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VOLCANIC ROCKS OF THE PALEOHELIKIAN DUBAWNT GROUP IN THE BAKER LAKE - ANGIKUNI LAKE AREA, DISTRICT OF KEEWATIN, N.W.T.

D.H. Blake

Energy, Mines and Resources Canada
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A.N. LeCheminant
K.E. Eade

Author's Address

Department of National Development
Bureau of Mineral Resources
Geology and Geophysics
Box 378
Canberra City, A.C.T.
Australia

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Preface

The results presented in this report derive from a study carried out in 1976 when the author was on a one year exchange visit to the Geological Survey of Canada from the Bureau of Mineral Resources, Australia.

Reconnaissance geological mapping in the District of Keewatin was initiated more than twenty-five years ago with the Geological Survey's first helicopter-supported operation. This identified many of the broad aspects of the geology of the region and enabled mapping at the scale of 1:250 000 to be directed to the more complex areas. The Dubawnt Group is one of the assemblages, disclosed by the more detailed mapping, that seemed to warrant further study because of its wide distribution and unmetamorphosed state. Several of the units comprising the group are host to uranium and minor base and precious metal mineralization.

In this report the author describes the seven, mainly unmetamorphosed, flat-lying to gently dipping volcanic and sedimentary formations that unconformably overlie the Aphebian and Archean basement. He concludes that environmental conditions at the time of Dubawnt volcanism were similar to those of present day southeast Papua where numerous volcanic centres are distributed across a broad fluvial plain flanked by a high, young, mountain range. The volcanic rocks of both Papua and the Dubawnt Group include potassium-rich alkaline lavas and neither area appears to be directly related to subduction processes.

This report adds considerably to our understanding of the volcanic rocks of the Dubawnt Group a subject of interest because of their relatively high uranium content. Because these rocks are the likely source for the known uranium mineralization the results of Dr. Blake's study will aid in developing new exploration guides to be used in the search for additional occurrences.

D.J. McLaren
Director General
Geological Survey of Canada

Ottawa, February 1979

VOLCANIC ROCKS OF THE PALEOHELIKIAN DUBAWNT GROUP IN THE BAKER LAKE-ANGIKUNI LAKE AREA DISTRICT OF KEEWATIN, NORTHWEST TERRITORIES

Abstract

In the area described the Dubawnt Group consists of mainly unmetamorphosed flat-lying to gently dipping volcanic and sedimentary rocks unconformably overlying Aphebian and Archean crystalline basement rocks. The group, isotopically dated at about 1786 Ma., comprises seven named units: Angikuni Formation (new name), mainly sandstone and mudstone; South Channel Formation, mainly conglomerate; Kazan Formation, mainly arkose; Christopher Island Formation, mainly subaerial potassium-rich alkaline volcanics; Pitz Formation, mainly subaqueous rhyolitic volcanics; Thelon Formation, mainly sandstone; and Martell Syenite, high level intrusive equivalents of the Christopher Island volcanics. The South Channel, Kazan, and Christopher Island formations are hosts to uranium and minor base and precious metal mineralization.

The Christopher Island Formation, maximum thickness probably more than 2000 m, consists of mafic trachyte, felsic trachyte, and minor rhyolite lava flows; various pyroclastic rocks; tuffaceous and volcaniclastic sedimentary rocks; minor intrusions; and intrusive breccia. Several probable and possible eruptive sites have been located. The trachytes, most of which are extensively propylitized, contain phenocrysts of mica (biotite-phlogopite), clinopyroxene (diopside-salite), feldspar (plagioclase and/or K-feldspar), olivine (pseudomorphed), quartz, and amphibole (pseudomorphed); alkali feldspar is the dominant primary groundmass phase. The Pitz Formation is about 100 m thick and consists of two richly porphyritic (in feldspar) rhyolitic lavas, the more extensive of which shows autobrecciation features indicating probable subaqueous extrusion. The Martell Syenite forms several laccolithic bodies more than 1 km across and numerous smaller intrusions; it consists essentially of K-feldspar, biotite, augite, and commonly sodic plagioclase, hornblende, and olivine.

Environmental conditions at the time of Dubawnt volcanism are thought to have been broadly similar to those of present day southeast Papua, Papua New Guinea: numerous volcanic centres mainly on a broad fluvial plain flanking a mountain range partly bounded by faults.

Chemically analyzed samples of Dubawnt volcanics show a range in SiO_2 content of 52 to 76 per cent, and are characterized by high $K_2O + Na_2O$, K_2O/Na_2O, P_2O_5, Ba, and generally Sr and U, and low TiO_2 and total iron.

Résumé

Dans la région décrite, le groupe de Dubawnt consiste surtout en roches volcaniques et sédimentaires non métamorphisées, de pendage nul à modéré, qui recouvrent en discordance le soubassement cristallin aphébien et archéen. Ce groupe dont l'âge radiométrique a été évalué à environ 1 786 Ma, comprend sept unités désignées: la formation d'Angikuni (nouvelle appellation), surtout composée de grès et mudstone; la formation de South Channel, surtout composée de conglomérat; la formation de Kazan, surtout formée d'arkose; la formation de Christopher Island, surtout composée de roches volcaniques alcalines subaériennes riches en potassium; la formation de Pitz, surtout formée de laves rhyolitiques subaqueuses; la formation de Thelon, surtout composée de grès; et la syénite de Martell, qui est l'équivalent intrusif peu profond des laves de la formation Christopher Island. Les formations de South Channel, Kazan et Christopher Island ont été le siège de minéralisations uranifères et de minéralisations accessoires en métaux précieux.

La formation de Christopher Island, dont la puissance maximale dépasse probablement 2 000 m, consiste en trachyte mafique, en trachyte felsique et en quelques coulées de laves rhyolitiques; en diverses roches pyroclastiques, tufacées et volcanoclastiques; en intrusions mineures; en brèches intrusives. On a déterminé plusieurs sites d'éruption probables. Les trachytes, dont la plupart sont fortement propylitisées, contiennent des phénocristaux de mica (biotite-phlogopite), de clinopyroxène (diopside-salite), de feldspath (plagioclase ou K-feldspath, ou les deux à la fois), d'olivine (remplacée par des pseudomorphes), de quartz et d'amphibole (remplacée par des pseudomorphes); le feldspath alcalin est la phase primaire de la matrice. La formation de Pitz a une puissance d'environ 100 m; elle est constituée de deux laves rhyolitiques, fortement porphyriques (grands cristaux de feldspath); la couche la plus volumineuse contient des brèches de friction, qui indiquent sans doute une éruption subaqueuse. La syénite de Martell forme plusieurs corps laccolithiques de plus de 1 km de diamètre, et plusieurs intrusions moins importantes; elle est essentiellement constituée de K-feldspath, de biotite, d'augite, et généralement aussi de plagioclase sodique, de hornblende et d'olivine.

A l'époque où s'est manifesté le volcanisme de Dubawnt, on pense que le milieu était plus ou moins semblable au milieu actuel du sud-est de Papua (Papua New Guinea) avec la présence de nombreux volcans, principalement situés sur une vaste plaine fluviatile qui bordait une chaîne de montagnes partiellement limitée par des failles.

L'analyse chimique d'échantillons de laves de Dubawnt montre que ces roches ont une teneur en SiO_2 comprise entre 52 et 76%, et qu'elles sont caractérisées par une teneur élevée en $K_2O + Na_2O$, K_2O/Na_2O, P_2O_5, Ba, et généralement en Sr et U, et par une faible teneur en TiO_2 et en fer total.

VOLCANIC ROCKS OF THE PALEOHELIKIAN DUBAWNT GROUP IN THE BAKER LAKE-ANGIKUNI LAKE AREA DISTRICT OF KEEWATIN, NORTHWEST TERRITORIES

INTRODUCTION

This report describes the volcanic units, and to a lesser extent the sedimentary units, of the Paleohelikian Dubawnt Group in the Tulemalu Lake (65J), Thirty Mile Lake (65P east half) and MacQuoid Lake (55M west half) map areas and on Christopher Island (in the Baker Lake, 56D, map area), District of Keewatin, Northwest Territories.

The areas described lie within the southeastern barren grounds, between 62° and 65°N and 94° and 100°W (Fig. 1), in the Churchill Structural Province. They are uninhabited, the closest settlement being Baker Lake, (Fig. 1). Access is mainly by fixed-wing aircraft or helicopter.

Outcrop areas of Dubawnt Group rocks consist of low hills and flat to gently undulating terrain with innumerable lakes. Bedrock is largely covered by surficial deposits supporting a vegetation of grasses and low shrubs. Exposures are generally widely separated, and most have a lichen cover.

The climate is characterized by short summers, during which daily maxima may rise to over 25°C, and long cold winters. Annual precipitation averages about 150 mm.

History of investigations

The Dubawnt Group was named, and its regional distribution outlined, during the reconnaissance geological mapping of operations Keewatin, Baker and Thelon in 1952, 1954 and 1955, respectively (Lord, 1953; Wright, 1955, 1957, 1967). More detailed mapping of parts of the group was carried out in 1963, 1965 and 1966 by Donaldson, who concentrated his work on the sedimentary units (Donaldson, 1965, 1966a, 1966b, 1967a, 1967b), and in 1972 by Reinhardt and Chandler (1973), during mapping of the eastern half of the MacQuoid Lake map area.

