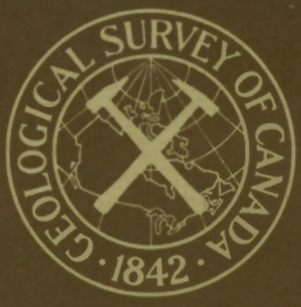

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 62-18

PRE-MISSISSIPPIAN SUCCESSION OF NORTHERNMOST AXEL HEIBERG ISLAND, DISTRICT OF FRANKLIN

Part of Sheet 560D/S W

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P. E. Fricker and H. P. Trettin

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By

P.E. Fricker and H.P. Trettin

DEPARTMENT OF
MINES AND TECHNICAL SURVEYS
CANADA

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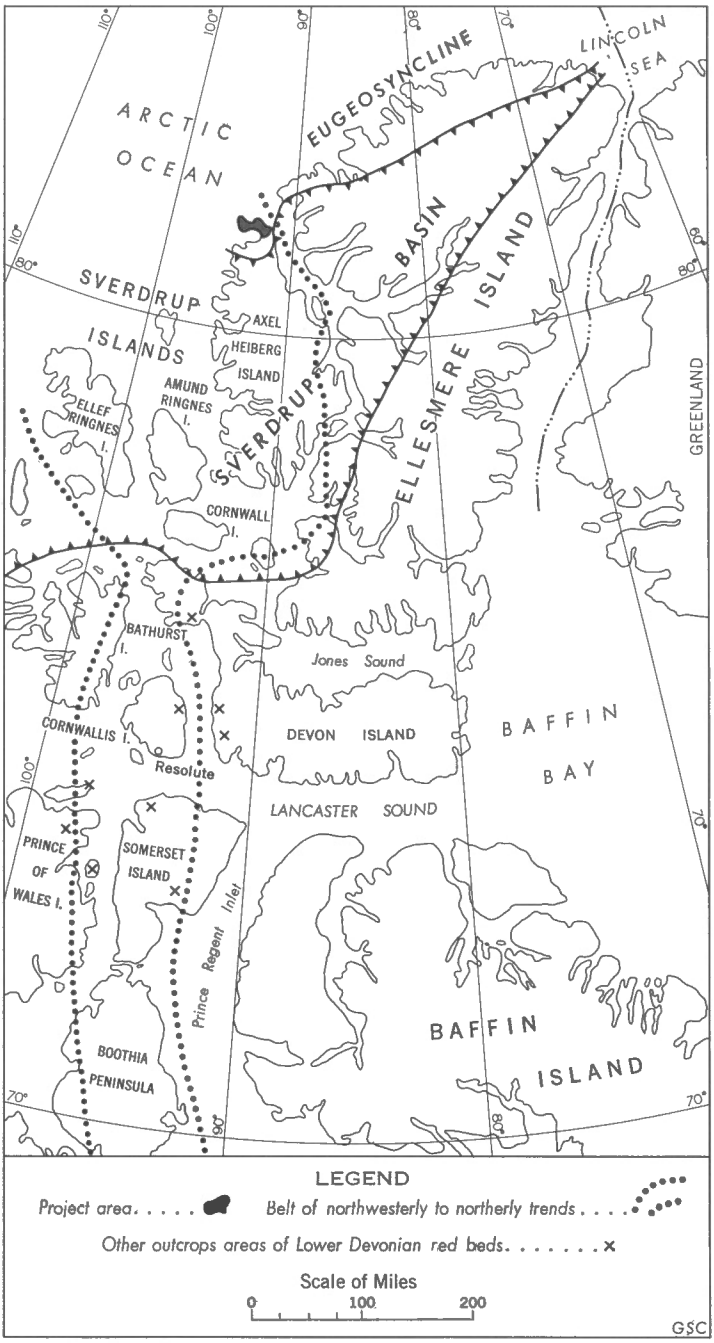

Figure 1. Map showing location and tectonic setting of project area. Based on Thorsteinsson, 1958; Geol. Surv. Canada maps 19-1959 and 20-1959; Thorsteinsson and Tozer, 1960 Fig. 2; and Thorsteinsson, personal communication.

PRE-MISSISSIPPIAN SUCCESSION OF NORTHERNMOST AXEL HEIBERG ISLAND, DISTRICT OF FRANKLIN

INTRODUCTION

The pre-Mississippian succession of northernmost Axel Heiberg Island is of key importance in elucidating the stratigraphy of the Franklinian eugeosyncline, but fossils are sparse and the tectonic history is complicated. The succession has been studied independently by members of the Geological Survey and of the Jacobsen-McGill University Arctic Research Expedition, and the results of these investigations are combined in this preliminary report.

Acknowledgments

Fricker wishes to express his thanks to F. Müller, scientific leader of the Jacobsen-McGill University expedition, for his great interest and help during the field season and the evaluation. E.H. Kranck and C. Duesing (McGill University) offered valuable assistance. Able field assistance was given in 1960 by H.U. Maag.

Palaeontological identifications were made by B.S. Norford and R. Thorsteinsson.

Regional Setting

Two major stratigraphic provinces are exposed on Axel Heiberg Island: (1) The Franklinian eugeosyncline which includes a limited part of the island extending from lat. 80°50' to its northern extremity and is centred approximately at Rens Fiord, a prominent indentation on the northwest coast of Axel Heiberg Island. In this area is exposed a thick sequence of partly metamorphosed sedimentary and volcanic rocks intruded by small granitic plutons and ranging in age from Lower Silurian or older to Lower or Middle Devonian. (2) The Sverdrup Basin which covers the remaining nine tenths or more of the island. Strata in this basin consist of unmetamorphosed rocks ranging in age from Mississippian to early Tertiary, and rest with profound angular unconformity on the rocks of the Franklinian eugeosyncline.

The major outcrop areas of the eugeosynclinal succession are shown on the map by Tozer and Trettin (1962)[1]. The present map

[1] Names and/or dates are those of references cited at the end of this report.

and report are concerned only with the region north and east of Rens Fiord in which detailed studies were carried out.

Accessibility

The project area is accessible only by helicopter or small aircraft equipped with skis or over-sized wheels, or, in winter and spring, by dog sledge. The nearest air base is the weather station Eureka, which lies about 120 miles southeast of the project area on Slidre Fiord on the northwest coast of Ellesmere Island.

Physical Features

The topography of the area is mainly determined by the lithology and structure of the bedrock formations. It is characterized by northwesterly trending ridges formed in steeply dipping resistant strata, such as volcanic rocks, greywacke, conglomerate, carbonates, and quartzite. These ridges are separated by open valleys or hilly lowlands underlain by recessive rocks such as shale, slate, phyllite, and siltstone. There are three major ice-fields, the largest of which is on the northeast coast of the island and calves into Nansen Sound. The central ice-cap is surrounded by extensive gravel deposits. A coastal flat southeast of Cape Thomas Hubbard is covered with marine Pleistocene deposits. Local relief is in the order of 2,000 feet.

