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PRE-MISSISSIPPIAN ROCKS OF NANSEN SOUND AREA, DISTRICT OF FRANKLIN

H. P. Trettin

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CONTENTS

ABSTRACT

A reconnaissance of parts of the Lower Palaeozoic Franklinian eugeosyncline and the Lower Cambrian or older Cape Columbia Group has been carried out. The Cape Columbia Group consists of argillaceous, quartzose, and calcareous sediments showing low grade regional metamorphism. The pre-Silurian succession of the eugeosyncline is incomplete, strongly faulted, and not fossiliferous. A thick sequence of slate, phyllite, sandstone, ribbon chert, dolomite, limestone and volcanic rocks has been assigned to the Rens Fiord Complex. The area probably contains the most complete Silurian and Devonian section of the eugeosyncline. The Lower Silurian and (?) older Imina Group, composed chiefly of lithic arenite and siltstone, was derived from metamorphic rocks and limestone off the north coast of Ellesmere Island. The Middle and Upper Silurian strata of Ellesmere Island - more than 10,000 feet thick - consist of slaty siltstone and shale with quartzose sandstone, volcanic rocks and some conglomerate in the Upper Silurian. Devonian strata preserved only in Axel Heiberg Island comprise 12,000 feet of largely non-marine clastic sediments (Stallworthy Formation) overlain by 10,500 feet of turbidites and volcanic rocks, (Svartevaeg Formation).

There is evidence for several pre-Silurian orogenies. Caledonian movements - probably confined mainly to Axel Heiberg Island - took place between Middle Silurian and Middle Devonian time with intermittent tectonism and keratophyric volcanism in the late Middle and early Upper Silurian. Strong Mid-Palaeozoic movements affected the whole area between Lower Devonian and Upper Mississippian time and probably culminated in Upper Devonian (?) granitic intrusions.

PRE-MISSISSIPPIAN ROCKS OF NANSEN SOUND AREA, DISTRICT OF FRANKLIN

INTRODUCTION

The area investigated, comprising northernmost Axel Heiberg Island and northwesternmost Ellesmere Island, is bounded by 80°45' and 82°09'N lat., and by 83°00' and 95°05'W long.; the northwestern part has not been mapped completely.

Geological reconnaissance in parts of the area was carried out by Schei in 1902 (1903, 1904)[1], Christie in 1954 (1957), Roots in 1955 (1963), Thorsteinsson in 1957 (Thorsteinsson and Tozer, 1960, pp. 8, 10, 11), and by P.E. Fricker of the Jacobsen-McGill University Arctic Research Expedition in 1960 and 1961 (Fricker, 1961; Fricker and Trettin, 1962).

During the 1961 and 1962 field seasons the writer was a member of 'Operation Eureka', an airborne operation of the Geological Survey of Canada based at Eureka, Ellesmere Island. The object of this operation was a geological reconnaissance of Axel Heiberg Island and the central and northwestern parts of Ellesmere Island. The program was directed by R. Thorsteinsson and the responsibilities were divided as follows: pre-Mississippian miogeosyncline — J.W. Kerr; pre-Mississippian eugeosyncline — H.P. Trettin; Carboniferous and Permian rocks of Sverdrup Basin — R. Thorsteinsson; and Mesozoic and early Tertiary rocks of Sverdrup Basin — E.T. Tozer. The writer spent most of the two field seasons in Nansen Sound area.

The brief summary of the geology of northernmost Axel Heiberg Island in the first part of this paper is based on an earlier report (Fricker and Trettin, 1962), with some additions and modifications resulting from subsequent work by the writer.

Acknowledgments

The writer is indebted to P.E. Fricker for information and advice. The fossil identifications were made by J.W. Kerr, B.S. Norford, and R. Thorsteinsson, and the age determinations by J.A. Lowdon and R.K. Wanless. Professor K.C. McTaggart and Professor J.V. Ross of the University of British Columbia have

[1]Dates and/or names in parentheses refer to publications listed in the References.

given advice on some thin sections. The pilots, V. Andreasen, J. Jamieson and J. Kershaw of Bradley Air Services, Ottawa, skillfully operated their Piper Super Cub aircraft under difficult conditions.

Accessibility

The nearest settlement and airstrip is at Eureka, a weather station on Slidre Fiord on the west coast of Ellesmere Island (85°54'W long., 80°00'N lat.), jointly operated by the Department of Transport and the United States Weather Bureau. The geological investigation of this region prior to 1955 was carried out in the spring and early summer with dogs and sledges. Since 1955, helicopters and small planes equipped with skis or oversized wheels have been used. In the summers of 1961 and 1962, the seasons for aircraft-supported field work lasted approximately from the middle of June to the middle of August. Before the middle of June most of the outcrops were covered with snow, and after the middle of August low hanging clouds and partial snow cover seriously hindered flying.

Regional Setting

Nansen Sound area is underlain by rocks ranging in age from Cambrian or Proterozoic to Triassic, and forming part of three geological provinces: a metamorphic-plutonic complex, Cambrian or older in age, termed "Cape Columbia Group"; the Lower Palaeozoic Franklinian eugeosyncline; and the Sverdrup Basin (comp. Thorsteinsson and Tozer, 1960).