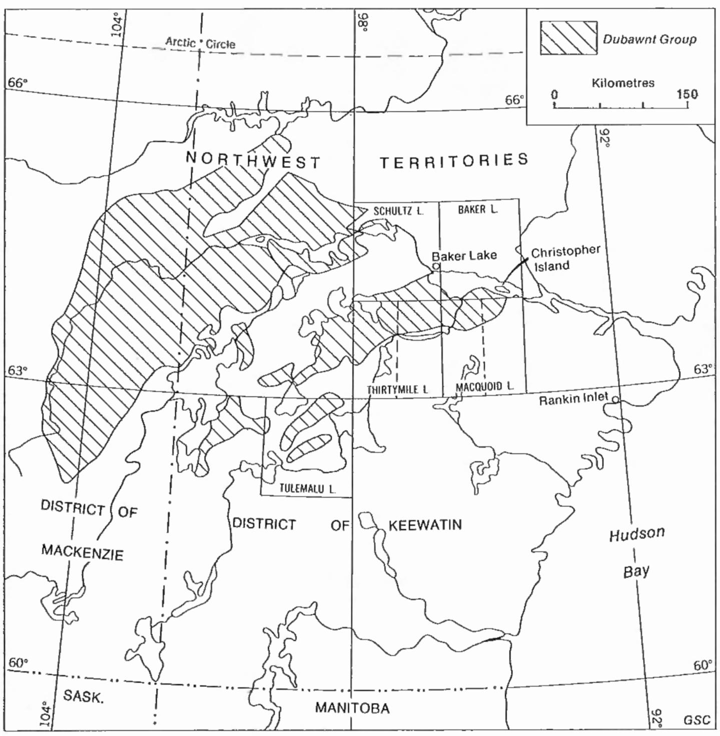


Figure 1. Locality map

The present study is a part of projects carried out in 1975 and 1976 in the Tulemalu Lake map area (Eade, 1976, Eade and Blake, 1977), in Thirty Mile Lake (east half) – MacQuoid Lake (west half) map area (LeCheminant et al., 1976, 1977) and in part of Baker Lake map area (56 D/1) (Schau and Hulbert, 1977). The author took part in the 1976 field work while on a twelve month exchange visit to the Geological Survey of Canada from the Bureau of Mineral Resources, Australia. He spent one month in the Tulemalu Lake map area, one and a half months in the Thirty Mile-MacQuoid Lakes map area and five days on Christopher Island.

Other work on the Dubawnt Group includes a refraction seismic survey (Overton, 1971), isotopic age determinations (Wanless and Loveridge, 1972), and a palaeomagnetic study (Park, et al. 1973). The seismic survey indicates that the Dubawnt cover in the Baker Lake region may be generally less than 1500 m thick. This is supported by the aeromagnetic maps, which show that the cover is sufficiently thin to enable magnetic features of the basement to be traced underneath. The age determinations show that the Dubawnt Group is Paleohelikian. The paleomagnetic results suggest that the area was near the equator during Dubawnt Group time.

Nomenclature of the volcanic rocks

The Dubawnt Group volcanics are taken to include not only lavas and pyroclastics but also associated volcaniclastic sedimentary rocks and high level intrusives.

Most of the lavas and pyroclastics are fine grained, potassium-rich rocks which were classified in the field as either mafic or felsic trachytes. This broad classification is maintained, as they do not fit readily into established classification schemes. The mafic trachytes contain mainly mafic phenocrysts (biotite – phlogopite and clinopyroxene) and generally have less than 60 weight per cent SiO_2, whereas felsic trachytes have mainly feldspar phenocrysts – either sodic plagioclase or sanidine – orthoclase or both – and 60-68 weight per cent SiO_2. Some more silicic extrusives, termed rhyolites, are also present: these generally contain abundant plagioclase and potassium feldspar phenocrysts and less abundant quartz phenocrysts.

Pyroclastic rocks are described as tuffs if their general grain-size is less than 4 mm and agglomerate if it is greater than 4 mm. Rock fragments in agglomerate are generally subangular to rounded. Rocks made up of angular fragments more than 2 mm in diameter are termed breccias.

Rocks described as hyaloclastites are formed of detritus resulting from lava being emitted into water, getting drastically chilled, and exploding in the steam produced.

All dark, fine grained dyke rocks containing biotite and pyroxene phenocrysts are termed lamprophyres.

Acknowledgments

The author worked closely with K.E. Eade and A.N. LeCheminant during all stages of the project. He is also indebted to R.W. Johnson (Bureau of Mineral Resources, Australia) and D.F. Sangster for critically reviewing the original manuscript.

GENERAL GEOLOGY OF THE DUBAWNT GROUP

Regional setting

A major unconformity separates the Dubawnt Group from the underlying basement, which consists of Archean and Aphebian metasediments and metavolcanics, gneisses and migmatites derived in part from them, granulite, gneissic to massive granitic intrusives, gabbro, anorthosite and diabase dykes. The basement is cut by lamprophyre and felsic porphyry dykes, especially near Dubawnt Group outcrops, by larger intrusions ranging in composition from biotite pyroxenite to syenite, and by perhaps slightly younger granite bodies: most, if not all, of these intrusions are probably genetically related to, and comagmatic with, the Dubawnt Group volcanics.

The Dubawnt Group forms a mainly flat-lying to gently dipping cratonic cover. It was laid down on an irregular surface, and in places has a fossil regolith preserved beneath it. The volcanics within the group are mainly potassium-rich alkaline types and were probably erupted from central vent volcanoes. Initial dips of the volcanic and sedimentary rocks probably ranged from less than 1° up to about 35°. Local steeper dips are attributed to the effects of penecontemporaneous and younger faulting.

The Dubawnt Group rocks retain their original igneous and sedimentary textures. However, the volcanic rocks are generally much altered, and commonly primary minerals other than quartz are largely replaced by secondary minerals such as calcite, dolomite, quartz and chlorite. This alteration is attributed to hydrothermal effects (propylitization) associated with the Dubawnt volcanism, and not to regional metamorphism.

The youngest Precambrian rocks in the area are gabbro and diabase forming northwest trending dykes that cut Dubawnt Group rocks as well as the basement. These dykes are part of the Mackenzie dyke swarm, dated at about 1200 Ma (Patchett et al. 1978).

Age of the Dubawnt Group

Volcanic rocks of the Dubawnt Group have been dated isotopically by both Rb-Sr and K-Ar methods (Wanless and Loveridge, 1972). The results are in broad agreement. An age of 1725 ± 26 Ma was obtained from a Rb-Sr whole rock isochron, using $1.47 \times 10^{-11}\ yr^{-1}$ as the decay constant of ^{87}Rb. If $1.42 \times 10^{-11}\ yr^{-1}$ is used as the decay constant, as provisionally recommended by the August 1976 meeting of the IUGS International Commission on Stratigraphy (Subcommission on Geochronology), the age becomes 1786 ± 26 Ma.

K-Ar determinations on micas from the Dubawnt volcanics give a mean age of 1698 ± 45 Ma, which is slightly younger than the "mean" K-Ar age of 1735 Ma for the Hudsonian orogeny (Donaldson, in Wanless and Loveridge, 1972).

The Rb-Sr and K-Ar dates are in accord with the field evidence which indicates that the Dubawnt Group, being unaffected by any regional metamorphism or major folding event, is post Hudsonian: a Rb-Sr age of 1834 ± 23 Ma (^{87}Rb decay constant $1.42 \times 10^{-11}\ yr^{-1}$) for a syntectonic quartz monzonite gives the Rb-Sr age of the Hudsonian orogeny in the general region (Wanless and Eade, 1975), and 1735 Ma is the "mean" K-Ar age for this orogeny (Donaldson, in Wanless and Loveridge, 1972).

Stratigraphy of the Dubawnt Group

The Dubawnt Group was subdivided by Donaldson (1965) into six formally named units, and this subdivision is followed in the present work. The six units are the South Channel, Kazan, Christopher Island, Pitz, and Thelon formations and the Martell Syenite. An additional unit, here named the Angikuni Formation, is present in the Tulemalu map area. General descriptions of these units are summarized in Table 1.

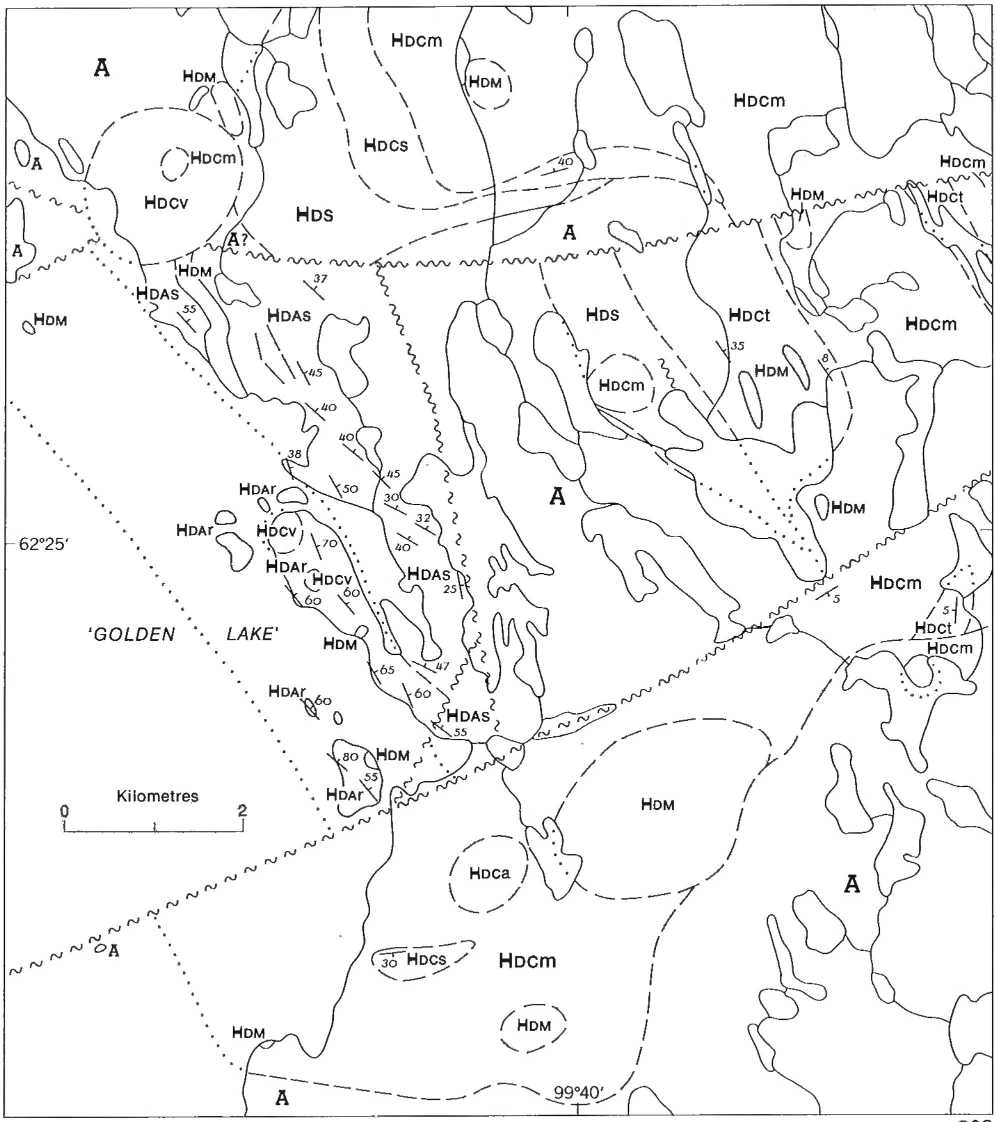
The oldest unit is probably the clastic Angikuni Formation, which is exposed in a relatively small area in the southeast of the Tulemalu Lake map area. Elsewhere the oldest unit present is generally the South Channel Formation, which consists mainly of conglomerate. The Kazan Formation, which is not present in the Tulemalu Lake map area, is a unit of arkosic sandstone which is conformable on South Channel Formation. The South Channel and Kazan formations together form a redbed sequence. Extrusive volcanic rocks are confined to the Christopher Island Formation, which has extensive outcrops in all three of the areas mapped, and the Pitz Formation, which, like the overlying clastic Thelon Formation, is exposed in the Thirty Mile Lake map area but not in the other areas mapped. Dykes related to the volcanics of the Christopher Island Formation intrude basement rocks and all units of the Dubawnt Group except the Pitz and Thelon formations.