Vegetation is extremely sparse and is less abundant than in other parts of Axel Heiberg and Ellesmere Islands that are of comparable topography and altitude. Wild life is accordingly scarce. A few caribou and arctic foxes, tracks of a polar bear, and arctic hares, weasels, jaegers, and snow buntings were seen.

Geological Investigations

In 1955, during 'Operation Franklin', E.F. Roots paid a brief visit to Svartevaeg and examined parts of the rock unit herein described as Svartevaeg Group (Fortier et al., in press).

In 1958, R. Thorsteinsson, in the course of investigations in northern Axel Heiberg Island and Ellesmere Island, made a geological reconnaissance of Svartevaeg and the Rens Fiord area (Thorsteinsson and Tozer, 1960, pp. 8, 10, 11). He was the first to recognize a thick eugeosynclinal sequence in northern Axel Heiberg Island and that this sequence was overlain with angular unconformity by Carboniferous strata of the Sverdrup Basin. A few fossils found indicated a lower Palaeozoic age for much of the eugeosynclinal succession. Dioritic intrusions were noted.

In 1960, geological and glaciological studies were undertaken by members of the Jacobsen-McGill University expedition in the northern part of Axel Heiberg Island (Fricker, 1961, pp. 157-158; Müller, 1961, p. 43). P.E. Fricker, assisted by H.U. Maag, carried out a 10-day geological reconnaissance. The pre-Carboniferous complex was subdivided into three major stratigraphic groups, each

Table of Formations

Era	Period or Epoch	Formation and Thickness (feet)	Lithology
	360 ± 25 million years (?) Upper Devonian (?)[1]		Quartz diorite, granodiorite
	Intrusive contact with Rens Fiord Complex		
	Post-early Lower Silurian pre-Mississippian (Visean)[2]	Svartevaeg Group Division B (7,000+)	Volcanic arenite; minor siltstone, tuff, conglomerate, breccia, volcanic flows, shale, slate
		Division A (3,500±)	Tuff and volcanic flows, partly spilitic, volcanic arenite; minor siltstone, shale
Palaeozoic	Normal contact probable, fault possible		
	Lower or Middle Devonian	Stallworthy Group Division C (8,000±)	Red siltstone, multicoloured shale; minor quartzose sandstone, cherty conglomerate and breccia
	Middle Devonian and/or (?) earlier	Division B (1,000 ?-2,500)	Quartzose sandstone, cherty conglomerate and breccia, siltstone (red beds)
		Division A (0 ?-3,000±)	Siltstone; minor quartzose sandstone, cherty conglomerate, shale (mostly red beds)
	Disconformity and/or (?) fault contact		
	Lower Silurian or later	Map-unit 2	Siltstone; minor conglomerate, slate
	Fault contact		
Palaeozoic (?)	Silurian and/or earlier	Rens Fiord Complex	Slate, phyllite, quartzite, chert, dolomite, greenschist, metamorphosed volcanic flows; minor limestone, hornfels, marble

[1]K-Ar age may indicate time of metamorphism and not of emplacement.

[2]The Svartevaeg Group may be older than the Stallworthy Group

consisting of smaller units. Intrusive and volcanic rocks of acid to basic composition were found to play an important part. Two major orogenic phases were noticed within the pre-Carboniferous strata. Fricker and other members of the Jacobsen-McGill University expedition pursued studies in that area during 4 days in 1961.

In 1961, H.P. Trettin worked in the area for 21 days, mostly making foot traverses in the project area and a brief aerial reconnaissance of the outcrops south of Rens Fiord. Ten rock units were mapped and studied, several fossil collections were made and samples were taken for radioactive determination. The information obtained allowed tentative age assignments, correlations, and conclusions about the tectonic history of the area. For one week J.W. Kerr participated in the studies.

GENERAL GEOLOGY

The pre-Mississippian eugeosynclinal succession of northernmost Axel Heiberg Island comprises more than 35,000 feet of sedimentary, volcanic, and metamorphic strata and has been subdivided into four major stratigraphic units ranging in age from Lower Silurian or older to Lower or Middle Devonian. The regional structure is characterized by northwesterly trends and moderate to steep, predominantly northeasterly dips. Several major strike faults have been mapped. Only one fold was recognized.

Sedimentary, Volcanic, and Metamorphic Rocks

Rens Fiord Complex (Map-unit 1)

Rens Fiord, the northernmost bay on the east coast of Axel Heiberg Island, was discovered and named by Sverdrup and Fosheim in 1900. Map-unit 1 is named after this bay.

The Rens Fiord Complex outcrops north and south of the bay and in a narrow belt along its eastern shore. The complex comprises more than 10,000 feet of slate, phyllite, quartzite, chert, carbonates, and volcanic rocks which show low-grade regional metamorphism and, in the vicinity of calc-alkaline and basic intrusions, thermal metamorphism. The age of the complex is unknown but is believed to be Lower Silurian and/or earlier. Because of severe faulting and the lack of fossils the internal structure of the complex could not be worked out with assurance. Several lithological sub-units are shown on the map. Only one of them—map-unit 1d—is a stratigraphic unit of formational rank. The others signify rock types that may occur in more than one stratigraphic position.

Map-unit 1a is composed of light grey to dark grey and partly reddish phyllite and slate and lesser amounts of siliceous slate, ribbon chert, and quartzite (see Appendix, Section I). A unit particularly rich in ribbon chert has been designated 1a-ch, although chert rarely exceeds 20 per cent of the total assemblage. Included in this unit are several outcrop areas that may in part occupy different stratigraphic positions. The slates and phyllites are poorly exposed and the contacts of map-unit 1a with the other lithological units are rarely exposed.

Under the microscope, slate and phyllite are seen to consist predominantly of white mica and chlorite, minor amounts of relatively clear albite, and small grains of detrital quartz. A narrow belt of slate and phyllite in the southwestern part of the project area is rich in authigenic pyrite. The chert is mostly light grey and occurs in thin beds separated by laminae of phyllite. Cherty units are a few to some 20 feet in thickness. The chert consists of silica grains, microns in size, that show undulose extinction. Associated with the silica are minor amounts of white mica.