The area probably contains the most complete Silurian and Devonian section of the eugeosyncline, but fossils are sparse and structures complicated. The pre-Silurian succession is incomplete, strongly faulted, and apparently barren of diagnostic fossils.

Structurally, the area belongs to two different belts. Northern Axel Heiberg Island lies near the northeastern margin of a belt of northerly to northwesterly trends and was involved in Caledonian (*sensu stricto*) movements. Northwestern Ellesmere Island, on the other hand, is characterized by predominantly northeasterly trends and may not have been deformed by these Caledonian movements.

Table of Formations

Northernmost Axel Heiberg Island

Period or Epoch	Formation and Thickness (feet)	Lithology
Upper Mississippian and younger		Limestone; minor quartzose sandstone, siltstone, shale, conglomerate, chert, dolomite
		— Angular unconformity with unit 7 and older rocks
360 ± 25 m.yrs. Upper (?) Devonian*	Unit 8	Quartz diorite, granodiorite, diorite, dacite, and related rocks
		— Intrusive contact with units 1a, 1b
Devonian	Svartevaeg Formation Member B (7,100 +)	Volcanic arenite; minor siltstone, tuff, conglomerate, breccia, volcanic flows, slaty shale
	Member A (3,400 +)	Tuff, volcanic flows, volcanic arenite; minor siltstone, slaty shale
		— Conformable contact
Devonian and (?) Upper Silurian	Stallworthy Formation Member C (8,000 +)	Red siltstone, multicoloured shale; minor quartzose sandstone, conglomerate, lithic and tuffaceous arenite
	Member B (1,000 - 2,500)	Quartzose sandstone, cherty conglomerate and breccia, siltstone (mostly red beds)
	Member A (0 - 3,000)	Red siltstone; minor quartzose sandstone, cherty conglomerate, shale
		— Angular unconformity
Middle Silurian	Unit 2	Slaty siltstone and shale; minor lithic and tuffaceous arenite, tuff, conglomerate
		— Fault contact
Pre-Silurian	Rens Fiord Complex	Slate, phyllite, quartzose sandstone, chert, dolomite, greenschist, volcanic flows; quartzite, hornfels, marble

*K-Ar age determination may indicate age of metamorphism and not of emplacement.

Table of Formations

Northwesternmost Ellesmere Island

Period or Epoch	Formation and Thickness (feet)	Lithology
Tertiary or older	Unit 10	Serpentinite, dunite
		— Intrusive or faulted contact with Imina Group and Bourne Group
Upper Mississippian, Pennsylvanian, Permian, and Triassic		Limestone, shale, volcanic flows; minor quartzose sandstone, siltstone, conglomerate, chert, dolomite, tuff, breccia
		— Angular unconformity with unit 7 and older rocks
Lower Mississippian and/or older	Unit 8	Diorite, syenodiorite, quartz monzonite, and related rocks
		— Intrusive contact with Imina Group and older rocks
Upper Silurian	Unit 7 (5,000 +)	Slaty siltstone, quartzose, partly calcareous sandstone, slaty shale; minor chert-pebble and granule-conglomerate
		— Conformable contact
Early Upper, Middle, and(?) Late Lower Silurian	Unit 6	Slaty siltstone and shale; minor lithic and tuffaceous arenite, tuff Unit 6a (intercalated in upper part of 6): tuff, slaty siltstone and shale, arenite; minor agglomerate and/or volcanic conglomerate, volcanic flows, limestone
		— Conformable contact or fault
Lower Silurian and (?) older	Imina Group	Lithic arenite, siltstone, both calcareous, slaty shale; minor pebble- and granule-conglomerate
		— Fault contact
Pre-Silurian (?)	Bourne Group	Slaty siltstone and shale, green phyllite, volcanic flows; hornfels; abundant diabase intrusions of unknown age
		— Not in contact
	Unit 3	Phyllite, slate; phyllitic, partly argillaceous limestone
		— Fault contact
	Unit 2	Volcanic flows, limestone; minor volcanic breccia, tuff
		— Probable fault contact
Lower (?) Cambrian or older	Cape Columbia Group	Mica schist, mica-garnet schist, quartzite, marble, amphibolite; minor phyllite, greenschist, hornfels

On the Tables of Formations the rock units of Sverdrup Basin have not been differentiated. These will be dealt with in separate reports by Thorsteinsson and Tozer. Geological maps of the area covered by this report are in preparation. They are to follow the N.T.S. system of subdivision and will be on a scale of 4 miles to 1 inch.

PRE-MISSISSIPPIAN ROCKS OF NORTHERNMOST AXEL HEIBERG ISLAND

Rens Fiord Complex

The Rens Fiord Complex outcrops north and south of the bay it is named from. It consists of a thick assemblage of clastic sediments, carbonates, chert, and volcanic rocks that have been assigned to four lithological sub-units. One of these, sub-unit 1a, may comprise strata of different ages; the others appear to be stratigraphic units of formational rank.

