness from about a half metre to about two metres. Some of the limestone bands possess markedly convex and hummocky bedding planes, a feature which strongly suggests an origin partly due to algal activity.

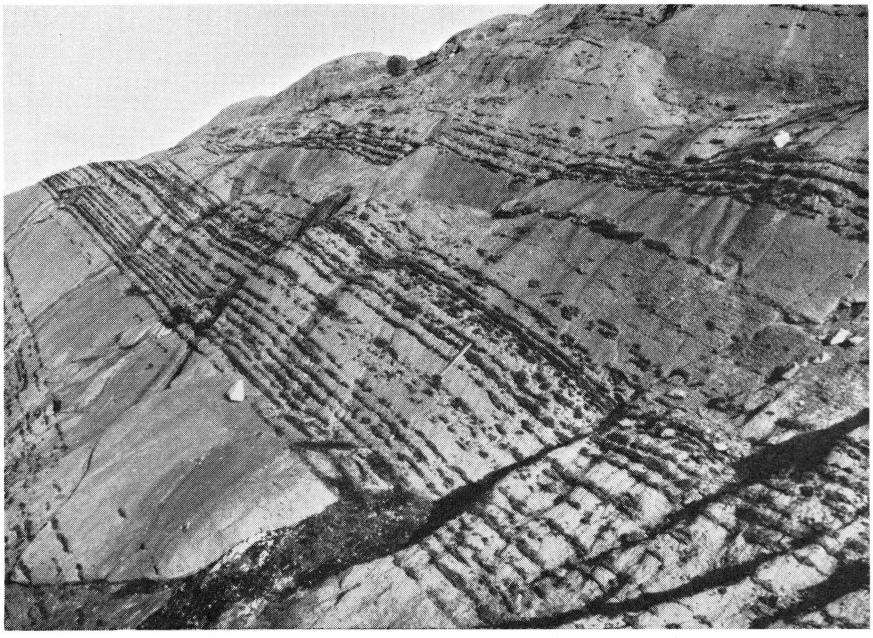


Fig. 57. Black-weathering chert as blebs, stringers and thin bands in massive grey limestone. 540—560 m above base, Main Limestones, Kap Weber Formation. Central plateau of Ella Ø.

Intraformational limestone conglomerates are present in many parts of the sequence, and are often on such a fine scale that they become almost indistinguishable from the homogeneous limestones. They are particularly noticeable where interbedded with the thinly-stratified, nodular and lenticular limestones and shales, which crop out occasionally in the succession.

Chert is encountered as small blebs and lenticles at some horizons, but is not widely disseminated, and is of only minor significance.

Thickness: 220 m.

Fossils:— Orthid ind. (AZ), *Hormotoma* sp. (AX, AY), *Bathyurellus* sp. A (BB), *B.* sp. (cf. *teicherti* POULSEN) (BC), *B.* sp. (BF), *B.* sp. ind. (BD), Bathyurid ind. (AZ, BA), *Bolbecephalus* sp. (cf. *seelyi* WHITFIELD), '*Hystricurus*' spp. (BF), Trilobite ind. (BF), *Isochilina* sp. (BB, BC, BD, BE, BF), ?*Peltabellia* sp. (BG).

Main Limestones.

The Main Limestones comprise a thick sequence of essentially massive-bedded, grey limestones and dolomitised limestones. Although minor variations in lithology occur through the subdivision, weathered surfaces

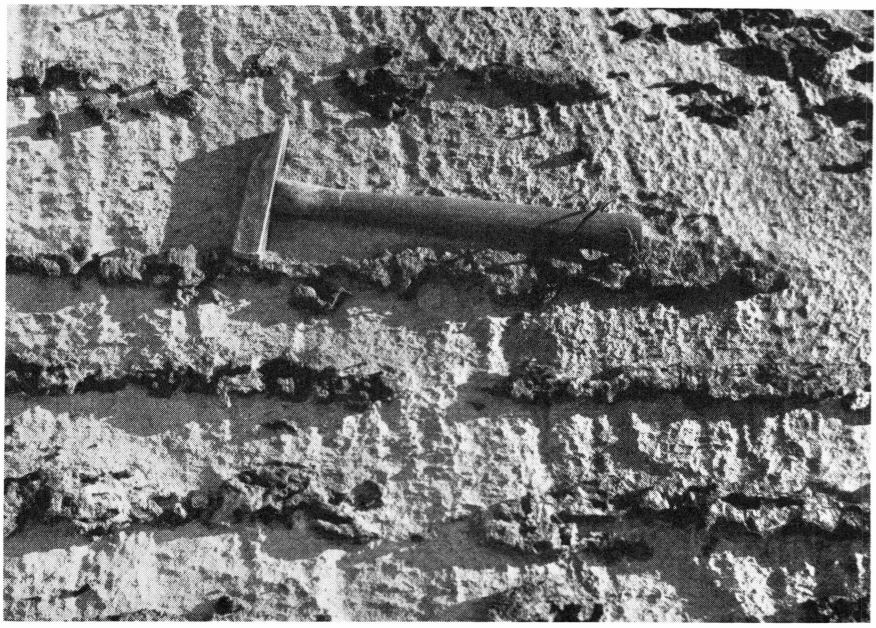


Fig. 58. A close-up view of the chert disseminations seen in fig. 57. Note the carious weathering of the limestone. 545 m above base, Main Limestones, Kap Weber Formation. Central plateau of Ella Ø.

acquire a uniformly light-grey coloration, only modified by the presence of brownish-black chert and dark greyish-buff dolomitic segregations parallel to the bedding. The uniform coloration is also accentuated by the almost ubiquitous carious weathering of the glaciated surfaces, which cover the greater part of the rock outcrops on the central plateau of the island.

Thickness: 680 m.

Fossils:— Porifera ind. (BP), *Helicotoma* sp. (BQ), *Holopea* sp. (BR), *Hormotoma* sp. (BQ), *Maclurites* sp. (BO), '*Orthoceras*' sp. ind. (BO), *Bathyurellus teicherti* Poulsen (BH), Bathyurid ind. (BH, BI), *Bathyurina* sp. A. (BN), '*Gignopeltis*' sp. (BL, BM, BN), *Goniotelina* sp. (cf. *brighti* (Hintze) (BQ), *Hystricurus* sp. ind. (BJ), ?*Niobe* sp. A (BJ), *Raymondaspis* sp. B (BK), *Uromystrum affinis* (Poulsen) (BH), Styginid ind. (BH), Trilobite ind. (BQ, BL), *Isochilina* sp. A (BR), ?*Peltabellia* sp. (BM).

Dolomites and Dolomitic Limestones.

The topmost group of strata in the Kap Weber Formation of Ella Ø consists of massive-bedded, grey limestones, which have been more or less transformed by extensive secondary dolomitisation. Such dolomitisation is revealed on exposed surfaces as dark-grey streaks and bands,

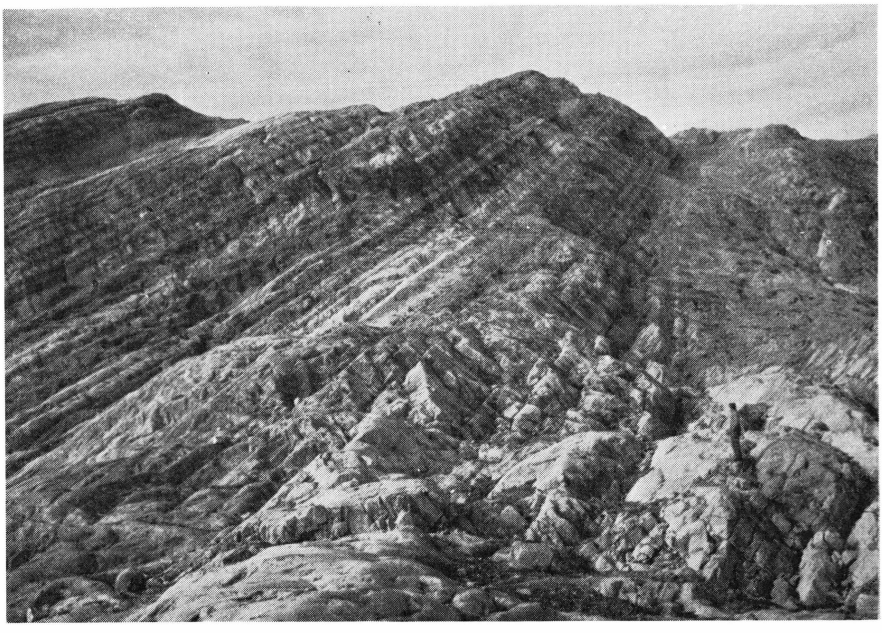


Fig. 59. Higher beds of Main Limestones, central plateau Ella Ø. Typical form of extensively glaciated outcrop in foreground—note figure on right.

which weather more resistantly than the light-grey weathering limestone. Towards the top of the sequence these dolomitic segregations become so heavily concentrated as to impart a strongly banded appearance to the strata. Lenticular masses of greyish-white cryptocrystalline silica also occur in these higher beds, but lower down in the group silicification is manifested as scattered lenticles of brown to black chert. The junction with the Basal Dolomites of the overlying Narhvalsund Formation is conformable, sharp and well-defined. Thickness: 140 m.

Fossils:— *Bathyurellus* ? sp. (BT), Bathyurid ind. (BS), *Bolbocephalus groenlandicus* ?POULSEN (BT).

Correlations with the Albert Heims Bjerge sequence.

(1) Banded Limestones. The succession of alternating light and dark-grey limestones seems to have its counterpart in the Lower Limestones of Hudson Land. Algal limestones form an important contribution to the lithology displayed by the subdivisions of both areas, although no direct correlations can be made between any particular strata. An examination of the faunas yielded by the two comparable sections shows that *Bathyurellus* sp. 'A', present in horizon BB of Ella Ø, also occurs at horizons 75 and 77 of Hudson Land.

(2) Main Limestones. This sequence of strata must be, broadly speaking, equivalent to the Black Limestones and Upper Limestones of Hudson Land, but in the absence of distinctive marker horizons, no direct lithological correlations can be attempted. Tentative faunal correlations may be made between horizon BN (*Bathyurina* sp. A, '*Gignopeltis*' sp.) and horizon 87 of the Black Limestones, and between horizon BR (*Isochilina* sp. A) and horizons 92 and 93 of the Upper Limestones.

(3) Dolomites and Dolomitic Limestones. Sufficient lithological similarities exist between the two measured sections in the upper part of the Kap Weber Formation to warrant the same name being applied to both subdivisions. The paucity of fossils precludes any faunal correlations.

Locality 2.

Situated on the east coast of the island, on the col between Ingridbugt and Marabugt (Plate X), Locality 2 is formed by grey, crystalline limestones of the Kap Weber Formation. Fossils found at this locality include *Bathyurellus* sp., ?*Bathyurina megalops* Poulsen and *Isoteloides* sp.

Although lithological and faunal evidence is insufficient for the locality to be related to any particular part of the measured section, the geological map of Ella Ø (Plate X) indicates its approximate location in the middle of the formation, probably in the Main Limestones. This conclusion is supported by the presence in the fauna of *Isoteloides* and questionable *Bathyurina megalops*, both of which have closely allied forms occurring in the Black Limestones (fossil horizon 87) of northern Hudson Land, which are thought to represent part of the Main Limestones of Ella Ø.

Locality 22.

Near the hut at Kap Margrethe the exposed rocks are massive, medium-grey limestones, of a fine-grained to granular-crystalline texture, which are so irregularly jointed and fractured as to form much fragmented and rubbly outcrops. Fine calcite veining is also in evidence, and occasionally imparts a conglomeratic appearance to the limestone. A few metres south of the locality considerable brecciation of the limestone, accompanied by red staining and calcite veining, suggest the presence of a fault, which probably strikes northwards beneath the cover of glacial debris occupying the low-lying ground. The postulated fault is shown in Plate X. Fossils:— Orthid ind., *Bathyurellus* sp., *Benthamaspis problematica*? Poulsen, *Bolbocephalus* sp. (cf. *seelyi* Whitfield), *B.* sp. ind., ?*Hystricurus* sp., ?*Peltabellia* sp., *Pliomerops* sp. A, *Raymondaspis* sp. A, *R.* sp. B, *Remopleurides* sp. A, Trilobite ind., ? *Paenaequina* sp., *Isochilina* sp., *Leperditia* sp.

The fauna includes several genera, and possibly also a species, which are represented in the measured sections of the Kap Weber Formation. *Raymondaspis* sp. 'B' is thought to occur in the Main Limestones on Ella Ø, at a height of 360 metres (fossil horizon BK), and may be indicative of the stratigraphical position in the formation of the whole assemblage. However, this faunal correlation on the evidence afforded by one fossil, the precise identification of which in the measured section is open to some doubt, is not sufficiently conclusive. *Benthamaspis problematica* is known from the Nunatami Formation, of upper Canadian age, in Northwest Greenland (Poulsen, 1946, 325), and its occurrence in the limestones of Locality 22 would add weight to the argument for a similar age to be ascribed to the associated fauna. *Bolbocephalus* is also a Beekmantown and upper Canadian fossil (Whittington, 1953, 657).

The genera *Pliomerops* and *Remopleurides*, on the other hand, have strong affinities with post-Canadian faunas. *Pliomerops* is considered to be an important index fossil of the North American Chazyan (Twenhifel *et al.*, 1954, Chart 2; Stubblefield, 1939, 58), and *Remopleurides*—although having a wide stratigraphical range within the Ordovician—is more commonly associated with the higher series (see fauna of Heimbjerge Formation, page 41). The presence of these two trilobites in the fauna from Locality 22 does not, however, preclude the upper Canadian age suggested for the assemblage. It is thought that the limestones cropping out at the locality, although faulted, are part of the Kap Weber Formation.

Locality 28.

Locality 28 is situated at the southwestern promontory of Pederpynt, on the east coast of the island (Plate X). The lithology exposed at the locality consists of grey limestones, partly altered by blebs and, streaks of yellowish-buff dolomitisation. Chert is present as thin bands, isolated lenticles and stringers, which weather to a reddish-brown colour. The whole of the limestone promontory has a much shattered appearance, with strong jointing and calcite veining.

The few fossils extracted from the limestones comprise remains of two trilobites—*Goniotelina* sp., and an unidentified asaphid. It is not possible to state precisely which part of the measured section is represented but the higher beds of the Main Limestones, about 600 metres above the base, are probably cropping out along the coast in this area.

Narhvalsund Formation.

The lowermost 250 metres of the sequence on Ella Ø were measured on the central plateau between the principal Tømmerbugt and Kløftelv

faults, immediately to the north-west of the Devonian unconformity (Plate X). The higher beds of the formation are only seen in the precipitous main cliffs on the south coast, Poulsen's type locality (1930, 316), and were not examined.

Basal Dolomites.

Massive-bedded, coarsely crystalline dolomite forms the dominant lithology of the subdivision. Based by buff-grey dolomite, the sequence is mainly composed of a light-grey rock which weathers to a light-grey or cream-buff colour, and frequently displays the small cavities so often characteristic of crystalline dolomites. The texture of the rock is invariably coarsely crystalline and saccharoidal, features which are probably responsible for the sandy appearance of weathered surfaces. Towards the top of the sequence occasional beds of almost pure limestone crop out between the massive dolomites.

Some silicification is indicated by the presence of light-brown weathering chert, as thin stringers and lenticles, sparsely distributed along bedding planes at intervals in the succession.

Thickness: 70 m.

Dolomitic Limestones.

The junction between the two divisions of the Narhvalsund Formation is transitional; there is no sudden change in lithology, and no suggestion of a disconformity. However, the boundary has been drawn at that point in the succession where the coarsely crystalline dolomite effectively ceases, and where limestones and dolomitic limestone become the dominant lithological types. This mixed sequence at the base of the Dolomitic Limestones passes upwards into grey-banded limestones, in which finely disseminated veins and patches of calcite are a common feature, before returning once again to a predominantly dolomitic lithology near the top of the measured section. These dolomites at the top of the section often include thin bands of finely crystalline character, which show irregular bedding and are light-grey and streaky pink-grey in colour.

Thin stringers and lenticles of brownish-weathering chert occur on exposed surfaces of the lower beds, where they are associated at one horizon with silicified gastropod remains.

Thickness: 180 m.

Fossils:— *Hormotoma* sp. (BU), *Lophospira* sp. (BU), *Pagodispira* sp. (BU), *Isochilina* sp. (BV), *Leperditia* sp. (BU).

Correlations with the Albert Heims Bjerge sequence.

(1) Basal Dolomites. The coarsely crystalline, saccharoidal dolomite, which constitutes a striking lithological feature at the base of the Narhvalsund Formation on Ella Ø, is also recognizable in the Albert Heims Bjerge

sequence, although dolomitic limestones are found interbedded at intervals. There are no faunal correlations.

(2) Dolomitic Limestones. There is close correspondence between the two sections in general lithology. Comparisons clearly indicate that the strata examined on Ella Ø represent only the lower part of the full succession; the reduced thickness is due to pre-Devonian erosion. No faunal correlations are possible.

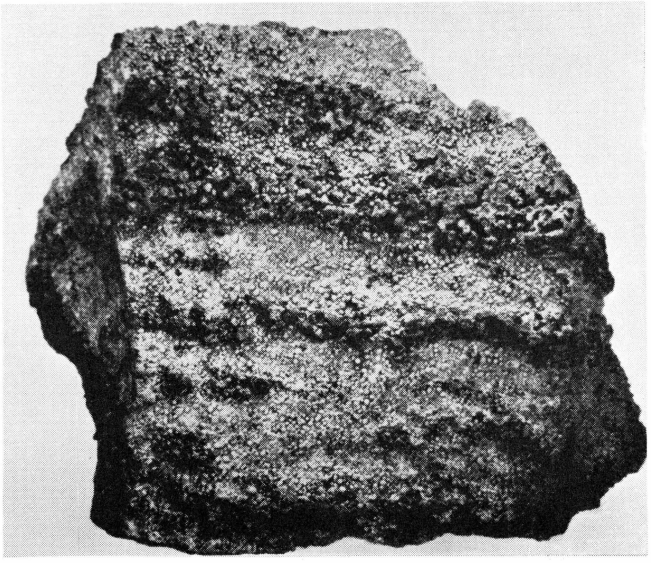


Fig. 60. Weathered strike surface of oolitic limestone, showing tendency to stratification according to size of ooliths. 162 m above base, Dolomitic Limestones, Narhvalsund Formation. Central plateau of Ella Ø. (×1).

B. Structure.

The major structures of Ella Ø are a western syncline flanked to the east by an anticline, folds which are of regional importance and can be traced from southern Lyells Land northwards to Ole Rømers Land. (See pp. 43—45). The names Eremitdal-Bastion Syncline and Border Anticline (HALLER, 1955, fig. 13) seem appropriate for regional use, but in describing these structures in Ella Ø the terms Bastion Syncline and Kap Oswald Anticline are used. For convenience in description the structure of Ella Ø may be considered under four headings:—

i) Bastion Syncline
ii) Kap Oswald-Antiklinalbugt area
iii) Fimbulfjeld-Lemmingdal area
iv) Devonian

The limits of the first three must perforce be somewhat arbitrary: the lines chosen are the boundary between the Bastion and Ella Ø Formations at the east end of Bastionen from Antiklinalbugt to Bastionbugt, and the eastern Kløftelv fault.

i. Bastion Syncline.

a. *Folding.*

The structure is a plunging syncline which varies considerably in character from the northern coastal exposures to the southern, even when allowance is made for the fact that the cliff section in the north is not at right-angles to the strike, although more closely corresponding to that direction in the south. On the north the symmetrical syncline is boat-shaped (Plate XI, section AA_1) while to the south the V—shape can be seen in the Narhvalsund cliffs (Plate VI; Plate XI, section AB). Dips over 60° were obtained in the eastern limb in the cliff overlooking Bastionbugt. Close above sea-level near Bastionpynt a dip of the western limb of 60° was recorded, and this is probably a typical value. Another dip of 75° taken near sea-level, close to an east-west fault 600 metres north-north-east from Bastionpynt, probably owes its high value to the action of the fault, although the direction is not atypical. As shown in section AA_1 of Plate XI the steep dips of the synclinal limbs shallow very rapidly and markedly some distance away from the axial plane and give rise to a flat-bottomed shape with dips approaching the horizontal over many hundreds of metres.

On the plateau of Bastionen the rocks are not generally well-exposed, although outcrops can be found of the Kap Weber and Narhvalsund Formations. At the eastern end moraine and superficial deposits almost entirely cover the solid rock, and the outcrops, shown by dotted lines on Plate X, are merely inferred from the cliff exposures to the north and south. Due to the unfortunate lack of measured dips in the cliffs of the south coast the local dip of the eastern limb of the Bastion syncline must be estimated and, as shown in section AB of Plate XI, it is considered to be approximately 50°, becoming shallower near the axial plane. A comparison of sections AA_1 and AB shows that on the synclinal axis the Cass Fjord Formation barely reaches sea-level in the northern cliffs of Bastionen while in the southern cliffs it is well below sea-level. This reflects the plunge of the fold of approximately 25° to the south-south-west; this value for the plunge is an average and it is not possible with the information available to say whether there is a variation from north to south across Bastionen.

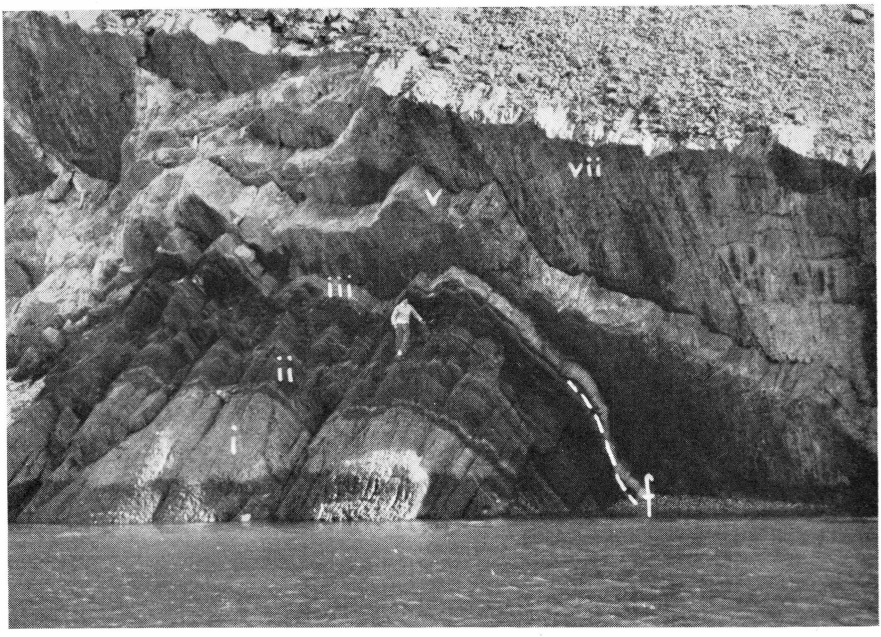


Fig. 61. Faulted sequence at Bastionpynt, Ella Ø. Bastion Formation: i and ii; Kløftelv Formation: iii to vii.

b) *Faulting.*

The fault which affects the Cass Fjord and contiguous formations in the northern cliffs of Bastionen is a thrust with a fault-plane dip to the west of approximately 20°. The heave is considerable, almost a kilometre, and brings the Dolomite Point Formation over the Kap Weber Formation. As part of a hypothesis to be outlined later the thrust is thought to become a bedding-plane fault in the deeper parts of the syncline, below sea-level, as shown in section AA_1. It cannot be followed in the upper parts of the coastal cliffs—it may eventually be taken up in bedding-plane movements there, or be continous across the plateau to the south coast: in the complete absence of evidence no inference is attempted on the map. This thrust was noted by Bütler in 1937, as were the two faults which strike up the cliff towards the highest point (1367 metres). Eha also inserted the thrust on his geological map and sections (1953, pls. 2 & 3). These recorded faults were for long thought to be the only significant ruptures and it was not until 1951 that the existence of considerable faulting was deduced at Bastionpynt; the faults near Bastionbugt were not seen until 1953. The reason for the non-detection of these important structural features, in areas which are probably the most frequently visited by geologists in eastern Green-

land, is presumably because they are strike-faults, and are thus not easily seen.

The faults at Bastionpynt were suggested primarily by the anomalous stratigraphical relationships there. Koch (1929 a, 26—27) first described the succession in the lowest part of the cliff and collected two suites of fossils; the Bastion and Ella Ø Formations were proposed with Bastionpynt and the "north-west corner of Ella Island", respectively, as type-localities (Koch, 1929 b, 21—22). Poulsen later examined the section and identified the strata as the upper part of the Bastion Formation, which he had studied elsewhere, and described them as consisting of "grayish green, glauconitic, arenaceous shale with brachiopods alternating with more or less thick beds of gray quartzite".

The authors measured the following section (fig. 61):—

Formation	Subdivision		Description	Thickness in metres
Ella Ø	Upper Limestone	xii	Limestones	Inaccessible
	Shaly Beds	xi	Shales	5 approx.
	Lower Limestone	x	Limestones showing slumping	5
Postulated Fault		ix	Gap of observation	10
Kløftelv		viii	Quartzites	30
		vii	Massive white or pale grey quartzites	5
		vi	Band of rubbly glauconitic material—greensand	0.1
		v	Massive quartzite flecked with rust-orange spots	1
		iv	Band of glauconite of variable thickness resting on a very irregular, pitted and cracked surface of iii	0.02 average
		iii	Quartzite with rust-orange-brown spots	0.2
Postulated Fault				
Bastion	Upper Shell-Limestones	ii	Dark brown arenaceous shales and mudstones with abundant shells and thin harder bands of limestone and siltstone	2
	Lower Shales	i	Green glauconitic arenaceous shales and mudstone with harder bands—no base seen	4

Nowhere in an undisturbed succession on Ella Ø, or for that matter elsewhere in Central East Greenland, is quartzite found in the upper part

of the Bastion Formation. The authors would not therefore consider, with POULSEN, that the subdivisions above ii belong to the same formation as the fossiliferous shales, nor that they are conformable with them. A number of possibilities were rejected, the following may be mentioned:—

1) the succession i to viii might be inverted. To establish the correct sequence current-bedding, graded bedding and the attitudes of brachiopod shells were examined. Only graded bedding was useful and suggested that the beds were not inverted.

2) The quartzite and greensand of subdivisions iii to viii might be of Pre-Cambrian age—the only possibility seemed to be the Quartzite Series of the Eleonore Bay Formation. This cannot be disproved but, as many thousands of metres of the geological column separate the Quartzite Series from the Lower Cambrian, the likelihood seems remote. At the eastern end of Bastionen the same beds are affected in a similar fashion: if a similar explanation should be invoked for both limbs of the syncline the presence of the Quartzite Series seems virtually impossible. The solution favoured by the authors is that two strike-faults occur: the lower one between subdivisions ii and iii, causing repetition; the upper one within subdivision ix cutting out a large thickness of strata. These reverse faults are shown in section AA_1. The fault between the Bastion Formation and the Kløftelv Formation persists as a high-angle reverse fault down to some depth below sea-level; the dip of the fault between the Kløftelv Formation and the Ella Ø formation becomes shallower with depth, changing from a reverse fault to a thrust. It is clear that the faults at Bastionpynt escape notice easily because they are strike-faults with fault-planes which, in the limited exposure at the point, do not appreciably depart from parallelism with bedding-planes. Field evidence indicating movement in subdivision ix is absent, and between subdivisions ii and iii there is little to suggest it. Subdivisions iv and vi suggest a fault-gouge or mylonite, and there may be subsidiary faults at these horizons. According to the succession established elsewhere, and even allowing for lateral variation in the sediments, it seems essential to postulate faulting between ii and vii, and similarly between viii and x.

When the cliff exposures 150—200 metres above Bastionbugt were being examined for fossils in 1953 it was discovered that an anomalous sequence exists there which is similar to that described at Bastionpynt.

The sequence is as follows:—

Formation	Subdivision	Description	Thickness, in metres
Ella Ø	Upper Limestones ix	Dark-grey limestone with black, lustrous, slickensided surfaces	Inaccessible
	Postulated Fault		
Kløftelv	viii	Pale grey and white quartzite weathering brown	30 approx.
	vii	Hard, glauconitic, quartzitic siltstone with dark glauconitic shales	5
	Postulated Fault		
Bastion	vi	Very highly glauconitic—shaly greensand (possibly a mylonite)	0.1
	Lower Shales v		25
	Lower Shell-Limestone iv		1 approx.
	Glauconitic Shales iii		10 approx
	Glauconitic Sandstones ii		40 approx.
Kløftelv	Upper Quartzites i		30 approx.

The succession below subdivision i is normal, descending to the Limestone-Dolomite Series of the Eleonore Bay Formation towards Tømmerbugt. Arguments which have already been put forward for Bastionpynt suggest that subdivision vi is a mylonite and that a strike-fault occurs between subdivisions v and vii. The dip of the fault-plane is greater than the dip of the beds it affects so that there is a repetition of part of the Kløftelv Formation on top of part of the Bastion Formation. Between subdivisions viii and xi another strike-fault is thought to occur, causing the Kløftelv Formation to outcrop immediately below the upper part of the Ella Ø Formation. The fault-plane dip, less than the dip of the beds affected, cuts out the Bastion Formation, part of the Ella Ø Formation, and part of the Kløftelv Formation. This latter, more westerly fault does not remain near the same stratigraphical level in the higher cliff exposures. This is not easy to see from a position on the steep cliffs, but is best observed from a boat or sledge on Kempes Fjord, or with binoculars from the Kap Oswald headland. Viewed from these vantage points the Bastion Formation appears again between subdivisions viii and ix towards the top of the cliff; the dark shaly character of the formation aids identification from a distance. This detailed point has not been shown on the geological map or sections (Plates X & XI).

As shown in section AA_1 the reverse strike-faulting just postulated in part of the eastern and western limbs of the Bastion syncline affects the same part of the geological column in such a similar way that a common cause is suggested. This is discussed later in the interpretation.

The upper strike-fault at Bastionpynt appears again approximately half a kilometre to the north-east close to the level of the fjord. The Kløftelv Formation is faulted against the Ella Ø Formation, cutting out the Bastion Formation. The cause of this reappearance of the strike faulting is the high-angle dip-fault which strikes almost due east up the cliff and throws down on its southern side; it can be assumed that most of its movement must have been later than the Bastionpynt faulting. A similar high-angle dip-fault is seen a further half a kilometre or so east along the cliff—in contrast it is downthrown to the north.

A minor fault, with a NW—SE trend, occurs within the outcrop of the Dolomite Point Formation near fjord level in the eastern limb of the syncline. Although the fault-line can be clearly seen, it has a relatively small displacement and only moves beds within the formation.

c) *Intrusions.*

The only known outcrops of igneous rocks on Ella Ø are intrusions into the western limb of the Bastion syncline. Rittmann has published a report of studies on eruptive rocks collected by Wegmann and Bütler between 1932 and 1936, which includes a consideration of the dyke in the Bastion syncline (1940, 8, 146—147). The material evidently belongs to the group of the lamprophyres: hornblende-vogesite and vogesitic odinite. Details of the occurrence are given by Eha (1953, 92, 98, Plate 2). Figure 62 has been drawn by utilising Plate VI, the authors' observations in the field, and a sketch by E. Fränkl. It seems clear that the intrusions, even if not of a lit-par-lit nature, as suggested by Poulsen and Rasmussen (1951, 24), were originally connected. The portions which are now seen, were probably torn apart by tectonic forces which caused sliding along bedding-planes. From the way they transgress the bedding-planes, the outcrops were possibly part of a single dyke, intruded after the Kap Weber Formation and probably also after the Narhvalsund and Heimbjerge Formations were laid down, and may thus be post-Middle Ordovician in origin. Bedding-plane movements which broke up the dyke into its present parts may have been directed parallel to the present dip, but were presumably not part of the adjustments during the main folding of the syncline as the displacements are in the wrong sense. The igneous intrusion of the Bastionen dyke probably occurred at an early stage of the orogeny. The available evidence is insufficient to decide whether the dyke is a linear or a planar body, and its orientation is unknown except for a few metres near the fjord,

where it appears to strike into the cliff. The extrapolation needed for representation in section AB has not therefore been attempted.