The unit appears to be of pelagic origin. The origin of the ribbon chert poses a problem. It has long been held that bedded chert can originate under normal conditions by the precipitation of silica or by the coagulation of silica gel contained in sea water. However, experimental data show that the sea as well as rivers are normally highly undersaturated with respect to silica and that precipitation is unlikely to occur (Krauskopf, 1959). The ribbon chert of the Rens Fiord Complex is not associated with volcanic flows or tuff and cannot be considered as the product of volcanic emanations or the submarine weathering of glassy pyroclastic material. On the other hand, the strata resemble certain Permo-Carboniferous and Triassic ribbon cherts of British Columbia and Yukon Territory, which are probably of radiolarian origin (Aitken, 1959, p. 19; Wheeler, 1961, p. 29; Trettin, 1961, p. 24; and others). Radiolarian (?) nodules as reported from the latter cherts have not however been detected in the four thin sections of Rens Fiord cherts examined. Only in detrital chert grains from sandstones of map-unit 2 and the Stallworthy Group have such structures been recognized. These detrital grains may well have been derived from strata equivalent to the Rens Fiord Complex, as no other rock unit known in the vicinity carries much chert. It is possible that the cherts are of bioclastic origin but that the organic structures have partly been destroyed by processes of diagenesis or metamorphism.

Map-unit 1b is made up mostly of quartzose metamorphic rocks, whose grains range from silt to granules in size. The unit occupies most of the western part of the project area and may form a single stratigraphic unit. The rocks are moderately to poorly sorted and locally show crossbedding and graded bedding. The examination of five thin sections reveals a fairly uniform composition and texture. The sections contain 72 to 82 per cent quartz, 1 to 8 per cent feldspar (mostly albite), 1 to 2 per cent rock fragments, 4 to 17 per cent white mica and minor chlorite, 1 to 2 per cent 'iron ore' (mostly altered pyrite), and traces of apatite and zircon. The grains are mostly subrounded, indicating a long history of abrasion and perhaps derivation from older quartzose sandstones. Differences in metamorphism between grains of the same thin section show differences in source material. Poor sorting suggests textural immaturity. The coarse-grained strata were probably laid down in a near-shore environment.

Map-unit 1c comprises dolomite and limestone beds not associated with volcanic rocks. A narrow belt of dolomite and limestone extends from the southeast shore of Rens Fiord northwest for about 10 miles. In the northeast the carbonates are bounded by a major fault. Their southwestern contact is very poorly exposed and its nature is unknown. At least 500 feet of strata were seen in a single outcrop,

and the total thickness of carbonates in this belt is probably between 500 and 1,000 feet. At the base of the unit is a green to grey-weathering, laminated quartzite, less than 100 feet thick. The quartzite is overlain by about 200 feet of silty and sandy laminated to thin-bedded dolomite and minor limestone. Soft sediment deformations such as primary folds and intraformational brecciation were locally observed. Tectonic breccias are common in the vicinity of faults. The middle and upper parts of the section are composed predominantly of laminated microcrystalline dolomite and minor amounts of laminated microcrystalline to aphanitic limestone which are both partly brecciated. The limestone is overlain by silty and sandy phyllite (see Appendix, Section II). An isolated mass of laminated to thin-bedded dolomite and limestone has been mapped immediately south of the western ice-cap. The carbonates of this outcrop have been replaced extensively by chert. Apparently this outcrop is a fault slice and may belong to the same stratigraphic unit as the dolomite-limestone belt described above. A different carbonate unit outcrops about 4 miles southeast of Cape Thomas Hubbard where about 200 feet of medium grey, aphanitic, light-grey-weathering dolomite is intercalated in quartzite and minor phyllite. Two other outcrops of dolomite occur between 8 and 11 miles southeast of Cape Thomas Hubbard. The northern outcrop contains interbedded lenses and discontinuous layers, several feet in thickness, of light grey chert. Small patches of brownish weathering carbonate within the microcrystalline silica suggest that the chert has replaced the dolomite.

Map-unit 1d, comprising approximately 1,400 feet of volcanic rocks and carbonates, is the only division of the Rens Fiord Complex that can be considered as a formation. A comparatively little disturbed belt of these strata extends from the northeastern extremity of Rens Fiord to the bay between Cape Stallworthy and Cape Thomas Hubbard. Several fault slices were recognized in the western and northwestern parts of the area. The unit may be subdivided into three members: a lower member, composed of dolomite and meta-basalt or spilite with a comparatively thick dolomite unit at the base; a middle member, made up predominantly of spilite or meta-basalt; and an upper member consisting mostly of tuffaceous (?) greenschist and volcanic breccia. Most of the carbonate units are of small extent, some with a strike length of less than a mile. In a fault slice immediately to the east and southeast of the western ice-cap, stromatolitic 'cabbage head' structures were observed. The greenschist is made up predominantly of chlorite, minor biotite, and eye-shaped remnants of strongly altered volcanic fragments. The fragmental texture of the rock and the absence of associated sediments suggest a pyroclastic origin. The flows are highly vesicular or amygdaloidal. The fact that individual flows are only 1 foot to 2 feet thick suggests that they crystallized from a magma of low viscosity. The original mafic minerals in these flows have been replaced by chlorite and minor chloritized biotite. The feldspar consists of albite. It cannot be determined whether these flows are spilites or metamorphosed basalts.

Most of the strata of the Rens Fiord Complex strike northwesterly and dip steeply or moderately to the northeast. The internal structure of this rock unit is complicated by strike faults. Some of these faults are apparent from the repetition of map-units 1c and 1d, but many others may be present that could not be detected because of the lack of marker beds. Some of the faults may have been thrusts, but it is impossible to reconstruct the

original dips of the fault planes because of the effects of later deformations. The Rens Fiord Complex appears to be in fault contact with map-unit 2. This fault has been inferred from signs of brecciation and alteration and from pronounced changes in the apparent thickness of map-unit 1c.

Schistosity and slaty cleavage are well developed in all sub-units except for the volcanic flows and some of the carbonates. Schistosity and cleavage are commonly subparallel to bedding but are also at low to moderate angles with it. In several thin sections and samples from different sub-units, three sets of S-planes were detected. In some sections quartz and chert grains are stretched parallel with the schistosity of the rocks. The clay fraction of these strata has recrystallized to white mica and chlorite. The mafic silicates of the volcanic rocks have been converted to chlorite or chloritic biotite. Of the plagioclase series only albite, most of which is relatively free of inclusions, has been identified. The mineralogy and texture of the rocks thus indicate that they have been subjected to low-grade regional metamorphism.

The Rens Fiord Complex was intruded by basic dykes and sills and small granodiorite and quartz-diorite plutons of probable Upper Devonian age. In the vicinity of these intrusions, notably the diorites, the strata show thermal metamorphism characterized by the development of biotite. The thermal metamorphism appears to be younger than the regional metamorphism.