North of Rens Fiord, sub-unit 1a is composed of light to dark grey, partly reddish phyllite and slate with lesser amounts of 'ribbon' chert, quartzose siltstone and sandstone. A belt near Aurland Fiord differs from the assemblage north of Rens Fiord in containing argillaceous and pure dolomite and in lacking red phyllite. A unit north of Rens Fiord, particularly rich in bedded chert has been designated "1a-ch" although the chert content does not exceed 20 per cent of the whole assemblage.

Sub-unit 1b, which trends in a broad belt from the vicinity of Cape Thomas Hubbard towards the northern extremity of the map-area, is predominantly sandstone with lesser amounts of siltstone, slate, phyllite, and granule conglomerate. The sandstone is composed mostly of rounded grains of quartz and minor feldspar — mainly microcline and albite — cemented by silica or embedded in muscovite and chlorite. The sandstone is poorly to moderately well size-sorted, partly crossbedded, and mostly schistose. Light grey, cherty dolomite units associated with quartzose sandstone and phyllite occur north of Rens Fiord and near Cape Thomas Hubbard.

Sub-unit 1c comprises three carbonate belts exposed north and east of Rens Fiord and around Aurland Fiord. The carbonates east of Rens Fiord occur in a fault slice between 500 and 1,000 feet thick and consist of microcrystalline dolomite, partly dolomitized limestone, and microcrystalline limestone. The strata around Aurland Fiord, probably about 2,500 feet thick, consist predominantly of dolomite. In both areas the rocks are partly laminated, show some intraformational brecciation, and contain numerous stringers and

irregular lenses of chert. Southeast of Aurland Fiord, pisolitic stromatolites (classification after Donaldson, 1963), and some of the laminated strata in both areas may contain undulatory stromatolites.

An isolated mass of laminated to thin-bedded limestone and dolomite has been mapped immediately south of the western ice-cap. The carbonates of this outcrop have been replaced extensively by chert. The outcrop may be a fault block equivalent to the sequences described above.

Sub-unit 1d, composed of about 1,400 feet of carbonate rocks and volcanic strata, is exposed in three southeasterly trending belts of, in part, highly disturbed fault slices. Three members are recognized: a lower member composed of both dolomite and volcanic flow rocks including some pillow lavas; a middle member made up predominantly of flow rocks; and an upper member consisting mostly of fragmental volcanic greenschist. Some of the dolomite beds grade laterally into limestone. Most are of small extent, some with a strike length of less than a mile. The volcanic flows are generally only one or a few feet thick. The mineralogy of the volcanic rocks conforms with the greenschist facies of low-grade regional metamorphism (Fyfe, Turner, and Verhoogen, 1958, p. 229) but this is probably the result of spilitization and local alteration during faulting, rather than regional metamorphism.

The stratigraphic order of these four sub-units has not been worked out with certainty. Southeast of Aurland Fiord, sub-unit 1c is comparatively little deformed and seems to overlie parts of sub-unit 1a and probably also of sub-unit 1b with unconformity, either a depositional unconformity or a low-angle thrust fault; the contacts have not been seen exposed. The internal structure of the Rens Fiord Complex is characterized by northerly to predominantly northwesterly trends and severe faulting. The complex seems to form a northwesterly trending complicated horst or faulted arch, bordered in the northeast and southwest by unit 2, with sub-unit 1c at the flanks of the uplifted structure.

The complex is intruded by dioritic plutons of unit 8. Along the southern border of the map-area it is overlain with great angular unconformity by Carboniferous sediments.

The complex differs markedly in lithology and degree of deformation from the Silurian and Devonian units of Nansen Sound area and must be pre-Silurian in age. Muscovite from a phyllitic sandstone of sub-unit 1b has yielded a K-Ar age of 535 $\pm$ 35 million years. This result suggests that the schistosity of the rock developed

in Cambrian time (Kulp, 1961) but the age obtained could be too high because of incomplete recrystallization, or too low because of argon loss during later periods of deformation.

Parts of the Rens Fiord Complex are comparable in lithology and grade of metamorphism to parts of the Mount Disraeli Group of northernmost Ellesmere Island (Blackadar, 1954; Christie, 1962) and to units 2 and 3 of northwestern Ellesmere Island.

Unit 2

This unit is exposed in a belt extending from Cape Stallworthy for about 18 miles to the southeast and in an isolated outcrop about 3 miles southwest of Aurland Fiord. The thickness of the strata southeast of Cape Stallworthy is probably about 3,000 feet. The unit consists predominantly of dark grey slate and siltstone with lesser amounts of lithic arenite, tuffaceous arenite, and tuff. Tuffs and arenites are composed of varying amounts of volcanic material — chiefly keratophyric and quartz-keratophyric in composition — and carbonate and quartz. Most of the arenite is fine to medium grained but contains pebble- and granule-sized chips of dark grey shale. Penecontemporaneous deformations and graded bedding have been observed but the latter is not as well developed as in the Svartevaeg Formation. A few groove casts indicate southeasterly to easterly current directions.

East of Rens Fiord the internal structure of the unit is very complicated; south of Cape Stallworthy it is less disturbed. The main belt east and northeast of Rens Fiord is in fault contact with sub-unit 1c and overlain with low to moderate angular unconformity by the Stallworthy Formation. East of Rens Fiord the angular discordance is about 10 to 20 degrees. The isolated outcrop southwest of Aurland Fiord is probably in fault contact with sub-unit 1c.