An alternative explanation is that the bedding-plane movements were directed parallel to the plunge of the strata. Haller claims that axial culminations and depressions of the Pre-Devonian sediments are due to east-west folding which occurred before the main folding. If this is true the plunge in the syncline should represent a dip in the southern limb of an anticline following the line of the Gletscherland Culmination Zone (Haller, 1955, fig. 12). The displacement of the dyke may be due to bedding-plane movements which were part of the adjustments during the early-stage folding of this anticline structure.

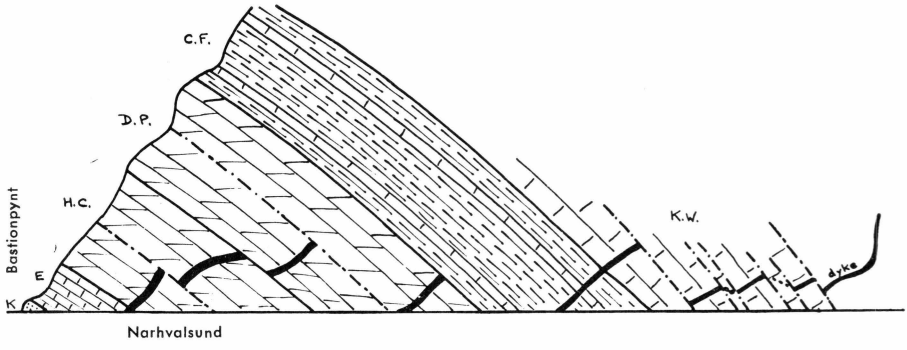


Fig. 62. Basic dyke in western limb of syncline, south coast of Ella Ø (see Plate VI). Formations: *K* – Kløftelv, *E* – Ella Ø, *H.C.* – Hyolithus Creek, *D.P.* – Dolomite Point, *C.F.* – Cass Fjord, *K.W.* – Kap Weber. Chain-dotted lines indicate bedding-plane movements.

ii. The Kap Oswald—Antiklinalbugt area.

A striking feature of the geological structure of Ella Ø is the Kap Oswald Anticline which is clearly seen in the deeply-eroded northern development stretching inland from Kap Oswald, and also in the magnificent cliff exposures on the south coast above Antiklinalbugt. (Plates IV & V).

a) *Folding.*

A glance at the dips recorded on Plate X reveals that the anticline is plunging, the bluntness of the outcrop V on the map is also partly due to rising ground in the direction of plunge. Dips recorded in the western limb near the coast between Bastionbugt and Kap Oswald (Plate X) generally vary between 55° and 65° with a direction only slightly north of west. The eastern limb has a considerably shallower dip, generally between 35° and 45° (see section CC_1), as recorded in the

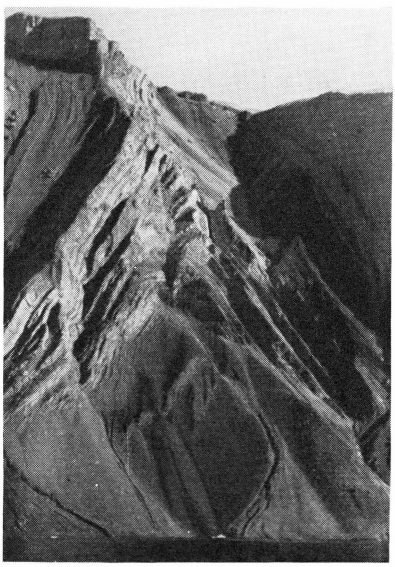
area between Septembersø and Kap Oswald; the average direction is midway between SE and SSE. Not infrequently the dips have abnormal values and directions due to faulting. The fold is therefore a plunging asymmetrical anticline in its northern development in Ella Ø: by means of stereographic projection the average direction of plunge is found to be approximately SSW (205°) at 30°, and the dip of the axial plane between ESE and SE (122°) at 78°. No dips have been recorded on the col between the northern area draining into Kempes Fjord and the cliffs of Antiklinalbugt. A comparison of sections AA_1 and AB in Plate XI shows that the Limestone-Dolomite Series should be expected on the axial line at sea-level in AA_1; in AB the Upper Tillite is probably at sea-level on the axial line, an outcrop of this formation below the screes of the Antiklinalbugt cliffs is inferred in Plate X.

The plunge becomes less to the south; also the outcrops show that on the south coast the anticline is nearly symmetrical (Plate V) with dips of 50° to 55° in the older formations below the Ordovician strata. Numerous dips were taken in the eastern limb when the section was measured, but unfortunately, as mentioned earlier, no dips were recorded from the southern cliffs of Bastionen. There seems little doubt that the plunge near the south coast is slight, only a few degrees, or even non-existent. Thus the point of maximum axial depression of the anticline, and also of the Bastion syncline, is probably reached somewhere near the south coast or in Narhvalsund. Eastwards along the coast from Antiklinalbugt dips in the successively younger rocks become steadily less. Dips recorded in the Narhvalsund Formation, for example, are 27°, and further east, only 12°. A similar change of dip also occurs in the Devonian conglomerates and sandstones.

The folding of the massive competent quartzites of the Kløftelv Formation near the sharp anticlinal crest has resulted in much puckering, crumpling and small-scale faulting, which can be seen in fig. 63 and Plate V. The quartzites of the western limb have ridden over the eastern limb by bedding-plane movement, so that the westerly-dipping strata are resting on the easterly-dipping shales of the Bastion Formation. This crestal fault, which cannot be closely examined, is not shown on Plates X and XI, but the thickening of the Kløftelv Formation, which is due to both faulting and folding, is shown on the map and in section AB.

Schaub has recorded on his structural map (1955, Plate II), which is to a scale of 1:10,000, three small plunging anticlines which are well seen in the coastal section between Kap Oswald and Solitærbugt.

The sections in his Plate III show the asymmetrical character of the anticline near Kap Oswald, and the plunge is given (*op cit.*, 15) as 25°—40°. The authors have not found that the plunge is ever as great as 40° over any distance; Schaub records high dips along the axial line,



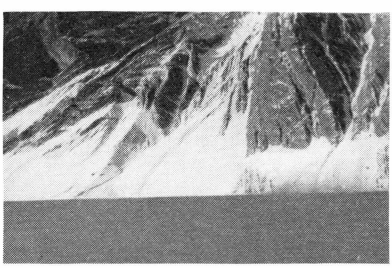




Fig. 63. Antiklinalbugt cliffs, Ella Ø.

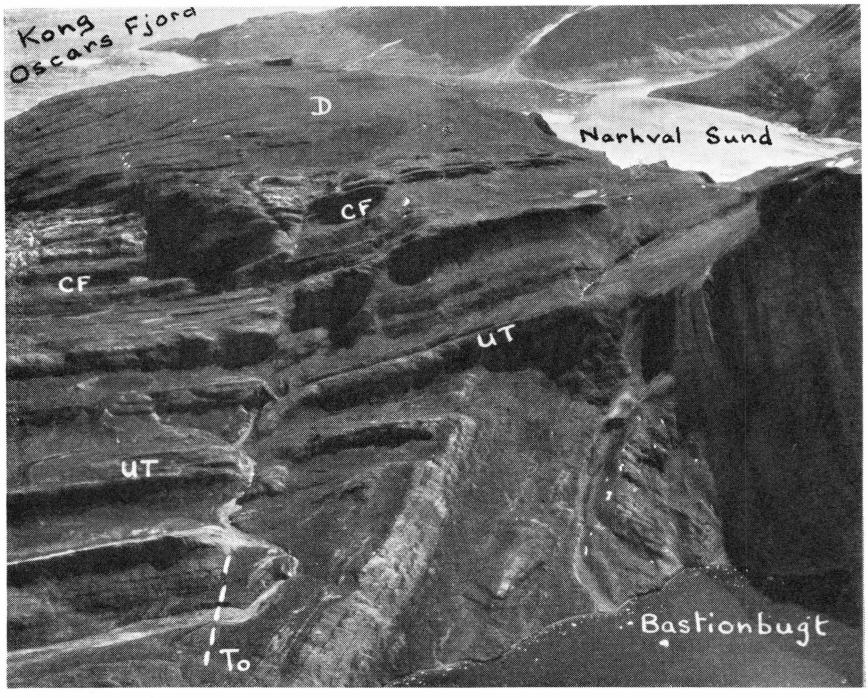


Fig. 64. Kap Oswald anticline above Bastionbugt. *To* – Tømmerbugt fault, *U.T.* – Upper Tillite, *C.F.* – Cass Fjord Formation, *D* – Devonian.

so presumably such a figure is reached locally due to flexuring. The direction of the anticlinal axis is shown as varying slightly, the changes being associated with displacement of the axis by faulting.

b) *Faulting.*

The eastern limb of the Kap Oswald anticline is displaced by two major fault-systems—the Tømmerbugt and Kløftelv faults (Plate IV). From the outcrop of the Cass Fjord Formation to the shore of Kempes Fjord the faults are subparallel, and have a trend which is approximately NNW-SSE; followed south from the Cass Fjord outcrop, through the rest of the Ordovician formations into the Devonian, the faults swing round to a more easterly direction. The Tømmerbugt faults have a more pronounced curvature in plan than the Kløftelv faults, and show a convergence to the south. Near Tømmerbugt a single fault displaces strata of the Limestone-Dolomite Series, but after crossing Storeelv the fault splits into two branches (fig. 64), both with important displacements although the eastern branch is evidently the more powerful. All these faults are dip-faults almost exactly at right-angles to the strike of the rocks. Outcrops are successively displaced towards the north on the eastern sides of these two faults, which enclose a wedge of strata

widening southwards and split into smaller parts by cross faults which run approximately north-south and slice up the succession. A few hundred metres south-west of Septembersø the main easterly Tømmerbugt fault is joined by two small branch faults (fig. 64). The easterly branch is wholly within the Kap Weber Formation, whereas the westerly one displaces both Kap Weber and Cass Fjord Formations; the movement is too small to be shown on the scale of Plate X.

From the manner in which the faults cut across the contours it would be expected that the fault-planes have a steep dip to the east. The variation in fault-trend is possibly due to change in the strike of the fault-plane, rather than fault-plane dip combining with relief to cause a sinuous outcrop. From the map, Plate X, the average displacement by the eastern main fault of the outcropping formations is measured in plan as 400 metres. Assuming the average slope of the ground to be 10° (see section CC, Plate XI), and the average dip of the beds to be 40°, the slip, if entirely dip-slip, would be approximately 400 metres, while a purely strike-slip movement would be nearly 500 metres. In the western fault the average plan displacement is apparently 250 metres which could be caused by a pure dip-slip of approximately 250 metres or a pure strike-slip of about 300 metres. The alternative end members (in the series of components of dip-slip and strike-slip which could make up the net slip) are a total dip-slip and a strike-slip, for the Tømmerbugt faults taken together, of approximately 650 metres and 800 metres respectively. The direction of slip cannot be determined from the faults themselves although, as outlined later, a hypothesis may be put forward from regional structural considerations: we would agree with Schaub (1955, 16) in doubting the validity of the statement that "the movement mainly followed vertical components" (Eha, 1953, 64), The displacement of the axial plane described by Schaub (*op. cit.*, 16, Plate II) does not give the direction and amount of slip, as there is a south-easterly dip to the axial plane, reflecting the asymmetry of the anticline. The plan displacement of the outcrop of the axial plane, along the fault-line, is given by Schaub as 250 metres: a pure dip-slip movement would be approximately 700 metres, while a pure strike-slip would be approximately 260 metres. There is therefore a discrepancy between the strike-slip calculated from the axial plane displacement, as given by Schaub, and from the total outcrop displacement averaged over a distance of 3 kilometres obtained from our map. The tectonics immediately south of Rundsø are probably more complex than shown on Schaub's Plate II. In the present paper Plate X shows a number of faults which are clearly visible in vertical aerial photographs and on the ground when it is free of snow. The authors are inclined therefore to attach more importance to the figures for possible fault movements deduced from

the average displacement of outcrops. SCHAUB also discusses another localised condition near "PT 95", close to the join of the western and eastern faults, where folding suggests that the western side of the fault moved while the eastern "remained in place". (*op. cit.*, 17—18, Plate II & Plate III, sections 4—6). This idea may be supported by the fact that the fault-wedges and slices between the two main Tømmerbugt faults are to the west of the main eastern fault-plane. Both Tømmerbugt faults appear to have smaller displacements near their southern limits, but owing to the limited accuracy of the topographical map the geological interpretation in this neighbourhood is merely tentative. Definite displacements of the Devonian rudaceous rocks are seen, the western fault has too small an effect to be shown on the map, but the movement of the eastern fault is fairly considerable—in plan about 100 metres along the fault line.

The fault along the river gorge of Kløftelv, the small stream which drains from Ulvesø, can be followed to the south-south-east where, east of Bjørnesø, it divides in a manner similar to the fault which can be followed north from Tømmerbugt, the main displacement being in its eastern branch (Plate IV). These faults are probably almost vertical, but they occasionally dip to the east during their course in the pre-Devonian rocks, the slight changes in direction seen elsewhere on the map being probably due to varying fault-plane strike. The faults can be followed southwards for some distance in the Devonian rocks, their direction then swings around to nearly south-east; the main eastern fault trends towards Kap Harry. In Kløftelv itself the Kløftelv Formation is faulted against the Limestone-Dolomite Series; a very considerable stratigraphical interval separates these two formations in normal circumstances. The plan displacement for the fault between sea-level and the 350-metre contour-line averages approximately 1200 metres and formation outcrops are displaced to the north on its eastern side. The direction of slip cannot be proved although it seems probable that the main component is strike-slip. If all the displacement is ascribed to strike-slip the value is approximately 1600 metres. The average plan displacement of the western branch is only 100 metres, a value which represents a pure strike-slip of about 120 metres. The main westerly Kløftelv fault has a displacement which varies considerably and appears to have an average plan displacement of approximately 1000 metres north of the point where it is joined by faults which swing round from the head of Lemmingdal. This value could represent a strike-slip of about 1200 metres or a dip-slip of approximately 1000 metres. On the col near the head of Lemmingdal, and south of it, the plan displacement is much less, reducing to about 200 metres in a short distance, and the displacement of the Narhvalsund Formation/Kap Weber Formation boundary

is slight. There is clearly some relationship between the Lemmingdal faulting and the Kløftelv faults. As already stated the Kløftelv faults can be seen to affect the Devonian strata, in which they were traced for some distance to the south. Bütler (1937, fig. 5) and Eha (1953, 64, fig. 14) maintain that the main Kløftelv fault can be followed to Kap Harry, causing the marked change in slope on the flank of the high ground. The evidence is not entirely convincing however, and the hypothesis seems to be based largely on the change in slope which might be due to glacial erosion rather than to any structural control. A glacier or ice-cap covering Fimbulfjeld, Lemmingdal and the lower ground of the east coast southwards to Kap Harry, could have caused the 'nick' in the Devonian outcrop as it flowed southeastwards (fig. 69).

A number of minor faults occur in the Kap Oswald peninsula within the outcrop of the Limestone-Dolomite Series, where some displace the anticlinal axis; a number have been recorded by Schaub on his structural map (1955, Plate II). The displacements they cause are usually small, and they are possibly adjustment faults between the main Tømmerbugt and Kløftelv systems. East of the Tømmerbugt faults, three minor faults have a direction ENE-WSW, and it may be significant that this direction is found in faults which meet the main Kløftelv fault on its eastern side. Other minor faults are mapped in the anticline on the south coast and there are many others in all parts of the island which are not recorded. A fault strikes up the cliff in the Dolomite Point Formation outcrop and reaches the boundary with the Cass Fjord Formation at the top, where it presumably is represented by bedding-plane movements which are commonly found along the boundaries of this incompetent formation with competent formations above and below.

The displacement of a fault which evidently parallels the shore of Antiklinalbugt for a distance of $1^1/_2$ kilometres, is considerable: the Kløftelv Formation is found contiguous with the Dolomite Point Formation. The formations exposed south of the fault-line, the Canyon, Spiral Creek and Kløftelv Formations, have the same southeasterly dip direction as those in the higher cliffs. Presumably the formations found in this faulted block have been moved from the eastern limb of the anticlinal core; their dip would support this hypothesis. Whether the fault movement was primarily dip-slip or strike-slip is unknown, but if there is a connection between this fault and the one already described near the synclinal "axis" on the south coast of Bastionen, where the Cass Fjord Formation is apparently displaced to the west, then they must both be dip slip faults with a downthrow to the north. It is not suggested that they are the same fault, but that they both possibly belong to a system of faults which strikes WNW-ESE through Narhvalsund.

iii. The Fimbulfjeld-Lemmingdal area.

The structure of the Cambro-Ordovician outcrops east of the Kløftelv faults is, of course, closely related to that to the west but exhibits differences in the character of some of the faulting.

a) *Folding.*

There is little variation in the direction of dip which is generally to the south, apart from disturbance near faults—especially in the Lemmingdal window. The angle of dip ranges widely, between the extremes of 20° and 80°, but the typical dip is probably about 35° over the greater part of the area; this value has been used in sections DD_1, EE_1, and FF_1, on Plate XI.

On the eastern side of the main Kløftelv fault the strata dip to the south-east and show outcrops oblique to the general trend. Eastwards along the north coast dips swing in a clockwise direction so that near Kap Elisabeth the direction is slightly west of south. High angles of dip were measured about 3 kilometres west along the coast from Kap Elisabeth and also near the cape itself. This steepening of dip is local and connected with bedding-plane movements in and near the Cass Fjord Formation which is expressed also by the strike-fault at its junction with the Kap Weber Formation. Near the section-line AA_1 three dips have a direction between SSW and SW, which is true also of the one near the hut at Kap Margrethe, although this may be affected by a fault. Near Pederpynt and Richardpynt, however, the dips are almost exactly due south and that direction is approached by many dips in Lemmingdal. The Fimbulfjeld—Lemmingdal area has a relatively simple folded structure and may be regarded as part of the eastern limb of the Kap Oswald anticline. There is little evidence of any synclinal structure in the east of Ella Ø. Not even in the extreme east of the island does the direction of dip compare with the direction of plunge of the Kap Oswald anticline. The dips recorded in the eastern limb of the anticline on the south coast preserve their direction of approximately to the south-east as far east as the Devonian. This direction is also recorded in the Narhvalsund Formation between the Tømmerbugt faults, but when the Kløftelv faults are crossed, near the lake south of the upper part of Lemmingdal, the dip is almost due south—a change of direction of about 45° from the south coast. There evidently is an important change of structure when the Kløftelv faults are crossed.

b) *Faulting.*

The main features are: a series of dip-faults which are often parallel to the Tømmerbugt and Kløftelv faults; a series of faults in the southern slopes of Fimbulfjeld are strike-faults in the west, but which when

followed eastwards, become oblique to the strike; and lastly, along the northern side of Lemmingdal and around the Lemmingdal window, strike-faults, which appear to have low fault-plane dips.

Along the northern slopes of the east-west valley of Lemmingdal a fault is clearly seen (fig. 65) which to a great extent follows the contours. Close examination shows the exposed fault-planes to be dipping northwards at an angle of 10° to 15°. This fault is displaced slightly by the high-angle faults f_1, f_2 and f_3 which cut it approximately at right-angles. When the fault is followed to the head of Lemmingdal, by means of brecciation, slickensiding and red-staining, it changes direction as the main eastern Kløftelv fault is approached, and finally swings round to the north. At the 400-metre contour it splits into two faults which continue, with slightly sinuous line, to the north-north-west, where they finally join at a slight, almost non-existent, angle with the main Kløftelv fault. As already noted the displacement of the Kløftelv fault is markedly increased north of the points where it is joined by the Lemmingdal faults.

The Kap Weber Formation limestone is found above the plane of the Lemmingdal fault along its whole length from the Kløftelv fault to Lemmingbugt; the particular horizons of this thick and uniform formation cropping out just above the fault-plane could not be determined. Between the Kløftelv fault and f_1 the formation just below the fault-plane is also the Kap Weber Formation, and limestone of this type is found southwards to its conformable boundary with the Narhvalsund Formation, just beneath the Devonian unconformity. Between f_1 and f_2 the Cass Fjord Formation appears just below the fault-plane; between f_2 and f_3 the Dolomite Point Formation underlies in the west following conformably on the Hyolithus Creek Formation in the east of this strip. A small fault-slice of Cass Fjord Formation is found up against the east side of f_2. From f_3 to the sea both the Hyolithus Creek Formation and the Ella Ø Formation are immediately below the fault plane. Thus the apparent stratigraphical displacement increases steadily from west to east: this increase is due, at least in part, to the deeper erosion and wider form of Lemmingdal towards the sea (compare sections DD_1, EE_1, and FF_1, on Plate XI). There may, however, be some increase in the amount of dip-slip of the fault towards the east.

The Lemmingdal window, separated by a ridge from the relatively flat lower part of the main valley, has itself been hollowed out by erosion into a minor valley drained by a small stream (fig. 67). From the valley bottom of Lemmingdal the outcrops in the window cannot be seen, but the Cass Fjord Formation is visible from the surface of the fjord between Pederpynt and Lemmingbugt. Poulsen and Rasmussen (1951, Plate 1, 19) indicate an outcrop of Cass Fjord Formation in approximately the correct position but presumably they did not investigate closely as the

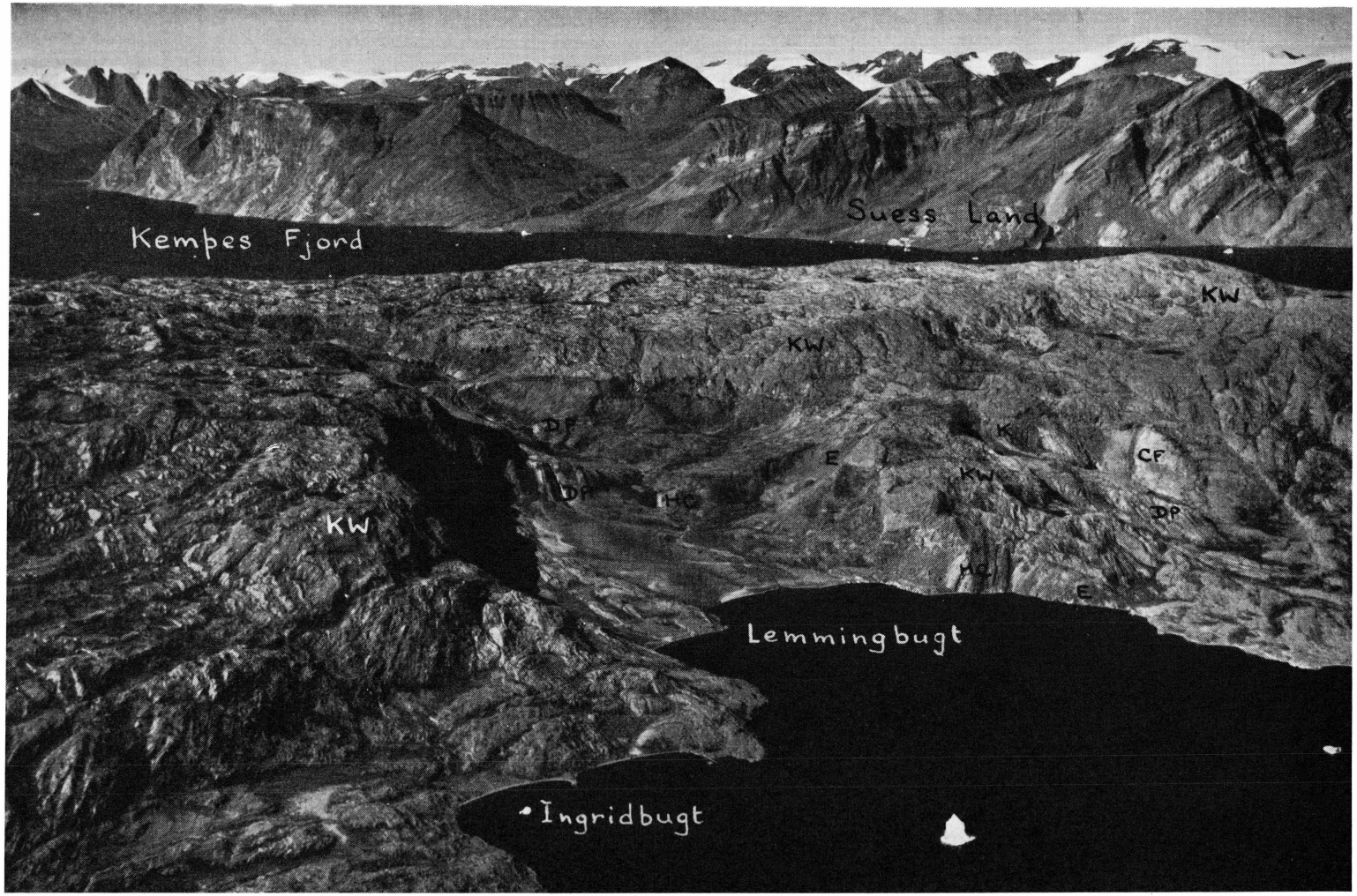


Fig. 65. Lemmingdal and part of Fimbulfjeld. (See plates X and XII). Formations: *K* – Kløftelv, *E* – Ella Ø, *HC* – Hyolithus Creek, *DP* – Dolomite Point, *CF* – Cass Fjord, *KW* – Kap Weber.

Lower Cambrian outcrops are not shown; the presence of the Cass Fjord Formation "in a 'window'" was thought to be due to erosion. These authors also show a fault along the northern side of Lemmingdal, but in the absence of sections or other comment an interpretation cannot readily be inferred. The most important feature of the Lemmingdal window is that, as shown in section EE_1 on Plates XI and XII, the outcrop of the Ella Ø Formation just below the fault-plane in the northern slopes of Lemmingdal conformably follows the Bastion and Kløftelv Formations found within the window (fig. 66). It is thought that the low-angle faults surrounding the outcrops in the window are part of the same fault-complex as the low-angle Lemmingdal fault; they apparently follow an undulating course and in places have a southerly fault-plane dip. There are a number of subsidiary low-angle faults which split and rejoin. The outcrops of the Dolomite Point and Cass Fjord Formations are assumed to be fault-slices and lenses left behind by the mass which moved northwards over the older rocks of the relatively undisturbed succession below the main fault-plane (fig. 66).

The movement of the younger rocks above the Lemmingdal fault has been relatively from south to north. The outcrops to the north, including the coastal cliff-sections composed of strata from the Canyon Formation to the Kap Weber Formation, appear to owe their separation from the succession found in the window and Lemmingdal to the movement of this east-west low-angle strike-fault acting in conjunction with east-west high-angle normal faults to be described later. The Lemmingdal faults may be described as lag-thrusts, low-angle tension faults or underthrusts, but all these names imply a particular mode of genesis, and that is a matter which can only be settled by a consideration of regional relationships, a task which is not being undertaken in this paper. The interpretation of the geological sketch of the Lemmingdal window (Plate XII) is probably best derived from a visual examination of the sections on the same plate, EE_1, FF_1, and GG_1; relationships with the rest of the island are seen in Plates X and XI. There is no evidence to suggest that the beds below the low-angle faults are folded, the dip is uniformly to the south at 25° to 35° (fig. 67). Although few dips are recorded on the maps it was seen in the field that the dips above the faults were also uniformly to the south at a moderate angle with only slight flexuring. The strata belonging to the Dolomite Point and Cass Fjord Formations which compose the slices between the low-angle faults show some folding, as might be expected, and are in one place horizontal and in another have a dip of 10° to the north-west. The undulating form of the low-angle faults, which is exposed by the erosion of the window, is probably the original form of the fault-planes and is not due to later folding. There may have been some degree of compensation for the undulating

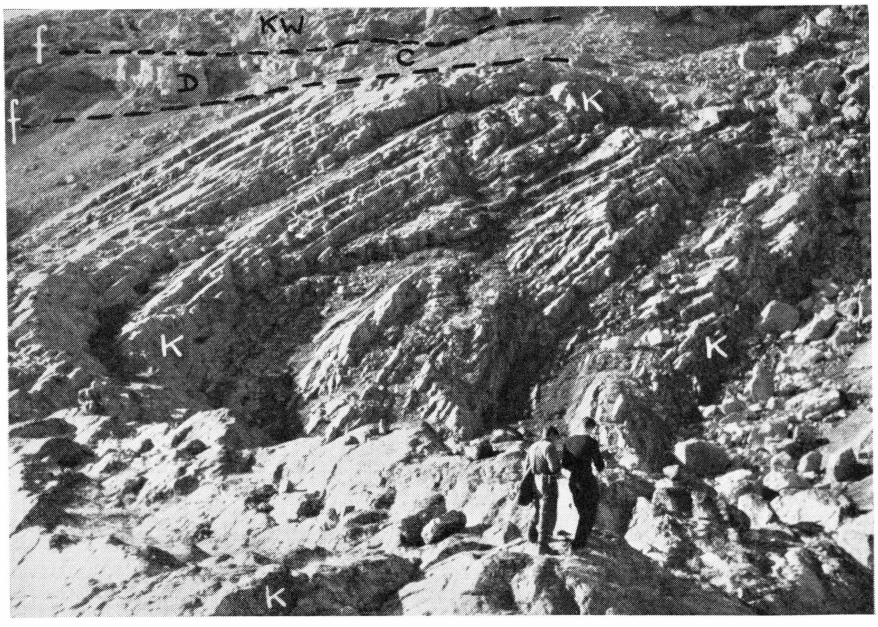


Fig. 66. Kløftelv Formation quartzites below the low-angle faults (f) in the Lemmingdal window. Formations: *K* – Kløftelv, *D* – Dolomite Point, *C* – Cass Fjord, *KW* – Kap Weber.

character by movement along the bedding-planes of the beds above and below the faults.

In Plate XII the fault f_6 displaces the low-angle faults and from its outcrop it probably has a fault-plane dipping to the north-west and is downthrown on that side. Other faults which affect the strata both above and below the low-angle faults are shown in sections FF_1 and GG_1; the Kløftelv Formation is delimited to the east by a fault which is of similar age. Thus there was evidently a phase of high-angle normal faulting somewhat later than the main translatory movements.

After the discovery of the Lemmingdal fault one of the remaining problems was the explanation of the great area of limestone cropping out on the Fimbulfjeld—Lemmingdal hills. Traverses of this upland region indicated that the dip was uniformly to the south at an angle which was rarely less than 30°. No dolomite was found which could be assigned to the Narhvalsund Formation. The whole area examined was composed of unfolded Kap Weber Formation, but from information derived from measured sections the formation could not be thicker than about 1100 metres, a thickness insufficient to give the width of outcrop without folding or faulting. When the area north-west of the Lemmingdal window, between faults f_2 and f_3, was examined a number of strike-faults was discovered: exposed fault-planes in places dipped at a moder-

ate angle to the north. In the uniform massive limestone the amount and direction of throw could not be measured, but probably these faults are repeating the beds of the Kap Weber Formation and causing the great width of outcrop. This hypothesis is illustrated in sections DD_1, EE_1 and FF_1 on Plate XI—the amount of the displacements shown has been adjusted so that the thickness of the Kap Weber Formation does not greatly exceed 1100 metres. The time of the movement of these east-west faults, relative to that of the Lemmingdal fault or to the north-south trending faults, has not been determined, but the hypothesis demands that it should be contemporaneous with the former and also with the initial movements along the latter.