The environments of deposition of the Rens Fiord Complex vary from near-shore (crossbedded quartzites, stromatolitic carbonates) to pelagic (bedded chert, slate, phyllite) conditions. Except for one period of volcanism, tectonic conditions seem to have been relatively stable. Such indicators of tectonism as graded greywackes, submarine slide deposits, and thick conglomerates are absent.

The higher grade of metamorphism suggests that the Rens Fiord Complex is the oldest unit in the project area. It is therefore tentatively considered to be Silurian and/or older.

Map-unit 2

This unit is exposed in a belt up to 2 miles wide that trends from Cape Stallworthy for about 18 miles to the southeast. The minimum thickness of strata present is in the order of 3,000 feet.

The unit consists predominantly of dark grey to medium grey, shaly to sandy siltstone and very fine grained silty sandstone. Intercalated with these predominantly silty strata are minor amounts of greywacke and conglomerate. The siltstone is laminated to medium bedded. Some laminated strata show soft sediment convolutions. The greywackes are greenish grey and weather green to buff or brown. They are predominantly fine grained but include granule- to pebble-sized chips of dark shale and siltstone and locally large, contorted fragments of siltstone that apparently have been torn from underlying strata. Groove casts have been observed. Greywacke units are

rarely more than a few feet thick. Graded bedding is common but not as well developed as in the type sections of Kuenen and Mignorini in the Alps. The greywackes are made up of various proportions of chert, quartzite, feldspar, quartz, carbonate, argillaceous and very fine grained igneous rock fragments, and minor 'iron ore' set in a matrix of 'clay' or chlorite. Only one bed of conglomerate has been observed. It could be traced only for a few hundred feet and probably is not extensive. The conglomerate consists of pebbles and cobbles of fossiliferous limestone in a matrix of greywacke. The underlying strata show soft sediment deformations.

The internal structure of map-unit 2 is complicated; particularly east of Rens Fiord are the attitudes irregular and minor folds and faults common. A slaty cleavage is well developed in the silty strata, which in some localities is subparallel with bedding and in others cuts across the bedding surfaces. Only two sets of S-planes were seen. There is no evidence of appreciable regional metamorphism.

The unit is believed to have originated in a pelagic environment. The abundance of silt in the sediments suggests a position intermediate between near-shore and deep-sea conditions—perhaps a continental slope. A slope environment is also suggested by the presence of a possible submarine slide—the conglomerate mentioned above. Turbidites and submarine slides are believed to originate either by tectonic movements or by overloading in areas of rapid accumulation.

Fossils from the limestone conglomerate mentioned above were identified by B.S. Norford as follows:

GSC Loc. 47510—3.7 miles south-southeast of Cape Stallworthy; 0.6 mile east-northeast of bay between Cape Stallworthy and Cape Thomas Hubbard.

echinoderm columnals
bryozoa
gastropods
brachiopod and foraminiferal fragments
cystiphyllid coral
Favosites sp.
Halysites sp.

Age: Silurian, probably Llandovery or Wenlock. The Halysites is similar to one described as H. catenularius by Poulsen from the Offley Island Formation of Greenland of Llandovery age.

The unit therefore is Llandovery or younger. It is lithologically similar to strata on Emma Fiord in which R. Thorsteinsson found Upper Silurian graptolites.

Stallworthy Group[1] (Map-units 3, 4 and 5)

Cape Stallworthy was named in honour of H.W. Stallworthy of the RCMP who in 1932 sledged around the northern

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[1]In this report the term Group is used in a reconnaissance sense and not strictly as defined in the Code of Stratigraphic Nomenclature.

capes of Axel Heiberg Island in search of Krueger's expedition. The Stallworthy Group, named after the cape, is here defined as a rock unit composed predominantly of red-weathering siltstone, quartzose sandstone, conglomerate, and minor breccia, and grey- and green-weathering shale, with a minimum thickness of 12,500 feet. The group outcrops in a belt between 2 and 3 miles wide that extends from a point about 1 1/2 miles southeast of Cape Stallworthy for 22 1/2 miles to the southeast. Three divisions are recognized. These divisions probably rank as formations but at present it seems inadvisable to give them formal names. Division C is Lower and/or Middle Devonian in age.

About 15 to 16 miles southeast of Cape Stallworthy, Division A has a minimum thickness of approximately 3,000 feet. The upper 2,500 feet is composed of recessive, poorly exposed, mostly brick-red-weathering siltstone, shale, and minor sandstone. This recessive unit is underlain by a cliff-forming member, about 400 feet thick, composed of quartzose sandstone in the upper part and chert-pebble conglomerate in the lower part. The sandstone is light grey, fine to coarse grained, and weathers reddish. The conglomerate is light grey and composed predominantly of rounded chert pebbles up to 4 inches in diameter, but mostly less than 2 inches. The conglomerate overlies poorly exposed, recessive, red- to grey-weathering siltstone and shale. The contact with map-unit 2 has not been investigated in this area. Division A was laid down in an oxidizing environment. It is probably in part or entirely non-marine.

Division B consists of quartzose sandstone, cherty conglomerate and breccia, and minor siltstone. Between 15 and 16 miles southeast of Cape Stallworthy the division is about 2,000 feet thick. About 2.5 miles southeast of the cape the thickness is approximately 2,500 feet, and near the north coast of the island it is in the order of 1,000 feet. In this northernmost part the division may have been truncated by a fault. The sandstone is light grey, very fine to very coarse grained, commonly crossbedded, and weathers reddish brown. It is moderately resistant to weathering. The examination of thin sections shows that it is composed predominantly of quartz, minor amounts of chert and white mica, and traces of feldspar, rock fragments, and 'iron ore'. The cement consists mostly of silica. As these specimens contain less than 95 per cent quartz they can be classified as protoquartzites (Pettijohn, 1957, p. 291). The fragments of conglomerates and breccias range in size from granules to cobbles, pebble-conglomerates being most abundant. The induration and hence the resistance of the strata to weathering varies. East of Rens Fiord a well-indurated breccia of pebble grade forms a prominent ridge. Granules, pebbles, and cobbles are mostly of chert. The finer grades are richer in quartz and comparable in composition to the sandstones. One chert fragment in a conglomerate showed radiolarian(?) nodules. Undeterminable plant remains were found in a sandstone. Division B probably is of non-marine origin and was laid down in an oxidizing environment.