Angikuni Formation

This formation, a new unit, is named after Angikuni Lake. Exposures are confined to the type area, on the east side of a northerly extension of Angikuni Lake known as Golden Lake (Fig. 2), where they consist of low mounds and scattered felsenmeer between marshy flats. The formation dips northeast to east-northeast at 30° to 80°, and is probably over 3000 m thick. Neither its top nor base is exposed. It comprises a lower sequence of at least 1400 m of arkosic sandstone, and a conformably overlying upper sequence at least 1500 m thick of thinly interbedded siltstone, mudstone and fine grained sandstone. The contact between the two sequences is gradational across 10-20 m. The rocks retain their original sedimentary textures and structures, and are similar in lithology and induration to sedimentary rocks in younger formations of the Dubawnt Group, hence they are considered to be part of that group.

The Angikuni Formation is faulted against basement gneisses to the east, against younger volcanics of the Christopher Island Formation to the south, and against South Channel conglomerate and basement rocks to the north. To the west, beneath Golden Lake, it is presumed to lie unconformably on crystalline basement rocks. The formation is cut by volcanic vents and intrusive sheets of syenite and trachyte associated with Christopher Island volcanism, and also by one or more north-northeast trending diabase dykes. The volcanic vents (described in a later section) were formed after the Angikuni Formation had been steeply tilted, indicating that the formation is probably separated from nearby Christopher Island volcanics by a local unconformity.

The arkosic sandstone of the lower sequence is generally pale grey to greenish grey or greyish maroon on fresh surfaces, and mainly buff on weathered surfaces. Because it has some carbonate cement, weathered surfaces tend to be crumbly. Most of the sandstone is medium- to coarse-grained and poorly sorted, but fine grained sandstone laminae are present locally, and gritty and conglomeratic beds are common in the lower part of the sequence, where many beds contain scattered subangular to angular pebbles and granules of pink granite and vein quartz. Individual beds average about 1 m in thickness, and most show trough crossbedding (Fig. 3).



GSC

HELIKIAN

DUBAWNT GROUP (HD)

HDM	*MARTELL SYENITE: syenite, monzonite, alkali granite*
HDC	*CHRISTOPHER ISLAND FORMATION:* m, *mafic trachyte lava;* t, *bedded tuff;* a, *agglomerate;* v, *vent breccia and agglomerate;* s, *volcaniclastic sedimentary rocks*
HDS	*SOUTH CHANNEL FORMATION: conglomerate; minor sandstone, siltstone, mudstone lenses*
HDA	*ANGIKUNI FORMATION:* r, *arkosic sandstone;* s, *thinly interbedded siltstone, mudstone, and sandstone*
A	*Crystalline basement rocks*

Geological boundary (defined, approximate, assumed)......

Bedding, tops known (inclined, dip unknown)............................

Fault (approximate, assumed)...............................

Figure 2. The Dubawnt Group north of Angikuni Lake, Tulemalu Lake map area.

Table 1

Summary of stratigraphy, Dubawnt Group — Tulemalu Lake, Thirty Mile Lake and MacQuoid Lake map areas and Christopher Island

Unit	Estimated maximum thickness (m)	Rock types	Stratigraphic relations	Remarks
Thelon Formation	150	Sandstone, conglomerate; cross-bedded; generally friable	Overlies and abuts against Christopher Island and Pitz formations	Not present in Tulemalu Lake and MacQuoid Lake map areas, nor on Christopher Island
Pitz Formation	100	Rhyolite lava, commonly with auto-brecciated flow margins mixed with volcaniclastic sedimentary rocks (hyaloclastites)	Overlies Christopher Island Formation apparently conformably	
Martell Syenite	–	Medium- to fine-grained and locally porphyritic syenite and monzonite containing biotite, pyroxene, olivine and/or horn-blende; minor alkali granite (Tulemalu Lake map area only)	Intrudes basement and all lower formations	Forms laccolithic bodies more than 30 metres thick and smaller sills, dykes and irregular intrusive sheets
Christopher Island Formation	2000	Mafic trachyte, felsic trachyte and rhyolite lava; massive agglomerate; vent breccia and agglomerate; bedded tuff; tuffaceous and volcaniclastic sandstone, siltstone, con-glomerate, and mudstone	Overlies conformably and uncon-formably and interfingers with Kazan Formation; conformably overlies South Channel Formation in the Tulemalu Lake map area. Locally unconformable on basement. Intruded by lamprophyre dykes	Potassium-rich alkaline volcanics erupted from numerous centres. Some associated U and minor Cu mineralization
Kazan Formation	1000	Medium- to fine-grained arkose; minor siltstone, sandstone con-glomerate, calcarenite. Small to large scale crossbedding	Conformable on South Channel Formation; locally unconformable on basement. Intruded by lamprophyre dykes	Not present in Tulemalu Lake map area. Upper part of redbed sequence. Host to some U and minor Cu mineralization
South Channel	1800	Polymictic conglomerate; minor sandstone, siltstone and mudstone	Unconformable on crystalline base ment. Intruded by lamprophyre dykes	Lower part of redbed sequence. Host to some U and Cu mineralization
Angikuni Formation	3000	Coarse- to fine-grained arkosic sandstone (lower part); thinly interbedded, siltstone, mudstone and fine-grained sandstone (upper part)	Presumably unconformable on base-ment; upper contact not exposed. Intruded by lamprophyre dykes	Tulemalu Lake map area only, where the formation appears to be older than South Channel Formation

Figure 3. Cross-bedded arkosic sandstone of the Angikuni Formation on the east side of 'Golden Lake', Tulemalu Lake map area. (GSC 170975)

Petrographic studies (partly by Mole, 1977), show that the sandstone contains subangular to subrounded grains of quartz and quartzite (about 35%); plagioclase (about 15%) and both orthoclase and microcline (about 5%); fine grained granitic, gneissic and schistose rocks (about 20%); and minor muscovite, opaque minerals, apatite, zircon, tourmaline, and garnet. The grains are enclosed in an abundant silty matrix. Carbonate, hematite, and quartz are present as cements. Significantly, the sandstone does not contain any clasts of Dubawnt volcanic rocks.

The interbedded siltstone, mudstone and fine grained sandstone of the upper sequence are generally brownish maroon on both fresh and weathered surfaces. Individual beds are mainly between 2 and 15 cm thick. The sandstone is similar in overall composition to the sandstone in the underlying sequence. Near the top of the upper sequence ripple marks are common and some mud cracks are preserved.

The sedimentary rocks are probably fluvial deposits. The combination of ripple marks and mud cracks in the upper sequence indicate shallow water conditions and periodic exposures during deposition.

Several features indicate that the Angikuni Formation is older than the other units of the Dubawnt Group. The formation has much steeper dips than nearby extrusive volcanics and associated sedimentary rocks of the Dubawnt Group, it does not contain any volcanic detritus, and it is cut by Dubawnt volcanic vents and intrusions. The Christopher Island volcanics nearby rest conformably on conglomerate, mapped as South Channel Formation, which overlies basement rocks; no similar conglomerate has been found within the Angikuni Formation.

South Channel Formation

This formation, is named (Donaldson, 1965) after the waterway leading to the type area at the east end of Baker Lake (Fig. 4). It is exposed in all three of the areas described in this report, and ranges in thickness from 0 to about 1800 m. Exposures consist mainly of glacially smoothed mounds.

The South Channel Formation rests on basement rocks, is overlain by Christopher Island Formation (in the Tulemalu Lake map area) and Kazan Formation (in the Thirty Mile Lake/MacQuoid Lake map area and on Christopher Island), and is intruded by lamprophyre dykes. It consists predominantly of massive, poorly sorted, polymictic conglomerate (Fig. 5), but lenses of finer grained clastic rocks are present locally and indicate bedding attitudes.