Fimbulfjeld and Lemmingdal are crossed by a considerable number of faults which are at an angle to the strike of the rocks and are parallel or subparallel to the Kløftelv and Tømmerbugt fault-systems. Outcrops adjacent to the fault f_1 are displaced northwards on the eastern side. f_2, although it has a variable trend, shows a similar displacement in the coastal cliff of Fimbulfjeld, but the outcrop movement is reversed in Lemmingdal. Between f_2 and f_3 a number of small faults are seen in the north coast—they all, with one exception, displace in the same way as f_1. f_3 displaces to the north all outcrops in the coastal cliff on its eastern side and has a negligible displacement of the Lemmingdal fault, but the outcrops below in the valley are displaced southwards on the eastern side. The displacement of f_4 cannot be judged near Lemmingbugt and it joins f_3 before reaching the north coast. Between f_4 and f_5 are a number of faults with planes which dip to the east at angles between 45° and 82°, and their displacement is only visible in the north coast where it is so slight in plan that it cannot be recorded on Plate X. f_5, however, is quite considerable, and has a sinistral displacement similar to f_1, f_2 and f_3 along the north coast. A fault crossing the peninsula between Ingridbugt and Marabugt may be a continuation of one of the faults between f_4 and f_5 on the other side of Lemmingbugt. The movements of these north-south trending faults are thus following a definite plan in the rocks which are above the low-angle Lemmingdal strike-fault: they are sinistral strike-slip faults, or normal faults downthrowing to the east. Below the Lemmingdal strike-fault, the movements are in the opposite sense, as shown by the displacement of outcrops by f_1, f_2 and f_3 in Lemmingdal. Movements along these faults must have taken place at more than one time and were probably of more than one kind.

A strike-fault occurs along the boundary between the Cass Fjord

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Fig. 67. Lemmingdal window. (See plates X and XII). Formations: *K* – Kløftelv, *B* – Bastion, *E* – Ella Ø, *HC* – Hyolithus Creek, *DP* – Dolomite Point, *CF* – Cass Fjord, *KW* – Kap Weber, *D* – Devonian.



Fig. 67 a.

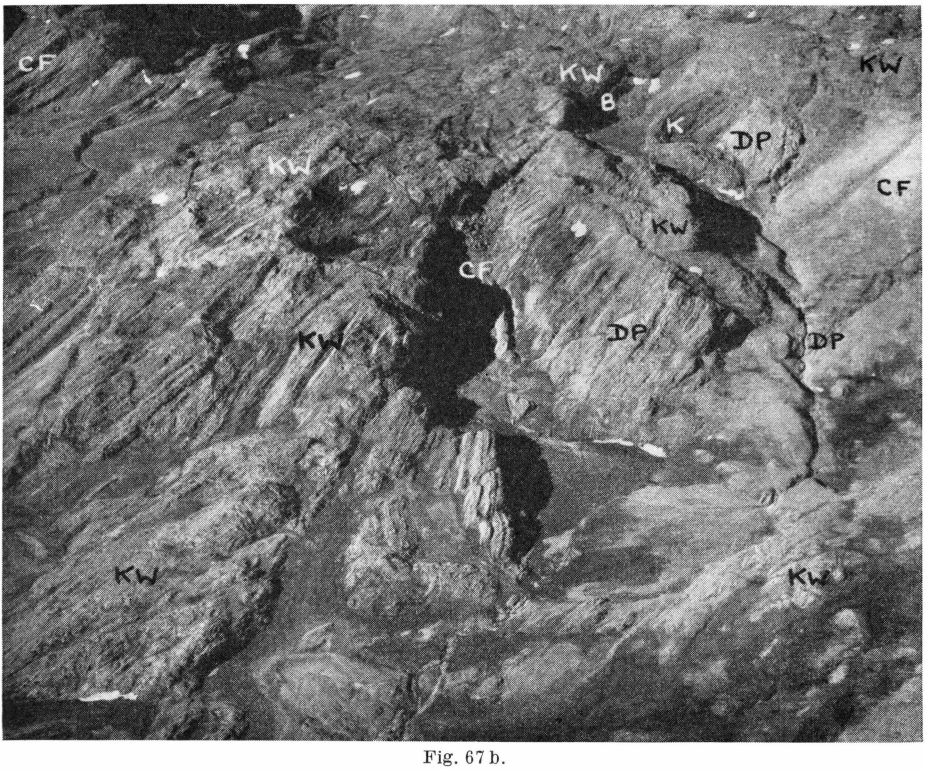

Fig. 67 b.

Formation and the Kap Weber Formation near Kap Elisabeth, giving an irregular undulating base to the outcrop of the latter formation. This type of bedding-plane fault is common at this particular formational junction between the competent limestone and the incompetent shaly beds, and is seen elsewhere on the island and also at Kap Weber (p. 145). A similar faulting movement has occurred near the southern shores of Lemmingbugt where a complex series of strike-faults have been displaced by later faults which can be followed southwards—some to the coast at Marabugt.

iv. The Devonian.

The unconformity at the base of the conglomerates and sandstones overlying the Cambro-Ordovician is most pronounced, as can be seen from the sections on Plate XI and from the relationships on Plate X. The Devonian does not rest on the Pre-Cambrian strata of Ella Ø, as elsewhere, but the overstep is from the Narhvalsund Formation on to the Kløftelv Formation. The strong relief of the old land surface is well expressed in the cliffs of the south coast (Plate V & fig. 68). The outcrop seen in the south coast near the crest of the anticline can be followed through to the northern cliffs of Bastionen, the surface of unconformity rising from 600 or 650 metres above sea-level to over 1200 metres in a distance of just over $2^1/_2$ kilometres. Wegmann (1935, fig. 6, 33—34) states that the "Ordovician limestone beds were slightly pushed upon the basal conglomerates of the Devonian" on the plateau of Bastionen. While agreeing with Wegmann's postulations as to the type of movement occurring in the Bastion syncline, this relationship of Ordovician to Devonian is not visible in the present outcrops although there is much masking by scree, and rock-falls commonly occur. Perhaps exposures seen by Wegmann are now obscured. This outcrop is also mentioned by Bütler (1948) whose invaluable papers are referred to for further information regarding the Devonian. We would agree with Eha (1953, 66) that the relationship of the Devonian to the Cambro-Ordovician rocks is purely unconformable. Only three dips are recorded from the main crop of the Devonian near the older rocks; as might be expected in such a coarse rudaceous deposit they are variable in angle and direction. However, they are within 45° of the direction of the dip in the nearby Ordovician strata, but with considerably smaller value, horizontal beds being recorded at one point. A syncline can be seen in the cliffs of the south coast below the point with a height of 1047 metres. As mentioned earlier the Kløftelv and the Tømmerbugt faults run into the Devonian outcrop, where their displacement is similar but much reduced in amount.

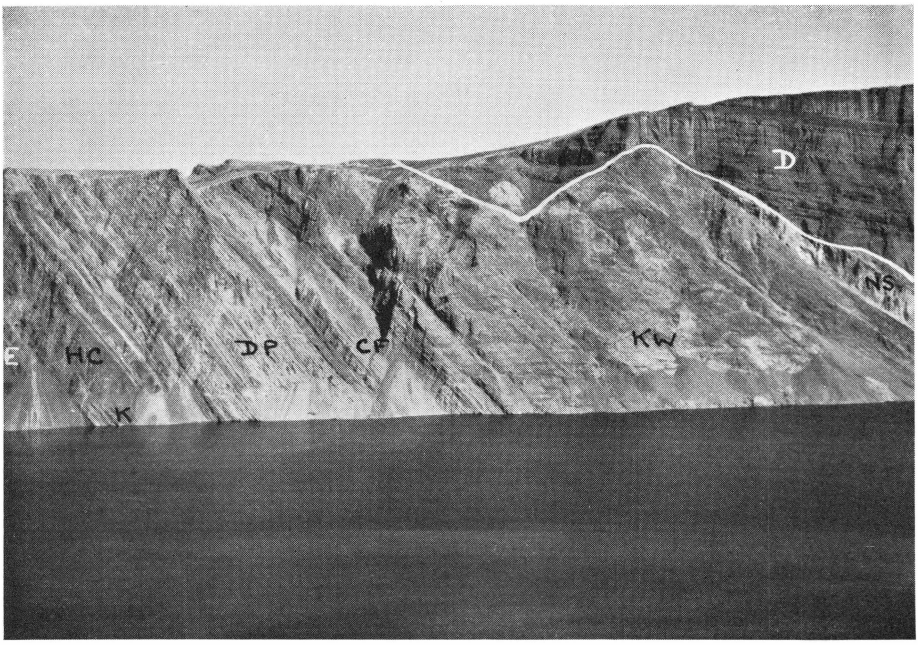

Fig. 68 a.

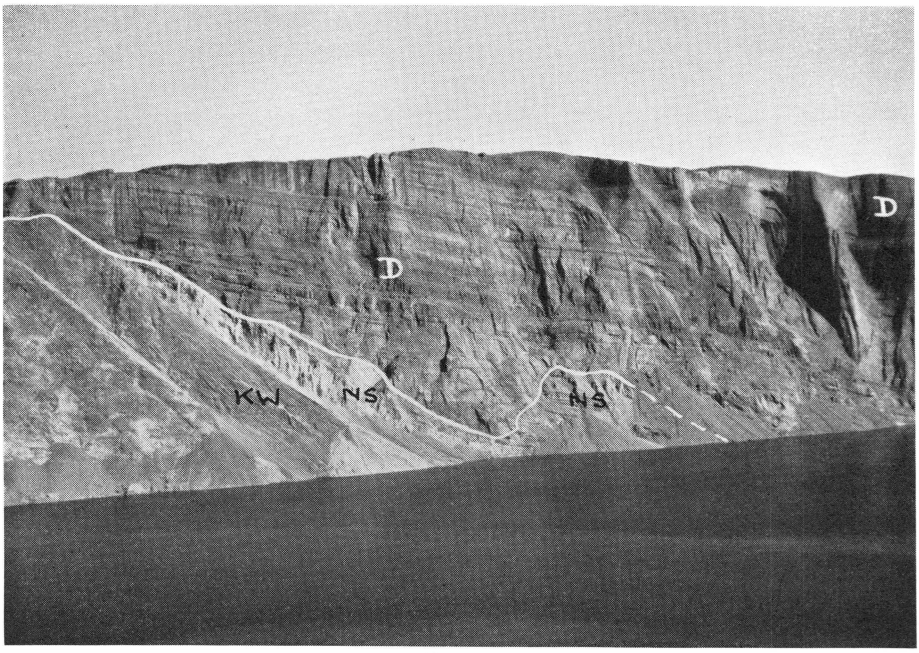

Fig. 68 b.

Fig. 68. Devonian unconformity on south coast of Ella Ø. Formations: *K* – Kløftelv, *E* – Ella Ø, *HC* – Hyolithus Creek, *DP* – Dolomite Point, *CF* – Cass Fjord, *KW* – Kap Weber, *NS* – Narhvalsund, *D* – Devonian.

v. Interpretation.

a) Main folding and faulting.

The present separation of the sections of the basic igneous dyke, seen in the western limb of the syncline, may represent the earliest tectonic element by indicating the bedding-plane movement, which occurred in the southern limb of the anticline along the east-west line of the Gletscherland Culmination Zone.

This bedding-plane movement was an adjustment to the forces which caused the folding of the anticline. The plunge of the present Bastion and Kap Oswald folds is attributed to these early east-west warpings.

The main folding of the Cambro-Ordovician with the rest of the Pre-Devonian sediments, followed soon after the deposition of the youngest Lower Palaeozoic rocks, viz., the limestones of Trentonian age found in the Albert Heims Bjerge area. If the terminology currently applied in the eastern part of North America is employed, the first orogenic phase would therefore be Taconian in age. Later phases of movement occurred before and during the Devonian period, but the main folding was Pre-Devonian. This point is evinced by the marked unconformity which exists between the Lower and Upper Palaeozoic rocks, and is also supported by the molasse character of the Devonian sediments.

The faulting in the limbs of the Bastionen syncline indicates that the folding of the pre-Devonian strata of Ella Ø into a syncline and anticline was accompanied by extensive adjustment faulting. Reverse-faulting near Bastionbugt and Bastionpynt and thrusting in the north and south faces of Bastionen were caused by the same compressional forces which gave rise to the main folding.

b) Lemmingdal fault and associated faulting.

At a later stage than the main folding and faulting, but possibly soon after the east-west compression had died away, a translatory movement with a predominantly horizontal component occurred. This movement was expressed in strike-slip faulting along the Kløftelv and Tømmerbugt faults and in the north-south faults of Fimbulfjeld; also by a movement either upwards to the south, or downwards to the north, with ruptures cropping out as the Lemmingdal fault and the strike-faults seen in Fimbulfjeld. The dragging of outcrops near the tear-faults, seen in plan as a sinistral rotation, supports the theory of a predominantly tearing movement. The character of the force, considered in plan, in this second phase of movement, was in effect a sinistral couple. Schaub (1955, 17, 18) suggests that stress causing the tear-faults came from the west and below, and quotes evidence from the lower valley of Storeelv in support. From a consideration of the fault wedges to the west of these main faults the western side moved while the eastern

remained in place and constituted a rigid block. The movement along the low-angle Lemmingdal fault running below the north-eastern part of the island is partly taken up in the west by the main Kløftelv fault. This is indicated by the sudden increase in displacement of the outcrops by the main Kløftelv fault north of its junction with the Lemmingdal faults. The north-south faults traversing Fimbulfjeld are also interpreted primarily as strike-slip faults with, in plan, a sinistral movement; they were initiated at the same time as the Tømmerbugt, Kløftelv and Lemmingdal faults—this applies to the faults f_1, f_2, f_3, f_4 and f_5 and other smaller faults of kindred character. These north-south faults were confined at this stage to the strata above the Lemmingdal fault, and were not found at the level at which they now appear south of the Lemmingdal fault. The undulations of the low-angle Lemmingdal fault seen in the Lemmingdal window were present as the fault first moved. A further set of faults, which moved at the same time as the Lemmingdal fault and the north-south tear faults, are the east-west normal faults downthrowing to the north. These are considered to have been part of the adjustment to the movement of the Lemmingdal fault. In addition the direction of Lemmingdal coincides with the trend of Sofia Sund on the other side of Kong Oscars Fjord and there may be some structural connection between the two features, as suggested by Eha (1953, 65) and Bütler (1955, fig. 2).

e) Later faulting.

Renewed movement probably took place along faults f_2 and f_3, and they were then extended downwards into the strata below the Lemmingdal fault, and hence are now seen in the older rocks of the valley floor and to the south. These new fault movements occurred at the same time as renewed movement of the Tømmerbugt and Kløftelv faults, and others of similar trend; possibly after the basal Devonian strata had been deposited. If the movements are considered to have been dip-slip in character then it appears that f_1, f_2 and f_3 were now downthrown to the west. A movement of such a type would counteract to a certain extent the displacement of outcrops caused by the earlier tear movement. A re-examination of faults f_2, and f_3 is desirable. There is little doubt that the displacement of the outcrops of formations in Lemmingdal by f_2 and f_3 is correct, but the displacement of the Lemmingdal fault by the north-south dislocations was incompletely and possibly incorrectly mapped, many exposures being inaccessible. A reassessment could not be attempted satisfactorily without a new, more detailed, topographical survey. Other faults which occurred later than the folding are the SE-NW faults along the south coast of the island. These may be downthrowing to the north-east and are probably part of the fault-complex which

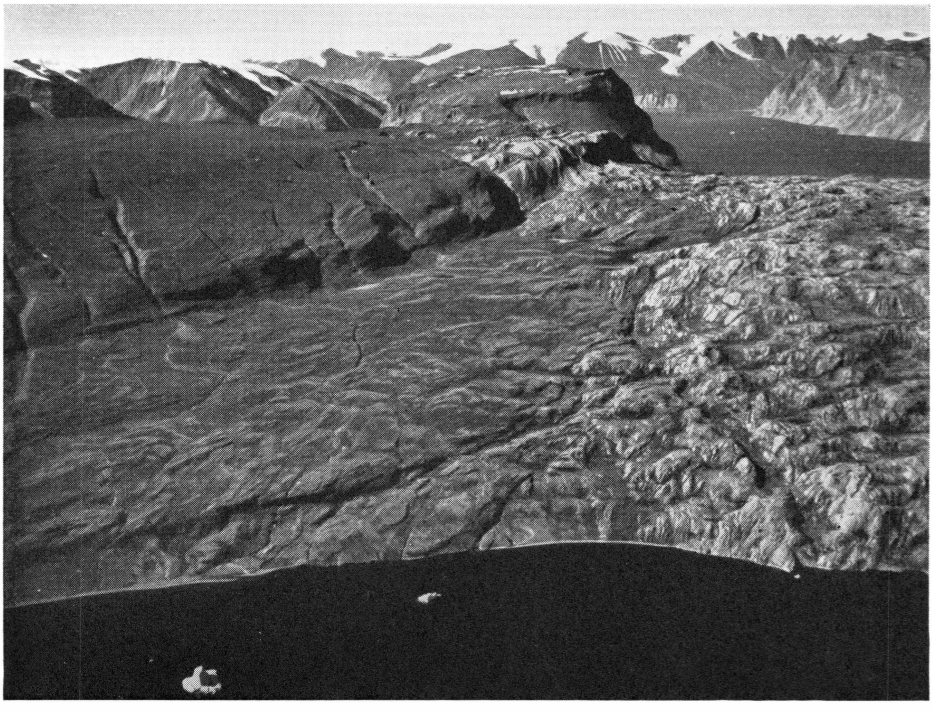

Fig. 69. Aerial view from above Kong Oscars Fjord of part of south-east Ella Ø showing the Devonian/Ordovician junction; Bastionen is in the background.

apparently follows the trend of Narhvalsund. Some of the fold structures can be followed from Ella Ø across Narhvalsund, but along the north coast of Lyells Land the pre-Devonian rocks are only represented by Pre-Cambrian sediments according to Sommer (verbal information). This may be due to a change in plunge, but is also probably due to extensive faulting along the line of the intervening fjord.

A certain reactivation of the Kløftelv and Tømmerbugt faults occurred during or after the Devonian period. The displacement of the Devonian strata is to the north on the eastern side, but the direction of slip is unknown. The age of the Lemmingdal and associated fault movements, together with the other examples of faulting which occurred after the main folding, cannot be established relative to the Devonian. The Acadian and even later phases of movement, described by Bütler elsewhere in Central East Greenland, may have affected Ella Ø.

C. Physical Features.

Contributions to this subject by Bütler (1937), Poulsen (1951), Eha (1953) and Schaub (1955) added to the illustrations in this paper make little comment necessary.

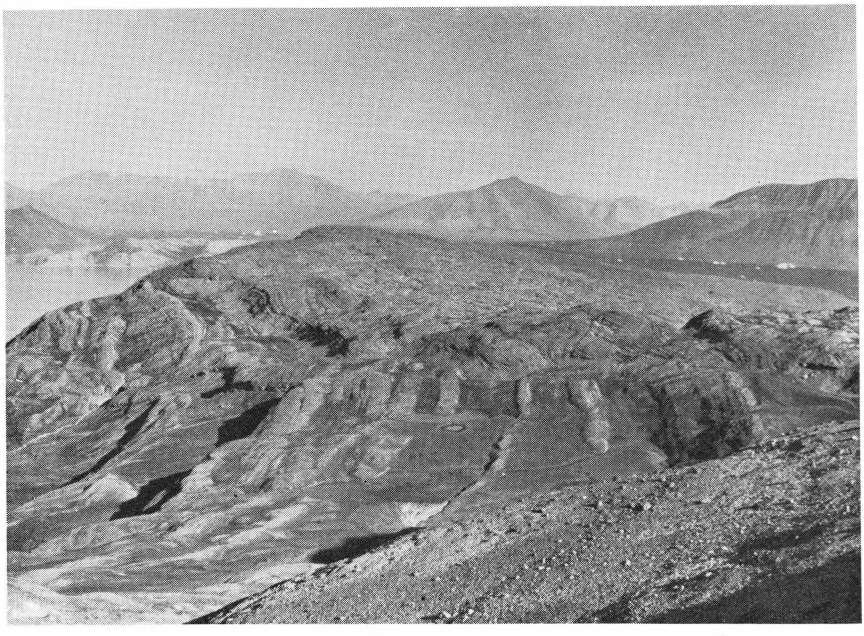

Fig. 70. Limestone uplands of central plateau and Fimbulfjeld, Ella Ø.

The resistant mass of the Bastion syncline, surrounded by precipitous cliffs except for a limited eastern approach, dominates the island and is flanked by the eroded Kap Oswald anticline; the plateau is part of an old peneplain, remnants of which are found in many parts of Central East Greenland. The superficial deposits, which largely cover it, contain many boulders of exotic origin and other evidence of past glaciation. In contrast the rest of Ella Ø is relatively free from glacial deposits and only a few moraines are found, chefly in the lower ground of the northern anticlinal area. The limestone uplands show much ice-scratching and the outcrops are extensively abraded into *roches moutonées* with numerous small lakes occupying rock basins (figs. 69 & 70).

V. OTHER AREAS

1. Ole Rømers Land, Hudson Land and the Muskox Fjord Inlier.

The outcrops of Cambro-Ordovician strata in Ole Rømers Land are comparable in area with those of northern Hudson Land and Ella Ø. An account of the region was given by BÜTLER in 1940 and 1950. The saddleback ridge of Søryggen is composed of Ordovician limestone and is flanked by two great lakes; its eastern and western ends are faulted (Plate VIII), and Devonian clastics lie unconformably on the northern slopes. The limestone uplands present the usual difficulties, but well-exposed sections in the older formations are found between Krumme Langsø and Sødal. The succession just below the Kløftelv Formation was found to vary from that of Albert Heims Bjerge: near the shore of Krumme Langsø the white to pale grey quartzite of the latter formation is underlain by pale grey dolomite weathering yellow and orange with rough carious surfaces. This Canyon Formation dolomite is stylolitic, cross-bedded and 7 metres thick; below it a yellow-weathering grey dolomitic siltstone followed downwards in the section gradually changes into dark grey to black shales with a purplish tinge and considerable efflorescence of gypsum.

In Sødal, approximately halfway between the great lakes, the Kløftelv Formation quartzites are again outcropping—white to pale grey in colour weathering pale yellow to pale orange and showing ripple-marking. All but the topmost 15 metres are obscured by scree. (fig. 71).

After an unobserved interval of 20 metres the typical lithology of the Bastion Formation is developed with stratigraphy strictly comparable to Albert Heims Bjerge. The Cambrian strata can be followed through to the top of the Ella Ø Formation but above this the succession becomes very faulted, and almost inaccessible. The slumping structures characteristic of the Ella Ø Formation are well-developed (fig. 72).

The section was measured to the topmost Cambrian fossil horizon, but as the lithological descriptions are almost exactly similar to those given for Albert Heims Bjerge thay are not repeated here: the stratigraphy given in figure 3 is fully applicable. The fossils will be described

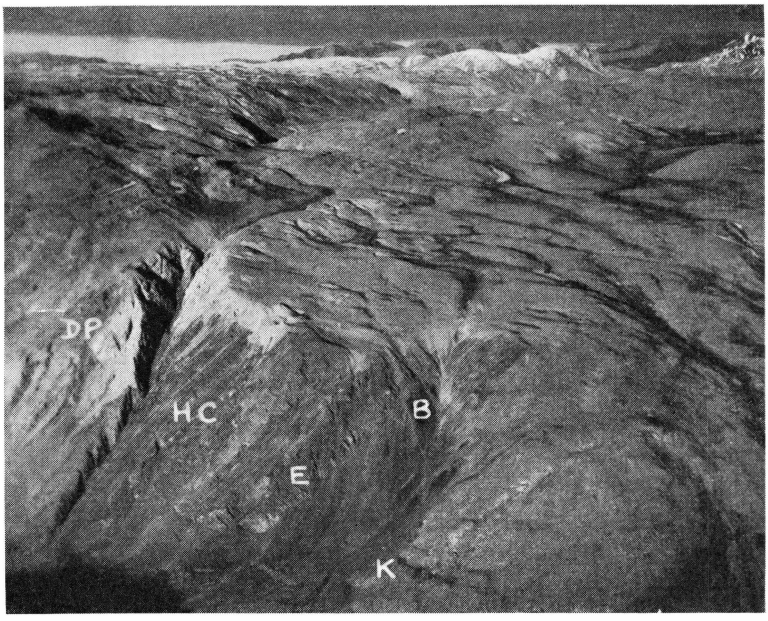

Fig. 71. Older part of section, west end of Søryggen, Ole Rømers Land. Formations: *K* – Kløftelv, *B* – Bastion, *E* – Ella Ø, *HC* – Hyolithus Creek, *DP* – Dolomite Point.

in a later publication but it may be mentioned here that *Calodiscus* is found in the Lower Limestones of the Ella Ø Formation and *Olenellus* cf. *truemani* WALCOTT in the Upper Shales of the Bastion Formation. The Ordovician formational succession can be traced to the shores of Vibekes Sø and presumably the greater part of the Kap Weber Formation is present south of the Sødal fault. Part of Randen north of the fault, the mountain overlooking the snout of Vibekes Gletscher, is formed largely in Kap Weber Formation, but the eastern peak is partly Narhvalsund Formation. It seems unlikely that Heimbjerge Formation is present in Randen or Søryggen.

Hjørnebjerget (fig. 73) and Posten (fig. 74) present large Cambro-Ordovician outcrops which are extensively faulted. The peaks of Klipperne, rising above Stordal, are composed of Kap Weber Formation (BÜTLER, 1940, Tafel 10) resting on a thrust-plane. Elsewhere in Hudson Land a number of small outcrops (page 45) are found, and the Muskox Fjord Inlier occurs on both sides of the outer part of the fjord. These scattered exposures show that the Cambro-Ordovician sediments originally had a more extensive outcrop.

A physical feature which bears relation to the lacustrine deposits of Promenadedal (page 80) is found in Johan Davidsens Dal close to Waltershausen Gletscher. Vrangelven has cut down through recent deposits of sand, silt and mud, forming meanders and ox-bow lakes (fig. 75).



Fig. 72 a.



Fig. 72 b.



Fig. 73. Hjørnebjerget. Ole Rømers Land. The exposures in this view are chiefly Kap Weber Formation.

The damming of the river by the seasonal advance of the glacier, and the formation of the lake in which these deposits were laid down, is evidently an event which still periodically occurs. In 1954 icebergs were observed stranded on the flats some way from the incised river: they were presumably not more than a few years old and were derived from the glacier by calving into the ice-dammed lake.

2. Strindbergs Land.

KATZ made a comprehensive survey of this region, in the period mid-1948 to mid-1949 and his publication (1952) also incorporates the results published by TEICHERT in 1933. Broadly three physiographic types are found corresponding to the metamorphic region in the far west, the main area of Pre-Cambrian sediments which in the east is succeeded by Cambro-Ordovician strata, and lastly the Devonian rudaceous and

Fig. 72. Slump structure in Ella Ø Formation arenaceous limestones. West end of Søryggen, Ole Rømers Land. a: general view with rucsac, b: closer view of part of *a* to the middle left.

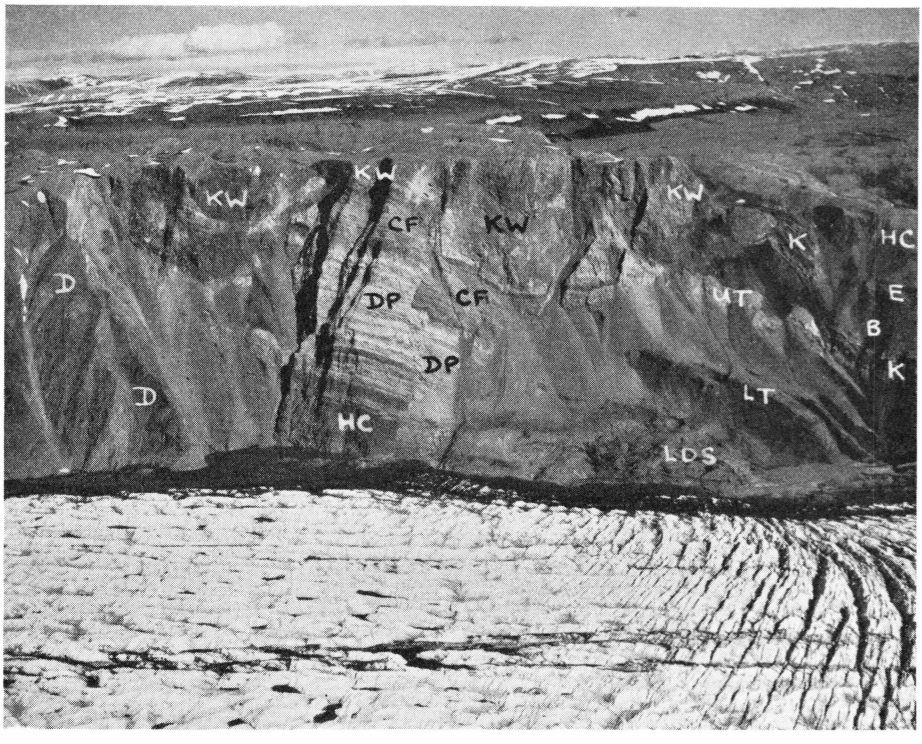

Fig. 74. Posten, Ole Rømers Land. Waltershausen Gletscher in the foreground. Formations: *LDS* – Limestone-Dolomite Series, *LT* – Lower Tillite, UT – Upper Tillite, *K* – Kløftelv, *B* – Bastion, *E* – Ella Ø, *HC* – Hyolithus Creek, *DP* – Dolomite Point, *CF* – Cass Fjord, *KW* – Kap Weber, *D* – Devonian.

arenaceous deposits which are faulted down along the eastern coastal strip. It is apparent from Katz's work (1952, Plates 3, 4 & 5) that the Cambro-Ordovician succession here, as elsewhere, participates in the tectonics of the late Pre-Cambrian sediments which it appears to succeed conformably. The Devonian is unconformable upon the earlier sediments in a number of exposures but the main contact at the surface is a fault trending NNE-SSW; there is a fold associated with the fault which becomes more acute followed northwards. The fault-line is the western margin of the graben termed by Katz the "Nordfjord—und Ole Rømers Land—Graben". Approximately 10 kilometres north of Blokken further outcrops of Cambro-Ordovician strata associated with underlying sandstones, shales and tillites appear to be delimited by faults. In conjunction with the Limestone-Dolomite Series in the lower part of Rævedal

Fig. 75. a) Vrangelven meandering across Recent deposits. Johan Davidsens Dal, Ole Rømers Land. *N* – Nordfjord, *S* – Strindbergs Land, *W* – Waltershausen Gletscher. b) An ox-bow lake in part of the river course shown in a).



Fig. 75 a.

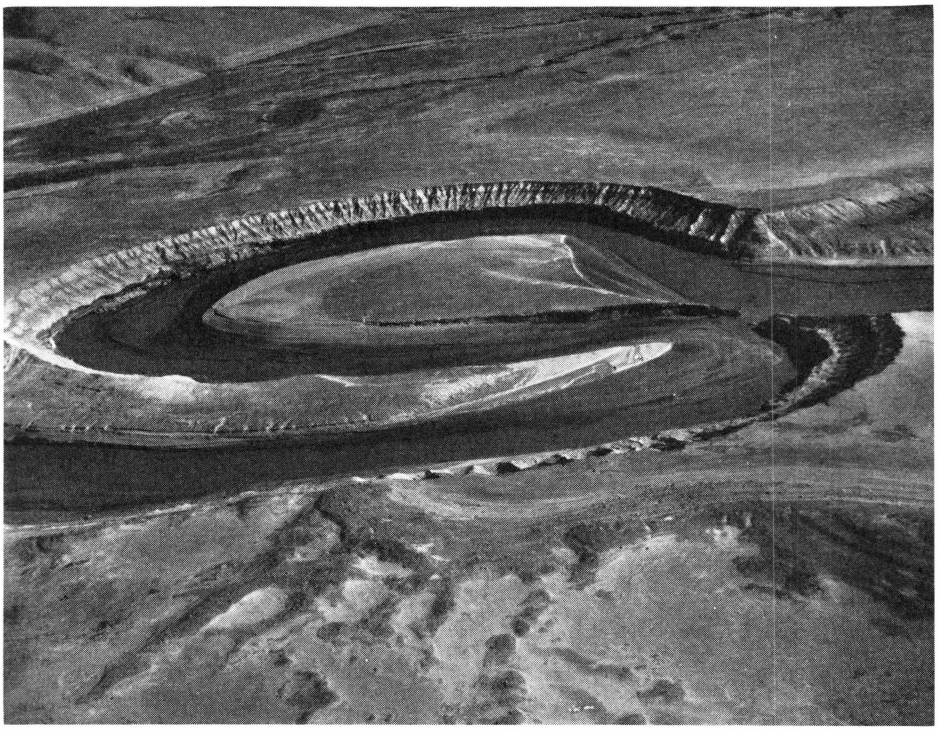

Fig. 75 b.

these outcrops of younger rocks are assigned by Katz to the "Rævedal—Ole Rømers Land—Mulde" which stretches north-eastwards across Waltershausen Gletscher.