Division C is composed of brick-red-weathering siltstone, green- and dark-grey-weathering shale, and minor amounts of quartzose sandstone, and cherty conglomerate and breccia. The upper half of the unit is poorly exposed and the upper contact is possibly a fault. The division probably has a minimum thickness of 8,000 feet. Whereas the lower two divisions are nearly barren of

fossils, a few gastropods, pelecypods, and fossil fish bones have been found in Division C. The presence of certain types of fish indicates that the division is at least in part marine—even the sandstones may be partly marine. The conglomerates and breccias are either non-marine or near-shore deposits. The red beds originated in an oxidizing environment, and the dark grey shales under rather reducing conditions.

The Stallworthy Group strikes northwesterly and most of the strata dip steeply to the northeast. In the northern part of the area some strata of Division B are overturned and dip to the southwest.

The nature of the lower and upper contacts of the Stallworthy Group is not fully understood. North of the central ice-cap the abrupt transition from dark siltstone and greywacke of map-unit 2 to the quartzose red beds of the Stallworthy Group indicates either a fault or a disconformity. The following observations suggest a fault: (1) Division A of the Stallworthy Group is absent. Over a distance of 3.5 miles Division B thins from approximately 2,500 to 1,000 feet; it appears that the lower part of the Stallworthy Group there is truncated by a fault. (2) The contact zone is intruded by basic sills. (3) If the Svartevaeg Group is older than the Stallworthy Group and younger than map-unit 2, it should underlie the red beds. Its absence there could only be explained by a fault. However, the following objections against a fault and in support of a disconformity could be given: (1) The thinning of the lower part of the Stallworthy Group could be due to a facies change. (2) Such signs of faulting as brecciation, alteration, contortion, and subsidiary faults have not been observed. (3) The age of the Svartevaeg Group is uncertain.

East of Rens Fiord the situation is even more difficult to explain. Between 4 and 5 miles south of the ice-cap, Trettin did not see the contact exposed, but outcrops with a stratigraphic separation of less than 1,000 feet showed similar lithologic differences as north of the ice-cap. South, Fricker noted strata that could be interpreted as transitional between map-units 2 and 5. The distribution shown on the map suggests a northwesterly thinning of Division A. Neither sills nor signs of structural disturbances have been observed. It is therefore possible that the boundary between map-unit 2 and the red beds north of the ice-cap is a fault, and south of the ice-cap it is a normal contact or a disconformity. The contact between the Stallworthy and Svartevaeg Groups is probably a normal contact, but possibly a fault. It is discussed below.

The strata show no signs of regional metamorphism and little dynamic metamorphism. In contrast to map-unit 2 the siltstones of the Stallworthy Group rarely exhibit well-developed slaty cleavage. The incompetent shales and siltstones of Divisions A and C are intruded by numerous sills.

Fossil fish from a dark grey, calcareous shale about 4,000 to 5,000 feet above the base of Division C have been assigned by R. Thorsteinsson to the Lower or Middle Devonian. Thorsteinsson favours a Lower Devonian age. Lower Devonian red beds have been mapped in the vicinity of Boothia Arch and Cornwallis Fold Belt (see Fig. 1). Apparently they are confined to the vicinity of an area with northwesterly to northerly structural trends that may coincide with a belt of Upper Silurian or Lower Devonian earth-movements.

Svartevaeg Group (Map-units 6 and 7)

The name "Svartevaeg" was given by Sverdrup and Schei to the dark-coloured, rugged sea cliffs on the northeast coast of Axel Heiberg Island near the entrance of Nansen Sound. The term "Svartevaeg Group" is given here to a cliff-forming rock unit, more than 10,000 feet thick, composed predominantly of tuffaceous volcanic arenite and tuff, with some volcanic flows and minor amounts of siltstone, conglomerate, shale, and slate. The volcanic rocks are partly spilitic in composition. Two sub-units are recognized. As the group is bounded by an angular unconformity at the top and possibly by a fault at the base these sub-units are not defined as formations but given the informal names Division A and Division B. The group is post-early Lower Silurian and pre-Mississippian (Visean) in age and either Silurian or Middle to Upper Devonian. At present a Middle Devonian assignment appears most probable, but a Silurian assignment is possible.

Division A is approximately 3,400 feet thick. The lowest outcrops exposed consist of dark grey laminated silty shale and grey to greenish, green-weathering siltstone and volcanic arenite, about 200 feet thick. These sediments are overlain by a predominantly volcanic sequence made up largely of tuff with less volcanic flows and still less sediments, mostly volcanic arenite and a little siltstone, shale, and slate. The volcanic rocks are partly spilitic in composition and some of the flows show pillow structure. A spilitic lithic tuff, the fragments of which consist predominantly of albite (around An_5) and lesser amounts of chlorite, carbonate and ore minerals, has the following chemical composition*:

Chemical	Per cent
SiO_2	57.6
TiO_2	0.71
Al_2O_3	17.3
Fe_2O_3	1.4
FeO	5.9
MnO	0.16
MgO	4.2
CaO	2.1
Na_2O	4.5
K_2O	2.6
P_2O_5	0.18
H_2O	3.6
CO_2	—
	100.2

* Analyst M. Weibel, Federal Technical Institute, Zurich.

The contact with Division B is gradational and is placed at the base of a more recessive sedimentary sequence that contains more siltstone than the underlying strata.

Parts of Division B are exposed in two sections in fault contact. These sections have tentatively been correlated, using a conglomerate with fossiliferous limestone cobbles and boulders as a marker. The composite section of Division B may be subdivided into three members. The lowest member, about 1,600 feet thick, is composed of massive to thin-bedded, mostly graded volcanic arenite with minor siltstone, shale, conglomerate, and tuff. The top of this member is marked by the conglomerate mentioned above. The middle member, about 750 feet thick, consists predominantly of siltstone and shale and is comparatively recessive. The content of volcanic arenite in this member increases upwards. The upper member, about 4,750 feet thick, is made up mostly of thick-bedded to massive greywacke with minor siltstone, shale, conglomerate, tuff, and volcanic flows. The upper 200 feet consists of basaltic breccia, probably of pyroclastic origin with fossiliferous limestone fragments. The sorting and bedding of the sediments depends on their grain size. The coarse conglomerates are massive and nearly unsorted. The volcanic arenites range from thick-bedded, poorly sorted, coarse-grained units, to laminated, well-sorted, fine-grained strata. The siltstones are mostly thin bedded to laminated and well sorted. Shale and slate are comparatively rare and occur mostly as thin layers at the top of graded sequences. The volcanic arenites are composed predominantly of volcanic fragments, less feldspar and carbonate, and small amounts of chloritized mafic minerals. They are in part tuffaceous, but the proportion of pyroclastic matter is difficult to determine. The matrix consists predominantly of chlorite locally replaced by carbonate, and to a lesser extent of submicroscopic particles. As, in the specimens analyzed, the matrix does not exceed 10 per cent, the rocks are classified as volcanic arenites (Gilbert, in Williams, Turner, and Gilbert, 1955, p. 293).