Allochthonous fossils from a conglomerate in the lower or middle part of the unit have been assigned by B.S. Norford to the Llandoverian or Wenlockian. Primary structures suggest that this conglomerate is a submarine slide. Graptolites collected approximately 50 feet below the contact with the Stallworthy Formation have been identified by J.W. Kerr and R. Thorsteinsson as Wenlockian, probably late Wenlockian in age. Lithologically similar strata of northwestern Ellesmere Island (units 6, 6a) are, on the basis of graptolite collections, considered as early Ludlovian in age.

Stallworthy Formation

The name "Stallworthy Group" was given by Fricker and Trettin (1962) to a thick succession of mostly red clastic sediments exposed near Cape Stallworthy. The term "group" was used in a reconnaissance sense and the sub-units mapped were informally termed "divisions". The Stallworthy Group is here redefined as a formation and the original divisions are now termed "members".

Outcrops of the formation, which is about 12,000 feet thick, extend from the vicinity of Cape Stallworthy for about 22 miles to the southeast. Member A (0-3,000 feet) thins rapidly along strike in a northwesterly direction and consists of basal pebble-conglomerate and sandstone (250 ± feet) overlain by red siltstone with minor sandstone and shale. Member B (2,500 - 1,000 feet) comprises conglomerate and breccia ranging from granule to cobble grade, current crossbedded quartzose sandstone, and a lesser amount of siltstone. The sediments weather in shades of grey, red, and brown. Member C (8,000 ± feet) comprises alternating units of red siltstone and green, minor dark grey shale, with several successions of crossbedded sandstone, pebble-conglomerate, and calcareous and tuffaceous arenite. The conglomerates and breccias of the Stallworthy Formation are composed mostly of chert; the quartzose sandstones are of rounded quartz, subrounded to subangular chert, and not more than a few per cent of rounded feldspar and muscovite. The induration of the strata varies but is generally lower than in other rock units of the area.

The incompetent shaly and silty units are intruded by numerous basic sills and some dykes. The strata strike regularly northwest and most dip steeply to the northeast. The Stallworthy Formation overlies unit 2 with low to moderate angular unconformity and is overlain with almost abrupt but apparently conformable contact by the Svartevaeg Formation. Red coloration, rapid facies changes, and current crossbedding suggest that much of the formation is non-marine in origin. The shale of Member C is probably in part marine.

Diagnostic fossils are rare. Fossil fish from a calcareous shale about 4,500 to 5,000 feet above the base of Member C are considered by R. Thorsteinsson as Lower or Middle Devonian, probably Lower Devonian in age.

Svartevaeg Formation

The name "svarte vaeg", meaning "black wall", was given by Sverdrup, the discoverer of Axel Heiberg Island, to the dark-coloured, rugged cliffs on the northeastern coast of that island. The Lower Palaeozoic volcanic and sedimentary rocks at Svartevaeg overlying the Stallworthy Formation were assigned by Fricker and Trettin (1962) to a group, composed of two divisions. The term "group" was used in a reconnaissance sense. The "Svartevaeg Group" is here redefined as a formation and the two divisions are now termed "members". Member A (3,400 ± feet) consists of volcanic flow rocks, partly pillow lavas, tuff, volcanic arenite, and minor amounts of slaty siltstone and shale. The volcanic rocks examined were keratophyric and spilitic in composition. Member B occurs in two fault blocks with a probable total thickness of about 7,000 feet. It consists predominantly of volcanic arenite and lesser slaty siltstone, conglomerate, breccia, slaty shale, tuff, and volcanic flows. The upper 200 feet or so is composed of basaltic breccia with fossiliferous limestone fragments.

The sedimentary rocks form numerous graded sequences suggestive of turbidity-current deposition. Most of the conglomerates and breccias appear to be submarine slides. The volcanic material in the sediments examined was mostly keratophyric in composition. The northern half of the Svartevaeg Formation forms a southeasterly plunging syncline with steeply dipping limbs. The contact with the Stallworthy Formation is not exposed but is probably conformable. The formation is overlain with angular unconformity by Viséan sediments (Kerr and Trettin, 1962).

No autochthonous fossils have been found in the formation. Fossils in a large slumped block of limestone and in limestone fragments included in basaltic breccia are Silurian. Other allochthonous fossils are Silurian or Devonian. The stratigraphic position of the Svartevaeg Formation above the Stallworthy Formation indicates that the Svartevaeg is Devonian or Lower Mississippian. The apparent absence of Lower Mississippian strata in the Arctic Archipelago would seem to favour a Devonian age.

Unit 8

Unit 8 comprises six quartz-diorite and granodiorite plutons north of Rens Fiord and at Svartevaeg, a diorite intrusion southwest of the entrance of Aurland Fiord, and two dyke-like masses of porphyritic dacite southeast of Aurland Fiord. Other relatively small outcrops of granodioritic rocks are present north of Rens Fiord. The pluton at Svartevaeg is in fault contact with the

Stallworthy Formation and carries roof pendants of thermally metamorphosed carbonate, shale, and chert. The other plutons and the dykes intrude sub-units 1a and 1b of the Rens Fiord Complex. The small size of these plutons (less than 1.5 miles in length), their crosscutting relation, and the low grade of metamorphism of the intruded succession, indicate high-level magmatic intrusions. Four plutons north of Rens Fiord lining up with a fifth at the entrance of Aurland Fiord may be surface extensions of a continuous body at depth. A K-Ar determination on biotite has yielded an age of 360 ± 25 million years (Upper Devonian ?, Kulp, 1961). The rocks are similar in mineralogy and setting to plutons of unit 8 in northwestern Ellesmere Island.