The stratigraphical framework used by Katz for the Cambro-Ordovician is, in general, that put forward by Poulsen in 1932 and 1937, with the exception that he places the boundary for the base of the Cambrian between our Kløftelv Formation (lower Bastion Formation of Poulsen) and our Bastion Formation (upper Bastion Formation of Poulsen). Exposures on the north side of Brogetdal give the following succession for the lower part of the Cambro-Ordovician series (*op cit.*, 36—37):—

"4. Helle, zuckerkörnige Dolomite der Dolomite Point Formation.

3. Graubraune Kalke mit einem Stich ins Violette, gut gebankt, schwach hell-dunkel gestreift . . . . der Hyolithus Creek-Formation.

2. Ella Island-Formation.

c) Knollige, dichte Kalke von graubrauner Farbe mit hellen, meist gelbbraunen Mergelüberzügen. 10—12 m.

b) Sandige und brekziöse Kalke, darunter massige, meterdicke Kalkbänke von violettbrauner Farbe, mit gelbbraunen, sandigmergeligen Zwischenlagen. 10—15 m.

a) Sandige Kalke mit Kreuzsschichtung und Ripplemarks, plattig oder in Banken bis 20 cm. Dicke; braun anwitternd. Auf den Schichtoberflächen grüngraue Tonhäute mit Kriechspuren, Wurmgängen etc. Oft auch dickere Tonschieferzwischenlagen. 20 m.

1. Bastion-Formation:

Rund 100 m mächtige Abfolge von grünshwarzen, z. T. auch rotschwarzen sandig-tonigen und glaukonitischen Shiefern und plattigen Sandsteinen. Fossilhorizonte im obersten Viertel: Einschaltungen von sandigen, 3—10 cm dicken Kalkbänken voller Brachiopodenschalen, gelbbeaun anwitternd.

Darunter folgen die dickgebankten, gelbroten Sandsteine der "unteren Bastion-Formation" . . . . ca. 25 m mächtig".

After mentioning "knollige Mergel der Cass Fjord-Formation" and the Kap Weber Formation limestone with '*Orthoceras*' and trilobites, Katz (*op. cit.*, 38) mentions dolomite and limestone which he assigns to the Narhvalsund Formation and estimates the thickness of these sediments to be 800 m. It seems likely therefore that the Heimbjerge Formation is represented in Strindbergs Land.

Further details are given (*op. cit.*, 38—39) of the development north of Rævedal of outcrops of the Bastion and Ella Ø Formations.

Fossils were collected by KATZ from three localities, shown on his geological map:— north of Rævedal, north of Lakseelv and in Moskusoksefjeld.

3. Andrées Land.

The eastern peninsula of Andrées Land, Kap Weber, composed of highly folded and faulted Pre-Cambrian, Cambrian and lower Ordovician rocks, has been described in considerable detail by FRÄNKL (1953). His geological map and sections (*op. cit.*, Plate 4) admirably illustrate the complex tectonic structure of the area.

More than 1000 metres in height, the steep, rocky walls of Kap Weber dominate this part of Kejser Franz Josef Fjord and the entrance to Geologfjord. The precipitous cliffs on the south-east of the cape provide only few localities for examination of the rocks and collection of fossils. Skirting the eastern extremity of the cape is a narrow coastal belt of moderately low-lying and easily accessible terrain, formed by glaciated rock outcrops and huge mounds of morainic debris (see Plate VII), where several of the Lower Palaeozoic formations were first defined and described (KOCH, 1929; POULSEN, 1930). The type localities for the Hyolithus Creek, Dolomite Point and Kap Weber Formations are all situated along this coastal region of Kap Weber. The Canyon and Spiral Creek Formations have their type localities about six kilometres northwest of the cape.

Complete stratigraphical sections cannot be measured owing to numerous faults with indeterminable throws. Details of fossils we collected from the Ella Ø, Cass Fjord and Kap Weber Formations will be included in later palaeontological papers.

POULSEN states that the Kap Weber Formation rests on an eroded surface of the Cass Fjord Formation, an opinion based on an examination of the junction between the formations exposed near the northern promontory of Kap Weber (1930, 313; 1937, fig. 5). The irregular junction is of tectonic origin: the boundary between the competent massive limestones of the Kap Weber Formation and the incompetent shaly strata of the Cass Fjord Formation has provided a plane of movement in response to strong folding stresses. FRÄNKL (1953, 86) has put forward a similar explanation.

4. Ymers Ø and Suess Land.

The Cambro-Ordovician outcrops found between Kap Weber and Ella Ø, in the western part of Ymers Ø and the peninsula of Suess Land, were described by EHA (1953), whose results incorporate the scattered earlier observations. The limited outcrops of Cambrian rocks in Suess Land and in the mountain just east of Kap Mohn are preserved due to

axial depressions of the Eremitdal-Bastionen Syncline. The Cambrian and Ordovician outcrops around the inner reaches of Duséns Fjord and stretching north from there to Kejser Franz Josefs Fjord are part of the faulted eastern limb of the Border Anticline; they are in many places unconformably overlain by Devonian clastics. Poulsen's stratigraphy of the Lower Palaeozoic was utilised by Eha but the base of the Cambrian is placed at the bottom of our Bastion Formation (the upper part of Poulsen's Bastion Formation).

Section, after Eha, 1953:—

Formation	*Description*	*Thickness*
Narhvalsund	Limestone and coarsely crystalline dolomite-pale grey or reddish	150 m
Kap Weber	Grey limestones with beds at the base resembling the Cass Fjord Formation; lenses of chert are associated with silicified fossils	600 m
Cass Fjord	Dolomitic marls with irregular flat grey limestone boulders cemented by a dolomite matrix	100 m
Dolomite Point	Pale grey dolomites with siliceous beds	300 m
Hyolithus Creek	Limestones, siliceous lenses, calcite veins—pitted weathered surfaces	280 m
Ella Ø	Brown sandstones interbedded with fine clayey beds. Subaquatic slidings	50 m
Bastion	Dark greyish-brown and deep red shales	170 m
Kløftelv	Yellow, orange and violet coarse-grained quartz-sandstones with cross-bedding	50 m
Spiral Creek	Deep red coloration. Sandy shales, fine clayey beds, ripple-marking and salt pseudomorphs	25 m
Canyon	Varved black sandy and clayey shales; grey limestone bands gradually become dominant in the upper 70 m	250 m

5. North Scoresby Land.

Fränkl in 1950 and 1951 commenced the survey of the north-western part of Scoresby Land; his work was continued by Haller in 1954 and a publication is forthcoming. The area includes the Staunings Alper and is one of alpine relief with high, often sharp, peaks and deep valleys. Small ice-caps and large glaciers with associated rivers have a radial drainage system into Alpefjord, Segelsällskapets Fjord and Kong Oscars Fjord (Plate VIII). The outcrops of Cambro-Ordovician strata are confined to a small area on the mountain slopes and ridges around Syltoppene (fig. 76) some 10—20 kilometres SSE from Kap Peterséns.

As shown by Fränkl (1953, Tafel 1) the exposures are considerably faulted, and are upthrown against the Carboniferous which occurs to the



Fig. 76. The Cambro-Ordovician outcrops on Syltoppene, north Scoresby Land. *Syl* – Syltoppene. *LDS* – Limestone-Dolomite Series, *TS* – Tillite Series, *CO* – Cambro-Ordovician, *D* – Devonian, *C* – Carboniferous, *SF* – Skeldal-Fault.

east; the basal conglomerate of the Devonian rests unconformably on the older sediments in the higher ground. The preservation of isolated outcrops of the youngest Pre-Devonian rocks in North Scoresby Land seems to be due to faulting, particularly in Kong Oscars Fjord; it may also be connected with the graben structure running NNW from Scoresby Land across Lyells Land and Suess Land and farther north (HALLER, 1955, fig. 15 & 16).

The Cambro-Ordovician formations from the Kløftelv Formation to the Kap Weber Formation were recognised by FRÄNKL with the following thicknesses (*op. cit.*, 29—32):—

Formation	*Description*	*Thickness*
Kap Weber	"grauen rötlich anwitternden Kalke"	over 400 m
Cass Fjord	"grüne knotige Kalkschiefer und knaurige Kalkbänke"	80–120 m
Dolomite Point	"hell anwitternder Dolomite, die häufig Schnüre von Silexkonkretionen führen"	300–400 m
Hyolithus Creek	"graue, bankig Serie . . . Die Kalke . . . sind stark umkristallisiert, oft auch dolomitisiert . .	280–320 m

Formation	*Description*	*Thickness*
Ella Island	"braune, etwas gestreifte, bankige Serie . . . Sie besteht aus einer Wechsellagerung teils toniger, teils sandiger Kalke, die oft Tonlagen zwischen den Bänken aufweisen"	80– 90 m
Bastion	"dunklen, schirfrigen Serie" "Sie wird von einer Wechsellagerung von Glimmersandsteinen, glauconitischen Sandsteinen, Tonschiefern und Kalken aufgebaut. Vor allem in den Letzteren treten Lagen mit Ansammlungen von Schalenfragmenten auf"	80–100 m
Kløftelv	"Es handelt sich um Quartzite, welche fast ausschliesslich aus primär äusserst gut gerundeten Quarzkörnern zusammengesetzt sind. Die Quarzkörner zeigen eine sekundäre Verzahnung, die auf das Ineinandergreifen der deutlich sichtbaren Zuwachsränder zurückzuführen ist". "In der Sandstein-Serie zeigen die Quarzkörner (ohne sekundäre Zuwachsränder) eine gute Rundung einen Durchmesser der um 2. 0–2. 5 mm liegt und ein durchwegs einheitliches Auslöschen	50– 90 m

The Base of the Cambrian.

The most striking result of the survey of north Scoresby Land from the present point of view is the opinion of Fränkl that the Canyon Formation, as well as the Spiral Creek Formation, is absent from the succession and the Kløftelv Formation was deposited on the Upper Tillite (*op. cit.*, 28—31, Tafel 3).

It is an important feature of the succession in the pre-Devonian sediments of Central East Greenland that there is no angular discordance within this great thickness of strata, few disconformities and little lateral variation in lithological character. It has long been considered that the fauna of the lowest fossiliferous layer does not represent the earliest Cambrian zone (a question which we propose to deal with in a later paper). This, coupled with the character of the sediments, no doubt influenced Poulsen in placing the base of the Lower Cambrian at the bottom of the Kløftelv Formation in his papers in 1951. In many, if not all, the regions of Cambrian outcrops around the north Atlantic the beds usually referred to the lowermost Cambrian are quartzites, in many places resting with angular discordance and irregular surface on undoubted Pre-Cambrian rocks. With Fränkl's discovery in Scoresby Land and our own in Hudson Land and Ole Rømers Land there are now good grounds for claiming the existence of an unconformity, in the broader sense of the word, at the base of the Kløftelv Formation. In the northern



Fig. 77. Erratic quartzite block with 'Scolithus', near Strömtangen, across the mouth of Loch Fyne from Kap Stosch (about 22° W, 74° N).

outcrops the varying sediments below the quartzites can be assigned to the Canyon Formation: the characteristic lithology of the Spiral Creek Formation is absent. In the central part of the main crop, Strindbergs Land to Ella Ø, the succession includes both Spiral Creek and Canyon Formations, but in Scoresby Land neither formation is found. The stratigraphy of the Kløftelv Formation is unaltered throughout. Lateral variation may have occurred or the quartzites may be diachronic. It is unlikely, however, that the tillite in Scoresby Land is contemporaneous with the salt casts and sun-cracked laminae in Ella Ø and the relatively deep-water shales of the northern outcrops. It is considered that a major break of sedimentation occurred and the Kløftelv Formation transgressed across strata below.

Examples of pipe-like structures, or trace-fossils, are found in quartzites of the basal Cambrian in many regions of the world and they are usually referred to 'Scolithus'. Close examination, wherever possible, of *in situ* quartzites of the Kløftelv Formation have not revealed any occurrences, and this is also the experience of other authors. Numerous rounded quartzite blocks containing 'Scolithus' can be recorded from morainic material, always associated with heterogeneous erratics which include igneous and metamorphic types. These blocks are found in areas where it is probable that in the past major ice-streams have issued from

the main Greenland ice-cap; their provenance may be from the nunatak region in the west, and their age is, of course, not necessarily Cambrian.

Wordie was probably the first to observe 'Scolithus' (page 13), and an example in quartzite was illustrated by Poulsen (1932, Pl. 6). Kap Stosch in Hold with Hope is a well known locality (fig. 77). Teichert observed "Scolithusquarzit" near Bessels Fjord (1933, 27—28). Professor Wenk of Basel found erratic scolithid quartzite and sandstone on the shores of Nordvestfjord near the inland ice (about 29° W, 72° N) where metamorphic rocks crop out (verbal information). We can add the following localities in northern Hudson Land and Ole Rømers Land:— the bed and banks of Vibekes Elv and its tributaries; below Randen near Vibekes Gletscher; the end of Sødal by Vibekes Sø; the northern shore of Krumme Langsø; Strömtangen at the mouth of Loch Fyne.

APPENDIX

DESCRIPTIONS OF MEASURED SECTIONS

Supplementary to those given in the main part of the text.

A. Albert Heims Bjerge.

Stream-gorge immediately south-east of f_2.

Lower Tillite.

1. Dark-grey tillite with large boulders of limestone and dolomite but some smaller ones are included; most of the boulders are of black limestone (39 m).
2. Medium-grey conglomerate or conglomeratic tillite with small limestone pebbles which weather yellow—the matrix weathers a ruddy brown. Lenticular and variable in thickness. (max. 1 m).
3. Green-grey tillites with rounded pebbles, cobbles and boulders, predominantly of black and grey limestones. Bedding not well-marked. (104.3 m)
4. Conglomerate or conglomeratic tillite—light-grey with pronounced yellow weathering and very numerous subangular or rounded pebbles of limestone or dolomite. Some interstratified greenish-grey tillite with sparser subangular fragments. (12 m).
5. Medium-grey tillite weathering dirty greyish-brown. Pebbles sparse with occasional boulders up to 20 cm. The included fragments are rounded and of limestone or dolomite. (2.6 m).

Inter-Tillite Beds.

1. Dark-grey to black shales with minor siltstone bands. Efflorescence of gypsum is general in the subdivision but is particularly abundant along certain bedding-planes in the lower part, (fig. 78). (49 m).
2. Medium-grey, fine-grained, massive, calcareous sandstone weathering maroon-brown, interbedded with minor shale layers. (31 m).
3. Dark-grey to black shales which are grey-hearted, bands of massive, grey, argillaceous siltstone. 'Beef' structure of prismatic calcite crystals are fairly common in the more massive bands. (142 m).

Upper Tillite.

1. Maroon and green arenaceous tillite containing igneous and sedimentary pebbles in small number. (6 m).

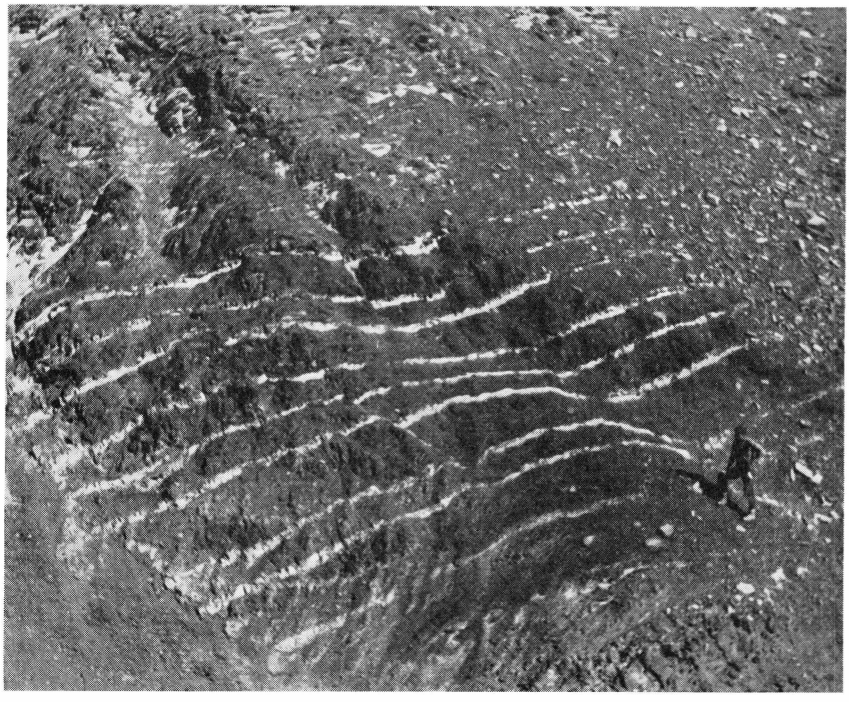

Fig. 78. Efflorescence of gypsum along bedding-planes, subdivision 1, Inter-Tillite Beds. Albert Heims Bjerge.

2. Grey-green tillite with pebbles of varied size and heterogeneous composition —acid and basic igneous as well as sedimentary. Quartzites and sandstones in lenticular beds with pockets of green arenaceous shale. (21 m).
3. Grey tillite with small included rock fragments, weathering grey-green and brown. (20 m).

Canyon Formation.

Stream gorge immediately south-east of f_7.

1. Dark-grey, medium to coarse-grained quartzitic sandstone, weathering pale brown and dark-buff, at some horizons assuming the character of a quartzite. On weathered surfaces the individual well-rounded quartz grains can be clearly seen. Cross-bedding occurs. (33 m).

2. Grey, very fine-grained, argillaceous dolomite weathering yellow to orange-brown, with intercalations of green and maroon shales. Near the top the dolomite is well-bedded, but lower down in the sequence it becomes less massive. (8 m).

3. Green-grey shale, weathering green-brown and buff. Bands of mudstone occur at intervals and weather brown. Bands of maroon shale are found in the topmost 15 metres and weather grey and maroon. (36 m).

4. Grey and green, calcareous shale and fissile mudstone, with laminae varying from less than 1 mm to 7 mm in thickness, and interbedded with very fine-grained grey limestone weathering green-grey. Fresh surfaces are green-grey, and sometimes show druses lined with pink calcite; weathered surfaces

are marked by thin lines and bands of dark-grey and rusty-brown colour. A maroon development of the same lithological types, 10 metres thick, occurs 40 metres from the base. (126 m).

5. Grey to dark-grey calcareous shales grading upwards into thinly-bedded, grey, argillaceous, arenaceous dolomite, the bedding of which is marked by light and dark streaks. In the lower part of the subdivision there are ill-defined lenticular nodules of more massive material, some of which are in persistent bands. These bands become less persistent higher in the bed, and are practically absent in the top 10 metres, where the strata become more uniformly fissile. The weathering colour as a whole is grey, black or brown, with a streaky brown and black appearance near the top. (23 m).

6. Black, highly fissile shales, weathering dark-grey to black. (54 m).

7. Grey, arenaceous dolomite, weathering light-brown, interbedded with dark-grey to black shales, weathering dark-grey. The dolomite has a blocky fracture and shows slight cross-bedding in places—the bedding generally is wavy and irregular. Top two metres are predominantly shaly. (19 m).

Kløftelv Formation.

Bank of Vibekes Elv, between f_8 and f_9.

Lower Quartzites.

i) White quartzite, varying in colour to dark-grey, yellow and pale green, and cross-bedded in streaky-grey. The bedding is irregular and wavy, especially near the junction with the shales in the topmost subdivision of the Canyon Formation. In general, the bedding is not markedly massive: in places the quartzites are thinly-bedded. Ripple-marking is common. (3.4 m).

ii) Greenish-yellow, fissile quartzitic sandstone, weathering greenish-yellow, and containing mica flakes. The bedding is wavy and irregular and the subdivision is of variable thickness, averaging 20 cm.

iii) Massive white quartzite with cross-bedding shown up by grey streaks, containing lenses of grey quartzite, with cross-bedding in white—better developed than in the basal subdivision i). Small pockets of pyrite are found occasionally. Near the base a fissile, micaceous and glauconitic siltstone occurs, showing irregular bedding-planes with longitudinal ridges and markings which may be interpreted as worm-trails. Another departure from the main quartzite lithology is seen for a thickness of 1 metre, at a height of 6 metres above the base of the subdivision, where a grey-green, well-laminated quartzitic sandstone is found which is medium-grained, micaceous and slightly glauconitic—the mica being chiefly concentrated on parting-planes. (20 m).

Lower Sandstones.

i) Green, glauconitic, micaceous sandstone, which is feldspathic and ferruginous, weathering a ruddy-brown. Interleaved with the sandstone are green and maroon, glauconitic, micaceous and arenaceous shales. The sandstone is banded in green and pale brown and is well-bedded. In thin-section the feldspar is seen to be fresh microcline with a little plagioclase; the angular quartz grains are of fine to medium grade. (40 cm).

ii) Green and maroon, micaceous, arenaceous shales interbedded with thinly-bedded sandstone of greenish-yellow and maroon colour. A bedding-plane shows protuberances suggesting a conglomerate, but the rock is inter-

nally homogeneous; on other bedding-planes possible worm-trails and casts are seen. (2 m).

iii) Yellowish-green, thinly-bedded sandstone with maroon streaks, with a more massive, quartzitic sandstone. Cross-bedding and ripple-marking are common thoughout this subdivision. (1.2 m).

iv) Green and maroon arenaceous shales, grading into maroon to yellow, thinly-bedded sandstones with occasional green shaly partings: the shales are impersistent laterally. (1.2 m).

Middle Quartzites.

White and dark-grey, massive, cross-bedded quartzite, weathering in shades of grey and brown. At a height of 3 metres above the base there is a laterally impersistent band of green arenaceous shale; another intercalation, of green-grey fissile and argillaceous sandstone, occurs for a thickness of 20 cm at 18.4 metres from the base. (20.4 m).

Upper Sandstones.

Greenish-yellow and maroon, fissile, argillaceous and micaceous sandstone, having 20 cms of dark-grey to black quartzite in the middle. (1 m).

Upper Quartzites.

Dark-grey and white massive quartzites, weathering in streaks of brown and grey. (20 m).

Bastion Formation.

Immediately to the north-west of f_7.

Glauconitic Sandstones.

1. A glauconitic, siliceous conglomerate—see page 52. (20 cm).

2. The basal 2 metres are grey to dark-grey, micaceous, glauconitic, quartzitic sandstone weathering brown. Colour-banding is seen in places. Above this is found a brown and green, ferruginous, feldspathic, glauconitic sandstone which is thinly-bedded (average thickness of lamina is 8 mm) and weathers brown. A common characteristic, well-seen on surfaces at right-angles to the bedding, is a grey-green coloration speckled with orange or rusty spots. These spots can almost certainly be attributed to the weathering of ferruginous concentrations.

In addition to ripple-marking, common throughout this subdivision, oval-shaped depressed maroon-brown marks are seen on bedding-planes. These are of varying size, the largest being 16 mm long. (6 m).

3. Grey, arenaceous, glauconitic, micaceous shales weathering buff. (4 m).

4. Grey-green speckled with orange, ferruginous, glauconitic sandstone weathering dark-grey to brown; in places the lithology is that of a quartzitic sandstone. The sandstone is also feldspathic in the lowermost 6 metres. The top 3.5 metres of the bed are much less ferruginous, and consist of micaceous, glauconitic sandstone. (22.5 m).

5. Dark-purple speckled with orange, fine-grained, micaceous, glauconitic, ferruginous, massive sandstone, with black to very dark-maroon, massive, dense, arenaceous and glauconitic ironstone. The sandstone is nearly black, with deep maroon to purple patches on bedding-planes, and weathers brown.

The ironstone weathers black with a deep purple tinge and thin-sections show it to be largely composed of opaque, black iron oxides. The whole subdivision is manganiferous. (1 m).

6. Brown—in places green and grey—micaceous and argillaceous siltstone, showing colour-banding and weathering yellow-brown. (8.5 m).

7. Dark-green speckled with orange-brown, ferruginous, glauconitic, dolomitic sandstone, weathering pale buff, green and brown. This sandstone grades upwards into green-grey arenaceous shales. (5 m).

Glauconitic Shales.

Grey, yellow and green, soft, glauconitic shales, weathering green, yellow and brown. (6 m).

Lower Shell-Limestone.

See page 55. (50 cm).

Lower Shales.

Glauconitic and arenaceous shales with bands of fine-grained limestone. The limestone is grey to brown in colour, and shows orange-coloured specks—a feature which probably indicates concentrations of ferruginous material. The rock is glauconitic in places, but weathered surfaces are grey to pale brown. This description applies to the lower part of the subdivision; in the uppermost 24 metres the shales are of similar lithology, although the resistant bands are composed of a hard, grey, arenaceous limestone, which weathers brown and buff. (32 m).

Upper Shell-Limestones,

See page 56. (10 m).

Upper Shales.

1. Grey, highly fissile, arenaceous shales, weathering grey to brown, are interbedded with subordinate bands of hard, grey, arenaceous mudstone—sometimes streaked dark-grey—weathering to a dark-brown colour. These thin (8—10 cm) bands of mudstone are often nodular in character, and are probably impersistent laterally. (30 m).

2. Grey, arenaceous and calcareous shale, weathering grey or a pale brown, intercalated with massive, hard, grey arenaceous limestone weathering pale brown. The strata are lenticular and nodular in character throughout the subdivision, with only few persistent and regularly-bedded massive bands. Some of the more persistent-weathering bands show slump structures of penecontemporaneous origin (fig. 18). Cross-bedding is only seen infrequently. In the upper beds hard massive bands predominate, and form a transition lithology into the lowest beds of the overlying Ella Ø Formation. (26 m).

Ella Ø Formation.

Immediately to the north-west of f_7.

Lower Limestones.

1. Fine-grained, hard, grey arenaceous limestone, massive in character with only minor intercalations of grey arenaceous shale. Weathered surfaces show banding in shades of brown, a feature which is quite characteristic of

the formation as a whole. At 23, 25, 27 and 29 metres above the base intraformational conglomerates are present and contain fragments of grey arenaceous limestone and coarsely crystalline limestone, which measure up to 2.5 cm across the greatest dimension. The maximum observed thickness for a band of such conglomerate was 20 cm (30 m).

2. Medium-grained, pale-grey crystalline limestone, weathers brown with a rough surface. Associated with it are some lenticular bands of hard, grey arenaceous limestone. Near the base of the subdivision are minor intercalations of grey, thinly-bedded argillaceous limestone which weather buff: the occurrence of this lithological type is much rarer higher up the sequence. (4 m).

3. Hard, fine-grained, grey arenaceous limestone, weathering buff, with some very minor intercalations of grey arenaceous shale. Large slump features are widely developed, with bedding surfaces generally irregular and wavy. A thin and impersistent intraformational conglomerate occurs at 9.5 metres from the base of the subdivision. Lenticular masses of a grey, coarse-grained clastic limestone are found between 10 and 10.5 metres, also appear between 18 and 19 metres above the base, and are embedded in a fine-grained and arenaceous limestone, also weathering grey. (21 m).

Shaly Beds.

Grey, hard, arenaceous limestone, and grey, arenaceous shales, weathering grey to brown. The shales, although still in the minority, constitute a much higher proportion than in the other parts of the formation. In the upper half the arenaceous limestone and arenaceous shales are interbedded with some grey, argillaceous limestone which is thinly-bedded. Markings on bedding-planes may possibly be worm-trails. (7.5 m).

Upper Limestones.

1. Grey, coarse-grained, crystalline limestone. (5 m).

2. Fine-grained, thinly-bedded, grey, arenaceous limestone, weathering in bands of grey and brown, inter-bedded with medium-grey, fossiliferous limestone, and grey arenaceous shales weathering grey to brown. Intraformational conglomerates occur at a number of horizons, their included fragments are tabular, rounded, and sub-parallel to the bedding planes, and generally less than 3 cm across the greatest dimension. A crystalline limestone, containing many fossil fragments, forms the matrix to the conglomerates. The most massive conglomerate band, 50 cm in thickness, is present at 9 metres from the base; others occur at heights of 4, 5, 8.5 and 10 metres. Bedding is wavy and irregular throughout the subdivision, but the colour of the rock becomes a darker grey up the sequence, and forms a gradual transition into the dark-grey to black colour typical of the Hyolithus Creek Formation. (34.5 m).

Hyolithus Creek Formation.

Less than one kilometre south of f_7.

In the younger formations metric units on the left indicate height above base of formation or subdivision.

Base: Dolomite, dark-grey or black, medium-grained and hard, weathering pale-buff with blocky fragments. Bedding irregular with laminae of 3—4 cm average thickness. Stylolites common parallel or subparallel

to the bedding; stylolitic partings covered with a jet-black substance with a greasy sheen. Calcite common. Lithology is relatively uniform, but variations are:— a band of small-scale intraformational conglomerate occurs at 17 and 33 m above base; at 36.5 m above base a bed of very pale grey dolomite, 50 cm in thickness, is seen—medium-grained and crystalline, it weathers yellow-brown and has a rough, sandy surface texture; 43 m above base chert lenses and bands occur —an usual phenomenon in this formation; between 55 and 61 m above the base, and also from 67 to 95 m irregular and wavy calcite veining is very abundant along the bedding.

95 m: Limestone, dolomitic, pale and dark-grey to black, weathering buff and dark-brown correspondingly.

105 m: Fossil horizon 52.

105 m: Dolomite, dark-grey or black, medium-grained and hard, weathering pale-buff with blocky fragments—similar to the basal part of the formation. Between 113 and 124 m above base intraformational conglomerates occur at very frequent intervals, comprising almost three-quarters of the thickness. At 124 m above base a band of oolitic dolomite occurs, banded in pale and dark-brown on weathered surfaces: the dark-grey ooliths are set in a pale-grey matrix and weather out conspicuously.

176 m: Dolomite, dark-grey, fine-grained, slightly porcellaneous, weathering buff with well-developed small-scale banding in places. On fresh surfaces of the banded dolomite individual laminae are alternately pale and dark-grey. The aspect of the dolomite is massive, beds averaging 30 cm in thickness, with stylolites occasionally developed. At many horizons intraformational conglomerates are seen, some of which are composed of large plates of dark-grey to black dolomite. Drusy cavities contain well-developed carbonate rhombs. Lenticles and irregular nodules of black chert, weathering a rusty-brown, occur frequently and are as large as 15 cm across in places.

185 m: Dolomite, dark-grey and black, medium-grained, hard, with isolated chert horizons, the majority in the basal 2 m. Stylolites are fairly frequently seen; calcite disseminations are numerous.

215 m:
(Base of Dolomite Point Formation).

Dolomite Point Formation.

East of f_7.

Lower Dolomites.

Base: Dolomite, light-grey, fine-grained to porcellanous, weathering light-buff with carious surfaces. Isolated blebs and lenses of dark-grey chert follow bedding planes.

6 m: Dolomite, calcareous, medium to dark-grey, finely crystalline, weathering brownish-buff.

8.5 m: Gap in observation.

11 m: Dolomite, well-bedded, light-grey, fine-grained, weathering yellowish-buff. Bedding generally even, individual bands averaging 15 cm in thickness, although sometimes lenticular in character. Chert appears in thin streaks, often intimately associated with hard,

crystalline dolomite. Thin intraformational breccias at heights of 22 and 26 m.