In the northern part of Svartevaeg the group forms a southeasterly plunging syncline. In the southern part the strata dip about 35 to 40°SE. The internal structure of the group is complicated by minor faults. The contact with the Stallworthy Group is mostly concealed and is either a normal contact or a fault. The examination of thin sections reveals no appreciable regional metamorphism. Argillaceous sediments locally show a well-developed slaty cleavage. Not more than two sets of S-planes have been observed.

The volcanic arenites showing graded bedding probably were deposited by turbidity currents. A block of fossiliferous limestone (described below) seems to have slumped before the lithification of the volcanic arenites. The limited areal extent and very poor sorting of a boulder-conglomerate indicates that it is a submarine slide. Turbidity currents and submarine slides may originate by earthquakes and are, if present in such large quantities as here and associated with volcanic rocks, indicators of crustal instability. Stratigraphic and oceanographic observations show that turbidites of this type occur only in deep-sea environments. The Svartevaeg Group may therefore be considered as a syntectonic deep-sea deposit.

The following fossils were identified by B.S. Norford:

GSC Loc. 47504—8 miles southeast of Cape Stallworthy; near northern extremity of eastern ice-cap; about 2 miles southwest of Nansen Sound.

Stratigraphic position: About 200 feet above base of Division A.

Occurrence: Limestone fragments in a tuff.

favositid coral
brachiopod fragments

Age: Probably Silurian or Devonian.

GSC Loc. 47511—8.2 miles southeast of Cape Stallworthy; 1.1 miles southwest of Nansen Sound; on east slope of mountain ridge.

Stratigraphic position: Approximately 200 feet above base of Division B.

Occurrence: Isolated block of limestone, about 15 feet in diameter, surrounded by volcanic arenites; strong pene-contemporaneous deformations. The bedding attitudes of the limestone do not conform to those of the volcanic arenite.

echinoderm columnals
fragments of solitary corals, 2 spp.
bryozoa
stromatoporoid(?)
cf. Favosites sp.
spire-bearing brachiopod, (?) Howellella
Encrinurus sp.

Age: Silurian probably late Llandovery or Wenlock.

GSC Loc. 47506—Svartevaeg, approximately 9 miles southwest of Cape Stallworthy.

Stratigraphic position: Approximately 1,800 feet (?) above base of Division B. Probably correlative with loc. 47505 but separated from that locality by a fault.

Occurrence: Limestone cobbles in a conglomerate that is probably a submarine slide deposit.

favositid and columnarid corals
? Syringopora sp.
stromatoporoid

Age: Silurian to Middle Devonian.

GSC Loc. 47505—Svartevaeg, approximately 8.5 miles southwest of Cape Stallworthy.

Stratigraphic position: Probably about 1,600 feet above base of Division B.

Occurrence: Limestone-cobble conglomerate; probably a submarine slide deposit.

Age: Silurian or Devonian.

In 1955, E.F. Roots (in press) collected Silurian fossils from limestone fragments in a pyroclastic deposit in the uppermost part of Division B. In 1958, R. Thorsteinsson added to this collection and confirmed the Silurian age.

As mentioned above, the contact of the Svartevaeg Group with the Stallworthy Group is very poorly exposed and the age relation of these two units therefore is uncertain. Fossils collected indicate only that the Svartevaeg Group is post-early Lower Silurian and pre-early Upper Mississippian in age. The following circumstances support the hypothesis of a fault contact and a late Silurian or earliest Devonian age assignment to the Svartevaeg Group: (1) The four collections made contain some Silurian fossils but no definitely post-Silurian fossils. Some of these collections may be only a little older than the Svartevaeg strata as they are from submarine slide and slump deposits. This holds true especially for lot 47511, late Lower or Middle Silurian in age, which probably was derived from a submarine source. (2) Both contacts with the Stallworthy Group are marked by pronounced and abrupt lithological changes, and map-unit 2 and the Svartevaeg Group have greater lithological affinity to each other than to the Stallworthy Group. South of Emma Fiord, fossiliferous Upper Silurian strata comparable to map-unit 2 apparently underlie a sequence of volcanic-derived sediments and spilitic volcanic rocks that is similar to the Svartevaeg Group. However, the stratigraphic relations at Emma Fiord are not entirely certain because of structural complexities. On the other hand the following considerations militate against a fault contact and support a Devonian age assignment: (1) None of the fossils collected were found in place and they could be considerably older than the enclosing sediments. In some parts of the Alps, for example, fossiliferous Jurassic limestone blocks occur in Cretaceous sediments. (2) The abrupt contacts of the Stallworthy Group could be explained by unconformities or, in the case of the upper contact, by a sudden start of volcanism. (3) Photogeology did not indicate that the Stallworthy Group is bounded by faults, and the attitudes of all map-units concerned are rather uniform. (4) The Svartevaeg Group appears to be syntectonic (but preclimactic) and could be related to a Middle or Upper Devonian orogeny.

Intrusive Rocks

Three groups of intrusive rocks are recognizable in the map-area: (1) small plutons of quartz diorite and granodiorite (map-unit 8); (2) dykes and sills of diabase and gabbro (not shown on the map); and (3) carbonatite (?) and sandstone dykes (not shown on the map).

Quartz Diorite, Granodiorite (Map-unit 8)

Several small plutons of calc-alkaline composition have intruded rocks of map-unit 1 along the west side of the peninsula between Cape Thomas Hubbard and Rens Fiord. These bodies show a conspicuous linear arrangement. They have irregular outlines and rarely exceed 1/2 mile in diameter. Two joint systems, one trending in a north-northwesterly direction and the other in a westerly direction, are present in a small pluton about 6.5 miles southwest of Cape Thomas Hubbard and 1 mile east of the Arctic coast on the west side of a small lake. Younger basic dykes have mainly intruded joints of the north-northwesterly directed system. Another small pluton has been mapped in the central part of the peninsula, about a mile north of Rens Fiord. Between Svartevaeg and Cape Stallworthy, at the entrance of Nansen Sound, a complex of quartz diorite, more than a mile long and about 1/2 mile wide, has been interpreted as a horst. Roof pendants of carbonate rocks, shale, and chert showing contact metamorphism are associated with the quartz diorite.

All these plutons are composed of light grey, generally fresh-appearing quartz diorite and granodiorite. The rocks are fine to medium grained and have an equigranular-subhedral texture. Porphyritic varieties with phenocrysts of feldspar occur locally. Several thin sections examined show a considerable range in composition.