The conglomerate of the South Channel Formation contains angular to rounded pebbles, cobbles, and boulders enclosed in a sparse to less commonly abundant sandy matrix. The largest clasts at different localities range in diameter from about 10 cm to over 50 cm, and consist of locally derived basement rocks. No clasts of Dubawnt volcanics are present (any conglomerate containing some clasts derived from Dubawnt volcanics is mapped as part of the Christopher Island Formation). Most clasts are of granitic and gneissic rocks, amphibolite, and vein quartz; other types recorded are quartzite, quartz schist, phyllite, purplish porphyritic microgranite closely resembling some Dubawnt volcanics, and rare carbonate rocks and banded jasper. The conglomerate has a matrix of poorly sorted arkosic sandstone which ranges in colour from buff to grey, reddish, and purplish brown, and commonly has a calcareous cement. Although the conglomerate is generally massive, some crude graded bedding is apparent locally, and pebble imbrication has been recorded. Pyrite occurs in some of the conglomerate near Nutarawit Lake, in the Tulemalu Lake map area.

Finer grained clastic lenses within the conglomerate range in thickness from less than 1 m to about 10 m, and consist of sandstone, siltstone, and, less commonly, mudstone. In many cases they are thin bedded to laminated, and show crossbedding and, less commonly, ripple marks. Locally they are present on the actual unconformity, filling depressions on the uneven basement surface. Sandstone, the main rock type, ranges in composition from lithic greywacke with an abundant matrix, to arkose with a sparse matrix.

The South Channel Formation is probably an alluvial fan/braided river deposit (cf. Donaldson, 1965, 1967b; Macey, 1973) laid down close to a mountain front marked in places by fault scarps. As such, it may have had depositional dips as high as 5°, or even higher, locally. However, now the formation generally has much steeper dips, over 70° in places; these are attributed to syndepositional and immediately post-depositional faulting.

Kazan Formation

The upper part of the Dubawnt redbed sequence is represented by the Kazan Formation, a unit consisting predominantly of arkose. The type area for this formation is west of Martell Lake in the MacQuoid Lake map area, along the Kazan River where this river flows eastward for about 3 km (Donaldson, 1965).

Scattered exposures of Kazan Formation are present on river banks (as in the type locality, Fig. 6) and on low hills and mounds. There are felsenmeer exposures on flat ground, and locally derived Kazan debris forms raised beaches on some hillsides. Outcrops are present in the Thirty Mile Lake, MacQuoid Lake and Baker Lake map areas (including the Christopher Island area) but not in the Tulemalu Lake map area. South of Baker Lake the formation has mainly gentle to moderate northward dips (10°-30°).

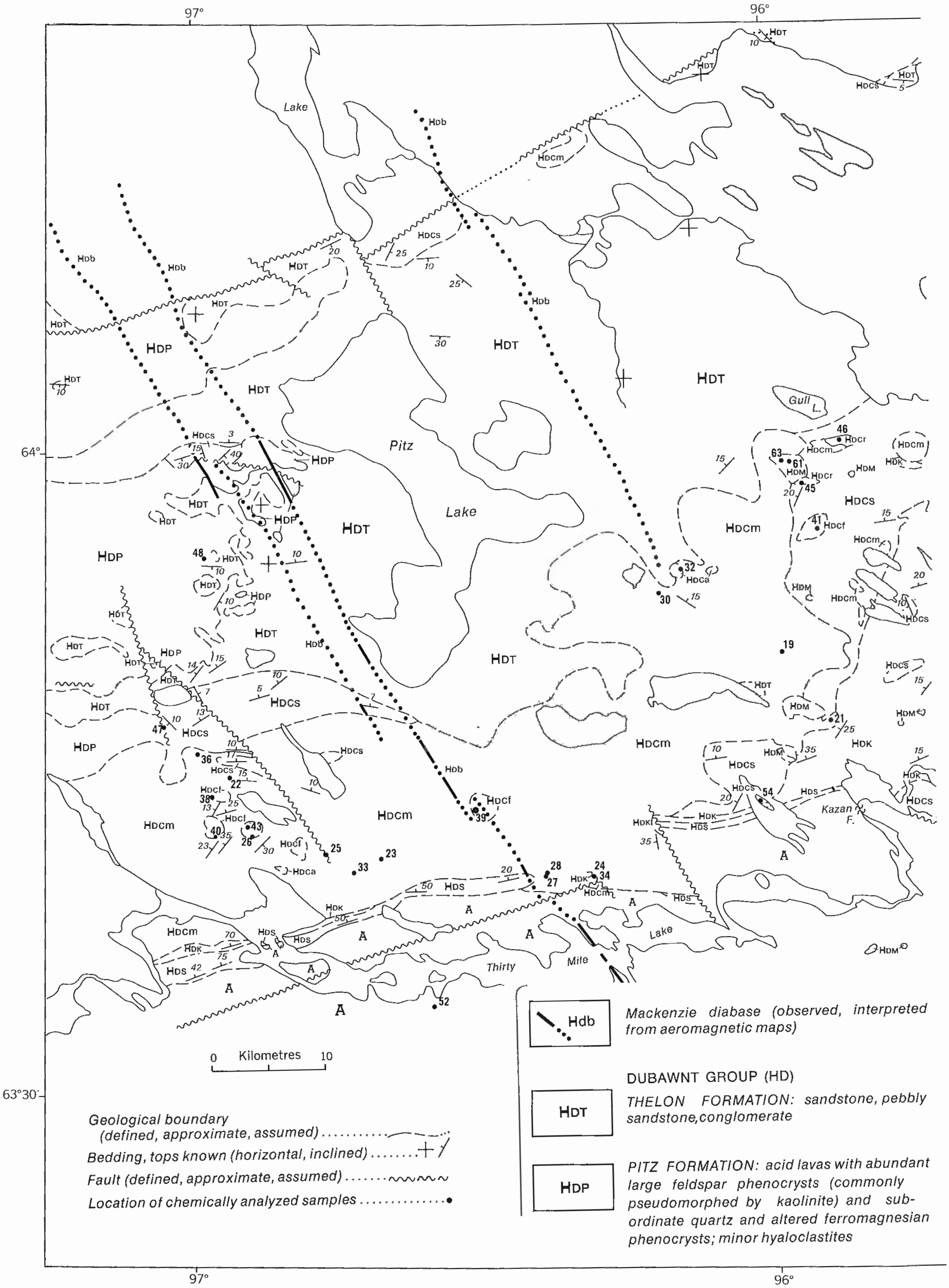


Figure 4. Dubawnt Group, Baker Lake region.

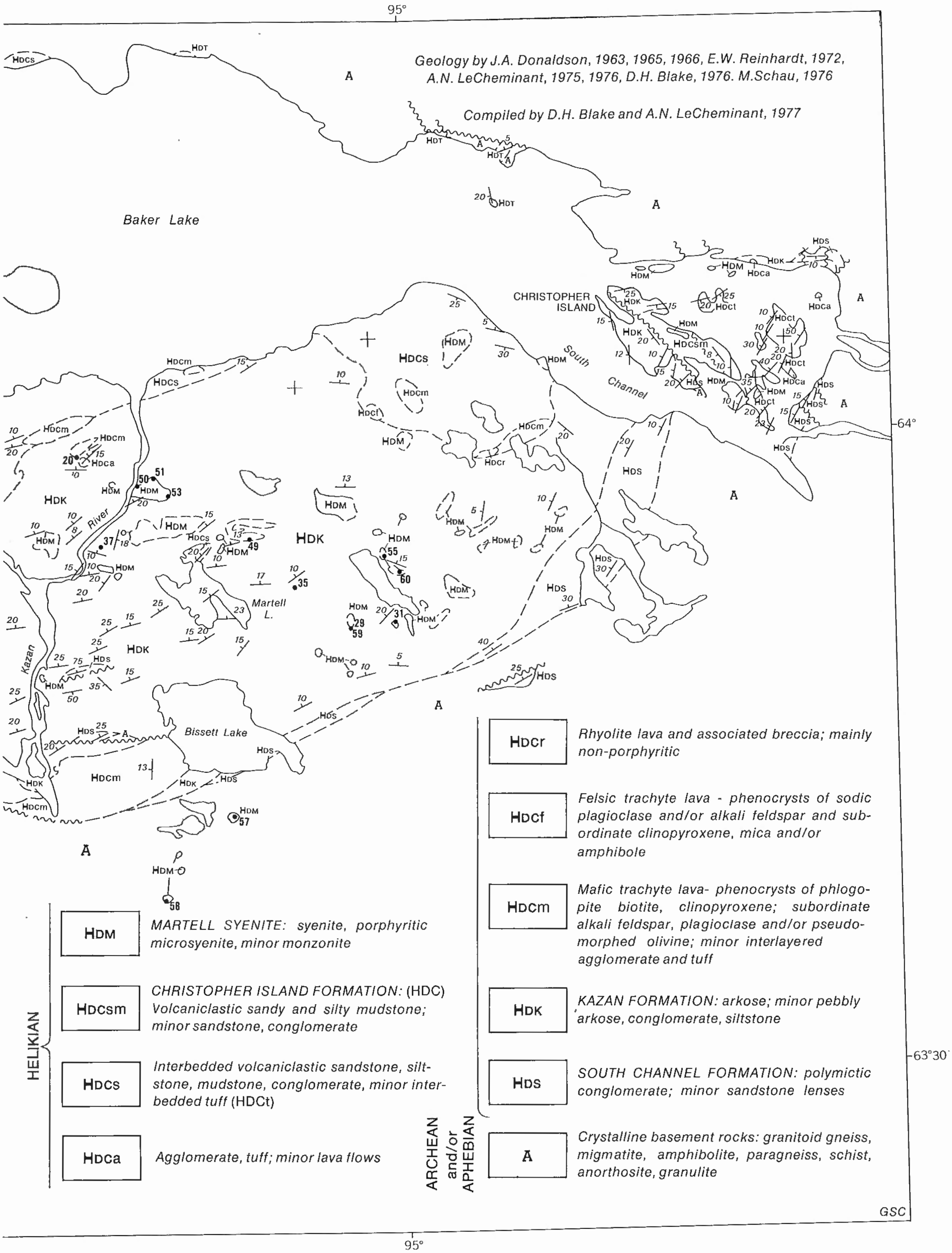


Figure 4 (cont.)