26 m: Dolomite, calcareous, dark-grey and coarsely crystalline, in three brownish-buff weathering bands, averaging 25 cm in thickness, interbedded with light-grey dolomite, weathering cream and buff. Irregular-shaped and ovoid flint bodies at 27 m.

28 m: Dolomite, streaky-grey and coarsely crystalline, in two bands averaging 20 cm in thickness, interbedded with light-grey variety.

31 m: Dolomite, light-grey and finely crystalline, weathering buff. Streaks of silicified dolomite, together with flint bodies, occur along bedding. A highly silicified band of coarsely crystalline dolomite—averaging 15 cm in thickness—recorded at a height of 41 m. Rock consists of minute, irregular-shaped plates and ooliths of finely crystallised dolomite, wholly or partly replaced by secondary quartz, in a matrix of coarsely crystalline dolomite permeated by quartz and chalcedonic silica (see fig. 20). Weathering orange-brown to dark-brown.

42 m: Gap in observation.

43 m: Dolomite, light-grey and finely crystalline, interbedded with bands of medium to dark-grey dolomitic limestone higher in the succession. Small nodules and lenticles of black chert sparsely distributed, but form definite horizon at a height of 47.5 m. Silicified dolomite, similar to /41, developed at 55 m from base.

69 m: Calcareous dolomite, dark-grey, in prominent band.

71 m:

(Base of Calcareous Dolomite).

Calcareous Dolomite.

See page 60.

Upper Dolomites.

Base: Dolomite, medium-grey and finely crystalline, containing black chert and silicified stromatolitic structures (see fig. 21). Buff weathering.

2 m: Dolomite, light-grey and fine-grained, weathering light-buff to cream. Thinly-bedded at lower levels, individual bands being between 5 and 10 cms in thickness, but becoming more massive in sequence. Bedding wavy irregular.

31 m: Gap in observation.

35 m: Dolomite, light-grey and fine-grained, weathering light-buff. Lithology is shaly in lower beds, but becomes thinly-bedded higher in the succession.

50 m: Dolomite, light-grey and fine-grained. Thinly bedded aspect gradually gives way to more massive character higher in sequence. Bands of finely crystalline, buff-weathering dolomite interbedded at higher levels. Bedding often irregular and stylolitic.

74 m: Dolomite, medium-grey, finely crystalline, weathering buff to grey.

75.5 m: Dolomite, alternating bands of light-grey and medium-grey, showing irregular wavy bedding. General weathering light-buff to cream. Impersistent intraformational conglomerate at 105 metres.

112.5 m: Dolomite, medium-grey, coarsely crystalline and highly silicified, weathering grey. Original dolomite largely replaced by authigenic silica in the form of quartz. Small 'drusy' cavities, abundantly distributed throughout the rock, are lined by minute quartz crystals and frequently filled with a soft, black, amorphous hydrocarbon.

113.5 m: Siltstone, dolomitic and thinly-bedded.

114 m: Dolomite, medium to dark-grey, fine-grained and weathering buff. Chert streaks at some levels. Bedding hummocky. A thin intraformational conglomerate developed at 136 metres.

157 m: Dolomite, silty, thinly-bedded and almost shaly in places, between beds of more massive character.

162 m: Dolomite, light-grey, finely crystalline, weathering buff. Massive aspect predominant, but thinly-bedded at intervals. Bedding wavy. Stromatolitic structures on weathered strike surface at 182 metres.

207 m: Dolomite, medium-grey, finely crystalline. Irregular bedding planes revealed by resistant weathering laminae. Light-buff weathering.

212 m: Dolomite, light-grey, finely crystalline, weathering light-buff. Massive aspect.

252 m: Dolomite, light-grey and finely crystalline, containing nodules and streaks of grey chert.

254 m: Gap in observation.

256 m: Dolomite, silty and thinly-bedded, grading upwards into purer dolomite of more massive character.

260 m: Dolomite, light-grey and finely crystalline, containing streaky and irregular shaped bodies of chert. Penecontemporaneous brecciation evident in places.

270 m: Dolomite, light-grey and crystalline, of massive character. Small irregular shaped cavities—generally less than 1 cm in diameter—are distributed throughout the rock. Weathering has produced a 'sandy' surface texture and a buff coloration. Streaks and lenses of cherty material permeate the dolomite. Bedding irregular.

272 m: Dolomite, light-grey and crystalline, containing lenticles and nodules of black chert, together with streaks and irregular shaped bodies of flintose material.

276 m: Dolomite, silty and thinly-bedded.

282 m: Dolomite, light-grey, finely crystalline, with flintose streaks and lenticles. Light-buff weathering. A massive band of grey flint—markedly irregular in thickness—at 287 m, contains abundant small rounded and elongated fragments of flint and dolomite. These fragments are generally oriented along the bedding.

290 m:
(Base of Cass Fjord Formation).

Cass Fjord Formation.

South of f_7.

Lower Transition Limestones.

Base: Limestone, black and fine-grained, weathering black with buff streaks. Wavy and irregular bedding revealed by these buff streaks.

Intraformational conglomerate of 10 cm maximum thickness developed at top of stratum.

1 m: Limestone, streaky light and dark-grey, fine-grained and silty, weathering grey and buff. Bedding highly irregular—showing 'swirl' structures—becoming thinner and more wavy irregular above 5 m. Irregular fracture. Intraformational conglomerates at 2, 3 and 4.5 m from the base.

6.5 m: Limestone, medium-grey and crystalline, weathering medium-grey. Bedding indistinct in lower part, but becoming hummocky and well-defined at top. Fossil horizon 53.

7.3 m: Limestone, grey, weathering grey with buff streaks. Bedding irregular, becoming thinner higher in sequence. Thin, impersistent intraformational conglomerates present.

23 m: Limestones, very thinly-laminated, silty, weathering streaky-grey and buff. Laminae are thin and evenly-bedded in character (see fig. 23).

29 m: Limestone, medium-grey, massive, weathering grey and buff. Intraformational conglomerate, 10 cm maximum thickness, associated with streaks and lenses of chert in lower strata. Bedding irregular. Fossil horizon 54.

35.5 m :
(Base of Limestone-Shales).

Limestone-Shales.

Base: Limestones, thinly-bedded, nodular and lenticular, with shale partings.

0.8 m: Limestone, massive, grey weathering, showing an intraformational conglomeratic nature in places. Fossil horizon 55.

2 m: Gap in observation (Lenticular limestones and shales?).

8.5 m: Limestone, medium-grey, fine-grained, with yellowish-buff streaks and patches. Grey-weathering, with buff streaks and patches tending to parallel the bedding. Small-scale intraformational conglomerates in part.
Limestones, nodular and lenticular, with shaly partings of greenish-grey colour interbedded at intervals. Gaps in observation of two metres at /26, and of nine metres at /31.

9.5 m: Fossil horizon 56. 26 m: Fossil horizon 57. 32 m: Fossil horizon 58.

40 m: Limestones, thinly-stratified, nodular and lenticular, with shaly partings, interbedded with massive bands of medium-grey, fine-grained limestone. Intraformational conglomerates frequently developed. Fossil horizon 59.

41 m: Fossil horizon 60. 45.5 m: Fossil horizon 61. 51 m: Fossil horizon 62. 52 m: Fossil horizon 63. 66 m: Fossil horizon 64. 71.5 m: Fossil horizon 65. 95 m: Fossil horizon 66. 101 m: Fossil horizon 67. 103 m: Fossil horizon 68.

121 m: Limestone, medium-grey, fine-grained, in massive bands interbedded with thinly-stratified, nodular and lenticular limestones and shales. Proportion of lenticular limestones and shales decreasing.

134.5 m: Fossil horizon 69. 153 m: Fossil horizon 70.

154 m:
(Base of Upper Transition Limestones).

Upper Transition Limestones.

Base: Limestone, medium-grey, fine-grained, with rusty-yellow patches due to dolomitic segregations. Weathering grey, with patches of yellow-brown. Intraformational conglomerates developed in places. Fossil horizon 71.

4.5 m: Limestones, medium-grey, thinly-bedded, with intercalations of shale. The limestone laminae are nodular and lenticular in the lower part of the sequence, but become thicker and more evenly bedded at higher levels, with only a small proportion of shale.

9.5 m: Fossil horizon 72. 21.5 m: Fossil horizon 73.

22.5 m:
(Base of Kap Weber Formation).

Kap Weber Formation.

Western side of river dividing Rødøen from Albert Heims Bjerge.

Lower Limestones.

Base: Limestone, massive, weathering uniformly light-grey, with dark-grey to black weathering dolomitic permeations. The limestone occurs as ill-defined bands, medium to light-grey in colour; the dolomitic permeations follow the bedding as distinct bands, but often show more irregular distribution. Finely conglomeratic nature at certain levels. Occasional streaks and small, irregular-shaped bodies of yellowish-brown chert.

43 m: Limestone, thinly-bedded, nodular and lenticular, with shaly partings. Wavy basal plane. Grades up into

44 m: Limestone, grey, weathering light-grey with very abundant irregular and dark-buff dolomitic streaks paralleling the wavy bedding. In places the dolomitic streaks form dome-like structures suggestive of algal growths (see fig. 28). Irregular shaped chert bodies sparsely distributed.

47 m: Limestone, fine-grained, in irregularly bedded, streaky bands of light to dark-grey colour, weathering streaky grey. Dolomitisation developed as buff-grey weathering streaks and patches. Carious.

54 m: Dolomite, calcareous, fine-grained, weathering buff, containing large lenticular and irregularly shaped masses of grey-white weathering chert.

55 m: Limestone, medium to dark-grey, fine-grained, showing irregular fracture and calcite veining, weathering light-grey. Lenticular yellow-brown weathering chert bodies elongated along bedding.

57 m: Limestones, medium-grey and fine-grained; light-grey, fine-grained and dolomitic. These developed as thinly-laminated bands—between which are more massive beds—weathering streaky grey and buff. Weathering gives rise to yellow-buff appearance where dolomitic limestone predominates. Individual laminae in the banded series are generally less than 0.5 cm in thickness, but vary laterally,

becoming streaky. Bedding even, but sometimes irregular and wavy on a small scale, with tendency to form intraformational conglomerates. Massive bands show hummocky topmost bedding planes, and average less than one metre in thickness. Buff-weathering dolomite bands, average thickness less than one metre, occur at heights of 74, 77 and 81 m. Brownish weathering chert present.

85 m: Gap in observation.

92 m: Limestone, massive, dark-grey, fine-grained, weathering grey with darker grey, resistant dolomitic streaks and patches. Hummocky bedding evident near top, where lighter coloured limestone predominates.

99 m: Fossil horizon 74.

100 m: Limestone, thinly and irregularly bedded, with shaly partings. Thinly-stratified lenticular and nodular limestones, with minor greenish shale partings, in topmost 20 cm. Thin bands of intraformational conglomerates well developed.

103 m: Limestone, pinkish-grey, compact and fine-grained, with pockets and thin bands of intraformational conglomerate.

103.4 m: Limestone, nodular, dark-grey, fine-grained, with buff weathering dolomitic permeations.

104.4 m: Dolomite, calcareous, light-grey, medium to finely crystalline, weathering cream-buff. Minutely banded in shades of grey.

105.4 m: Limestone, dolomitic, light to medium-grey, corresponding with laminations of fine and coarser grain lithology. Intraformational conglomerates of small fragments (1 mm—1 cm) developed at various levels. Weathering generally streaky in shades of light-grey colour.

107 m: Limestone, medium-grey to almost black, fine-grained; some horizons massive, others thinly-laminated. Intraformational conglomerates.

115 m: Limestone, dark-grey, medium-grained, minutely banded in shades of grey, and weathering light-grey.

117 m: Limestone, in bands medium-grey almost to black, medium to fine-grained and weathering to shades of grey—darker and more irregular bands more closely spaced. Buff dolomitic streaks and patches in places. Differential weathering at height of 130 m reveals hummocky nature of bedding (algal structures ?). Chert present.

136 m: Limestone, light-grey, fine-grained, weathering light-grey. Dolomitisation shown by buff streaks and patches, which weather darker grey than limestone. Infrequent bands and nodules of chert.

159 m: Limestone, massive, dark-grey, and weathering light-grey.

160 m: Limestone, dark-grey, weathering light-grey and carious with much disseminated white and pink calcite.

162 m: Fossil horizon 75.

163 m: Limestone, massive, dark-grey and calcite veined, weathering medium-grey, lying above 20 cm of thinly and irregularly bedded, lenticular and nodular dolomitic limestone.

163.5 m: Limestone, thinly-bedded and lenticular, medium-grey, fine-grained, with streaky dolomitisation along bedding planes. Weathering in

bands of grey and buff. Many thin intraformational conglomerates and much calcite veining.

170 m: Limestone, massive, dark-grey.

171.5 m: Limestone, more thinly-bedded, dark-grey.

172.5 m: Limestone, massive, dark-grey, with some thin bands of intraformational conglomerate and much calcite. Chert sparsely distributed.

176 m: Limestone, dolomitic, thinly and irregularly bedded, lenticular and nodular, medium-grey and fine-grained. Fossil horizon 76.

176.5 m: Limestone, massive, medium to dark-grey, weathering dark-grey. Calcite veins and segregations.

178 m: Limestone, finely banded and dolomitic. Thin laminae of brittle, fine-grained, grey-weathering limestone, interbedded with thin laminae of buff-weathering dolomitic limestone. Bedding uneven. Calcite segregations common.

188 m: Limestone, dark-grey, fine to medium-grained, with buff dolomitic streaks. Weathering generally carious and light-grey, but dolomitic streaks form more resistant, darker grey ridges. Calcite veining very abundant throughout rock. Chert occurs as isolated nodules. Intraformational conglomerates.

192 m: Fossil horizon 77.

218 m: Limestone, massive, dark-grey and fine-grained. Heavy buff-coloured dolomitisation in streaks and patches causes rubbly appearance in places. Irregular network of fine calcite veining often gives rise to conglomeratic or brecciated aspect. Chert in lower beds.

251 m: Limestone, predominantly massive, dark-grey, fine-grained, interbedded with bands of medium to light-grey limestone. Finely conglomeratic in places (= true 'calcarenite'), containing minute rounded fragments of limestone.

278 m: Limestone, massive, dark-grey, fine-grained, with streaks and patched of dolomitisation. Occasional bands of lighter grey colour show the irregular nature of bedding. Thin band of light-grey, coarsely crystalline dolomite, weathering grey to buff, at height of 288 m.

298 m: Limestone, predominantly medium-grey and fine-grained, interbedded with ill-defined lighter and darker bands. Dolomitic streaks and patches. Calcite veining.

318 m: Limestone, medium to dark-grey, with some light dolomitisation in streaks and patches. Weathered surfaces show banding in light and dark-grey.

390 m: Limestone, medium to dark-grey, medium to fine-grained, massive and well-bedded, weathering grey with darker grey patches corresponding to dolomitisation. Calcite impregnations.

393.5 m: Dolomite, buff, coarsely crystalline, weathering grey.

394 m: Limestone, dark to medium-grey, medium to fine-grained and banded in shades of grey. Some dolomitisation. Calcite common.

488 m: Limestone, medium-grey, fine-grained, weathering grey with darker grey dolomitic permeations. Calcite streaks and veins.

493 m: Fossil horizon 78.

538 m:
(Base of Black Limestones).

Black Limestones.

Base: Limestone, dark-grey to black, fine-grained, but coarsely crystalline in patches, with dolomitic disseminations of buff to dark-brown colour. Calcite veining plentiful, but no chert.

10 m: Fossil horizon 79. 12 m: Fossil horizon 80. 15 m: Fossil horizon 81.

30 m: Limestone, dark-grey to black, fine-grained crystalline, weathering brownish-grey. Thinly-bedded—bands average 5 cm in thickness. Little calcite.

35 m: Fossil horizon 82. 41 m: Fossil horizon 83.

45 m: Limestones, medium to dark-grey, fine-grained, with abundant buff-brown bands and patches of coarser grained, dolomitic limestone. More shaly horizons occur as intercalations in places. Thin bands of chert at approximately half-metre intervals. Veins of calcite common.

50 m: Fossil horizon 84. 51 m: Fossil horizon 85. 58 m: Fossil horizon 86. 69 m: Fossil horizon 87. 74 m: Fossil horizon 88.

80 m: Limestone, dark-grey, in irregularly bedded bands, with partings of greenish shaly material. Chert bands and calcite disseminations.

84 m: Fossil horizon 89.

85 m:

(Base of Upper Limestones).

Upper Limestones.

Base: Limestone, medium-grey, fine-grained, weathering light-grey. Abundant chert in lowermost 50 m, occurring as thin bands at approximately 5 cm intervals. Calcite disseminations common.

65 m: Limestone, light to medium-grey, weathering grey, with yellow-buff dolomitic patches weathering dark-grey. Chert not thickly distributed. Carious surfaces.

117 m: Limestone, light to medium-grey, fine-grained but crystalline, with buff dolomitic streaks and patches. Weathering light-grey, with darker streaks and patches. Some chert. At 138 m a distinctive band of light-grey limestone (1 metre in thickness) weathering grey.

137 m: Fossil horizon 90. 145 m: Fossil horizon 91.

169 m: Limestone, massive, medium to dark-grey, with maroon-coloured disseminations and patches (dolomite). Considerable carbonate veining. Chert in frequent bands.

222 m: Limestone, medium to dark-grey, massive, weathering grey and carious, with buff-brown dolomitic patches. Chert bands very numerous.

287 m: Limestone, massive, medium to dark-grey, fine-grained, weathering light-grey. Irregular fracture. Dolomitisation in streaks and patches weathering dark-grey to black. Brownish-weathering chert in thin lenticles and bands along bedding planes. Much carbonate veining.

295 m: Fossil horizon 92. 325 m: Fossil horizon 93.

327 m: Limestone, massive, medium to dark-grey, fine-grained, weathering light-grey. Dolomitic streaks and patches weathering dark-grey to

black. Abundant lenticles and thin bands of brown-weathering chert in lower 20 m.

339 m: Fossil horizon 94. 343 m: Fossil horizon 95.

372 m:
(Base of Dolomites & Dolomitic Limestones).

Dolomites and Dolomitic Limestones.

Base: Limestone, dolomitic, grey, finely crystalline, weathering dark-grey, with interbedded bands of light-grey-weathering limestone. Dark-grey to black-weathering dolomite noticeable near base. Carbonate veining and chert present.

80 m: Limestone, dolomitic, light-grey to medium-grey, fine-grained, weathering light to dark-grey. Streaks, bands and irregular shaped bodies at intervals, weathering dark-grey to black or yellow-buff. Fossil horizon 96.

170 m:
(Base of Narhvalsund Formation).

Narhvalsund Formation.

Southwest of the glacier offshoot between Rødøen and Albert Heims Bjerge, and west of f_{11}.

Basal Dolomites.

Base: Dolomite, massive, light-grey, coarsely crystalline and saccharoidal, weathering grey with a sandy surface texture. Bands of medium to light-grey, finely crystalline, dolomitic limestone, showing many blebs and streaks of dolomite along bedding, occur at intervals.

31 m: Fossil horizon 97.

35 m: Dolomite, light-grey, pink-tinted coarsely crystalline, saccharoidal, with sandy surface texture.

40 m: Limestone, dolomitic, medium to light-grey, finely crystalline. Dolomitic streaks along bedding.

55 m: Dolomite, massive, light-grey and coarsely crystalline, weathering grey.

70 m: Dolomite, mottled maroon-grey, even-textured and crystalline. Sporadic bands of chert.

80 m: Limestone, heavily dolomitised, finely crystalline. The dolomite segregations are more coarsely crystalline. Grey chert present as small blebs.

90 m: Limestone, finely crystalline, with dolomitic streaks and segregations parallel to bedding.

110 m: Limestone, medium to dark-grey, weathering dark-grey, with buff-weathering dolomitic streaks parallel to bedding.

112 m:
(Base of Dolomitic Limestones).

Dolomitic Limestones.

Base: Limestone, medium to dark-grey, finely crystalline, with patches of buff-coloured dolomitic segregations. Secondary calcite disseminated in thin veins. Bands of medium-grey, fine-grained dolomite also interbedded at intervals.

21 m: Limestone, mottled maroon-grey, finely crystalline.

23 m: Limestones, dolomitic, fine-grained to porcellanous, in well-bedded bands varying in colour from maroon-pink to light-grey. Finely banded at some horizons, individual laminae being less than 1 mm in width. Buff-weathering beds of dolomite occasionally present, but rarely over one metre in thickness. Some chert and calcite disseminations.

81 m: Dolomite, calcareous, massive, grey with maroon mottling, finely crystalline.

83 m: Limestone, dolomitic, medium-grey, fine-grained, weathering grey-brown with 'sandy' surface. Few chert lenticles.

96 m: Limestone, dolomitic, grey with purplish mottling.

96.5 m: Limestone, medium-grey, fine-grained, weathering grey.

98 m: Limestone, dolomitic, grey with purplish mottling.

98.5 m: Limestone, grey, fine-grained, weathering grey.

The alternation of the lithological types described in the basal 100 metres continues up the succession, the beds of grey limestone forming the dominant lithology.

125 m: Limestone, light-grey, fine-grained, in massive bands associated with thin beds of lilac-tinted grey, crystalline dolomite.

143 m: Limestone, dolomitic, medium-grained, finely banded in shades of pink and lilac-grey. In places the rock is light-grey in colour.

151 m: Limestone, medium to dark-grey, crystalline, weathering brownish-grey. Reddish-brown staining along bedding planes—due to iron-rich compounds?

153 m: Gap in observation.

164 m: Dolomite, light pinkish-grey, finely crystalline, showing sandy weathered surfaces, interbedded with occasional bands of medium to dark-grey dolomitic limestone.

175 m: Limestone, medium to dark-grey, fine-grained, with bands of buff-weathering dolomitic limestone. Some chert disseminated in small lenticles.

178 m: Gap in observation.

193 m: Limestone, dolomitic, light to medium-grey, medium to coarsely crystalline, weathering brownish-grey.

194 m: Dolomite, grey to pinkish-grey, coarsely crystalline.

197 m: Limestone, dolomitic, light-grey and finely crystalline, weathering grey.

199 m: Dolomite, medium-grey with pink-stained patches, finely crystalline, weathering grey and pinkish-grey.

201 m: Limestone, dolomitic, medium-grey, fine-grained, weathering grey with pinkish coloured staining. Two metres in thickness.

A similar alternation in lithology continues up the sequence, giving rise to a banded appearance on weathered outcrop.

217 m: Gap in observation.

221 m: Dolomite, calcareous, medium-grey, finely crystalline.

223 m: Limestone, dolomitic, pinkish-grey and finely crystalline.

225 m: Gap of observation.

240 m: Limestone, dolomitic, pinkish-grey, finely crystalline.

241 m: Limestone, grey, red-stained, coarsely crystalline with saccharoidal texture.

244 m: Dolomite, fine-grained, cream to pink-grey with red-coloured streaks and blebs.

245 m: Limestone, grey to pink and maroon, generally fine-grained, but coarsely crystalline and 'sugary' textured in some bands.

261 m: Limestones, dolomitic, medium-grey and crystalline. An intraformational conglomerate is present at 265 m.

278 m: Limestone, dolomitic, light-grey, fine-grained, weathering cariously.

283 m: Limestone, dolomitic, medium-grey with purple-maroon streaks, finely crystalline and weathering grey to maroon.

283.5 m: Limestone, mottled medium to light-grey, fine-grained, weathering grey.

292 m: Limestone, massive, medium-grey, weathering grey. The rock consists of minute rounded fragments of a fine-grained limestone in a matrix of more coarsely crystalline lithology. Fragments range in size up to 2 mm in maximum diameter, and suggest clastic origin of rock.

296 m: Limestone, mottled medium to light-grey, finely crystalline and weathering grey, interbedded with medium-grey to lilac-grey, 'calcarenitic' limestone.

322 m: Limestone, dolomitic, maroon-grey, finely crystalline, showing carious weathering.

325 m: Dolomite, grey to white-grey, fine-grained and hard, weathering light-grey and carious.

326 m: Limestone, grey, thinly and irregularly bedded, coarse-grained.

332 m: Limestone, maroon-grey, fine-grained, weathering grey and maroon-grey, interbedded with bands of light-grey, finely crystalline limestone. The latter type of lithology becomes more predominant up the succession.

350 m:
(Base of Heimbjerge Formation).

Heimbjerge Formation.

North-east of f_{10}.

Lower Limestones.

Base: Limestones, thinly-stratified, maroon-grey, finely crystalline, showing irregular and lenticular bedding. Small blebs and streaks of brownish chert occur parallel to bedding. Fossil horizon 98.

2 m: Fossil horizon 99.

10 m: Limestones, maroon-streaked grey, becoming more evenly bedded, with bands averaging 5 cm in thickness. Grades up into massive grey limestone.

13 m:
(Base of Grey Limestones).

Grey Limestones.

Base: Limestone, massive, medium-grey, finely crystalline, with little or no trace of bedding. Weathering carious and light-grey. 'Calcarenitic' texture. Few blebs of chert along bedding; some carbonate veining.

50 m: Limestone, massive, medium-grey, finely-crystalline, shows little change in lithology up the succession. Maroon-coloured blebs and streaks at 52 m.

67 m: Fossil horizon 100.

77 m: Limestone, massive, medium-grey, fine-grained, shows pockets of more granular crystalline appearance. Some chert present. Little change in lithology.

167 m: Limestone, massive, medium-grey, finely crystalline. Thin siliceous streaks along bedding direction, averaging less than 5 m in length, composed of almost horizontal laminae which are about 2—3 mm apart. Upper surfaces of laminae finely mammilose. Algal growths ? These continue up section. Fossil horizon 101.

207 m: Limestone, grey with maroonish tint, massive but more thinly bedded, in bands of 20 cm average thickness. Bedding irregular. Lithology remains fairly constant up succession.

212 m: Fossil horizon 102. 217 m: Fossil horizon 103.

232 m: Limestone, massive, medium-grey, with occasional algal streaks along bedding. Continues up section with same lithology.

247 m: Fossil horizon 104. 297 m: Fossil horizon 105.

307 m: Limestone, massive, medium-grey, finely crystalline, weathering patchy grey. More shattered appearance of rock due to well exposed state of strata forming summit of bluff. Carbonate veining present. Fossil horizon 106.

(Top of Heimbjerge Formation).

B. Ella Ø.

Canyon Formation.

Stream-gorge of Storeelv, near the eastern branch of the Tømmerbugt fault system.

a. At the base is a band of pale-grey dolomitic quartzite, flecked with orange to buff weathering grains, which is approximately 10 cm in thickness. This is followed by 40 cm of grey dolomitic siltstone weathering orange to brown —a very hard and massive rock which shows ripplemarking and irregular fracture. The main part of the subdivision consists of maroon and green, argillaceous, calcareous siltstone which shows little change in colour from fresh to weathered surfaces. It is well-bedded, fissile and flaggy in character, splitting and shattering into laminae which range between 7 mm and 10 mm in thickness. (29.5 m).

b. Grey, calcareous, arenaceous shale interbedded with bands of grey, calcareous, argillaceous siltstone weathering buff to brown. The harder bands are flaggy, with laminae 5 mm or slightly more in thickness, and fine-grained in texture. (33 m).

c. Grey-green, thinly-bedded, arenaceous limestone, which weathers to a dark-

buff colour, and grey shales. The limestone shows some colour-banding and has irregular bedding-planes. (12 m).

d. Micaceous, argillaceous, and thinly-bedded siltstone and shales. The predominant colour is maroon but some horizons are green. (17 m).

e. i) Medium-grey, massive and well-bedded arenaceous dolomite, colour-banded in shades of grey and weathering dark-brown. There is a small proportion of grey shale. (36.34 m).

ii) Dark-grey to black, argillaceous, arenaceous dolomite weathering pale-buff, with dark-grey to black shales. The dolomite is predominant, but there is some gradation between the two lithologies. (45 m).

iii) Dark-grey, thinly-bedded and arenaceous dolomite, weathering yellow to buff, has shaly partings and irregular bedding-planes which are nearly black and occasionally shining and lustrous. The dolomite is stromatolitic on a small scale at some horizons, and has shale interleavings which become more conspicuous towards the top of the subdivision. (21 m).

The faulted block of strata to the east of Antiklinalbugt on the south coast.

f. i) Dark-grey, dolomitic limestone, with blebs and vesicles of quartz, weathering grey to buff. The whole rock is very much shattered and brecciated. Large unbedded bodies, possibly stromatolitic, occur within the more regularly-bedded parts. (65 cm).

ii) Hard, pale-grey, medium-grained limestone weathering grey and buff. Towards the top it becomes finer-grained, grey and dolomitic, weathering pale-buff and comprising 5—10 cm out of the total thickness. A soft black shale which weathers almost to a powder is only 1—2 cm thick. (90 cm).

iii) Grey, cream-weathering dolomite is associated with large blebs of crystalline calcite and much calcite veining. Banding in shades of grey, together with stylolites, parallel the bedding. A shattered shaly horizon is found in the topmost 5—20 cm of the lowest metre of the subdivision. Grey, dolomitic limestone with calcite blebs, weathering pale-buff and becoming finer-grained towards the top, forms the remainder of the thickness. (4.8 m).

iv) Dark-grey shales showing harder bands and dark shining parting surfaces. (30 cm).

v) Fine-grained, thinly-bedded, dark-grey limestone and dolomitic limestone, with shale intercalations, is heavily jointed and shattered and has very irregular and wavy, sooty-black bedding-planes. The weathering is white to buff, and the more calcareous horizons have rough carious surfaces, possibly due to differential solution. In the upper part of the subdivision the bedding is most irregular and hummocky, a feature which is possibly due to the presence of algal colonies. (12.5 m).

g. i) Dark-grey, fine-grained dolomitic mudstone weathering cream to buff, having shaly partings and wavy, irregular bedding; some cross-bedding can be seen in places. Intercalated between the mudstones are grey to black shales, varying in hardness. Four distinct bands of such shale were observed. Near the top the beds of mudstone and shale become thinner and there is a higher proportion of shale. (3.9 m).

ii) Dark-grey shale, weathering greenish-grey, with a thin (4 cm) grey, buff-weathering dolomite band in the middle of the subdivision. Intraformational conglomerates with rounded fragments also occur. (50 cm).

Spiral Creek Formation.

Faulted block to the east of Antiklinalbugt, south coast.

a. i) A massive intraformational conglomerate of arenaceous dolomite laths in a matrix of partly broken-up dolomite with included large grains of quartz. The fragments of arenaceous dolomite are platy and lath-like, the majority being parallel or sub-parallel to the bedding and up to 12 cm in length, the few found at an acute angle to the bedding reach a maximum length of only 3 cm. All gradations in size between the large laths and the smallest grain-like fragments are present, but the general impression gained is that 5 cm is the commonest dimension parallel to the bedding, with 1.5 cm at an acute angle to it. The fragments weather buff, whereas the rounded sand grains of the matrix and the small fragments weather pale-brown or dark-buff. The junction with the Canyon Formation is sharp. This massive conglomerate, 30 cm in thickness, is surmounted by a pale-grey, hard, arenaceous dolomite which weathers to a buff colour. Interleaved with this dolomite are dark-grey shales which weather green-grey; these shale interleavings become thicker and more frequent upwards in the succession.