PRE-MISSISSIPPIAN ROCKS OF NORTHWESTERNMOST ELLESMERE ISLAND

Cape Columbia Group

The Cape Columbia Group was named and first described by Blackadar (1954) and studied further by Christie (1957, 1962). It comprises a great variety of sedimentary and plutonic rocks showing a wide range but distinctly higher grade of metamorphism than other units of the region. Blackadar and Christie have shown that these crystalline rocks outcrop intermittently along the northern coast of Ellesmere Island between Cape Aldrich and Phillips Inlet. Three isolated and incompletely mapped outcrop areas in the northwestern part of the present map-area seem to form a southwestern extension of this metamorphic belt. The areas are underlain by various types of schist, gneiss, amphibolite, quartzite, marble, hornfels, and minor phyllite showing low to intermediate grades of regional metamorphism, superimposed contact metamorphism and metasomatism, and subsequent local dynamic and retrogressive metamorphism. The rocks appear to have been predominantly pelitic, siliceous, and calcareous sediments but included, west of Phillips Inlet, also some volcanic strata. The structure of the metamorphic rocks appears to be extremely complicated. East and west of Phillips Inlet the rocks are intruded by numerous granitic bodies (units 8, 8a) probably related to a stock at the entrance of Phillips Inlet. In the outcrop area east of Henson Bay only one small pluton has been mapped but others may be present. The contacts of the Cape Columbia Group with adjacent map-units appear to be faulted. Lithology, grade of metamorphism, distribution, and contact relations suggest that the bulk of the strata assigned to unit 1 is not equivalent to other rock units of the area but represents uplifted older rocks. Some of the low-grade metamorphic phyllites, however, may be fault slices or infolds of younger formations. Blackadar (1960) and Christie (1957) have presented evidence that at least some

of the rocks of the Cape Columbia Group are Cambrian or older, and Haller (1961) has suggested that the metamorphism of the group is correlative with a Proterozoic orogeny of northern Greenland.

Unit 2

Unit 2 outcrops in two belts east and west of the main arm of Phillips Inlet. Two lithological sub-units are shown on the map. Sub-unit 2a consists of carbonate rocks, mainly light to dark grey, microcrystalline, in part laminated limestone. Sub-unit 2b is composed of basic volcanic flows with some flow breccias and acidic to intermediate tuffs. The two rock types are repeated several times and the contacts between them appear to be faulted. West of Phillips Inlet the sequence is a-b-a, and east of the inlet b-a-b. Individual fault slices are generally about a hundred or a few hundred feet thick. In both areas unit 2 overlies the Cape Columbia Group. This contact is — judging from the distribution of the sub-units — at least in one of the two areas and probably in both, a fault. West of Phillips Inlet unit 2 is overlain with fault contact by the Imina Group, and east of the inlet with faulted contact by unit 3. The volcanic rocks are partly altered but the preservation of clinopyroxene and zoned plagioclase suggests that they have not been subjected to regional metamorphism. On grounds of structural setting, metamorphic grade, and lithology, the rocks are considered as younger than the Cape Columbia Group and older than the Imina Group. They are comparable in lithology and degree of deformation to sub-unit 1d of the Rens Fiord Complex.

Unit 3

Unit 3 comprises argillaceous and calcareous phyllites of unknown stratigraphic relationships exposed in three separate areas designated units 3a, 3b, and 3c.

Units 3a and 3b outcrop west of the lower part of Phillips Inlet; unit 3c is exposed near the southeastern extremity of the map-area. Unit 3a is composed of light to dark grey slate and grey or greenish calcareous phyllite. Unit 3b is composed of light to dark grey, microcrystalline, phyllitic, partly argillaceous limestone with minor amounts of argillaceous and calcareous phyllite. Both units are pyritiferous. Unit 3c comprises at least several hundred feet of greenish grey, microcrystalline, phyllitic, argillaceous limestone. The internal structural relationships of all three units are complicated, and the external contacts are faulted. Unit 3c is intruded by a small quartz-diorite pluton (unit 8). On the basis of lithology and metamorphic grade, unit 3 is considered to be younger

than the Cape Columbia Group and older than the Imina Group. In lithology and grade of metamorphism it is comparable to the Mount Disraeli Group of northernmost Ellesmere Island (Blackadar, 1954), considered by Christie (1957) as Middle Ordovician or older. The argillaceous phyllite of unit 3a resembles strata of unit 1a of the Rens Fiord Complex.