The Kazan Formation is probably thickest between Bissett Lake and Baker Lake. However, the actual thickness here is uncertain because of widely scattered exposures, the difficulty of establishing regional dips where large scale cross-bedding is widespread, the general lack of marker beds, and the possibility of faulting and folding affecting the sequence. The only marker bed found within the formation is a conglomerate which contains distinctive clasts of feldspar porphyry and is underlain by a thin trachyte sill; exposures of this conglomerate northwest of Martell Lake indicate that there the Kazan Formation is gently folded. Hence Donaldson's estimate of 4000 m for the thickness of the formation north of Bissett Lake (Donaldson, 1965), based on the assumption of consistent northward dips, is probably excessive. A more realistic estimate for the maximum thickness may be about 1000 m.

The Kazan Formation overlies the South Channel Formation conformably, the gradational contact, which is poorly exposed, being taken where sandstone predominates over conglomerate. In places it may also lie directly on basement. The formation is overlain conformably by, and locally interfingers with, volcanics of the Christopher Island Formation, except at the west end of Thirty Mile Lake, where a local unconformity separates the two formations. Numerous lamprophyre and felsic porphyry dykes and several bodies of Martell Syenite have intruded and thermally metamorphosed the formation.

The predominant rock type of the Kazan Formation is medium- to fine-grained arkose which is mainly maroon, pink, or reddish brown. However, bleached reduction spots, streaks, and bands are normally present, and near intrusions the arkose is generally entirely bleached to white, pale pink or pale grey. Most of the arkose is well sorted and well indurated, although scattered pebbles and grit-size grains are present locally, and weathered surfaces may be pitted and friable where the arkose has a calcareous cement. Bedding is generally well defined, most beds being about one metre thick. The beds commonly show internal laminar banding, the individual laminae, typically less than 1 cm thick, being indicated by slight differences in colour and grain size. The laminae enable the arkose to be split readily into thin slabs.

The arkose commonly shows crossbedding (Fig. 6), and ripple marks are widespread. Other sedimentary structures include channel scours, and, especially on Christopher Island, intraformational slumps.

Figure 5. Coarse polymictic conglomerate of the South Channel Formation, Christopher Island. (GSC 203324-H)

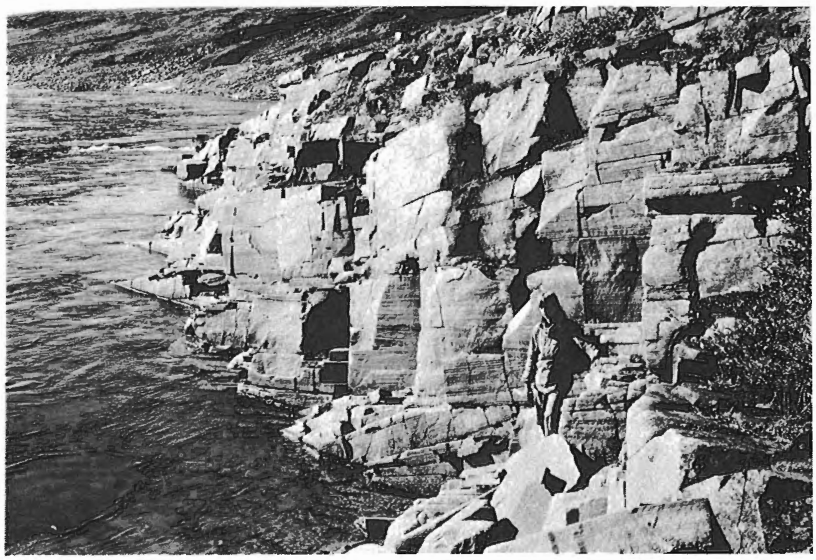


Figure 6. Crossbedded arkose at type locality of the Kazan Formation, Kazan River, MacQuoid Lake map area. (GSC 203324-I)

At least four main types of crossbedding can be distinguished within the Kazan Formation: small scale 'climbing ripples', low-angle sets up to 2 m long, large scale trough bedding sets (generally low angle, commonly more than 10 m long), and large scale high angle sets (angles of 30° or more, up to 10 m or more thick). The large scale types are made up of several beds, each showing internal laminar banding. Crossbedding measurements by Donaldson (1965) indicate that in the MacQuoid Lake map area the provenance for the Kazan arkose was to the southeast.

The arkose of the Kazan Formation is made up of subangular to rounded grains of generally unaltered sodic plagioclase and K-feldspar (about 50% of the rock), quartz (about 40%), lithic grains (less than 5%), and accessory tourmaline, zircon and opaques. It has a generally sparse, iron-stained, silty matrix, and is cemented by carbonate, hematite, and authigenic quartz albite, and potassium feldspar. Near intrusions of lamprophyre and syenite, where the arkose has been thermally metamorphosed and bleached, albite is the dominant cement.

In addition to arkose, the Kazan Formation also includes reddish brown to maroon siltstone and mudstone, some conglomerate lenses, and local thin beds of pale pink, medium grained calcarenite. The siltstone and mudstone form thin laminae and coatings on bedding planes, and commonly show desiccation cracks. Most of the conglomerate is similar to that in the underlying South Channel Formation, and consists entirely of basement clasts. An exception is the distinctive conglomerate forming a marker bed in the upper part of the Kazan Formation northwest of Bissett Lake, which contains clasts of feldspar porphyry probably derived from an outcrop of Dubawnt volcanics. These clasts (e.g., samples No. 37, Tables 3 and 7) contain phenocrysts up to 5 mm across of K-feldspar, subordinate altered mica and pyroxene, and partly resorbed quartz enclosed in a pinkish to maroon very fine grained quartzofeldspathic goundmass. The porphyry clasts make up between 5 and 50 per cent of the conglomerate, and form the largest clasts present. They are clearly locally derived and indicate that the deposition of the conglomerate may have been related to nearby contemporaneous volcanic activity.

Most of the Kazan Formation is probably fluvial but there may also be some shallow marine, lacustrine, and aeolian deposits (Donaldson, 1965, 1967b). A shallow water environment is indicated by the common occurrence of desiccation cracks together with ripple marks (Donaldson, 1965). The arkose showing large scale, high-angle cross-bedding may represent aeolian dunes (Donaldson, 1967b).

Christopher Island Formation

The type area of this unit is on Christopher Island and nearby islands at the east end of Baker Lake (Donaldson, 1965). The formation consists of mainly alkaline volcanic rocks and associated sedimentary rocks, and is the main unit of the Dubawnt Group exposed in the region. The most resistant rock types of the formation, mainly lava flows, form rounded to flat-topped hills and ridges partly bounded by cliff faces; other exposures are similar to those of the Kazan and South Channel formations.

The maximum known thickness of the formation is southeast of Tulemalu Lake, in the Tulemalu Lake map area (Fig. 7), where a sequence of lavas and pyroclastics dipping steeply northwest appears to be at least 2000 m thick. Thicknesses of well over 100 m occur in the Thirty Mile Lake-Macquoid Lake area and on Christopher Island and the formation is generally much thicker than suggested by Donaldson (1965).

The recent mapping has shown that the relationship of the Christopher Island Formation to the Kazan Formation is somewhat different from that suggested by Donaldson (1965, 1967b): the two formations are not separated by a regional unconformity. On Christopher Island the Christopher Island Formation is seen to be conformable on Kazan arkose, and in the MacQuoid Lake map area it interfingers with and conformably overlies Kazan Formation. However, it is locally unconformable on Kazan rocks in the Thirty Mile Lake map area. The Christopher Island Formation overlies basement rocks unconformably and conglomerate of the South Channel Formation conformably in the Tulemalu Lake map area. It is overlain concordantly by rhyolite lava of the Pitz Formation and is overlapped by sandstone of the Thelon Formation in the north part of the Thirty Mile Lake map area. In all areas it is cut by intrusions of comagmatic lamprophyre, feldspar porphyry, and syenite, and on Christopher Island it is also cut by pipes and fissures filled with volcanic breccia.

Rocks of the formation are mainly gently dipping. Original dips, on the flanks of volcanic cones may have ranged up to 35°. Steeper dips are related to penecontemporaneous and perhaps later faulting.

The main rock types of the Christopher Island Formation are mafic trachyte, felsic trachyte, and rhyolite lava; massive agglomerate; vent breccia and agglomerate; bedded tuff; and variably tuffaceous and volcaniclastic sandstone, siltstone, conglomerate, and mudstone. The formation is also taken to include various high level lamprophyre and feldspar porphyry dykes and sills. The volcanic rocks are various shades of red, purple, brown, grey, and greenish grey. The sedimentary rocks are mostly reddish, like those of the Kazan Formation, but tend to be darker and less pinkish than typical Kazan arkose.

Individual lava flows of mafic trachyte are generally sheet-like and probably average about 10 m in thickness; they typically have massive centres and autobrecciated and scoriaceous margins with abundant vesicles filled with secondary minerals, mainly carbonate. Felsic trachyte and rhyolite form thicker extrusive bodies, which are probably cumulodomes, partly filling craters. Unlike mafic trachyte, these rocks shatter readily, and exposures generally consist largely of small angular rock chips. Most of the lavas are probably subaerial flows. However at least one subaqueous mafic trachyte lava flow, consisting partly of hyaloclastitic breccia, has been identified in the Thirty Mile Lake map area, and another, showing pillow-like features and overlapped by mudstone, is exposed on Christopher Island.

The trachyte lavas are potassium-rich alkaline rocks containing phenocrysts of mica (biotite-phlogopite), clinopyroxene (diopside-salite), feldspar (plagioclase and/or K-feldspar), less commonly olivine and quartz, and rarely amphibole; some microphenocrysts of apatite are also generally present. Phenocrysts of mica and pyroxene predominate in mafic trachyte, those of feldspar predominate in felsic trachyte. The phenocrysts form from 5 to about 40 per cent of the total rock, and are commonly less than 5 mm in diameter. Those of olivine are always pseudomorphed, and those of mica and clinopyroxene are commonly at least partly replaced by secondary minerals. Alkali feldspar is the dominant groundmass mineral in both mafic and felsic trachytes. The widespread secondary alteration is associated with the volcanism, and not to later regional metamorphic effects.