The dolomite with shale interleavings grades up into another massive intraformational conglomerate, occupying the topmost 50 cm of the subdivision. The conglomerate, consisting of plates of grey, buff-weathering, arenaceous dolomite set in an arenaceous matrix, differs from the lower one by the presence of irregular-shaped siliceous bodies. The plates or laths are in random orientation, some being on end with respect to the bedding, and the brown-weathering matrix shows its coarse sandy character on bedding-planes. The siliceous bodies are very irregular in shape—blebs and streaks of whitish-grey quartz or chert which weather slightly pink. Lateral variation in texture and lithology occurs in the 50 cm thick band. There are intercalations of shale, and distinct lenticles of grey to white quartzitic sandstone containing small grains of darker material up to 1 mm in size, poorly graded in character and weathering buff to brown. On upper bedding surfaces ripple-marks of large wavelength occur in a grey shale veneer. (1.4 m).

ii) Irregularly-bedded, porcellaneous, pale-grey, arenaceous dolomite weathering cream to light-orange is found with intercalations of grey shale which cut right across the regional bedding, although following the bedding of the subdivision. One well-exposed bedding-plane displays a very irregular hummocky character. In the top 2 metres the lithological character is much the same but the bedding is more regular. The shale predominates over the dolomite in the middle of the subdivision, but in the upper part some of the dolomite horizons appear to be lenticular and arenaceous, with well-developed cross-bedding. There is evidently here a transition in lithology to the siltstones of the overlying subdivision b. (3 m).

b. Pale-grey, fine-grained, dolomitic siltstone, regularly interbedded with grey-green arenaceous shales; the siltstone weathers to a pale brown and the shales to a greenish tint. At the base of the subdivision a band of shale occurs, 75 cm thick, but ascending the sequence the proportion of shale becomes less in relation to the siltstone. The siltstone has an argillaceous content in the lower part and can be termed argillaceous, dolomitic siltstone; upwards in the succession the siltstone becomes more arenaceous and harder and is cross-bedded on a small scale near the top. Salt pseudomorphs are found on the lower surfaces of the siltstone bedding-planes (see page 81).

Ripple-marks are preserved only on the upper surfaces of bedding-planes in the siltstone, at junctions with shale interleavings which are ubiquitous on bedding surfaces. The impression of the ripples is never seen in the shales, probably because the shale is fragile and so rapidly reduced to fragments. In two examples measured one had a wavelength of 30 mm and an amplitude of 5 mm, while the other was 19 mm and 3 mm respectively, giving ripple indices (λ/a) of 6 and 6.3. These ripple-marks are common throughout the beds. (8.4 m).

c. Grey, thinly-bedded, feldspathic quartzite weathering grey or brown. Thin-sections show the grains of quartz to be well-sutured and that at least 20 % of the rock is formed by feldspar. A characteristic of the rock is the large number of small cavities which parallel the bedding-planes and are elongated in those planes. These cavities are easily seen on weathered surfaces and can also be found on freshly broken surfaces. The quartzite around the cavities is stained a rusty-brown, a phenomenon which is noticeable throughout the bed. Bedding surfaces are irregular, no doubt due to the cavernous nature of the rock. (1.5 m).

d. The top of subdivision c was not seen. It seems likely, however, that the recession of the cliff indicates that the gap in the observed succession of 2.5 m is occupied by shales. Only 20 cm of grey-weathering shales were actually seen at the top of this subdivision. (2.7 m).

e. At the base is a dark-grey calcareous sandstone of medium to coarse grain, and partly conglomeratic with small rounded pebbles. The weathered rock is brown and pitted, with glistening black surfaces which are probably due to the presence of a small proportion of cryptocrystalline silica in the form of black chert. Thin-sections show rounded quartz grains set in a fine-grained matrix of carbonate crystals. This sandstone band is laterally variable and impersistent and, in the small exposure available for examination—2 metres along the strike—varied in thickness from 4 cm to 10 cm.

Dark-grey to black, fine-grained dolomite weathering a buff colour is found higher in the sequence. Between beds of this lithological type there are thin intercalations of dark-grey to black shales which weather black. Prolific chert disseminations occur in the dolomite (see page 82).

Interbedded with the dolomite and shales are bands of massive calcareous sandstones which vary in thickness laterally, some being lenticular and up to 3 metres long and 60 cm at the thickest point. These sandstones weather grey and buff; grains of quartz and black chert can be seen in the hand-specimen. Other lithological types present are dolomitic sandstone, which is partly conglomeratic, and a true intraformational conglomerate, which is siliceous and dolomitic. In some of these rocks quartz bodies and granular quartz are found associated with flint and grey chert. In the shale bands there are frequent harder bands of dark-grey, fine-grained, argillaceous limestone.

A 20 cm thick band of grey impure chert, partly conglomeratic and weathering a rusty-brown, occurs at the top of the cherty dolomite subdivision, and on field evidence does not clearly belong to either the Spiral Creek Formation or the Kløftelv Formation: on lithological affinities it is included in the subdivision e. of the Spiraal Creek Formation. (14.3 m).

The main examination of the formation was carried out at fjord-level, but measurements at a height of 30 metres up the cliff indicated that there the subdivision is thicker by 3.5 metres and the overlying quartzite appears

to be arched above this thicker part of the bed. There is no evidence to suggest a fault, so these observations indicate the possibility of a disconformity at this horizon.

Kløftelv Formation.

1. Faulted block to the east of Antiklinalbugt, south coast.

Lower Quartzites.

White or grey quartzite weathering grey which varies in shade to black, white, pink, brown and yellow. The lower beds show small-scale jointing. At approximately 2 metres from the base lenticular bands with irregular bedding surfaces are seen associated with intercalations of shale, — each band of fissile material being a few centimetres thick. Cross-bedding is common throughout. On the lower surface of one bedding-plane sub-circular marks are found, roughly concentrically arranged, which possibly represent 'swash' marks due to "lobate fronts of waning waves, advancing over sandy beaches" (Shrock, 1948, 128). Another bedding-plane shows sedimentary structures akin to mud-cracks in appearance. (18 m).

Lower Sandstones.

i) A gully, full of snow at the time of measurement, probably indicates more easily eroded lithological types at this point in the succession. Therefore, although this interval could not be examined, it can be included in the Lower Sandstones. (2.5 m).

ii) Grey quartzite. (1.5 m).

iii) Grey, medium-grained, quartzitic sandstone weathering pink-grey and green-grey. Cross-bedding occurs, showing bands of grey to black on weathered surfaces. (1 m).

Middle Quartzites.

i) Cross-bedded white and grey quartzite weathering rose, orange and ruddy-brown. Grey quartzites predominate at the base but white varieties are more common at the top. (4.05 m).

ii) Maroon to red, micaceous, highly arenaceous shales grading into micaceous sandstone with a minor band of quartzite. (1.07 m).

iii) White and grey, cross-bedded quartzite weathering orange and ruddy-brown. (6.5 m).

Upper Sandstones.

Maroon, green and grey, glauconitic sandstone which weathers grey and maroon; gradations can be seen into more fissile rock, micaceous, arenaceous shale or argillaceous sandstone, which are maroon to red in colour. The shales also have a green and yellow coloration in places—the green being due to the presence of glauconite. The sandstone is cross-bedded and ripple-marked. Minor quartzite bands and lenticles are found within the shales: the colour of the fresh rock is white to grey and it weathers a buff hue. (5.05 m).

Upper Quartzites.

Massive, cross-bedded, pale-grey to white quartzite weathering yellow, orange and brown; on weathered surfaces some of the individual grains of quartz are easily visible to the naked eye, in thin-section however it can be

seen that the rock is relatively poorly graded and the well-sutured grains vary in size from fine to coarse. The cross-bedding near the base of the subdivision is marked by purplish streaks and the rock is generally purplish in colour.

In this section in the faulted block the top of the Upper Quartzites in not seen: the measured thickness of 16.9 metres is clearly a minimum value. The outcrop abuts against a scree—this change in topography from rock exposure to scree presumably indicates a sudden change of lithology. In the section from the core of the anticline the Upper Quartzites are considerably thicker. It seems likely that in the faulted block part of the Upper Quartzites are cut out by a fault.

2. Section near the core of the anticline on the south coast:—

Lower Quartzites.

Below this subdivision is found a band of grey and maroon chert, 30 cm thick, which has a very irregular base and rests on the cherty dolomite of the Spiral Creek Formation. The top bedding-plane of the cherty dolomites is quite regular and the chert seems to be associated more with the quartzite above. However, the basal bedding-plane of the quartzite above the chert band is also very irregular and hummocky, with lenses of grey-green and maroon shales; it is also of variable thickness. It would seem, on the basis of lithological affinity, best to include the chert band with the cherty dolomite of the Spiral Creek Formation. From this discussion it will be seen that the evidence for a disconformity between the formations is far from clear.

a) White quartzite of variable thickness. (Average 1.2 m).
b) Thin band of green shale. (5 cm).
c) Grey quartzite, the topmost bedding-plane is ripple-marked. (2 m).
d) Bands of white quartzite interstratified with thin bands of pale-green arenaceous shales. (1 m).
e) Grey quartzite weathering orange. (9.7 m).
f) An unobserved interval of 10—15 m thickness, the greatest part of which is probably quartzite.

Lower Sandstones.

a) Glauconitic, quartzitic sandstone showing banding in shades of maroon-brown and cream. (50 cm).
b) Cross-bedded, grey and maroon quartzite. (60 cm).
c) Thin bands of very fissile green shales. (5 cm).
d) Grey and maroon cross-bedded quartzite weathering orange-brown. (30 cm).
e) Intercalations of green and maroon arenaceous shales in finely banded quartzitic sandstone. (60 cm).

Middle Quartzites.

a) Grey quartzite which, for a small thickness at 1 m from the base, tends towards quartzitic sandstone. (8 m).
b) Impersistent green and maroon shales. (Average 50 cm).
c) Grey quartzite flecked in maroon colour. (35 cm).
d) Maroon and grey streaky quartzite, 15 cm thick.
Laterally this band of quartzite becomes attenuated into discrete

ovoid bodies, with the overlying shale sweeping down between them. The origin of this structure may be sedimentary—although there is no angular unconformity there may have been some penecontemporaneous erosion; it seems quite possible however that this is a small-scale example of 'boudinage', the quartzite having been attenuated by tensional stresses.

Upper Sandstones.

a) Maroon, micaceous, arenaceous shales with intercalations of maroon sandstone, quartzitic sandstone and quartzite. The harder bands range up to 15 cm in thickness and weather in shades of brown. (2.6 m).
b) Maroon and white streaked quartzite weathering ruddy-brown. (20 cm).
c) Green and maroon micaceous arenaceous shales. (15 cm).

Upper Quartzites.

a) Grey and white cross-bedded quartzite weathering red, yellow and orange (27.5 m).
b) Argillaceous sandstone. (50 cm).

Overlying the Upper Quartzites with no angular discordance is the basal horizon of the Bastion Formation, although there is a conglomerate for 50 cm at the base of the Glauconitic Sandstones.

Bastion Formation.

Eastern limb of anticline on the south coast.

Glauconitic Sandstones.

a. Glauconitic, silicious conglomerate — see page 86. (50 cm).

b. Speckled green and orange-brown, ferruginous, feldspathic, glauconitic sandstone. Of medium to coarse grain the sandstone is thinly-bedded and flaggy. At the top of the subdivision the bedding becomes hummocky with small spheroidal structures—nuclei of sandstone surrounded by more shaly material. (5 m).

c. Maroon or purple to grey, ferruginous, glauconitic siltstone which is also feldspathic and micaceous, flaggy, fissile and cross-bedded. (6 m).

d. In the lower part this subdivision is made up of maroon or purple to grey siltstone, which is similar to subdivision c. Higher up the rock is more massive and much more ferruginous — a glauconitic, ferruginous sandstone which is also feldspathic, micaceous, and cross-bedded. (6 m).

e. The principal lithological type is a siltstone: at the base a maroon to purple, glauconitic, micaceous ferruginous siltstone weathering dark-brown and very fissile. Higher in the sequence the siltstone is micaceous, dolomitic, glauconitic and argillaceous, sometimes with irregular bedding-planes and, in places, showing grooves or ridges which could be ascribed to such organic agencies as worms. A small part of the thickness consists of glauconitic, arenaceous, slightly micaceous shales, which are greenish-brown and weather brown. Thinly-bedded sandstone also occurs—highly glauconitic and ferruginous, sometimes containing feldspar and mica and colour-banded in grey and green; it weathers brown and buff. Maroon to purple sub-circular patches, weathering brown and buff occur on the bedding-planes: these appear under the binocular stereoscopic microscope to be richer in ferruginous material and

by their shape suggest the possibility of being completely replaced fossils (brachiopods?). However, in a conservative view a sedimentary origin is more probable.

In the middle of this subdivision a chloritic, glauconitic, vari-coloured and buff-weathering sandstone occurs, which laterally varies into a conglomerate containing fragments having long dimensions up to 7 mm. (20.8 m).

Glauconitic Shales.

Grey-green, micaceous, glauconitic shales, weathering brown tinged with green. (12.5 m).

Lower Shell-Limestone.

See page 87. (60 cm).

Lower Shales

For a thickness of 30 cm at the base is found a greyish-green, fine-grained, glauconitic arenaceous shale, showing rather poor fissility and slight banding in grey and brown on weathered surfaces. The shales above this basal shale band are frequently interrupted by limestone bands—grey, arenaceous shales weathering to a predominantly pale-buff colour, and fine-grained medium-grey limestone weathering pale-brown. There is considerable variation in the lithology of these harder bands: some examples are highly glauconitic with a green colour, others show only an occasional grain of that mineral; a considerable ferruginous content gives a maroon tinge in places; much of the limestone is massive and hard and is predominantly fine-grained in texture. Cavities filled with large crystals of calcite commonly occur. Harder bands of grey, calcareous, micaceous and argillaceous siltstone, weathering buff, are occasionally encountered in the sequence. (35.4 cm).

Upper Shell-Limestones.

This subdivision consists mainly of shales—green, glauconitic shales—and medium-grey, medium-grained, glauconitic brown-weathering limestone bands, containing small cavities lined with dark, shaly material and filled with pink calcite. At three horizons within this small thickness brachiopod shell-banks are found in a dark-grey to black, glauconitic, arenaceous, calcareous mudstone which weathers a pale-brown, leaving the shell fragments easily visible as rusty-brown traces. (2.4 m).

Upper Shales.

a. Dark-grey argillaceous siltstone bands interbedded with buff to yellow-brown, arenaceous shales. The bands are fairly massive, up to 20 cm thick, in the lower half of the subdivision where they dominate the sequence; higher up they become less important. Minor features are the low glauconite content, the variable percentage of ferruginous material, and the irregular, streaky banding in dark-grey and brown. A few of the harder bands are only slightly argillaceous and are true siltstones. (37.9 m).

b. Dark-grey arenaceous shales weathering buff with lenticles of dark-grey, fissile, calcareous and argillaceous siltstone which weather dark-brown. The siltstone shows grooves or ridges which may be trace-fossils. A few of the harder bands are only slightly argillaceous and are true siltstones. (8.2 m).

c. At the base is found a hard, massive, medium to coarse-grained, glauconitic, calcareous sandstone: the fresh rock is grey in colour but weathers

brown to grey. On lower bedding-planes are comple striated ridges, similar to 'Cruziana' and probably trilobite trails. This sandstone is intercalated with shale and varies in thickness, but the average is 20 cm. Above this basal sandstone a series of grey shales weathering grey, of varying hardness and fissility, have within them at a number of horizons bands of hard, medium-grey, fine-grained, arenaceous limestone, weathering pale-buff to pale-brown. This limestone breaks with a sub-conchoidal fracture and in places shows cross-bedding on weathered surfaces. (1.6 m).

Ella Ø Formation.

Eastern limb of anticline, south coast.

Lower Limestones.

Grey, very fine-grained, hard, arenaceous limestone, weathering brown, with intercalations of grey, arenaceous shales, weathering yellow to grey. This lowest part of the subdivision, of 4.3 m thickness, is transitional from the predominantly shaly Bastion Formation to the more massive overlying beds. The limestone has wavy irregular bedding, often giving a lenticular appearance; cross-bedding occurs on a small scale in some limestone bands, and ripple-marks are to be seen in places. The thickness of the harder bands varies from 5 cm to 40 cm.

Above the basal part is found pale-grey, medium-grained, oolitic, glauconitic and arenaceous limestone which weathers buff. This lithological type only persists for a limited but variable thickness, the observed maximum being 5 cm. Arenaceous shales are also intercalated, but are of minor importance. The arenaceous limestone contains a high proportion of quartz and, at a height of 5 m above the base of the subdivision, the rock becomes a glauconitic, calcareous sandstone containing patches of pure, very fine-grained, oolitic limestone. In places the rock is very highly glauconitic.

From 5 to 26 m above base the characteristic development is grey, very fine-grained, massive, hard arenaceous limestone weathering brown or ruddy-brown. Also present is a second type—medium-grey, medium-grained, crystalline limestone weathering to a buff colour and often almost entirely composed of fossil fragments chiefly trilobite tests. Both the arenaceous limestone and the crystalline limestone are sometimes glauconitic, but, in general, glauconite is not usual. Calcite disseminations are fairly common. Minor shale intercalations occur, but are generally not more than 5 cm in thickness and become rarer upwards in the succession. Considerable lateral variation occurs in lithology, and although a distant aspect gives the impression of regular bedding, on closer examination it is seen that individual bands have a somewhat irregular and wavy nature. Fossils are abundant in the crystalline limestone, occurring as bands and pockets packed with fragments, although an occasional specimen is more complete; although more sparsely distributed in the arenaceous limestone they generally show better preservation. Thin intraformational conglomerates are present between 25 and 26 metres above the base.

Between 4 and 5 m from the top of the subdivision a striking variation occurs in the lithology. This is the occurence of lenses, pockets and irregular-shaped bodies of very coarse-grained, earthy grey-brown limestone weathering brown, and consisting of badly-cemented, almost uncemented, angular calcite crystals with interstitial opaque dust. The bodies of this material are set in a dark-grey crystalline limestone which weathers brown; the difference between

the two lithological types is clearly visible on weathered surfaces, both in colour and roughness of surface. Other types of limestone found at this level are dark-grey, arenaceous limestone weathering buff, and pale-grey, buff-weathering crystalline limestone which consists almost entirely of fossil fragments. Some cross-bedding is to be seen. (31 m).

Shaly Beds.

Interstratified limestones and shales form this subdivision. The lower 2.5 m consist of a few flaggy, hard, grey, arenaceous limestone bands 5—10 cm thick weathering brown, with arenaceous shaly partings which are micaceous and shining—probably indicative of movement. The grey, arenaceous shales, which weather grey, are micaceous and sometimes glauconitic like much of the limestone. The upper part is predominantly flaggy, cross-bedded and irregularly-bedded, arenaceous limestone of lenticular character interbedded with micaceous shales. (3.5 m).

Upper Limestones.

a. Massive, hard, grey, very fine-grained arenaceous limestone weathering buff shows well-developed slumping. The weathered surfaces of the limestone show banding in shades of brown, the characteristic colour of the formation. Cross-bedding is also well-developed. There are occasional intercalations of green, glauconitic and arenaceous shales which sometimes contain lenticles of cross-bedded limestone.

At a height of 12.5 m above the base of the subdivision there is a 2 m thick band of grey crystalline limestone, weathering buff to brown which contains abundant fossil fragments. Above this, for 4.5 m is a grey, hard and arenaceous limestone showing slumping features in places; in the middle of it is a flaggy limestone band 50 cm thick.

From 19 m to 26 m above the base of the subdivision there is a hard, grey, fine-grained arenaceous limestone with black streaks, weathering brown with black streaks. Intraformational conglomerates occur throughout this thickness, they are usually only thin and laterally impersistent. One such conglomerate in the middle of the sequence is 10 cm thick, and is notable for having almost continuous, closely spaced laminae. A thinly-bedded limestone band 15 cm thick is present at a height of 22 m above base. (26 m).

b. A snow-filled gully gave an unobserved interval of 2 m in the succession at the base of this subdivision, and was succeeded by grey, dark-grey and black, fine-grained, arenaceous limestone interbedded with thin intercalations of a very thinly-bedded limestone containing some mica and shaly partings. The whole sequence weathers grey to brown with buff streaks. At irregular intervals more massive bands occur which are 5—40 cm thick, but shaly partings are found throughout the bed; the bedding is irregular and wavy. The harder, fine-grained arenaceous limestone bands have a conchoidal fracture, and on weathered surfaces display cross-bedding. At a height of 6.5 m above the base of the subdivision there is a fossiliferous band of grey crystalline limestone which weathers buff. Just above this level in the section the frequence of falling stones from the higher cliffs made a close approach to the rocks too hazardous. The sequence from 8.5 m to 16.5 m above the base of the subdivision was therefore carefully scanned from a short distance. It is very similar to the succession lower down: thin beds of limestone with occasional massive bands and less frequent shaly partings.

The topmost 3 metres consist of dark-grey to black fine-grained limestone weathering brown and buff. The bedding is generally thin and irregular, with occasional bands of more massive limestone. At the top is found a pale-grey, thinly-bedded, hard and brittle limestone which has a more crystalline texture. (19.5 m).

Hyolithus Creek Formation.

Eastern limb of anticline, south coast.

a. Black or dark-grey, medium to coarse-grained hard dolomite. The bedding is irregular and often stylolitic and in general the rock is thinly-bedded with an average thickness of laminae of 3.5 cm—there is little variation from this average. Weathering shatters the rock into blocky fragments and produces a pale-brown or buff colour with patches of white. Rust-brown faces perpendicular to the bedding are seen on splitting. Stylolites are abundant parallel or sub-parallel to the bedding and their surfaces are covered with a jet-black substance with a greasy sheen. On many weathered surfaces there is an arenaceous appearance and poorly-developed cross-bedding is seen, suggesting a clastic origin for part at least of the sequence. Calcite streaks and veins are fairly common and often show up along bedding lines on weathered ed surfaces. This description applies to the rest of the subdivision except for the variations noted below. Above 20 metres from the base of the subdivision the sequence is not so thinly-bedded but is still stylolitic. Pyrite concentrations are common, often in tubes, some of which have been weathered away leaving cylindrical cavities. The dolomite is in places a paler grey.

Between 30 and 35 m from the base the dolomite has a spotted appearance on weathered surfaces. On fresh faces and in thin-section this is seen to be due to circular brown stains — segregations of a brown dust (probably ferruginous) which is disseminated through the rock. This possibly indicates a weakly developed oolitic character. In general throughout the subdivision stylolites are almost ubiquitous and often occur at intervals of only a few centimetres — few bedding-planes are not stylolitic.

At 57 m above base a 10 cm thick band of very fine-grained hard grey dolomite occurs and from 58 to 61 m coarse-grained crystalline paler grey dolomite occurs. Between 57 and 59.5 m, and also from 61 to 63 m above base calcite veins are very abundant; they are parallel to the bedding, spaced at an average interval of 50 cm, and very wavy and irregular. (60 m).

b. In the section measured in the south coast cliffs the sequence of dolomite is unbroken. In Lemmingdal a subdivision of limestone is found which yielded *Salterella*. (5 m).

c. Black or dark-grey, medium to coarse-grained hard dolomite weathering pale-brown or buff with patches of white. This dolomite is very similar in all respects to the main part of subdivision a. From 13 to 23 m above the base the rock sporadically exhibits a banded nature — darker and paler grey medium-grained dolomite. Between 61 and 65 m above base stylolites are extremely common being spaced at an average of 1 cm apart. (105 m).

d. Pale-grey, fine-grained, slightly porcellaneous dolomite weathering pale-buff. Stylolites are common and hummocky bedding surfaces occur. This lithological type alternates with dark grey or black fine-grained dolomite which fractures irregularly and is thinly-bedded, laminae in places being less than 1 mm thick. Bands vary in thickness but never completely disappear when followed laterally. (17.1 m).

e. This is similar in general aspect to subdivision a. — hard, dark-grey to black, medium to coarse-grained dolomite weathering dark-brown, with abundant stylolites. (22 m).

Dolomite Point Formation.

Eastern limb of anticline, south coast.

Lower Dolomites.

Base: Gap in observation (deep, snow-filled gully).

15 m: Dolomite, calcareous, massive, dark-grey and weathering dark-grey. No chert present.

17 m: Dolomite, light-buff and pink-tinted, with irregular streaks and lenticles of black chert. Dark-grey weathering.

19 m: Dolomite, streaky light-grey and weathering yellow-buff, with a continuous band (5 cm in thickness) of black chert at the base.

19.5 m: Dolomite, calcareous, dark-grey to black and fine-grained.

20.5 m: Dolomite, calcareous, streaky-grey and dark-grey, fine-grained, weathering buff-brown.

21.5 m: Dolomite, calcareous, dark-grey to black, fine-grained, weathering buff-brown. Some penecontemporaneous brecciation evident in vertical fissures.

22.5 m: Dolomite, well-bedded, massive, light-grey, weathering yellow to buff. Some irregular bedding planes present; topmost plane hummocky. Lenticles of black chert.

25.5 m: Dolomite, well-bedded, light-grey, weathering yellow to buff.

27.5 m: Dolomite, calcareous, dark-grey to black, fine-grained and crystalline, showing irregular fracture.

28 m: Dolomite, laminated light and dark-grey, fine-grained, with irregular, wavy bedding.

29 m: Unobserved interval.

31 m: Dolomite, calcareous, dark-grey to black, fine-grained.

31.5 m: Dolomite, light-grey, fine-grained, containing streaks of grey chert.

32 m: Dolomite, calcareous, black, finely crystalline.

33 m: Dolomite, finely crystalline and brecciated, containing abundant rounded ooliths of crypto-crystalline silica in a matrix of similar composition which is seen to be diagenetically replacing the dolomite.

34 m: Dolomite, light-grey, fine-grained, with a thin breccia of small, angular dolomite fragments at the base.

34.3 m: Dolomite, fine-grained, laminated light and dark-grey, showing brecciation and fluxional bedding in places. 20 cm of streaky greyish-white weathering chert at the base.

36.3 m: Dolomite, calcareous, black and fine-grained.

36.8 m: Dolomite, light to dark-grey, fine-grained, with slightly irregular bedding.

37 m: Dolomite, calcareous, black, fine-grained, and thinly-bedded.

38 m: Dolomite, light to dark-grey, fine-grained, with irregular bedding laminae.

39 m: Dolomite, laminated light and dark-grey, fine-grained, with fluxional bedding picked out by weathering of laminae — light-grey to light yellow-buff. Lenticles of black chert present in the lowermost metre — some follow the fluxional bedding.

41 m: Dolomite, massive, medium-grey, weathering greyish-buff, with light-buff streaks. Grades up into

43 m: Dolomite, streaky-grey, thinly and irregularly bedded (average thickness of bands between 3 and 5 cm). Breccia well-developed at height of 45 m (see fig. 49) and consists of angular fragments of medium-grey, finely crystalline dolomite, weathering buff, in a more coarsely crystalline dolomite matrix. Lenticles of whitish-grey chert present in the two topmost metres. Highest 10 cm of a conglomeratic appearance due to white blebs of carbonate elongated along the bedding.

47 m: Dolomite, streaky-grey and fine-grained, thinly and irregularly bedded — more especially at top of bed where whitish-grey chert is developed. Light-buff weathering.

50 m: Dolomite, massive, streaky-grey, fine-grained, with irregular fracture. 15 cm greyish-white flinty chert partly replacing dolomite at top.

51 m: Dolomite, well-bedded, massive, medium-grey and fine-grained, weathering light-buff.

53.3 m: Dolomite, calcareous, dark-grey to black, fine-grained, weathering rusty-buff.

54.3 m: Dolomite, medium-grey, fine-grained, weathering light-buff and containing small nodules and blebs of black chert.

55 m: Dolomite, calcareous, dark-grey to black and fine-grained.

55.7 m: Dolomite, calcareous, streaky dark-grey to black.

56.7 m: Dolomite, streaky dark-grey and grey, thinly and irregularly-bedded in bands 1—5 cm in thickness. Laterally impersistent brecciation evident in places. Black chert lenticles at top of unit.

61.7 m: Dolomite, streaky-grey and fine-grained. Most irregular bedding suggests highly disturbed deposition — slumping, or intermediate stage of brecciation.

62 m: Dolomite, streaky medium-grey, with black chert nodules and lenticles. Rusty-buff weathering.

64 m: Dolomite, silty, thinly and regularly laminated, weathering buff; shaly appearance in places.

65.1 m: Dolomite, calcareous, dark-grey to black, generally fine-grained but more coarsely crystalline in one band of 0.5 m thickness. Buff to brown weathering.

67.8 m: Dolomite, grey, fine-grained, in bands which show variations in colour but weather yellowish-buff. Bedding slightly wavy and irregular. Black and greyish white-chert nodules are present at many horizons, especially at 75 m where they average 10 cm across maximum diameter parallel to bedding.

77 m:
(Base of Calcareous Dolomite).

Calcareous Dolomite. See page 96. (17 m).

Upper Dolomites.

Base: Dolomite, fine-grained, medium to light-grey and weathering yellowish-buff. Thinly, and slightly irregularly, bedded — almost lenticular in places — the bands of dolomite average 10 cm in thickness.

4.5 m: Dolomite, shaly, grey, containing discrete lenticular bands of fine-grained dolomite. Rusty-grey weathering in places.

5 m: Dolomite, thinly-bedded, grey to black and weathering yellow-buff. More massive dolomite bands occur, averaging 0.75 m in thickness and showing wavy irregular bedding-planes. Siliceous disseminations in the form of chert in massive band at 7 m which also shows thin breccia pockets at top.

12 m: Dolomite, silty, streaky-grey, thinly and irregularly bedded, with shale intercalations.

24 m: Dolomite, silty, in nodular and lenticular laminae with shale intercalations.

25 m: Dolomite, silty, thinly-bedded, medium-grey, weathering yellowish-buff to grey with some erosion-resistant laminae.

34 m: Dolomite, light-grey, finely crystalline, weathering yellowish-buff. More massive aspect than underlying beds.

41 m: Dolomite, silty, grey, thinly-bedded and almost shaly in places, with bands of massive, light-grey fine-grained dolomite weathering yellowish-buff.

46 m: Dolomite, streaky-grey, finely crystalline, weathering yellowish-buff, in bands of more massive aspect than underlying bed. Breccia at 54 m; breccia and intraformational conglomerate at 58 m.

Similar lithology continues up the succession.

Dolomite, massive, light-grey, finely crystalline, weathering buff, with interbedded bands — averaging 0.5 m thickness — of brownish-weathering, dark-grey to black, coarsely crystalline, calcareous dolomite, at 72, 76, 78, 82, 84 and 85.5 m.

90 m: Dolomite massive, light-grey, fairly coarse-grained and weathering buff. Some small cavities observed, lined with white crystals of dolomite.

91 m: Dolomite, grey to black, very thinly bedded, becoming shaly at top of unit.

95 m: Dolomite, medium to light-grey and weathering buff, finely crystalline in massive bands averaging 20 cm in thickness, passing upwards after 2 m into more thinly-bedded dolomite — average thickness of bands less than 5 cm — with shale intercalations. Discrete beds of shaly dolomite occur at 99 m (20 cm thick) and 108 m. Below a similar band at 111 m is an intraformational conglomerate of fine-grained, light-grey dolomite, which includes rounded and plate-like fragments — up to 3 cm in maximum diameter — parallel to bedding direction.

117.5 m: Dolomite, silty, very thinly-bedded and shaly, medium-grey and weathering buff to grey.

118 m: Dolomite, medium-grey, finely crystalline, thinly-bedded. Black chert and grey flinty disseminations at the base of unit.

120.5 m: Shales, dolomitic, medium-grey.

122 m: Dolomite, medium-grey, finely crystalline, thinly-bedded and buff-weathering, acquires more massive aspect after 127 m, but shows shale intercalations again between 134 and 136 m. Breccia developed at 140 m.

144 m: Dolomite, dark-grey, finely crystalline, in a massive band of 1 m thickness, weathering brownish-buff.

145 m: Dolomite, compact, light-grey, very fine-grained, weathering creamish-buff. Thinly-bedded, with shale intercalations at 150 m.

153 m: Dolomite, streaky-grey, in massive bands.

158 m: Dolomite, dark-grey to black, coarsely crystalline, has hummocky topmost bedding plane. Thickness 1 m.

Massive aspect continues up the succession.

167.7 m: Dolomite, silty, thinly-laminated, fine-grained, with partings of greenish-grey dolomitic shale. Bedding irregular and lenticular; laminae average 0.5 cm in thickness.