Bourne Group

Sedimentary, volcanic, and intrusive rocks on the northwest coast of Kleybolte Peninsula between Cape Bourne and Krueger Island were assigned by Christie (1957) to a reconnaissance unit which he named the "Bourne Group". The thickness of these rocks is unknown but probably exceeds 1,000 feet. The sedimentary and volcanic rocks present include light greenish grey, partly laminated siltstone and slate, dark grey argillite and hornfels, altered andesite, and tuffaceous (?) green phyllite. More than half of the unit consists of porphyritic diabase intrusions with coarse and abundant phenocrysts of plagioclase and less-abundant, finer-grained phenocrysts of clinopyroxene. The Bourne Group is severely faulted. It is in fault contact with the Imina Group and Permo-Carboniferous strata overlying that group. About 9 to 13 miles south of Cape Colgate the contact of the Bourne and Imina Groups is intruded by a large ultrabasic dyke (unit 10). The intrusions and the sedimentary and volcanic strata of the Bourne Group are partly altered but do not show regional metamorphism. The volcanic and sedimentary rocks are considered as pre-Mississippian and — on structural relations with the Imina Group and Carboniferous beds — possibly pre-Silurian in age. In Nansen Sound area, diabase intrusions occur in consolidated strata of all ages, but sills and dykes with abundant coarse-grained plagioclase phenocrysts have been observed only in the Bourne Group.

Imina Group (unit 5)

This group was named by Christie (1957) to include a sequence of sedimentary rocks of unknown thickness, age, and contact relations described as fine- to medium-grained, limy greywacke, sub-greywacke, and argillaceous greywacke outcropping along the north coast of Ellesmere Island between Phillips Inlet and Cape Bourne.

The Imina Group as mapped and described by Christie has been extended southward to the north shore of Emma Fiord. In its typical geomorphic expression it forms rolling plains and rounded hills covered with slabs of bedrock, weathered in place and crossed by numerous basic dykes more resistant to weathering. The

thickness appears to be in the order of thousands of feet and the lithology is rather uniform. The group consists predominantly of light greenish grey, partly buffish weathering lithic arenite (terminology after Gilbert, 1955, p. 293), and siltstone with a lesser amount of dark grey, slaty shale and a little granule- and pebble-conglomerate. Nearly all of these rocks are calcareous, and some carry authigenic pyrite. The lithic arenite is composed of carbonate grains (mostly microcrystalline limestone and individual crystals of calcite), quartz, and quartzite with smaller fractions of muscovite, feldspar, chert, chlorite, schist, phyllite, and 'iron ore'. The matrix consists of calcite and relatively coarse flakes of muscovite and chlorite. Arenite beds are mostly a few feet thick, and the finer-grained rock types are thin-bedded to laminated. Ripple-marks are common; crossbedding, graded bedding, and soft sediment deformations are comparatively rare.

The structure is poorly exposed and appears to be complicated. The lower contact has not been seen. In a south-westerly plunging anticline in the southeastern part of the map-area, strata lithologically similar to the Imina Group are overlain with abrupt but structurally conformable contact by unit 6. This contact may be a fault but graptolite collections indicate that the stratigraphic separation would not be large. The Imina Group is in fault contact with the Bourne Group and the Cape Columbia Group. In some localities it is unconformably overlain by Carboniferous strata; in others the contact is a fault. The heterogeneous composition of the plagioclase suggests that the group has not been subjected to regional metamorphism.

The uppermost strata underlying unit 6 carry graptolites assigned by J.W. Kerr and R. Thorsteinsson to the Llandoverian. The Imina Group appears to be correlative with parts of the Cape Phillips Formation (Thorsteinsson and Kerr, 1962) and the Cape Rawson Group (Kerr, in Jenness, 1963, p. 6) of central and northern Ellesmere Island but is of coarser grade.

Unit 6

Unit 6 outcrops in several belts northeast and southwest of Emma Fiord, and near the southeastern extremity of the map-area. Two members can be distinguished; the lower member, more than 1,200 and perhaps as much as 2,000 to 3,000 feet thick, consists predominantly of dark grey, slaty shale, dark grey to light grey, partly calcareous and mostly slaty siltstone, and a small amount of arenite. The strata are laminated to medium bedded. The upper member comprises at least 850 feet but perhaps more than 2,500 feet of slaty shale and siltstone with interbedded lithic

and tuffaceous arenite and tuff. The siltstones and shales are similar to those of the lower member. Arenite and tuff are light green and weather in shades of green, grey, and brown. The thickness of individual beds ranges from a few millimetres to several feet. The strata are partly crossbedded and poorly to moderately well size-sorted. Tuff, lithic arenite, and tuffaceous arenite are all composed of varying amounts of sedimentary and volcanic material and cannot be distinguished in the field. The volcanic material is mostly keratophyric and quartz keratophyric in composition but also includes more acidic and basic rock types. The sedimentary material consists predominantly of grains of carbonate and quartz with minor amounts of chert, muscovite, phyllite, schist, penecontemporaneous argillaceous sediments, carbonaceous matter, and 'iron ore'. The internal structure of the unit is complicated and poorly exposed. Unit 6 overlies the Imina Group with abrupt, possibly faulted contact, but fossil collections indicate that the stratigraphic separation would not be large. It is conformably overlain by unit 7. Locally, it is unconformably overlain by Carboniferous strata.