Massive agglomerate and volcanic breccia are widespread, and in many places indicate probable eruptive sites. Locally they occupy volcanic pipes, fissures, and vents. Although consisting mainly of volcanic material, they commonly also contain some fragments of basement rocks. Massive agglomerate is made up largely of angular to rounded fragments up to 1 m or more across of scoriaceous lava and pale altered pumice enclosed in an abundant, poorly sorted, tuffaceous matrix; some of the volcanic fragments probably represent lava bombs. Bedded pyroclastics, both tuff and agglomerate, are interlayered with lava flows at many localities, and indicate subaerial volcanism.

The fine- to coarse-grained tuffaceous and volcaniclastic sedimentary rocks are generally medium to thin bedded. Crossbedding is common, and graded bedding, ripple marks, desiccation cracks, and slump structures are present locally. Bedding planes in the coarser clastics tend to be less well defined than in the Kazan arkose. Conglomerate and sandstone at or near the base of the formation consist chiefly of basement clasts, whereas higher up in the formation they consist mainly or wholly of volcanic detritus (Fig. 8).

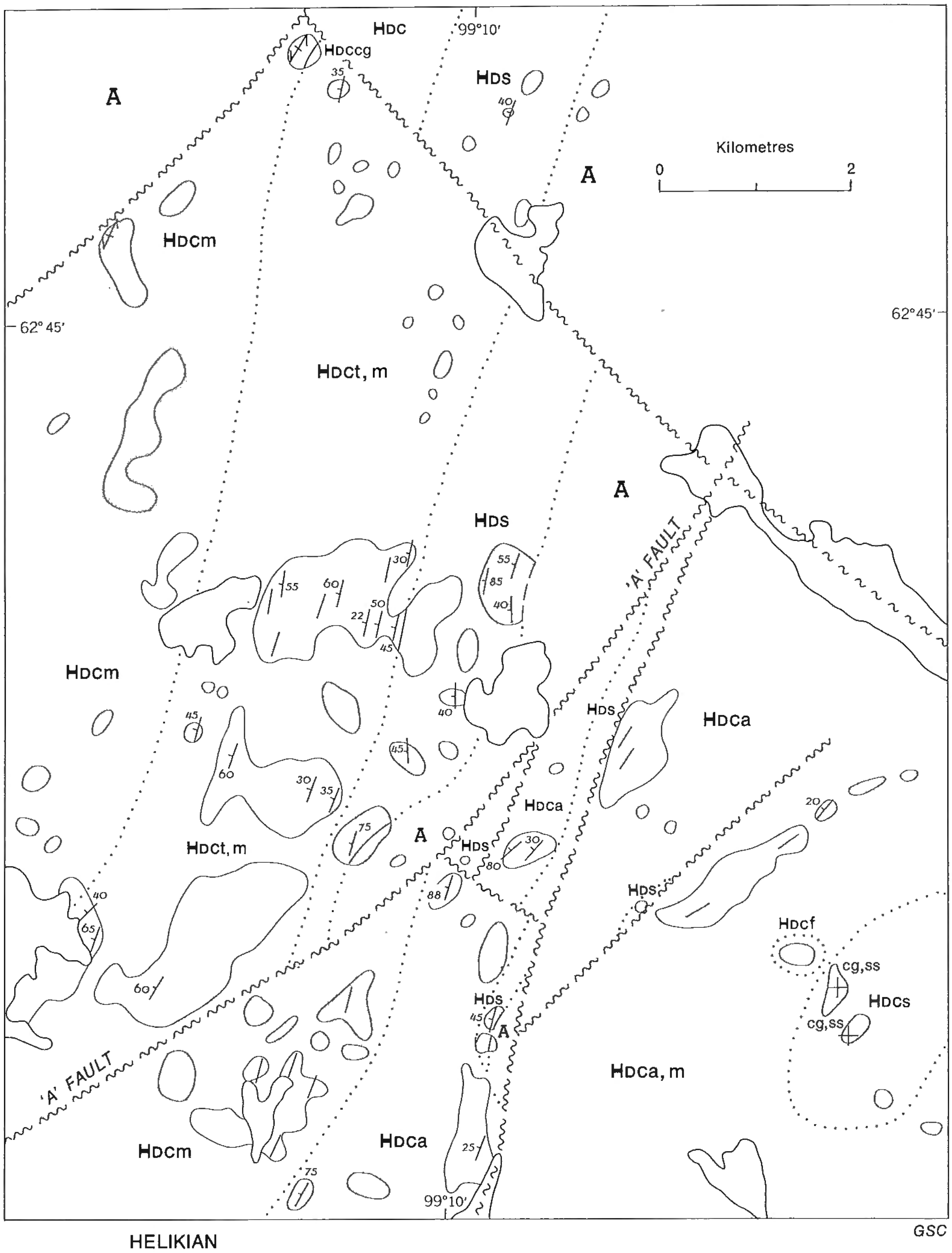
High level intrusions genetically related to the Christopher Island Formation include most if not all of the lamprophyre and feldspar porphyry dykes and sills cutting the basement, as well as those intruding the trachyte lavas of the Christopher Island Formation. The dykes range in width from less than 1 m to over 20 m. Many contain xenoliths, generally rounded, of basement rocks. The intrusions are similar in mineralogy and chemistry to the trachyte lavas of the Christopher Island Formation, and are considered to be genetically related to these.

Table 2

Modal composition (volume %) of mafic trachyte and lamprophyre, Christopher Island Formation

No.	PHENOCRYSTS Biotite	Bio/phlogopite	Phlogopite	Clinopyroxene	Orthopyroxene	Olivine	Amphibole	Opaques	Apatite	Plagioclase	K feldspar	Quartz	Vesicles	Groundmass	Main secondary minerals	GSC sample no.	Sample type
1		(5)		(14)	-	(1)	-	-	tr	-	-	-	1	78	dolomite	EA-509-75	lava flow
2	-		16	(13)	-	-	-	-	tr	-	-	-	-	71	calcite	EA-117A-75	lava flow
3	-		17	(17)	-	?	-	-	tr	-	-	-	-	66	calcite	EA-117-75	lava flow
4		5		(8)	-	(1)	-	-	tr	-	-	-	7	80	calcite, amphibole, mica, opaques	EA-214-75	lava flow
5		~8		(~5)	-	-	-	-	-	-	-	-	~5	~82	amphibole, mica	EA-119-75	lava flow
6	11		-	21	-	-	-	-	2	-	-	-	2	64	calcite, chlorite	EA-1053B-76	sill
7	8		-	14	-	-	-	tr	tr	-	-	-	1	78	calcite, opaques	EA-1029-76	lava flow
8		(1)		6	-	-	-	-	-	-	tr	-	tr	93	chlorite, calcite	EA-248A-75	lava flow
9	5		-	8	-	(tr)	-	-	1	-	-	-	10	75	calcite, amphibole, mica	EA-1032-76	lava flow
10	-		12	(8)	-	-	-	tr	tr	-	7	-	8	65	dolomite, quartz	EA-207-75	lava flow
11		2		6	-	-	-	-	1	(?)	-	-	9	81	calcite, sericite	EA-1024-76	lava flow
12		7		(6)	-	-	-	-	tr	-	-	-	1	86	calcite, amphibole, mica, opaques	EA-277-75	lava flow
13		7		10	-	-	-	-	tr	-	-	-	5	77	amphibole, epidote, opaques	EA-187-75	lava flow
14		5		18	-	-	-	-	tr	-	tr	-	1	77	amphibole	EA-1039-76	lava flow
15		8		21	-	-	-	-	1	-	-	-	-	69	calcite	EA-1083-76	lava flow
16	4		-	24	-	-	-	-	tr	-	-	-	-	71	amphibole	EA-1060-76	sill?
17		12		8	-	-	-	-	1	1	10	-	-	69	calcite, amphibole	EA-1013-76	agglomeratic lava
18	(7)		2	(5)	-	-	-	-	tr	tr	3	-	?	83	dolomite, opaques	EA-198-75	lava flow
19	7		-	(11)	-	(6)	-	-	-	-	-	-	-	75	dolomite, chlorite	76LAAD038-1	lava flow
20		4		7	-	(3)	-	-	-	tr	-	-	-	86	calcite, opaques	76LAAD356-5	lava flow
21	-		6	16	-	(4)	-	-	-	-	-	-	-	76	chlorite, opaques	76LAAD048-1	lava flow
22	-		1	19	-	(2)	-	-	tr	-	1	-	-	77	carbonate	76LAAD338-1	lava flow
23		(3)		2	-	(tr)	-	-	tr	-	-	-	8	86	chlorite, opaques	76LAAE105-1	lava flow
24	-		6	(7)	-	(2)	-	tr	-	6	1	-	-	77	dolomite, chlorite	76LAAD006-2	boulder in conglomerate
25	4		-	15	-	(tr)	-	-	tr	-	-	-	-	81	chlorite, calcite	76LAAE097-1	lava flow
26	-		-	8	-	-	-	-	-	-	-	-	-	72	chlorite, hematite	76LAAD174-1	lava flow
27		(5)		16	-	-	-	-	-	-	-	-	1	78	chlorite, hematite	76LAAD010-1	lava flow
28		(4)		13	-	-	-	-	-	-	tr	-	tr	83	chlorite, hematite	75LAAT462-1	lava flow
29	5		-	4	-	-	-	-	tr	-	-	-	tr	91	—	76LAAD284-1	dyke
30		4		12	-	(1)	-	tr	tr	-	-	-	2	81	—	76LAAD279-1	lava flow
31	2		-	8	-	(tr)	-	-	-	-	-	-	-	90	opaques	76LAAD288-1	dyke
32		14		10	-	-	-	-	-	-	-	-	-	76	opaques	76LAAD275-1	lava flow
33	(8)		5	7	-	(1)	-	-	tr	1	tr	-	-	77	calcite, opaques	76LAAE102-1	lava flow
34		(5)		(5)	-	(tr)	-	-	tr	4	tr	-	-	80	calcite, chlorite, opaques	76LAAD006-1	lava flow
35	14		9		-	(1)	-	-	-	5	-	-	-	71	chlorite	75LAAP468-2	dyke?
36	-		4	(7)	-	(tr?)	-	-	tr	tr	-	-	2	87	chlorite, quartz calcite, opaques	76LAAT463-1	lava flow

( ) = entirely pseudomorphed



HELIKIAN

DUBAWNT GROUP (HD)

HDC	*CHRISTOPHER ISLAND FORMATION:* m, *mafic trachyte lava;* f, *felsic trachyte lava;* a, *agglomerate;* t. *bedded tuff;* s, *volcaniclastic sedimentary rocks (conglomerate* - cg, *sandstone* - ss)
HDS	*SOUTH CHANNEL FORMATION: conglomerate*

ARCHEAN

A	*Crystalline basement rocks*

Geological boundary (defined, approximate, assumed) ....