168 m: Dolomite, medium to light-grey, finely crystalline, weathering buff, forms dominant lithology. Greyish-white chert disseminations at approximately 169 m. At height of 173 m there occurs an intraformational conglomerate of fine-grained dolomite fragments, in a matrix containing abundant minute ooliths of dolomite almost wholly replaced by finely crystallised quartz. These ooliths weather out conspicuously on the surface of the rock (compare fig. 20). More thinly-bedded aspect at 174 m, with some shaly intercalations. Intraformational conglomerates — not exceeding 10 cm in thickness — present at 179 and 181.5 m. 20 cm of shale at 183.5 m.

185 m: Dolomite, dark-grey, as a massive band, weathering brownish-buff.

185.5 m: Dolomite, silty, medium-grey, thinly-bedded and almost shaly in places, weathering rusty-buff.

186 m: Dolomite, medium to light-grey, finely crystalline, weathering buff. Intraformational breccia at 188 m and bands of shale at 195 m (15 cm) and 197 m (50 cm).

202 m: Dolomite, mottled dark-grey, coarsely crystalline, irregularly but massive-bedded — bands averaging 50 cm in thickness. Greyish-white chert disseminations at 210 m.

215 m: Dolomite, light-grey, finely crystalline, weathering buff. Bedding irregular and wavy at 221.5 m. A thin brecciated horizon at 223 m.

230 m: Dolomite, massive, medium-grey, finely crystalline, weathering light-buff. Some silty partings developed along irregular bedding planes.

235 m: Dolomite, massive, medium-grey, finely crystalline, with thin even laminae of slightly silty composition appearing more weather resisting. Buff-weathering, with brownish-buff laminae. Some penecontemporaneous deformation evident — disturbed laminae broken and re-deposited as 'edgewise breccia' (see fig. 50). Thin shale band at 242 m.

256 m: Dolomite, massive-bedded, finely crystalline, dark maroonish-grey and weathering brownish-buff.

266 m: Dolomite, medium-grey, finely crystalline, weathering light-buff. More massive aspect after 277 m. Pockets of penecontemporaneous brecciation at 287 and 289 m, with a thin and laterally impersistent intraformational conglomerate at 292 m.

294 m: Dolomite, massive, grey, coarsely crystalline, containing streaks and lenticles of grey siliceous material. A thin section shows crystalline to cryptocrystalline silica enclosing and partly replacing minute rounded ooliths of finely crystalline dolomite.

301 m: Dolomite, massive, medium-grey and finely crystalline, weathering yellow-buff to red-buff. Arenaceous at certain levels. Intraformational conglomerate developed at 302 m, in association with current-bedding (see fig. 51).

312 m: Dolomite, massive, mottled medium to light-grey, coarsely crystalline. Intraformational conglomerate in small pocket.

313 m: Dolomite, thinly and irregular bedded, grey.

313.5 m: Dolomite, massive, medium-grey, finely crystalline, weathering carious and brown-buff. Large area of bedding-plane exposed at 317.5 m, showing large spherical structures in black-weathering chert (see fig. 52). Chert streaks and lenticles at 324 m.

324 m: Dolomite, massive, medium-grey, coarsely crystalline, weathering buff. An irregular band, averaging 40 cm in thickness, is seen to consist of coarsely crystalline dolomite, heavily permeated by siliceous material as minute ooliths of cryptocrystalline silica in a matrix of similar composition. These siliceous disseminations weather grey to white.

325.5 m: Limestone, dolomitic, medium-grey, fine-grained to porcellanous, with a sub-conchoidal fracture. Grey-weathering.

326 m: Dolomite, medium-grey, finely crystalline, weathering yellow-buff.

327 m:

(Base of Cass Fjord Formation).

Cass Fjord Formation.

Eastern limb of anticline, south coast.

Lower Transition Limestones. See fig. 53.

Base: Limestone, black, fine-grained, with thin yellow-buff weathering dolomitic streaks revealing irregularities in the bedding. Intraformational conglomerate developed near the top of the bed.

0.6 m: Limestone, medium-grey, fine-grained, weathering brown to light-buff and grey. Irregular laminae of silty limestone, rarely exceeding 1 cm in thickness, also occur; some cross-bedding observed. More evenly bedded higher in the succession. Distinctive intraformational conglomerate at 6.6 m consists of large, platy fragments of limestone (dimensions up to 4 cm × 1 cm), in a matrix of similar composition.

12.6 m: Limestone, massive, uniformly grey, with irregular, buff-weathering,

silty streaks which become more pronounced and even near the top of the unit.

20.1 m: Limestones, silty, very thinly-laminated, weathering buff and brown. The thin, evenly-bedded laminae break with a brittle fracture (see fig. 23).

22.8 m: Limestones, silty and thinly-laminated — similar to underlying strata but containing two 5 cm bands and discrete lenticles of dark-grey to black chert.

24.3 m: Limestone, massive, medium to dark-grey, fine-grained, weathering grey. Black chert present as small blebs and stringers, but only sparsely distributed in upper three metres.

29.8 m: Fossil horizon AI.

31.8 m:

(Base of Limestone-Shales).

Limestone-Shales.

Base: Limestones, grey, fine-grained, very thinly-bedded nodular and lenticular, with partings of green-grey weathering, calcareous shale. Conspicuous bands of massive, grey, finely crystalline limestone are interbedded at intervals, but their junctions with the shaly beds are often transitional. These resistant-weathering bands — rarely more than 3 m in thickness — show small patches and streaks of dolomitisation, which weather to a rusty-buff colour. Intraformational conglomerates comprise a high proportion of the limestone in the massive and shaly beds.

Limestone, conspicuous massive band at 34 m (3 m thick).

47 m: Fossil horizon AJ.

50 m: Fossil horizon AK. Limestone, conspicuous massive band at 54 m (1 m thick).

63 m: Fossil horizon AL. 68 m: Fossil horizon AM.

73 m: Fossil horizon AN. Limestone, medium to dark-grey, fine-grained, grey-weathering, with finely crystalline dolomitic streaks and patches weathering rusty-brown, as a discrete band at 74 m (1 m in thickness).

93 m: Fossil horizon AO. Limestones, thinly-stratified, nodular and lenticular, with shale partings. Greenish-grey, calcareous shale in higher proportion than at base of succession. Few bands of massive limestone.

134 m: Fossil horizon AP.

156 m: Conglomerate, intraformational limestone, consisting of flattened, elongated and rounded pebbles of fine-grained, medium-grey limestone in a calcareous matrix which includes greenish-grey argillaceous material. The pebbles are generally parallel to the bedding, and decrease in size up the bed (see fig. 54). Weathered surfaces show a superficial coloration of green-grey to dull red (due to iron staining?). Maximum observed thickness 10 cm.

Limestones, very thinly-bedded, nodular and lenticular, with partings of greenish-grey, calcareous shale. More massive bands occur

where the limestone lithology predominates, and weather brownish-grey in colour. Thin and laterally impersistent bands of finely crystalline limestone and intraformational conglomerate are also present.

174 m: Fossil horizon AQ. 175 m: Fossil horizon AR.

199 metres:
(Base of Upper Transition Limestones).

Upper Transition Limestones.

Base: Limestone, light to medium-grey, fine-grained but coarsely crystalline in small pockets, weathering brownish-grey, with rusty-buff blebs tending to parallel the bedding. Fossil horizon AS.

6 m: Limestones, thinly-bedded, nodular and lenticular, with greenish-grey shale partings. Sharp and irregular junction with underlying bed.

6.8 m: Limestone, light to medium-grey, fine-grained, massive, weathering grey with rusty-buff blebs. Fossil horizon AT.

8.8 m: Limestones, lenticular and nodular bands, with greenish-grey shale partings. Fossil horizon AU.

10 m: Limestone, massive, light to medium-grey, fine-grained but coarsely crystalline in places, weathering brownish-grey with rusty-buff blebs tending to parallel the bedding. Irregular junction with overlying bed. Fossil horizon AV.

10.8 m: Limestones, thinly-bedded, nodular and lenticular, with fine partings of greyish-green, calcareous shale. Discrete, thin bands of limestone also occur, but are of impersistent lateral extent. Thin intraformational conglomerates common.

13.5 m: Limestone, light to medium-grey, massive, fine-grained, with pockets of a more coarsely crystalline lithology. Rusty-buff blebs and streaks on weathered surfaces. Transition junction with underlying bed, but sharp contact with bed above.

17.5 m: Fossil horizon AW.

18 m: Limestones, thinly-bedded, with argillaceous intercalations. The limestone laminae become thicker and more evenly-bedded higher in the sequence; they appear more massive and homogeneous as the argillaceous components decrease up the succession.

39.2 m:
(Base of Kap Weber Formation).

Kap Weber Formation.

Banded Limestones.

Eastern limb of anticline, south coast.

Base: Limestone, massive, dark-grey, fine-grained, passing upwards after 75 cm into closely-laminated, grey and buff-weathering limestone and dolomitic limestone. The individual laminae are evenly bedded and contain small nodules and lenticles of white-grey chert.

1.2 m: Limestone, intraformational conglomerate, containing platy fragments of dark-grey limestone. Irregular thickness, with wavy topmost bedding plane.

1.7 m: Limestone, medium-grey, finely crystalline, in massive bands, which give way upwards to finely-laminated limestone and dolomitic limestone weathering grey and cream.

8.7 m: Limestone, blotchy light and dark-grey. Topmost plane wavy and irregular.

9.2 m: Limestone, dolomitic, finely-laminated cream and grey.

12.2 m: Limestone, blotchy light and dark-grey, as an irregular band with wavy topmost bedding plane.

12.5 m: Limestone, dolomitic, finely-laminated cream and grey.

14.5 m: Limestone, dolomitic, massive, light-grey to pink-grey, finely crystalline, containing irregular lens-like bodies of white, crystalline quartz. Irregular top bedding plane.

16 m: Limestone, dolomitic, laminated light and medium-grey, weathering cream and grey (see fig. 56). Appreciably silty at some horizons.

21 m: Limestone, massive, dark-grey, with fine laminae revealing undulose bedding of algal origin.

22 m: Limestone, massive, light-grey, fine-grained, with darker grey streaks, passing upwards into thinly-bedded limestones with laminae averaging 1 cm in thickness. Thickness of unit 3 m.

Alternating bands of light and dark-grey limestone continue up the succession. The beds of dark-grey limestone show fine, undulose bedding laminae, suggestive of algal activity, but often pass upwards into a lighter coloured limestone containing small, rounded pellets of dark limestone (= intraformational conglomerates). Black and pearly-grey chert occurs as streaks and lenticles.

Thin bands of medium to dark-grey intraformational limestone conglomerate, composed of very small, rounded and irregularly rounded pellets of fine-grained limestone (about 4 mm average diameter), together with numerous fragments of small gastropods, in a matrix of finely crystallised carbonate. These occur at intervals in the succession.

27 m: Fossil horizon AX. 46 m: Fossil horizon AY. 62 m: Fossil horizon AX.

69 m: Limestone, medium and dark-grey, in massive bands, alternating with beds of thinly-stratified, lenticular and nodular limestones and shales, which average 2 m in thickness. Intraformational conglomerates are common as lenticles and thin bands (up to 5 cm in thickness) within the thinly-bedded limestones.

71 m: Fossil horizon BA.

88 m: Limestone, intraformational conglomerate. Rounded, platy pebbles (average dimensions 2×0.4 cm) of medium-grey, finely crystalline limestone, embedded in a matrix of more coarsely crystalline limestone containing fragments of fossils. Minute pyrite cubes present in matrix. Thickness of band 5 cm. Fossil horizon BB.

100 m: Limestone, medium and dark-grey, in massive bands alternating with beds of thinly-stratified limestones and subordinate shales.

111 m: Limestone, massive, fine-grained, dark-grey.

114 m: Limestones, thinly and irregular bedded, medium-grey, fine-grained, with buff-weathering dolomitisation along bedding planes.

115 m: Limestone, massive, dark-grey, fine-grained, with more coarsely crystalline patches.

118 m: Limestones, thinly-bedded.

119 m: Limestone, massive, dark-grey.

121 m: Limestone, thinly-bedded and lenticular. Thickness 1 m.
Limestone, massive, in alternating bands of light, medium to dark-grey. Dolomitisation at some levels as yellow-buff weathering blebs and permeations. Bedding indistinct due to poor exposure. Calcite veining.

139 m: Fossil horizon BC. 154 m: Fossil horizon BD. 159 m: Fossil horizon BE. 161 m: Fossil horizon BF. 168 m: Limestone, massive, dark-grey, finely crystalline. Thickness 4 m.

178 m: Limestone, massive, light-grey, finely crystalline. Thickness 5 m.

186 m: Limestone, massive, light-grey, containing yellow-buff dolomitic permeations.

188 m: Limestone, massive, dark-grey, containing yellow-buff dolomitic permeations. Thickness 1 m.

211 m: Fossil horizon BG.

212 m: Limestone, massive, light-grey, fine-grained. Thickness 4 m.

220 m:
(Base of Main Limestones).

Main Limestones.

Central plateau.

The following lithological descriptions do not necessarily apply to all the strata between the indicated heights; the great thickness of essentially similar rocks has necessitated sample description at selected intervals.

Detail.

Base: Limestone, medium to light-grey, fine-grained, but showing more crystalline patches, in massive bands weathering uniformly light-grey and carious.

110 m: Limestone, massive, medium-grey, finely crystalline, with yellow-buff dolomite streaks and segregations.

130 m: Limestone, medium-grey, finely crystalline, with more coarsely crystalline patches, permeated by streaks of cream-buff, dolomitised limestone.

140 m: Limestone, grey, thinly-bedded, nodular and lenticular. Fossil horizon BH.

160 m: Fossil horizon BI.

170 m: Limestone, massive, medium-grey, finely crystalline, with permeations and streaks of yellow-buff dolomitised limestone. Limestone weathers light-grey and carious; dolomitised limestone weathers dark-grey and is more resistant.

250 m: Limestone, dolomitised. Similar to 170 m.

280 m: Limestone, massive, finely crystalline, medium-grey and weathering grey. Calcite veins and disseminations.

295 m: Limestone, massive, medium-grey, finely crystalline, with some fine veins and disseminations of white calcite. Fossil horizon BJ.

315 m: Limestone, massive, medium-grey, finely crystalline with coarser crystalline developments in places. Grey weathering and calcite veined.

360 m: Fossil horizon BK.

420 m: Limestone, massive, medium-grey and finely crystalline, weathering grey. Marked irregular fracture. Some calcite disseminations and black chert present. Fossil horizon BL.

465 m: Limestone, massive, medium-grey, calcite veined on a small scale. Black chert present as thin bands, blebs and stringers along bedding-planes (see figs. 57 & 58). Fossil horizon BM.

530 m: Limestone, massive, medium-grey, medium to finely crystalline and grey weathering. Some black chert and dolomitisation. Fossil horizon BN.

590 m: Fossil horizon BO.

603 m: Limestone, dolomitic, massive, medium to dark-grey, finely crystalline, with bedding-plane streaks and bands of dark-grey weathering dolomitic limestone. Scattered blebs of brownish-weathering chert. Fossil horizons BP.

620 m: Limestone, dolomitic, medium-grey, permeated by streaks and blebs of buff-coloured, silty, dolomitised limestone. Fossil horizon BQ.

640 m: Fossil horizon BR.

660 m: Limestone, medium-grey, with dark-grey weathering streaks and bands of dolomitised limestone.

680 m:
(Base of Dolomites and Dolomitic Limestones).

Dolomites and Dolomitic Limestones.

Central plateau.

Sequence sampled in a similar manner to the Main Limestones, see page 187.

Detail

Base: Limestone, dolomitic, weathering light-grey with resistant dark-grey streaks along bedding. Thin section shows well-developed dolomite rhombohedra aggregated in streaks and pockets amongst the fine-grained limestone. Some brownish-black chert.

60 m: Fossil horizon BS.

72 m: Limestone, dolomitic, finely crystalline. Dolomitisation is chiefly concentrated along bedding-planes, which weather out more resistantly, and to a darker grey colour, than the unaltered limestone.

100 m: Limestone, dolomitic, finely crystalline, grey-weathering, containing abundant disseminations of yellow-buff dolomite which weathers more resistantly and to a darker grey colour. Fossil horizon BT.

139 m: Dolomite, calcareous. The original limestone has been almost com-

pletely replaced by dark-grey weathering dolomitic segregations. Greyish-white cryptocrystalline silica as lenticles along bedding.

140 m:
(Base of Narhvalsund Formation).

Narhvalsund Formation.

Central plateau.

Basal Dolomites.

Base: Dolomite, buff-grey, crystalline and saccharoidal textured, weathering dark-buff. Abundant pockets and blebs of moderately soft, fine-grained, cream-white weathering, 'rotten' dolomite with cryptocrystalline disseminations of silica, averaging 1—2 cm maximum diameter. Derived from topmost beds of Kap Weber Formation?

2 m: Dolomite, cream-grey, massive, coarsely crystalline, weathering cream to light-grey. 'Sugary' textured and possessing arenaceous 'feel'. Small cavities developed which tend to parallel the bedding-Light-brown weathering chert present as thin lenticles along bedding-planes at approximately 30 m.

45 m: Dolomite, massive, light-grey, coarsely crystalline, with small cavities tending to parallel the bedding direction. Some cavities filled or partly lined with finely crystallised quartz. Streaks of cryptocrystalline silica are also present and weather out to a light brown-buff colour.

50 m: Limestone, light-grey weathering, finely crystalline, interbedded at intervals with the dominant dolomite. Average thickness of bands 2—3 m.

70 m:
(Base of Dolomitic Limestones).

Dolomitic Limestones.

Base: Limestone, massive, light-grey, finely crystalline, with white calcite disseminated as thin veins and blebs, interbedded with subordinate bands of cream-grey weathering dolomite. Thin stringers of brown chert occasionally present in the limestone.

27 m: Fossil horizon BU. 30 m: Fossil horizon BV.

50 m: Limestone, fine-grained, in massive bands alternating in shades of medium to light-grey. Some beds show abundant disseminations of calcite in the form of thin veins and small patches. Bands of finely crystalline dolomite interbedded at intervals.

95 m: Limestone, dolomitic, medium-grey, containing yellowish-buff patches and streaks of dolomitisation. Abundant veins of calcite.

Banded lithology, consisting of light to medium-grey limestones and dolomitised limestones, continues up the succession.

153 m: Dolomite, medium-grey and maroon tinted, finely crystalline, irregularly and thinly-bedded (bands average 50 cm in thickness) with occasional beds of limestone and dolomitic limestone.

162 m: Limestone, medium-grey, oolitic. A distinctive band, one metre in thickness, consisting almost entirely of minute ooliths and irregularly

rounded fragments of carbonate, all less then 1.5 mm in maximum diameter. Stratification is shown by aggregation according to particle size. A thin section reveals the nature of the ooliths as coarsely re-crystallised calcite, in a matrix of finely crystalline calcite. Several ooliths are partly replaced by microcrystalline silica. Fig. 60.

170 m: Limestone, dolomitic, massive, medium-grey, finely crystalline, weathering pinkish-buff. Sub-conchoidal fracture.

175 m: Limestone, dolomitic, coarsely crystalline and weathering buff-grey. Large blebs and patches of calcite occur throughout the rock, and are responsible for the pitted appearance of weathered surfaces.

177 m: Dolomite, massive, finely crystalline to porcellanous, medium-grey and weathering cream-buff, with abundant flecks and streaks of red-coloured staining which tend to parallel the bedding. Patchy pink tint on weathered surfaces.

179 m: Limestone, medium to dark-grey and finely crystalline, with white calcite disseminated as network of thin veins.

180 m:

(Base of unconformable Devonian conglomerates).

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PLATES

Plate I.

Aerial view of the western end of Promenadedal showing Vibekes Sø and Søryggen (see Plate VIII); Vib. Sø—Vibekes Sø, L—flat-topped lacustrine deposits. K—Kløftelv Formation, CF—Cass Fjord Formation, KW—Kap Weber Formation. f_2 and f_7—faults (see Plate IX). The distance to the near end of Vibekes Sø is approximately 11 kilometres.

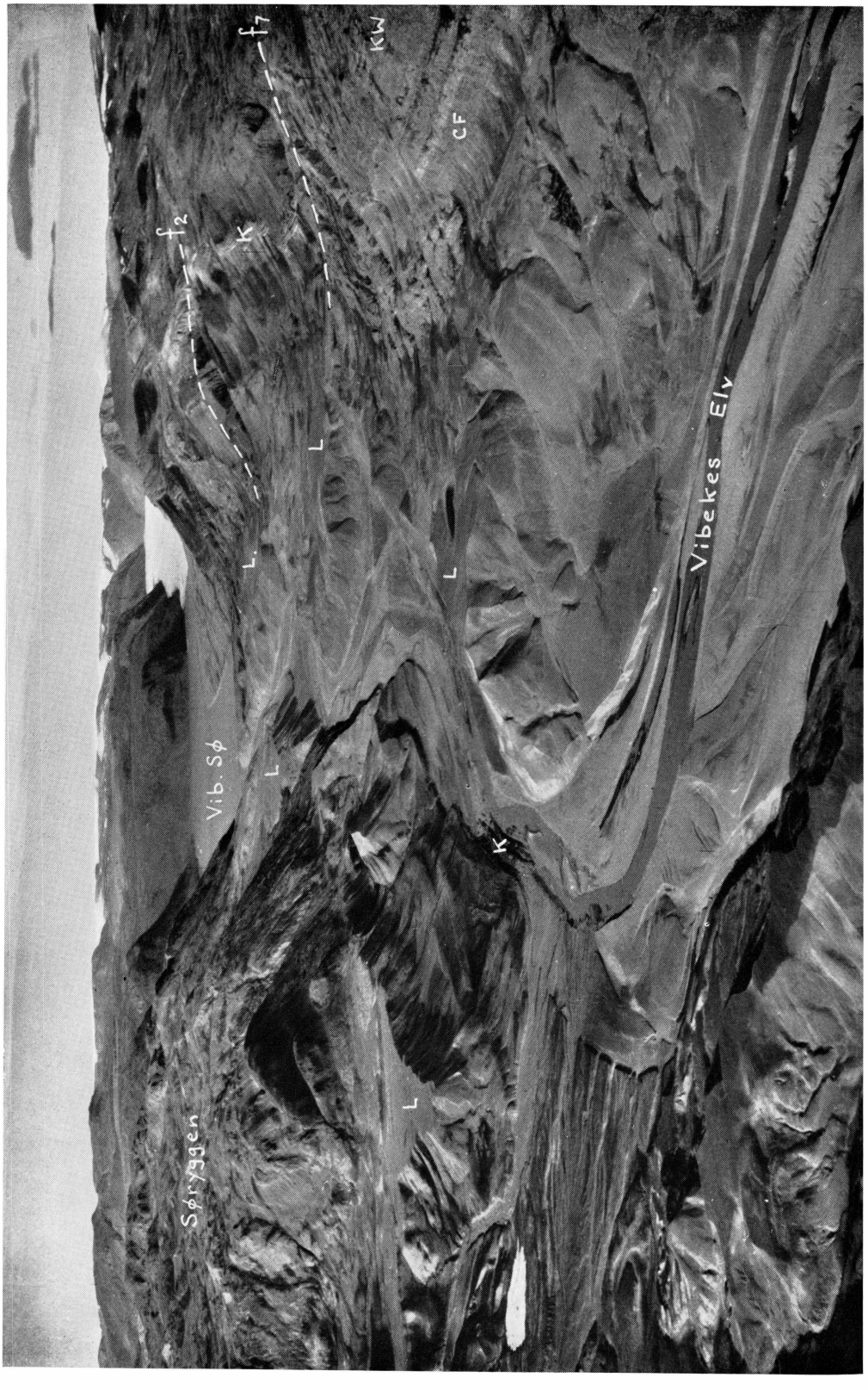

f7
KW
CF
f2
K
L
L
L
Vibekes Elv
Vib. Sø
L
K
L
Søryggen

Plate II.

Aerial view of part of Albert Heims Bjerge in the neighbourhood of fault f_7 (see Plate IX). C—Canyon Formation, K—Kløftelv Formation, B—Bastion Formation, E—Ella Ø Formation, HC—Hyolithus Creek Formation, DP—Dolomite Point Formation, CF—Cass Fjord Formation, KW—Kap Weber Formation, D—Devonian. T—terrace-level. The scale may be judged by the white tents indicated by the arrows.

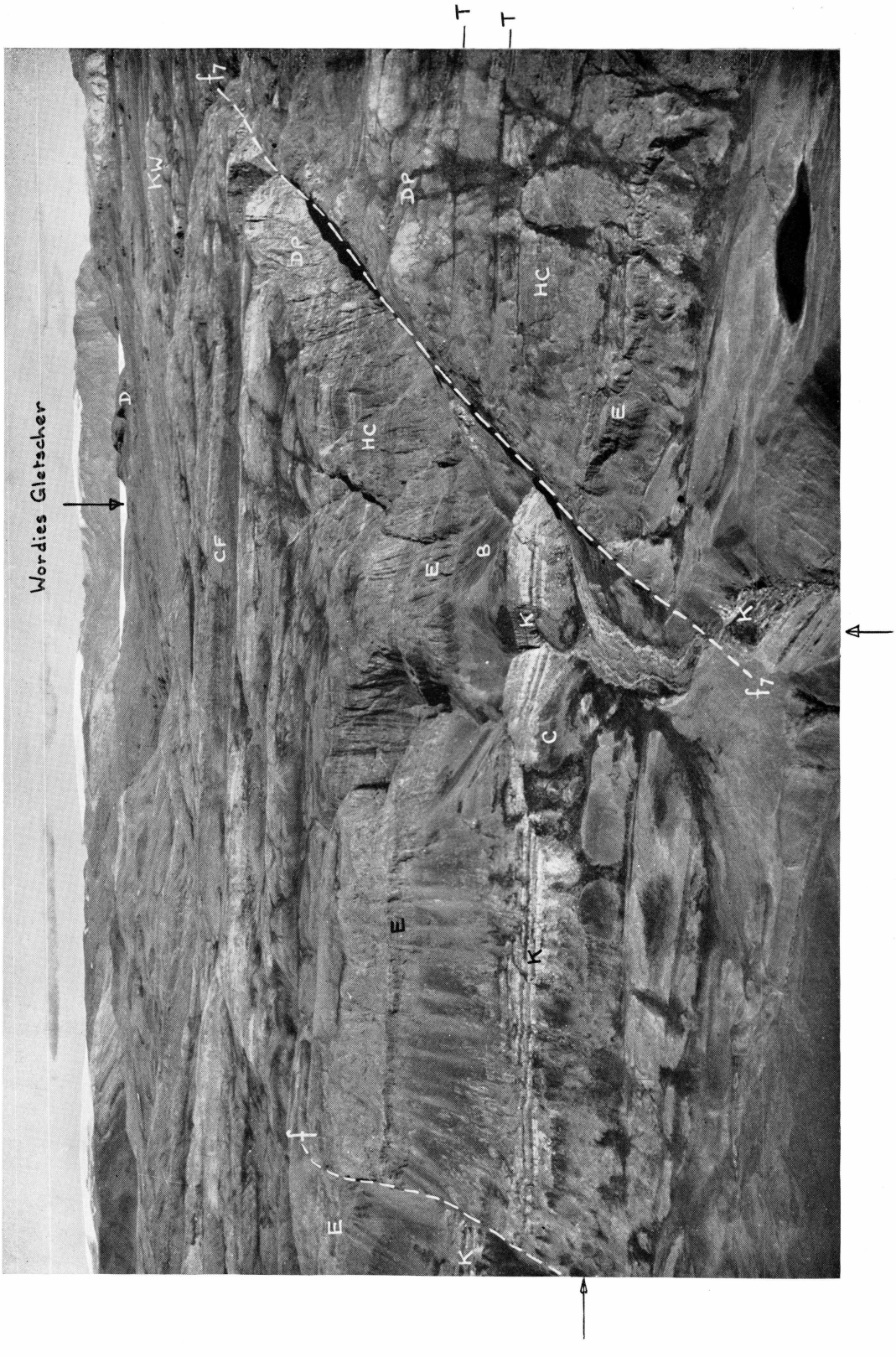

T
T
f7
KW
DP
DP
HC
HC
D
Wordies Gletscher
CF
E
E
B
K
K
f7
C
E
K
f
E
K

Plate III.

Aerial view of Albert Heims Bjerge, near the fault f_{10}, showing the type-locality of the Heimbjerge Formation (see Plate IX). KW—Kap Weber Formation, NS—Narhvalsund Formation, H—Heimbjerge Formation, D—Devonian. The highest point of the mountain is approximately 500 metres above the foreground.

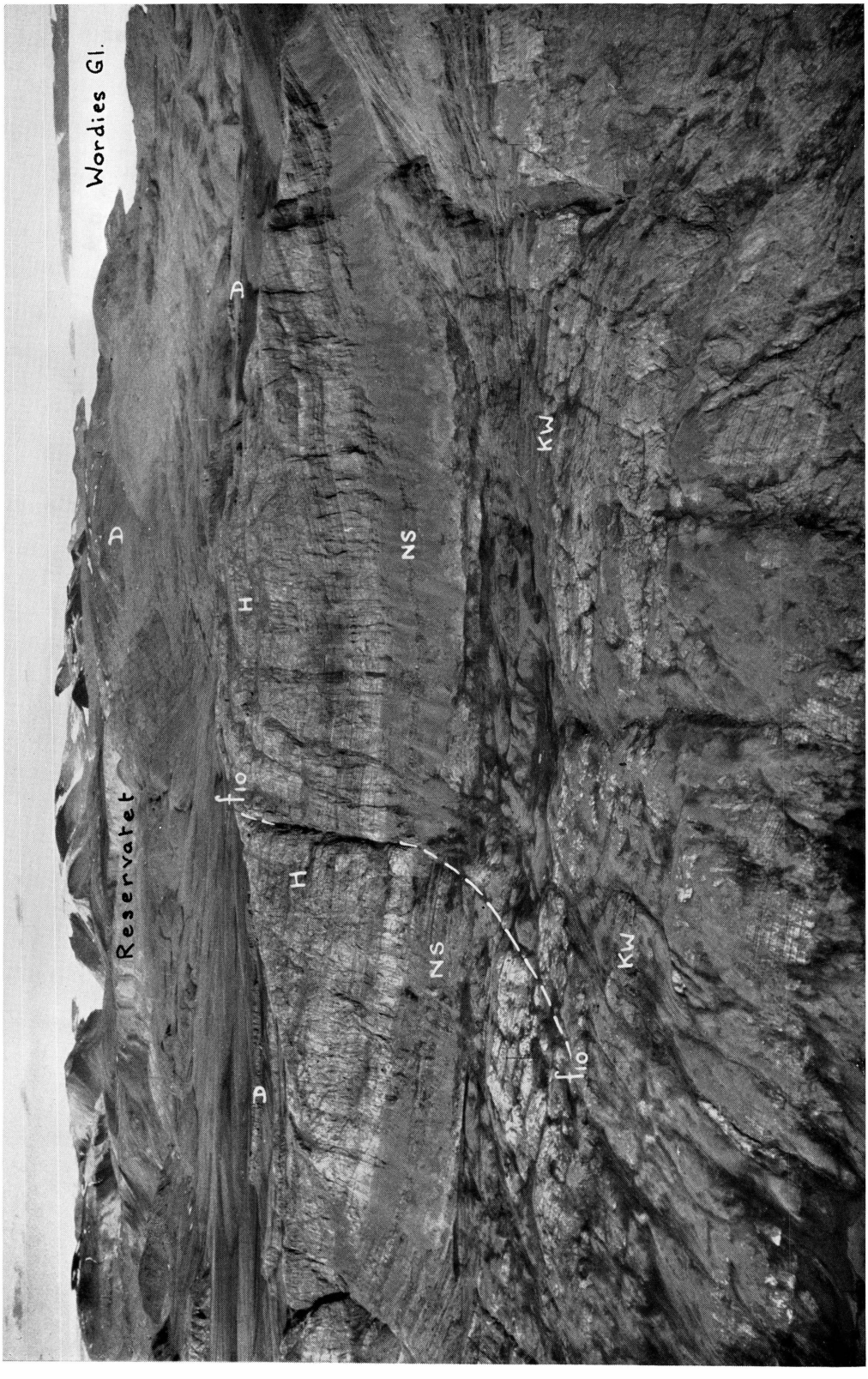

Wordies Gl.
Reservatet
A
A
A
H
H
NS
NS
KW
KW
f10
f10

Plate IV.