A representative specimen of granodiorite is composed of about 45 per cent of strongly zoned plagioclase (average composition An_{28}), approximately 15 per cent of subhedral microcline, about 20 per cent of interstitial quartz, and of green hornblende and partly altered biotite.

A typical specimen of quartz diorite contains only a few per cent of alkali feldspar. The subhedral to anhedral plagioclase is zoned and has the composition of oligoclase to andesine (core: An_{34}; rim: An_{27}). Comparison with other thin sections reveals that the amount of quartz (at least 15 per cent), biotite, and hornblende is variable and that the amount of mafic minerals ranges from 15 to 25 per cent. This type of quartz diorite is predominant in the plutons.

A sample from the small pluton 6.5 miles southwest of Cape Thomas Hubbard and about a mile west of the Arctic coast has been analyzed by M. Weibel (Federal Technical Institute, Zurich). The specimen represents a transitional type between granodiorite and quartz diorite as described above.

Spec. A 342

Chemical	Per cent
SiO_2	63.1
TiO_2	0.53
Al_2O_3	15.5
Fe_2O_3	2.35
FeO	2.4

Chemical	Per cent
MnO	0.10
MgO	3.1
CaO	5.1
Na_2O	3.6
K_2O	3.1
P_2O_5	0.23
H_2O	0.8
CO_2	—
	99.9

According to the Niggli method, k is 9.36; mg is 9.55 (P. Niggli, 1946, p. 56; E. Niggli, in Cadisch, 1953, p. 25).

The intrusive rocks carry inclusions of contact-metamorphic quartzite. The size of the fragments rarely exceeds 1 foot. Hornfels facies of the adjacent metasediments of the Rens Fiord Complex shows the effect of contact metamorphism. Small zones of migmatite are locally present. Two specimens of migmatite are characterized by the recrystallization of the quartz grains, by the presence of small plates of biotite which are partly clustered in aggregates or in veinlets, and by the incipient formation of feldspar crystals. Aplitic dykelets have been injected into the country rock.

The plutonic rocks are considered to be magmatic intrusions. A mica sample from a quartz-diorite outcrop about 4.7 miles southwest of Cape Thomas Hubbard yielded a K-Ar age of 360 $\pm$ 25 million years[1] (Lower Devonian to Middle Mississippian, probably Upper Devonian). This age indicates either the time of emplacement of the intrusions or of a later metamorphism. As the plutons intrude only the oldest rock unit in the area a Silurian age or older is possible but, as Devonian and Mississippian strata show no appreciable regional metamorphism, an Upper Devonian age is more probable.

Diabase, Gabbro

Numerous dykes and sills of basic rocks have intruded all strata from the Rens Fiord Complex to Division C of the Stallworthy Group. The thickness of the sills and dykes is generally in the order of 10 to 50 feet. The dykes follow a northerly to northeasterly trend, but in a few places small deviations from this favoured direction occur.

Two main types of basic rocks are present: (1) olivine-bearing diabase—dark grey, fine grained, and brown weathering; and (2) olivine-free diabase to gabbro—medium to dark grey, fine to coarse grained, and buff to brownish weathering.

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[1]Determination by R.K. Wanless and J.A. Lowdon, Geological Survey of Canada.

A typical specimen of olivine diabase is composed of pyroxene (32.2%), plagioclase (43.3%), olivine (4.6%), biotite and chlorite (2.9%), quartz (1.3%), ore minerals (6.7%), and zircon (0.4%)[1]. Both clinopyroxene and minor orthopyroxene are present. The clinopyroxenes vary in composition and seem to consist mainly of diopsidic augite (Duesing and Fricker, unpublished data). The plagioclase is slightly zoned (average composition, An_{56}). The olivine commonly is altered to biotite and chlorite. Carbonate and quartz occur in small patches. The ore minerals consist mainly of ilmenite and magnetite. The ophitic texture of the fine-grained rock is characterized by slender plagioclase laths and anhedral to subhedral grains of pyroxene and olivine. Other specimens show a similar composition. Olivine diabase has only been established in the Rens Fiord Complex and the dioritic plutons. However, strongly altered specimens from sills intruding the Stallworthy Group may belong to the same type. A pre-Carboniferous age of these sills and dykes seems possible. A typical specimen of gabbro consists of pyroxene (32.2%), plagioclase (52.8%), biotite, chlorite, and minor hornblende (7.3%), quartz (0.4%), and ore minerals (4.3%)[2]. Only clinopyroxene is present. The plagioclase is partly zoned and averages about An_{60}. Biotite, chlorite, and hornblende are secondary. The ore minerals consist of ilmenite and magnetite.

The texture of the medium-grained rock is subhedral-granular. Fine-grained diabasic varieties show a similar composition and a predominantly sub-ophitic texture. This rock type is widely represented by dykes and sills intruding both pre-Carboniferous and younger strata.

Detailed studies now in progress point to the relationship of these dykes and sills to certain basic rocks to the south associated with Mesozoic sediments of the Sverdrup Basin (Duesing and Fricker, unpublished data).

Carbonatite(?) and Sandstone Dykes

About 8 miles south-southeast of Cape Thomas Hubbard and 1/2 mile east of the Arctic coast, small dykelets have been injected into a sill of olivine diabase. The light grey, massive, buff-weathering dyke rock is mainly composed of carbonate but contains numerous quartz grains with irregular outlines. It is possible that this fine-grained dyke rock, which outcrops immediately west of a dolomite complex, is a carbonatite (Williams, Turner, and Gilbert, 1955, pp. 85-86).

Sandstone dykes, up to 100 feet in thickness, cut map-unit 2 and the basal(?) part of the Stallworthy Group east of Rens Fiord. The fine-grained, unstratified sandstone shows an affinity with the protoquartzites of map-unit 5 because of the high content of detrital quartz and chert fragments embedded in a silty matrix. Albite forms

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[1] A 326: Specimen from a small dyke cutting a quartz-diorite body; volumetric analysis of 1,550 points.

[2] A 756: Specimen from a gabbroic dyke intruding strata of the Rens Fiord Complex on the peninsula between Rens Fiord and Aurland Fiord; volumetric analysis of 1,200 points.

about 7 per cent of the rock. The amount of carbonate is considerable.

PRELIMINARY NOTES ON THE TECTONIC HISTORY OF THE AREA

Three or four major phases of tectonic history are represented by the pre-Carboniferous succession of northernmost Axel Heiberg Island.