Bedding, tops known (horizontal, inclined, dip unknown) ....

Cleavage (vertical) ....

Fault (approximate, assumed) ....

Outcrop ....

Figure 7. The Dubawnt Group southeast of Tulemalu Lake, Tulemalu Lake map area.

Pitz Formation

This formation is named after Pitz Lake, which is east of the type locality. It consists mainly of reddish to purplish maroon rhyolite lava containing abundant phenocrysts of feldspar more than 5 mm across and subordinate smaller phenocrysts of quartz. Exposures occur in the Thirty Mile Lake map area and in the adjoining Schultz Lake map area to the north (Donaldson, 1966b). Much of the formation in the Thirty Mile Lake map area consists of intimately associated auto-brecciated lava and volcaniclastic sedimentary rocks, interpreted as hyaloclastites, which grade outwards into sandstone of the Thelon Formation.

The Pitz Formation overlies the Christopher Island Formation, in places concordantly, and it is overlapped by sandstone of the Thelon Formation. No lamprophyre or felsic porphyry dykes have been found intruding either the Pitz or Thelon formations.

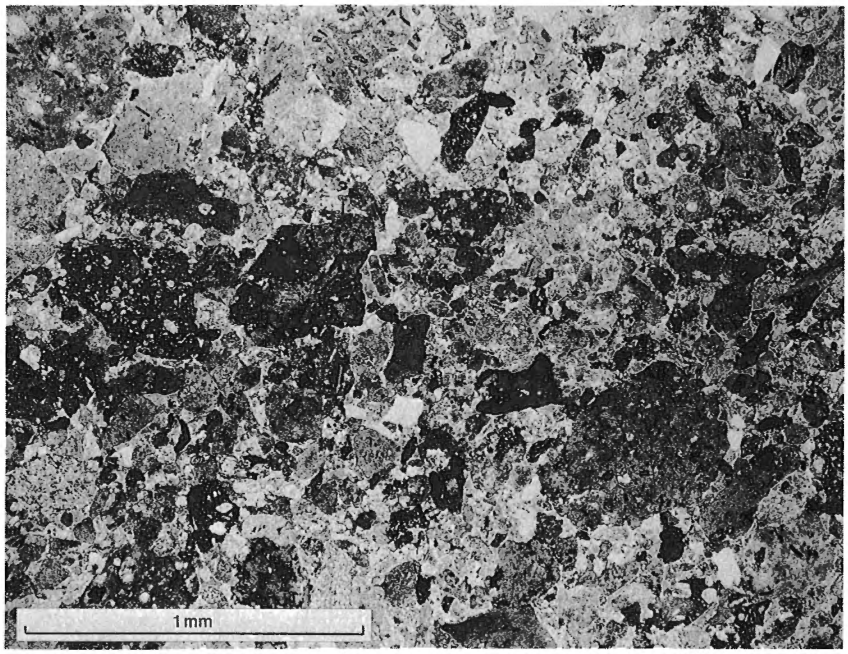


Figure 8. Photomicrograph of volcaniclastic sandstone, made up almost entirely of mafic trachyte clasts, Christopher Island Formation. (GSC 203172-B)

Thelon Formation

Donaldson (1965) stated that this formation "is defined as the relatively flat-lying sequence of clastic sedimentary rocks that outcrop for the most part across the Thelon plain north and west of Dubawnt Lake ... Outliers occur as far east as Baker Lake, and are well exposed on hills east and west of Pitz Lake." The formation is exposed in the north part of the Thirty Mile Lake map area, but not in the Tulemalu Lake and MacQuoid Lake map areas, and it does not extend as far east as Christopher Island. On the east side of Pitz Lake, exposures range in altitude from about 50 to 200 m above sea level; as the formation is more or less flat-lying, this indicates that the Thelon Formation was probably at least 150 m thick in places.

In the north of the Thirty Mile Lake map area (Fig. 9) the Thelon Formation overlaps Christopher Island volcanics and fills depressions between and overlies the lava lobes of the Pitz Formation. It consists of sandstone and conglomerate and probably reaches a thickness of about 100 m. The sandstone and conglomerate are mainly pale pink, pale purple, white or buff, much paler than most of the Kazan arkose. As they typically have a clay matrix, they are generally more friable and more easily eroded than most Dubawnt rocks, and are readily incised by streams to form gorges. However locally, especially within a metre or so of Pitz lava, they are well indurated due to the presence of a silica cement.

The sandstone beds are commonly flaggy and generally show crossbedding. This is of both large scale, shallow trough type, with sets ranging up to about 10 m in thickness, and medium scale festoon type, with wedge-shaped sets up to about 1 m thick. Crossbedding measurements by Donaldson (1965) indicate a provenance to the southeast. Some beds also show ripple marks.

Poorly sorted medium- to coarse-grained sandstone and conglomerate predominate west of Pitz Lake. The conglomeratic beds contain rounded to angular fragments of locally derived pink to red feldspathic sandstone, chert and mudstone (volcaniclastic sedimentary rocks of the Christopher Island Formation) and porphyritic red to purple rhyolite (in the immediate vicinity of Pitz lava), and also of vein quartz and grey quartzite.

The sandstone of the Thelon Formation consists largely of quartz and kaolinized feldspar grains probably derived from the nearby porphyritic rhyolite lava of the Pitz Formation. Derivation from Pitz lava, some of which contains about 40 per cent kaolinite (pseudomorphing feldspar phenocrysts), also readily accounts for the high clay content of the sandstone. There is little evidence in this area of the compositional maturity that characterizes much of the Thelon Formation (Donaldson, 1965, 1967b; Cecile, 1973).

The Thelon Formation in the Thirty Mile Lake map area may be marine fluvial, or lacustrine. Its close spatial and temporal association with hyaloclastites of the Pitz Formation indicates that some of it was deposited in water which was deep enough to cover the 100 m thick Pitz lava lobes.

Martell Syenite

Intrusive rocks mapped as Martell Syenite are present in the Tulemalu Lake, Thirty Mile Lake, MacQuoid Lake and Baker Lake map areas. The unit was named by Donaldson (1965) after Martell Lake, in the MacQuoid Lake map area. The type area is presumed to be prominent domical hills north of Martell Lake, where the unit is particularly well exposed.

The Martell intrusions form laccolithic bodies (Fig. 10) up to 30 m or more thick and also sills, dykes and irregular sheet-like bodies generally less than 5 m thick (Fig. 11). These all have chilled margins and sharp contacts with adjacent country rocks; the latter are thermally metamorphosed within a few metres of the intrusions. The laccoliths mainly occur within more easily eroded Kazan arkose, and typically form steep sided, rounded hills whose shape probably closely approximates the original form of the intrusive bodies. Their basal contacts, where exposed, are more or less concordant with the bedding in the underlying rocks, and are flat-lying or gently dipping. Their sides, however, are commonly steep and highly irregular in detail,

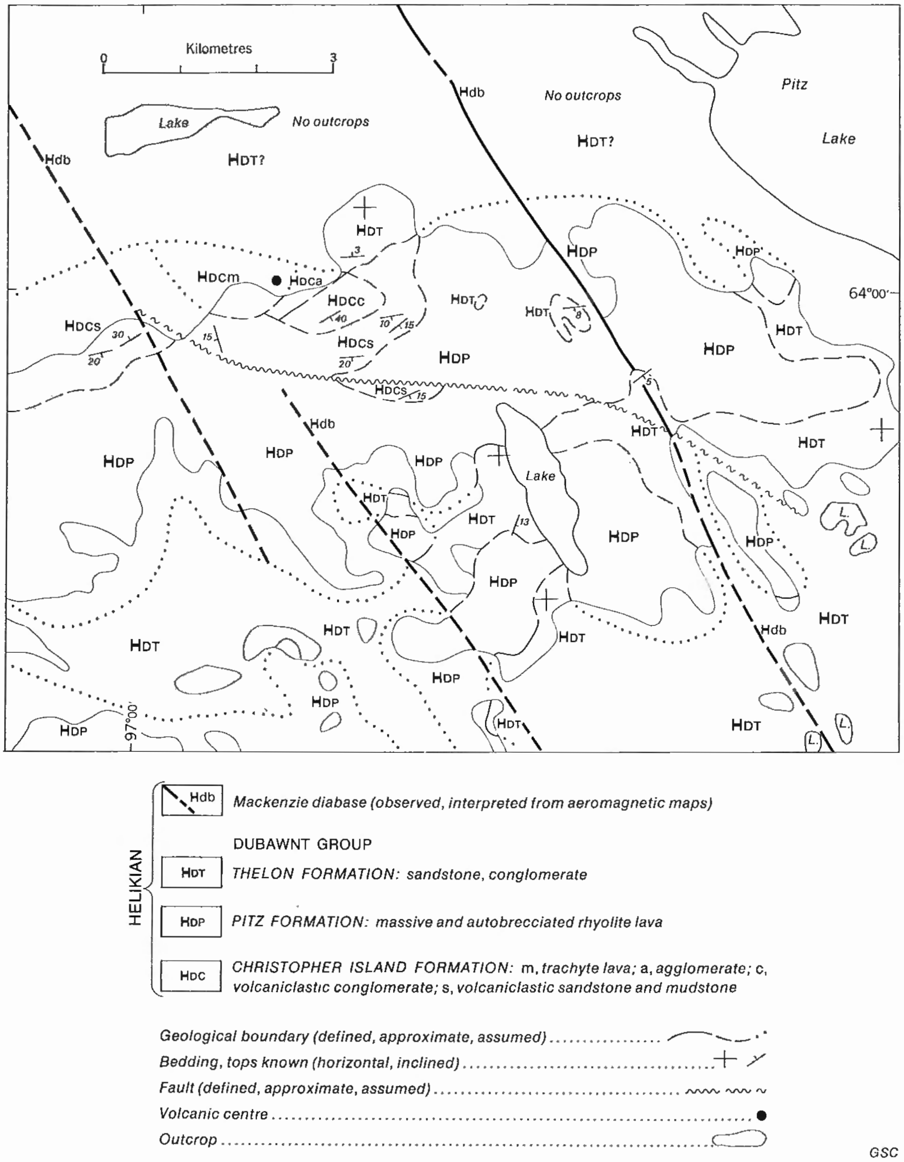


Figure 9. The Dubawnt Group west of Pitz Lake.