Aerial view of part of the plunging Kap Oswald anticline, taken from the north-west looking south-east towards Lemmingdal. LDS—Limestone-Dolomite Series, LT—Lower Tillite, ITB—Inter-Tillite Beds, UT—Upper Tillite, C—Canyon Formation, S—Spiral Creek Formation, K—Kløftelv Formation (the type-locality can be seen), B—Bastion Formation, E—Ella Ø Formation, HC—Hyolithus Creek Formation, DP—Dolomite Point Formation, CF—Cass Fjord Formation, KW—Kap Weber Formation, D—Devonian. Scale may be judged by the small ships moored in Solitærbugt indicated by the arrows (the 'Gothaab' and the 'Gustav Holm').

Kongeborgen
Lemmingdal
Kong-Oscars Fjord
Kemþes Fjord
Kap Oswald
Sol.
Tömmerbugt
Bastionbugt
D
KW
CF
DP
HC
E
S
C
UT
ITB
LT
LDS
K
f

Plate V.

The cliffs overlooking Antiklinalbugt on the south coast of Ella Ø, which are approximately 600 metres high. C—Canyon Formation, K—Kløftelv Formation, B—Bastion Formation, E—Ella Ø Formation, HC—Hyolithus Creek Formation, DP—Dolomite Point Formation, CF— Cass Fjord Formation, D—Devonian. The photograph was taken from the frozen fjord with the camera tilted; the dark hue of the ice is due to the near-shadow effect of the low March sunlight which is striking the cliffs almost at right-angles.

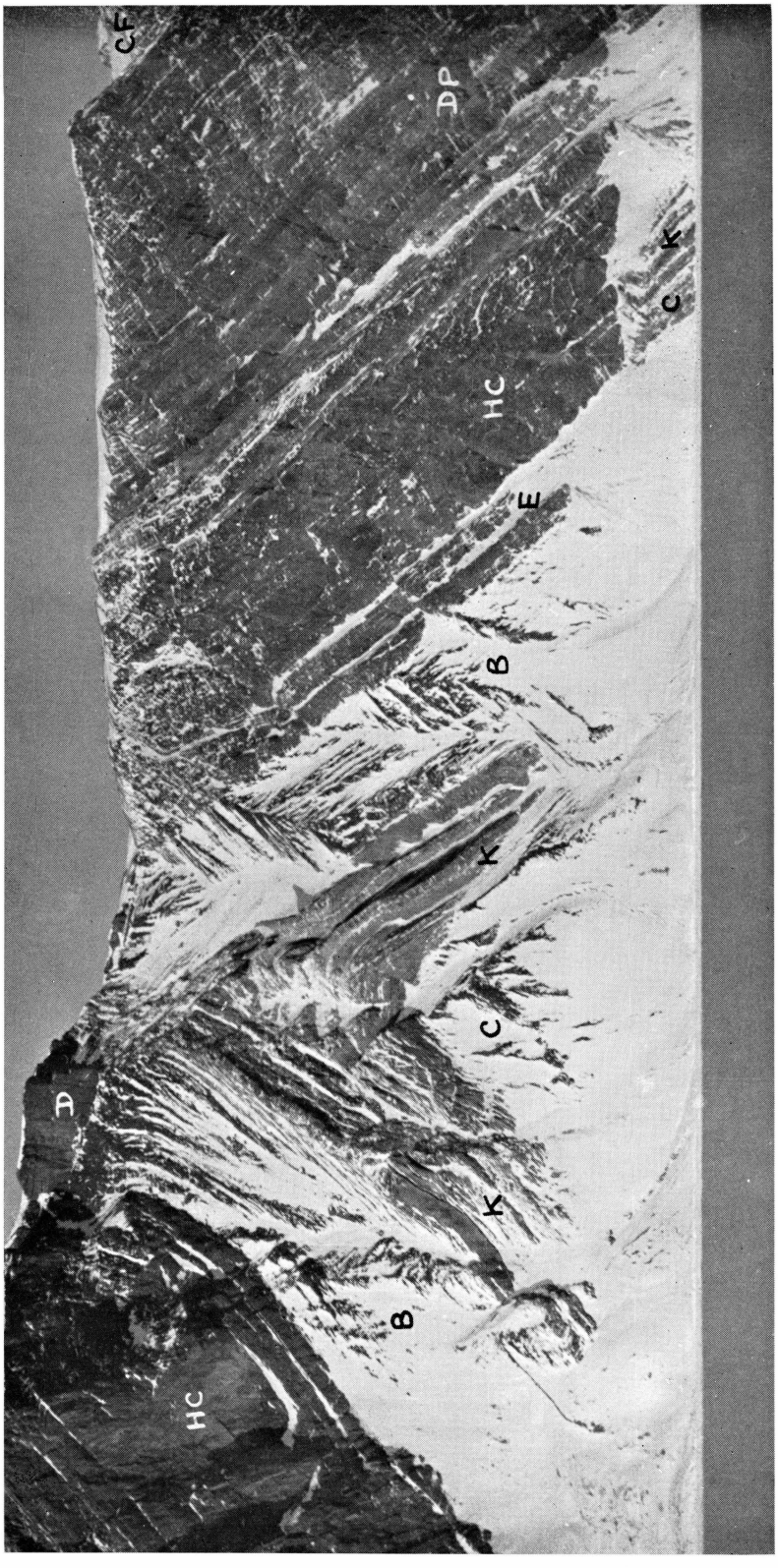

CF
DP
HC
C
K
E
B
K
C
K
B
A
HC

Plate VI.

Aerial view of part of the south face of Bastionen, Ella Ø; the highest point visible is approximately 1250 metres above sea-level. B—Bastionpynt, type-locality of the Bastion Formation and the Ella Ø Formation. HC—Hyolithus Creek Formation, DP—Dolomite Point Formation, CF—Cass Fjord Formation, KW—Kap Weber Formation, NS—Narhvalsund Formation, Dy—Dyke.


NS
KW
KW
Dy
Dy
Dy
Dy
Dy
CF
DP
HC
Dy
Dy
Suess Land
B
Narhval Sund

Plate VII.

Aerial view of Kap Weber, Andrées Land, from the north-east, showing 1—south cape, 2—north cape, 3—Dolomite Point, 4—Hyolithus Creek. Physical features of interest include the outwash fan of Hyolithus Creek, the fault-gully of the creek, lateral moraines, and the old peneplain surface of the plateau which reaches a height of 1230 metres above sea-level.



Plate VIII.

Cambro-Ordovician outcrops in Central East Greenland. Scale 1:500,000. A compilation from various authors. Minor Cambro-Ordovician outcrops in Hudson Land have been omitted. The Metamorphic Series may include metamorphosed Lower Palaeozoic sediments. Places mentioned in the text but not shown on a plate are:—

a) *Rævedal*—in eastern Strindbergs Land across *Waltershausen Gletscher* from Posten.

b) *Vrangelven* flows from Krumme Langsø through *Johan Davidsens Dal* and passes Waltershausen Gletscher to Nordfjord.

c) *Vibekes Gletscher* flows into Vibekes Sø.

d) *Randen* is the area north of Sødal and west of Vibekes Sø and Vibekes Gletscher.

Further outcrops of Cambro-Ordovician strata are now known on *C. H. Ostenfelds Nunatak* (Wordies Gletscher)—see footnote on page 45.

THE CAMBRO-ORDOVICIAN outcrops in CENTRAL EAST GREENLAND

1:500000

5 0 5 10 15 20 25 kms.

0 5 10 15 miles

edge of ice caps and glaciers

Topography after the map of the Geodetic Institute

24° 23° 25° 74° 73°30'N 73°30' 73° 72°30 25°W

PLATE IX

PLATE X

OLE RØMERS LAND

Iris Gl.

RESERVATET

WORDIES GL.

Vibekes Sø

Søndal

Søryggen

ALBERT HEIMS BJERGE

Krumme Langsø

Hjørnebjerget

Klipperne

Stordal

Posten

HUDSON LAND

STRINDBERGS LAND

GEOLOGFJORD

Blokken

Torbern Bergmans Bj.

MOSKUSOKSE FJORD

NORDFJORD

Gunvors Bjerg

ANDRÉES LAND

Solstrand

Kap Weber

KEJSER FRANZ JOSEPHS FJORD

GAUSS HALVØ

Hammeren

GUNNAR ANDERSSONS LAND

DUSÉNS FJORD

Margelies Dal

Kap Mohn

YMERS Ø

ANTARCTICS SUND

SOFIA SUND

SUESS LAND

Ruth Ø

Maria Ø

GEOGRAPHICAL SOCIETY Ø

VEGA SUND

KEMPES FJ.

ELLA Ø

NARHVAL SUND

TRAILL Ø

KONG OSCARS FJORD

LYELLS LAND

FORSBLADS FJ.

SEGELSÄLLSK. FJORD

NATHORST LAND

ALPEFJORD

Syltoppene

SCORESBY LAND

Legend:

- Devonian and younger rocks.
- Ordovician, (Cass Fjord to Heims Bjerge fms.)
- "Cambrian," (Kløftelv to Dolomite Point fms.)
- Cambro-Ordovician, undivided.
- Pre-Cambrian sediments; Metamorphic Series; and associated igneous.

Limits of Plates IX and X indicated.

Reproduceret ved Geodætisk Institut. København 1955

Plate IX.

Geological map and section of Albert Heims Bjerge—Reservatet area, northern Hudson Land. Scale 1:100,000. In the section the vertical scale equals the horizontal. Dips were measured at the tips of the arrows.

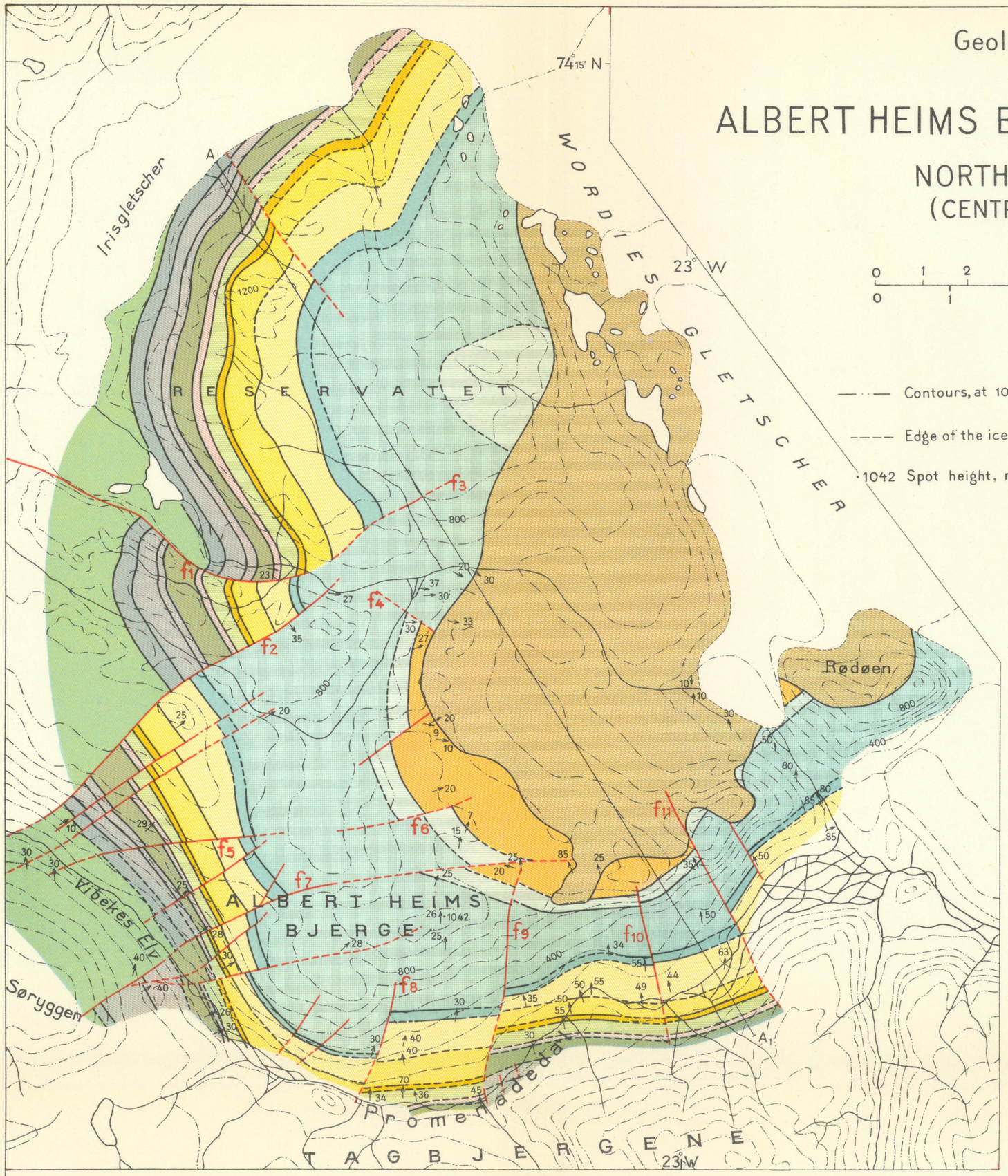
Geological map & section of the ALBERT HEIMS BJERGE–RESERVATET AREA

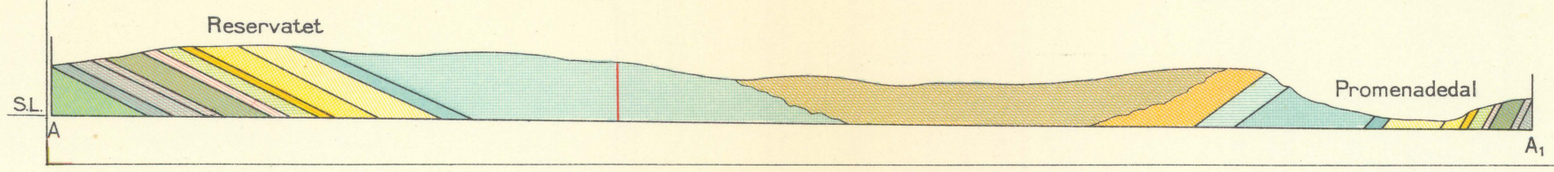
NORTHERN HUDSON LAND (CENTRAL EAST GREENLAND)

1 : 100 000

0 1 2 3 4 5 6 7 8 9 10 kms

0 1 2 3 4 5 6 miles





— · — Contours, at 100 metre intervals

– – – – Edge of the ice–cap and glaciers

·1042 Spot height, metres

↘ 30 Dip direction and angle

Geological boundary observed

Geological boundary inferred

Fault observed

Fault inferred

Devonian

Middle Ordovician — Heimbjerge Formation

Lower Ordovician
- Narhval Sund Formation
- Kap Weber Formation
- Cass Fjord Formation

Lower Cambrian
- Dolomite Point Formation
- Hyolithus Creek Formation
- Ella Ö Formation
- Bastion Formation
- Klöftelv Formation

Late Pre–Cambrian (Greenlandian)
- Canyon Formation
- Upper Tillite
- Inter–Tillite Beds
- Lower Tillite
- Limestone–Dolomite Series

Reproduceret ved Geodætisk Institut. København 1955

Plate X.

Geological map of Ella Ø. Scale 1:40,000. Dips were measured at the tips of the arrows.

Geological map of ELLA Ö (Central East Greenland)

1:40 000

0 1 2 3 kilometers
0 1 miles

Contours, at 50 metre intervals

750 Spot height

Cliff

Hut

Kap Oswald Triangulation Point
(Position 25° 8' W, 72° 53' N. approximately).

KEMPES FJORD

KONG OSCARS FJORD

NARHVAL SUND

Kap Elisabeth

Kap Margrethe

Richardpynt

Pederpynt

Kap Oswald

Kap Harry

Bastionpynt

Tømmerbugt

Solitærbugt

Bastionbugt

Antiklinalbugt

Lemmingbugt

Ingridbugt

Maråbugt

Rundsø

Langsø

Storeelv

Kløften

Ulvesø

Bjørneø

Septembersø

FIMBULFJELD

LEMMINGDAL

BASTIONEN

1367

1200

634

1047

752

A A1 B C C1 D D1 E E1 F F1 f1 f2 f3 f4 f5 f6

30 Dip + Horisontal strata

Geological boundary observed

Geological boundary inferred

Fault observed

Fault inferred

45 Fault-plane dip

D Dyke

Devonian

Lower Ordovician
- Narhval Sund Formation
- Kap Weber Formation
- Cass Fjord Formation

Lower Cambrian
- Dolomite Point Formation
- Hyolithus Creek Formation
- Ella Ö Formation
- Bastion Formation
- Klöftelv Formation

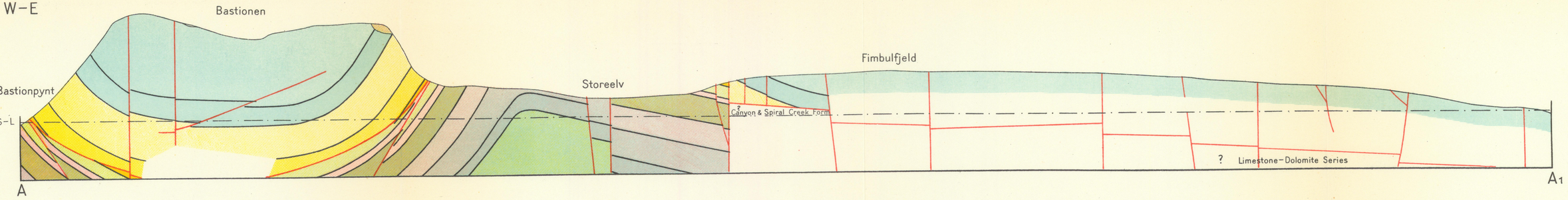
Late Pre-Cambrian (Greenlandian)
- Canyon & Spiral Creek Formation
- Upper Tillite
- Inter-Tillite Beds
- Lower Tillite
- Limestone-Dolomite Series

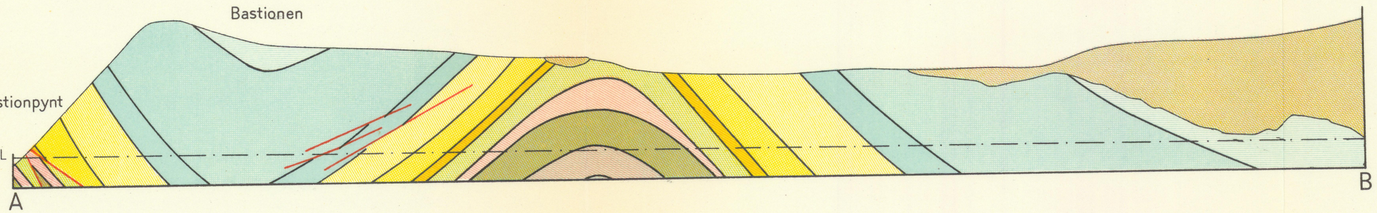
Reproduceret ved Geodætisk Institut. København 1955

Plate XI.

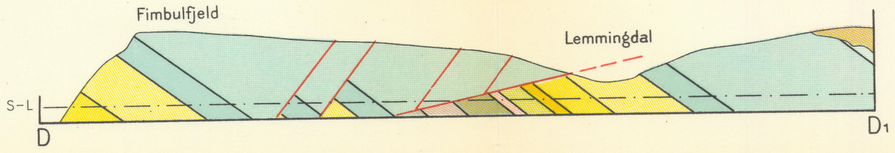
Geological sections of Ella Ø. Scale 1:40,000. Vertical scale is equal to the horizontal: variation in the apparent thickness of beds in parts of the same section can usually be ascribed to the section being at varying angles to the strike of the beds of these plunging folds. Variation due to this factor is most noticeable in sections AA_1 and AB, reaching its extreme expression in the Lower Tillite of the Kap Oswald anticline in AA_1. As far as the accuracy of the mapping would allow, the attempt has been made when drawing the sections to keep the true thickness close to an average value.

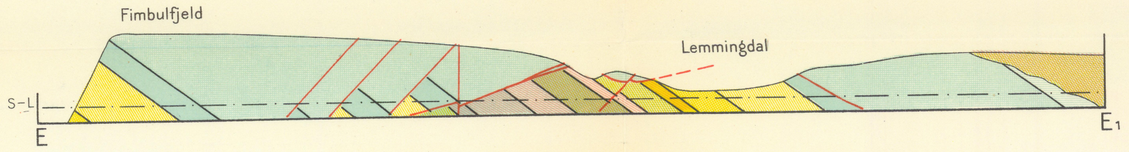
W–E

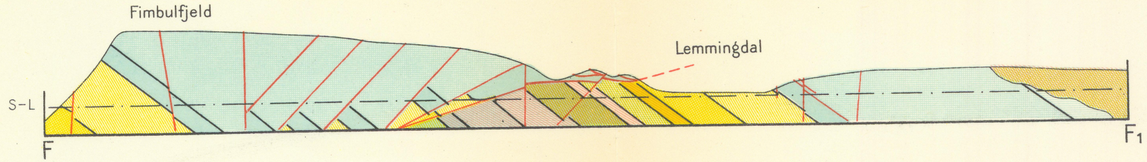




N–S







Geological sections

ELLA Ö

(Central East Greenland)

1:40000

0 500 1000 2000 3000 4000 metres

0 1 2 miles

Vertical Scale = Horizontal.

Sea-level

Geological boundary

Fault

Devonian

Lower Ordovician
- Narhval Sund Formation
- Kap Weber Formation
- Cass Fjord Formation
- Dolomite Point Formation
- Hyolithus Creek Formation

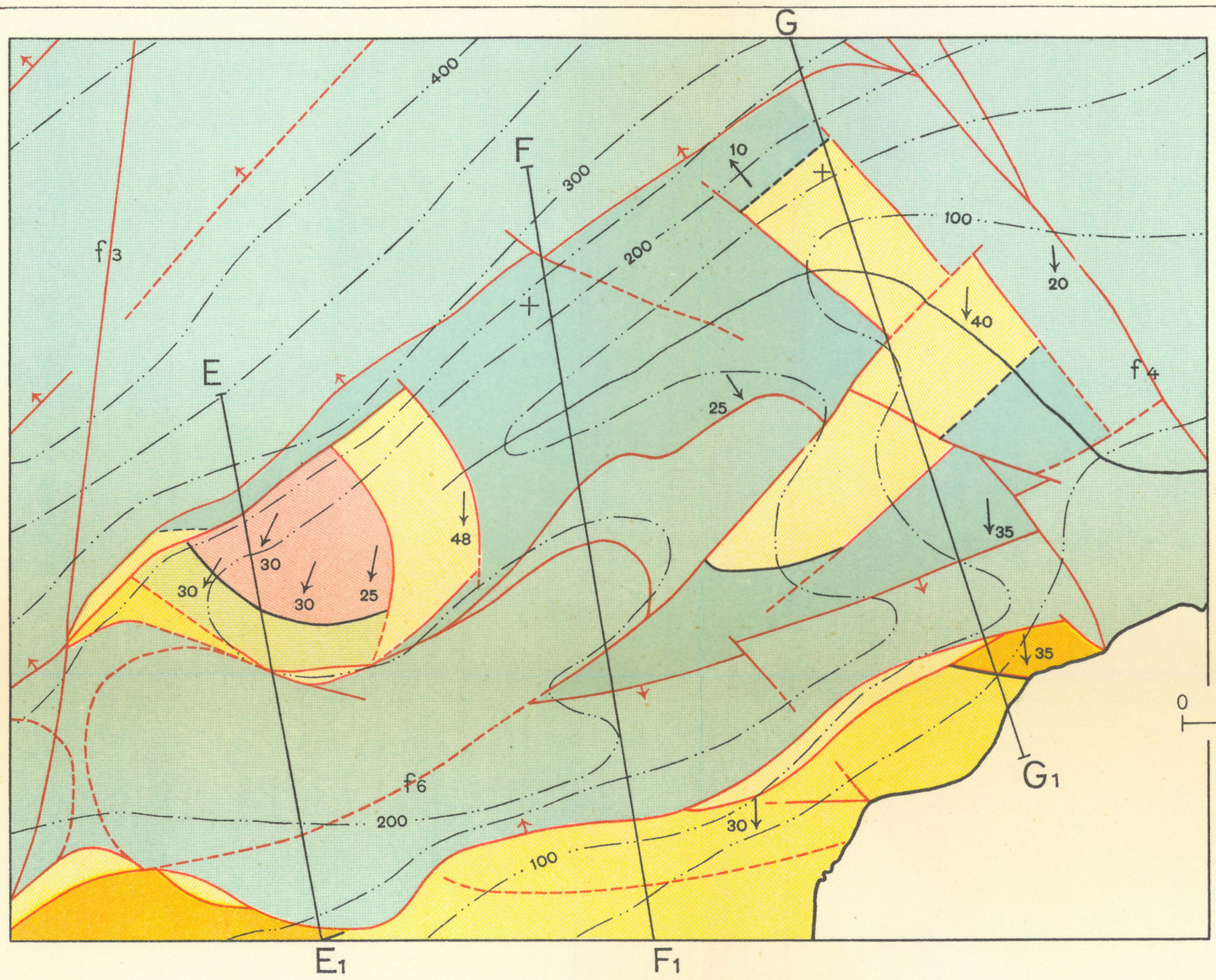
Lower Cambrian
- Ella Ö Formation
- Bastion Formation
- Klöftelv Formation

Late Pre-Cambrian (Greenlandian)
- Canyon & Spiral Creek Formations
- Upper Tillite
- Inter-Tillite Beds
- Lower Tillite
- Limestone–Dolomite Series

Reproduceret ved Geodætisk Institut. København 1956

Plate XII.

Geological sketch map and sections of the Lemmingdal window, Ella Ø. Scale ca. 1:10,000. In the sections vertical scale equals horizontal. Dips were measured at the tips of the arrows.



Geological sketch of Lemmingdal Window

E L L A Ö

(Central East Greenland)

ca. 1 : 10 000

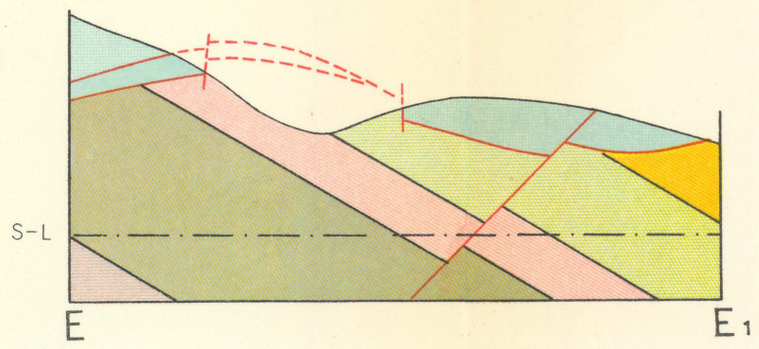
0 100 200 300 400 500 1000 metres

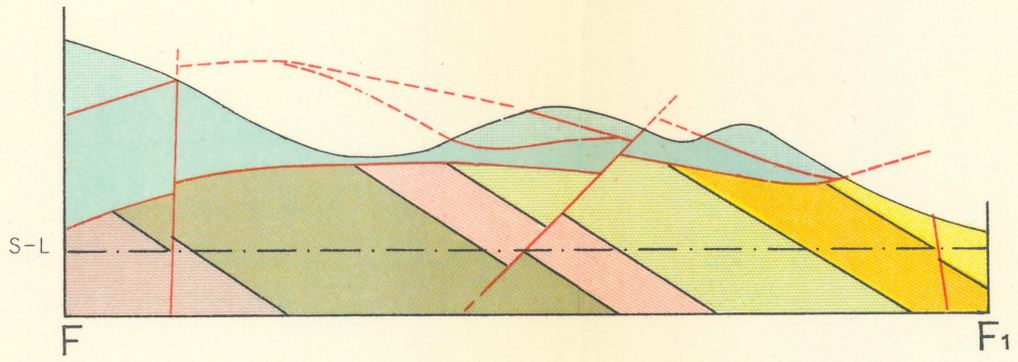
1000 yards

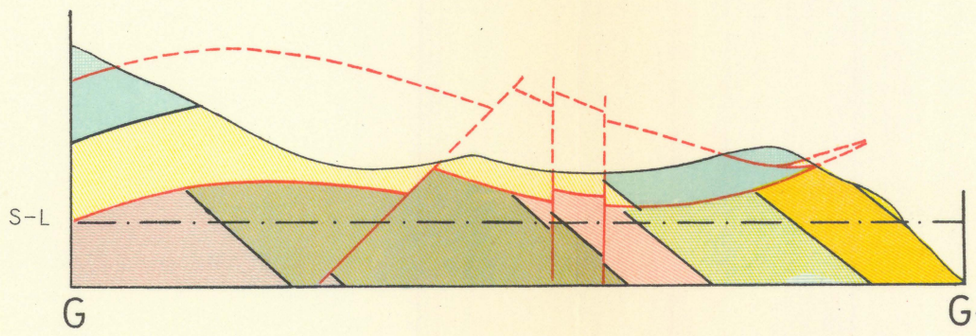
The area covered by this Sketch is outlined by a rectangle on Plate X

N–S Sections:

Vertical Scale = Horizontal







— ·· — Contours, at 50 metre intervals

— · — Sea-level

30 Dip + Horisontal strata

——— Geological boundary observed

– – – – Geological boundary inferred

——— Fault observed

– – – – Fault inferred

——↑—— Fault-plane dip

Lower Ordovician
- Kap Weber Formation
- Cass Fjord Formation

- Dolomite Point Formation
- Hyolithus Creek Formation

Lower Cambrian
- Ella Ö Formation
- Bastion Formation
- Klöftelv Formation

Late Pre-Cambrian (Greenlandian)
- Canyon & Spiral Creek Fms.
- Upper Tillite

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Plate XIII.

Comparative vertical sections measured in Cambro-Ordovician rocks of Albert Heims Bjerge and Ella Ø. Dotted lines in the left-hand column indicate that the age is not based on fossils found in the strata. The key to the ornament shows most of the main types and some examples of combinations.

COMPARATIVE VERTICAL SECTIONS
MEASURED IN
THE CAMBRO-ORDOVICIAN ROCKS
OF
ALBERT HEIMS BJERGE & ELLA Ö
(CENTRAL EAST GREENLAND)

Quartzite
Sandstone & siltstone
Calcareous sandstone
Arenaceous Limestone
Limestone
Dolomitic Limestone
Dolomite
Shell-limestone
Chert
Glauconitic Sandstone
Ferruginous Sandstone
Conglomerate

ALBERT HEIMS BJERGE

ELLA Ö

DEVONIAN

CHAMPLAINIAN

HEIMBJERGE FORMATION — Limestones

NARHVAL SUND FORMATION — Limestones / Dolomites

CANADIAN

KAP WEBER FORMATION — Limestones / Limestones

CASS FJORD FORMATION — Shales and Limestones

DOLOMITE POINT FORMATION — Dolomites

HYOLITHUS CREEK FORMATION — Dolomites

LOWER CAMBRIAN

ELLA Ö FORMATION — Limestones

BASTION FORMATION — Shales / Sandstones

KLÖFTELV FORMATION — Quartzites

DATUM LINE

LATE PRE-CAMBRIAN

CANYON FORMATION — Shales

UPPER TILLITE

SPIRAL CREEK FORMATION — Shales, dolomites & siltstones

Limestones / Limestones / Dolomites / Dolomites / Limestones / Limestones / Shales and Limestones / Dolomites / Dolomites / Limestones / Shales / Sandstones / Quartzites

700 600 500 400 300 200 100 50 0
METRES