Several graptolite collections identified by J.W. Kerr and R. Thorsteinsson indicate that the age of the unit ranges from late Llandoverian or early Wenlockian to early Ludlovian, and that the upper member is early Ludlovian in age. Unit 6 is correlative with, and to some extent similar in lithology to parts of both the Cape Rawson Group of northern Ellesmere Island (Christie, 1962) and the Cape Phillips Formation of central Ellesmere Island (Thorsteinsson and Kerr, 1962). Tuffaceous rocks, however, have not been reported from either the Cape Rawson Group or the Cape Phillips Formation.

Unit 6a

Unit 6a, exposed only in the vicinity of Emma Fiord, appears to be a local volcanic lens intercalated in the upper part of unit 6. The thickness of the strata exposed is estimated to be in the order of 1,000 feet. The unit consists predominantly of tuff, dark grey, slaty siltstone and shale, greenish grey arenite, agglomerate and/or volcanic conglomerate, a few lenses of limestone, and a few volcanic flows. The volcanic rocks appear to be mostly keratophyres and quartz keratophyres. The strata are strongly faulted. South of Fire Bay the volcanic rocks overlie slaty siltstone from which R. Thorsteinsson has collected early Ludlovian graptolites. Unit 6a is therefore probably Ludlovian in age.

Unit 7

Unit 7, outcropping in the southern part of the area, comprises at least 5,000 feet of strata. About 6 miles south of the head of Emma Fiord the lower 1,500 feet contains about 80 per cent recessive siltstone and shale and 20 per cent sandstone with minor conglomerate. The overlying, ridge-forming 3,500 feet is composed of the same rock types but has a higher percentage of sandstone and conglomerate. About 6 miles southeast of the head of Emma Fiord this member is overlain by more recessive, silty rocks which, however, may represent older strata repeated by faulting. The siltstone of unit 7 is light to medium grey and weathers in shades of brown. The rock is mostly laminated to thin-bedded and shows soft sediment deformations and low-angle crossbedding. The sandstone is light to medium grey and ranges from fine to coarse grained, medium-grained rocks being most common. The sandstones are mostly thin to medium bedded and moderately well size-sorted. Coarse-grained and conglomeratic strata, however, are thick bedded to massive and range from moderately well to poorly sorted. The sandstones are composed predominantly of chert and quartz, generally less than 10 per cent carbonate, not more than a few per cent of feldspar, chlorite, muscovite, 'iron ore', schist, and phyllite with only traces of volcanic rock fragments, biotite, and hornblende. Most of the quartz and some of the feldspar is subrounded to well rounded. The chert is subrounded to subangular.

Unit 7 seems to form a syncline disrupted by faults and unconformably overlain by Carboniferous strata. It overlies unit 6 conformably.

Graptolites from the lower part of unit 7 or from a fault slice of older strata associated with the unit collected about 6.7 miles southeast of the head of Emma Fiord are considered by R. Thorsteinsson to be Ludlovian and contemporaneous with two collections from the upper part of unit 6. Another collection is of unspecified Silurian age. It seems that unit 7 is largely or entirely Upper Silurian and is probably correlative with parts of the Cape Rawson Group (Christie, 1962; Kerr, in Jenness, 1963, p. 6) and an unnamed clastic formation of Middle (?) and Upper Silurian age on northern Canyon Fiord (Thorsteinsson and Kerr, 1962).

Unit 8

Unit 8 comprises a small number of widely scattered mineralogically related, granitic intrusions and several migmatite terranes in which these intrusions are associated with sedimentary and volcanic rocks. The intrusions can be classified as quartz

monzonite, granodiorite, quartz diorite, and diorite. Their texture varies from equigranular to porphyritic. Two types representing different levels of exposure may be distinguished. The plutons on Kleybolte Peninsula which are small — generally less than 1.5 miles in diameter — mostly massive and discordant, and which intrude strata showing very low grades of metamorphism, represent relatively high crustal levels. The intrusions on Phillips Fiord, on the other hand, which are of larger dimensions, in part foliate, mostly concordant, and which intrude metamorphic rocks, represent intermediate crustal levels. The latter intrusions seem to be related to a stock at the head of Phillips Inlet which according to Christie (1957, p. 24) is composed of fresh-looking adamellite. Although the intrusions seen by the present writer are partly schistose and altered, their metamorphism is probably due to local structural adjustments during and after emplacement rather than to regional metamorphism.

The youngest unit intruded is the Lower Silurian and (?) older Imina Group. The plutons on Kleybolte Peninsula are similar in lithology and setting to bodies in northern Axel Heiberg Island from which a K-Ar age of 360 $\pm$ 25 million years has been obtained. Biotite from a foliate intrusion west of Phillips Inlet has yielded an age of 335 $\pm$ 25 million years (Upper Devonian to Lower Pennsylvanian — Kulp, 1961) suggesting that the mica formed or recrystallized during Mid-Palaeozoic movements. Muscovite from the foliate border zone of a pluton east of Henson Bay has an apparent K-Ar age of 260 $\pm$ 25 million years (Permo-Pennsylvanian — Kulp, 1961). This pluton lies within 1/2 mile of a major fault, and the rocks of the area show some retrogressive metamorphism. The anomalously low age is probably the result of argon loss during fault movements in Pennsylvanian or younger time.