The earliest is represented by the Rens Fiord Complex which is Lower Silurian in age or older. The sediments of this complex range from shallow-water deposits, such as coarse-grained and crossbedded quartzites and stromatolitic carbonates, to pelagic rock types such as slate, phyllite, and ribbon chert. These sediments indicate relatively stable tectonic conditions interrupted by only one episode of volcanism. The Rens Fiord Complex is the only rock unit in the area that shows appreciable regional metamorphism. As the complex is in fault contact with Lower Silurian or younger strata the difference in metamorphism could be explained in two different ways. Either the complex was subjected to an orogeny that took place before the deposition of map-unit 2, or the metamorphism is related to a later orogeny and a major thrust or wrench fault has brought into contact strata of different metamorphic facies. The writers favour the first hypothesis because the greywackes of map-unit 2 were derived from sources similar to those of the Rens Fiord Complex.

There is twofold evidence suggesting that the area was subjected to Upper Silurian or Lower Devonian earth-movements: (1) The northwesterly trends of the area are parallel with those of the Cornwallis Fold Belt and diverge considerably from the easterly to northeasterly trends of the Parry Islands Fold Belt (see Thorsteinsson and Tozer, 1960, fig. 2; and fig. 1 of this report). Northerly to northwesterly trends can be traced from Cornwallis Island and Bathurst Island through the Ringnes Islands as well as Axel Heiberg Island. It is reasonable to suppose that they were established during an Upper Silurian or Lower Devonian orogeny (Thorsteinsson and Tozer, 1960, p. 8) and have impressed themselves upon all subsequent deformations. (2) Apparently Lower Devonian red beds are confined to the vicinity of the belt of northwesterly to northerly trends and can be interpreted as post-tectonic deposits related to Caledonian orogeny. The possible disconformity at the base of the Stallworthy Group may be related to that orogeny.

The angular unconformity at the base of Sverdrup Basin is related to an orogeny that took place between Lower Devonian and early Upper Mississippian time. A Middle and Upper Devonian uplift of the eugeosyncline has been inferred by Thorsteinsson and Tozer (1960, p. 11) from the nature, thickness, and distribution of Upper Devonian clastic sediments. A major deformation in Upper Devonian time is also suggested by the K-Ar age obtained from the dioritic intrusions (360 $\pm$ 25 million years). The age may indicate the time of emplacement of these intrusions or of a later metamorphism.

The stratigraphic positions of map-unit 2 and the Svartevaeg Group are still uncertain. The large amount of graded sediments, tuffs, and volcanic flows in the Svartevaeg Group and the presence of submarine slide and slump deposits suggest that it is a syntectonic but probably preclimactic rock unit. It is probably related

to Middle Devonian earth-movements, but could have been connected with Silurian tectonism.

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- APPENDIX -

STRATIGRAPHIC SECTIONS

Section I

Part of map-unit 1a, Rens Fiord Complex

Location: Creek about 2 miles northeast of Barrel Lake.

Lithology	Thickness (feet - inches)	
Top of section: Glacial drift.		
Quartzite, light grey, fine-grained, partly phyllitic, thin-bedded, grey weathering	1	
Phyllite, wine-red, homogeneous, laminated, greenish weathering		8
Phyllite, light grey, homogeneous, laminated, greenish weathering		4
Quartzite, medium grey, fine-grained, thin-bedded, grey-weathering		1.2
Phyllite, light grey, thinly laminated, greenish weathering		0.01
Siliceous phyllite, light grey, fine-grained, laminated, grey-weathering		0.4
Phyllite, light grey, laminated, partly microfolded, greenish weathering	1	8
Phyllite, wine-red, silty, laminated, partly microfolded, reddish weathering		8
	4	4.7
Bottom of section: Creek bed.		

(Measured by P.E. Fricker)

Section II

Part of map-unit 1c, Rens Fiord Complex

Location: About 2 miles north of northeastern part of Rens Fiord.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Top of section: Fault contact with map-unit 2.		
9	Limestone, light grey, microcrystalline to aphanitic, massive; weathers light grey to buff.....	32	517
8	Limestone, argillaceous and silty, medium grey, microcrystalline, thin-bedded; weathers light grey to buff.....	20	485
7	Limestone, light grey, aphanitic, medium- to dominantly-thin-bedded, light grey to buff-weathering, recessive..	50	465
6	Limestone as above, but thin- to very-thin-bedded, partly fissile, very recessive.....	35	415
5	Limestone as above but massive, cliff-forming.....	35	380
4	Limestone as above, but thin-bedded, recessive	35	345
3	Dolomite, light grey, aphanitic, partly laminated; weathers light grey, recessive.	80	310
2	Covered interval, recessive, with talus of calcareous silty and sandy quartzose phyllite; weathers grey to green	70	230
1	Limestone, medium grey, aphanitic, laminated; lower 15 feet cliff-forming, remainder recessive	160	0
	Bottom of section: Poorly exposed silty and sandy phyllite of map-unit 1a. Nature of contact unknown.		

(Measured by H.P. Trettin)

Section III

Map-unit 1d, Rens Fiord Complex

Location: Immediately east of a small lake, about 2 miles north of the northeastern part of Rens Fiord.

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
	Top of section: Talus of volcanic rocks. The top coincides approximately with the base (?) of map-unit 1a. The contact is covered and its nature unknown.		
7	Tuffaceous (?) greenschist and volcanic breccia, dark green, poorly stratified, with fragments up to 1 foot in diameter; poorly developed schistosity at low angles to or subparallel with bedding.....	305	1,395
6	Dolomite, light to medium grey, microcrystalline to very fine crystalline, medium-bedded, buff-weathering; some vuggy porosity. Contact relations with underlying tuffaceous beds (intra-formational breccia) indicate that stratigraphic tops are facing southwest ..	15	1,090
5	Tuffaceous (?) greenschist and volcanic breccia as above	140	1,075
4	Meta-basalt or spilite, flows about 1 foot to 2 feet thick, boundaries marked by highly vesicular layers; green- and brown-weathering; minor tuffaceous (?) greenschist as above.....	65	935
3	Dolomite, light grey, microcrystalline, massive to medium-bedded, buff-weathering; upper 30 feet with stringers of chert, dark grey; dolomite grades laterally to limestone, light grey, microcrystalline, laminated to thin-bedded.....	215	870
2	Meta-basalt or spilite as above; upper 30 feet showing pillow structure; stratigraphic tops facing southwest.....	395	655

Unit	Lithology	Thickness (feet)	Height Above Base (feet)
1	Dolomite, light to medium grey, fine crystalline to microcrystalline, massive, buff-weathering; many quartz veins	260	
	Bottom of section: Talus of dolomitic and volcanic rocks. The topography indicates that the base of the measured section approximately coincides with the base of map-unit 1d.		
	Base of dolomite outcrops near bottom of slope. The dolomite probably is in contact with fine-grained clastic sediments of map-unit 1a. The nature of the contact is unknown.		

(Measured by H.P. Trettin)