Unit 10

Unit 10 designates an ultrabasic dyke more than 5 miles long, composed of serpentinite and minor dunite which intrudes the contact between the Bourne Group and the Imina Group on Kleybolte Peninsula. The contact is a fault which displaces Permo-Carboniferous strata, and the ultrabasic bodies were therefore probably emplaced during the Late Cretaceous or Tertiary orogeny (Thorsteinsson and Tozer, 1960; Christie, 1962) but may represent 'cold' intrusions of an originally older age. The only other ultrabasic rocks known in the Queen Elizabeth Islands are dunite, norite, and peridotite discovered by Christie (1957) in the vicinity of Cape Richards in northernmost Ellesmere Island.

STRUCTURAL HISTORY

Throughout the geological record the structural trends of northernmost Axel Heiberg Island were northerly to predominantly northwesterly and those of northwestern Ellesmere Island, with the exception of a small area west of Fire Bay, Emma Fiord, were predominantly northeasterly. The pronounced difference in trends and the high concentration of volcanic units on either side, not only in the Lower Palaeozoic but also in the Permo-Carboniferous, suggest that Nansen Sound may be the site of a major fault zone.

During the Lower Palaeozoic and probably also the Late Precambrian the area was part of a mobile belt subjected to several periods of deformation. The Silurian and Devonian tectonic history has been partly worked out, but most of the pre-Silurian history is unknown.

The Cape Columbia Group is the only unit of the area that shows true regional metamorphism. The metamorphic rocks occur mainly in uplifted fault blocks and seem to represent the oldest strata known in the region. The age of the metamorphism is not precisely known but stratigraphic observations by Christie (1957) and a K-Ar age determination of 550 $\pm$ 35 million years (Blackadar, 1960) suggest that it is Cambrian or older. If these rocks have been affected by more than one pre-Ordovician orogeny the K-Ar age would probably indicate only the latest recrystallization. Haller (1961) suggested that the original metamorphism is related to the late Precambrian Carolinidian orogeny of northern Greenland.

The Rens Fiord Complex of northern Axel Heiberg Island and units 2 and 3 of Ellesmere Island show a higher degree of structural deformation and a better developed schistosity than the Silurian and younger rocks of the area, which suggests that they have been subjected to a pre-Silurian orogeny. A K-Ar determination on muscovite from a schistose sandstone of the Rens Fiord Complex has yielded an age of 535 $\pm$ 35 million years and coincides, within the limits of confidence stated, with the apparent age of the metamorphism of the Cape Columbia Group. According to Kulp's (1961) time scale both lie in the middle part of the Cambrian, and the determination from the Rens Fiord Complex lies in the late Middle Cambrian. It is possible that both are related to an orogeny of the eugeosyncline contemporaneous with or somewhat earlier than an epeirogeny of the miogeosyncline and the Arctic Lowlands indicated by an extensive post-Middle Cambrian disconformity (Douglas, Norris, Thorsteinsson, and Tozer, 1963; Cowie, 1961).

The significance for the present map-area of unconformities reported by Christie (1957, 1962) at the bases of the Ordovician (?)

M'Clintock Group and the Middle and Upper Ordovician Challenger Group of northernmost Ellesmere Island is unknown.

Composition, textural features, order of thickness, and facies relations of the Lower Silurian and(?) older Imina Group suggest that it is a post-tectonic deposit derived by uplift and erosion of an area off the present north coast of northwestern Ellesmere Island. The source area of the sediments was underlain by metamorphic rocks comparable to the Cape Columbia Group and by little metamorphosed limestone.

An unconformity with low to moderate angular discordance between late(?) Middle Silurian and Lower or Middle Devonian(?) strata shows that northern Axel Heiberg Island was affected by Caledonian movements (Trettin, 1963). The presence here of a great thickness of Upper Silurian rocks removed from northern Axel Heiberg Island by Caledonian erosion, and deviating structural trends, suggest that most of northwestern Ellesmere Island was not involved. Intermittent Middle and early Upper Silurian tectonism in the vicinity of Nansen Sound is indicated by turbidites, a submarine slide, and keratophyric volcanic rocks intercalated with normal siltstone and shale. In northwestern Ellesmere Island the greatest thickness of volcanic strata occurs on Fire Bay, Emma Fiord, where northeasterly and northwesterly trends intersect. Upper Silurian sandstone and conglomerate of great thickness exposed on Emma Fiord were probably derived from areas elevated by Caledonian movements.

The volcanic rocks, turbidites, and submarine slides of the Devonian Svartevaeg Formation mark the beginning of Mid-Palaeozoic earth movements which culminated in folding, faulting, and probably granitic intrusion. The Mid-Palaeozoic structures are overlain with angular unconformity by Viséan sediments (Kerr and Trettin, 1962).

The deformations of Permo-Carboniferous and Triassic strata seen are attributed to Late Cretaceous or Tertiary orogeny (Thorsteinsson and Tozer, 1960; Christie, 1962). In the northern parts of Ellesmere Island these deformations consist mostly of faults. In the southern parts of the Ellesmere Island map-area faults and southwesterly plunging folds have been recognized.

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