and have offshoots penetrating adjacent country rocks. Some of the laccoliths show layered jointing; the joints are typically 1 to 2 m apart and are oriented parallel to upper and lower contacts of the intrusions. Many of the larger bodies are multiple intrusions as is indicated by the presence of two or more intersecting sets of closely spaced joints, resembling very large scale crossbedding, and by sharp contacts between different varieties of syenite.

The intrusions were emplaced within basement rocks, Kazan Formation and Christopher Island Formation, but not within either the Pitz or Thelon formations, nor, apparently, within the South Channel Formation. Locally they are cut by lamprophyre dykes, and also by pink feldspathic veins. These relationships indicate that the intrusions are essentially the same age as the volcanics of the Christopher Island Formation.

The Martell Syenite intrusives consist of medium- to fine-grained, locally porphyritic rocks which range in composition from syenite to monzonite and, at one locality in the Tulemalu Lake map area, alkali granite. These rocks are pale to dark red, purplish or greyish. Essential minerals (Table 4), any of which may form phenocrysts, are K-feldspar, biotite, augite, and commonly sodic plagioclase, hornblende, and olivine (almost invariably pseudomorphed). Accessory minerals include apatite, opaques, and in some cases zircon, quartz, hypersthene and allanite. Quartz is an essential mineral only in the alkali granite. The colour index is mainly between 10 and 40. Many intrusions contain small xenoliths of basement rocks, and some have miarolitic cavities filled with carbonate.

Field relationships, mineralogy, and chemistry (discussed in a later section) all indicate that the Martell Syenite bodies are high-level intrusive equivalents of the trachyte lavas of the Christopher Island Formation. Deeper level equivalents may be represented by coarser grained bodies, ranging in composition from biotite pyroxenite to syenite, which are exposed south of the Dubawnt unconformity in the Thirty Mile Lake-MacQuoid Lake area (LeCheminant et al., 1977). These bodies, together with associated granite, intrude basement gneisses and postdate the regional metamorphism.

Mineralization

Volcanic and sedimentary rocks of the Dubawnt Group are hosts to uranium and minor associated base and precious metal mineralization. Four types of mineralization have been recognized (A.R. Miller, pers. comm., 1978). One type consists largely of quartz, hematite, chlorite, chalcopyrite and pitchblende occupying fractures associated with faults. This type is present in volcanics of the Christopher Island Formation and also in basement rocks close to the Dubawnt unconformity. Good examples are known on Christopher Island, and north of Thirty Mile Lake and near Kazan Falls in the Thirty Mile Lake-MacQuoid Lake area. On Christopher Island the fracture fillings also contains a variety of selenide minerals and native gold and silver (Pringle and Miller, 1977; Miller, pers. comm., 1978). A second type, consisting mainly of pitchblende and copper minerals, forms impregnations and thin fracture fillings in Kazan arkose which has been thermally metamorphosed and albitized by nearby lamprophyre dykes. This type has been found mainly on the east side of the Kazan River in the MacQuoid Lake map area, but also occurs on Christopher Island. The remaining two types have been found only in the Christopher Island area. In one of these a complex stockwork of intersecting veins contain pitchblende, chalcopyrite and digenite in a gangue of carbonate and quartz. This stockwork type has been found in Kazan arkose on Christopher Island. In the other type the mineralization occurs in breccia pipes, where it forms the matrix or cement; it consists of pitchblende, chalcopyrite and sphalerite in a gangue of carbonates, quartz, hematite, chlorite and barite.

Table 3

Modal composition (volume %) of felsic trachyte and rhyolite, Christopher Island and Pitz formations.

No.	PHENOCRYSTS: Biotite	Bio/phlogopite	Phlogopite	Clinopyroxene	Orthopyroxene	Olivine	Amphibole	Opaques	Apatite	Plagioclase	Plagioclase/ K feldspar	K feldspar	Quartz	Vesicles	Groundmass	Main secondary minerals	GSC sample no.	Sample type
CHRISTOPHER ISLAND FORMATION: FELSIC TRACHYTE																		
37		(1)		(?)	-	-	(2)	tr	tr	-		18	tr	-	78	calcite, opaques	76LAAD316-2	cobble in conglomerate
38		5		9	-	(1)	-	1	tr	4		6	-	-	73	carbonate, chlorite	76LAAD335-1	cumulodome
39	4		-	8	(7)	-	-	tr	tr	12		tr	-	1	69	chlorite	76LAAT314-1	cumulodome
40		2		(tr)	-	-	-	1	tr	tr		50	-	-	46	calcite	76LAAD164-3	cumulodome
41		~2		(~2)	-	-	(?tr)	-	tr		(~20)		-	-	~75	calcite, sericite	76LAAD032-2	cumulodome
42		5		(7)	-	-	-	-	tr	tr		9	-	1	78	dolomite, opaques	EA-1012-75	cumulodome?
43	-		-	-	-	-	(2)	tr	-	4		6	-	-	88	calcite, quartz	76LAAD173-1	cumulodome
44		(~4)		-	-	-	(~4)	tr	-	16		tr	tr	-	75	opaques	EA-507-75	cumulodome?
CHRISTOPHER ISLAND FORMATION: RHYOLITE																		
45		(1)		(?)	-	-	(?)	-	-	4		4	-	tr	91	sericite, opaques	76LAAD021-1	cumulodome?
46	-		-	-	-	-	-	-	-	-		-	-	-	100	—	76LAAD124-1	cumulodome
PITZ FORMATION: RHYOLITE																		
47		(?)		(2?)	-	-	(2?)	-	-	23		8	2	-	63	calcite	76LAAD349-1	lava flow
48		(?)		(1?)	-	-	(?)	1	-		(26)		3	9	60	kaolinite, quartz	76LAAT253-1	lava flow

( ) = entirely pseudomorphed

Table 4

Modal composition (volume %), Martell Syenite

No.	Biotite	Bio/phlogopite	Clinopyroxene	Orthopyroxene	Olivine	Hornblende	Opaques	Apatite	Plagioclase	Plagioclase/ K feldspar	K feldspar	Quartz	Main secondary minerals	GSC sample no.
49	17		23	-	(7)	-	tr	tr	18		34	-	opaques	76LAAD301-1
50	7		(18)	-	(2)	1	3	tr	31		35	1	calcite, chlorite	76LAAD293-1
51	4		16		(6)	-	2	tr	36		33	1	chlorite, calcite	75LAAG028-2
*52	22		(42)	-	-	-	1	tr		34		-	amphibole, calcite	76LAAT266-1*
53	6		18	-	(6)	-	1	tr	29		38	1	chlorite	75LAAG036-2
54		(~4)	20	-	(4)	~2	tr	-	10		57	-	chlorite, opaques	76LAAD053-1
55	15		12	-	-	-	2	1	-		70	-	chlorite, calcite	75LAAT410-1
56	21		2	-	-	30	tr	2	2		40	-	calcite	EA-1058-76
57	12		21	-	(2)	-	1	tr		63		-	opaques, amphibole, chlorite	76LAAT060-1
58	12		26	6	(tr)	-	tr	tr	22		35	-	—	76LAAT050-3
59	20		15	-	-	2	2	tr		60		tr	—	76LAAD284-2
60	18		13	-	(?)	6	tr	tr		62		tr	—	76LAAD051-4
61	6		10	-	(3?)	tr	2	1	16		30	2	chlorite	76LAAD024-1
62	9		17	-	-	2	3	1	9		55	5	—	EA-1068-76
63	6		(?)	-	-	7	3	1	25		54	3	chlorite	76LAAD028-1

( ) = entirely pseudomorphed * Lamprophyre dyke

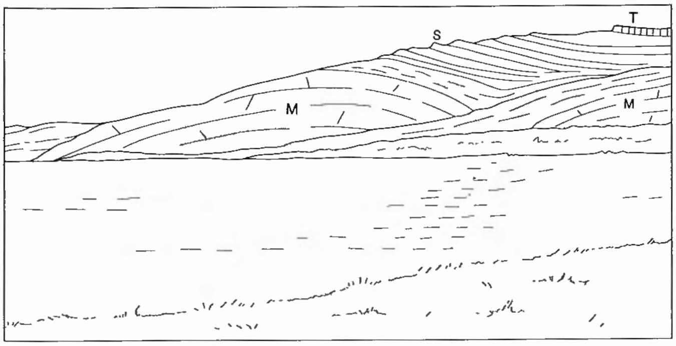


Figure 10. Laccoliths of Martell Syenite (M) intruded into volcaniclastic sediments (S) of the Christopher Island Formation; capped by mafic trachyte lava (T); 8 km northwest of Kazan Falls, MacQuoid Lake map area.

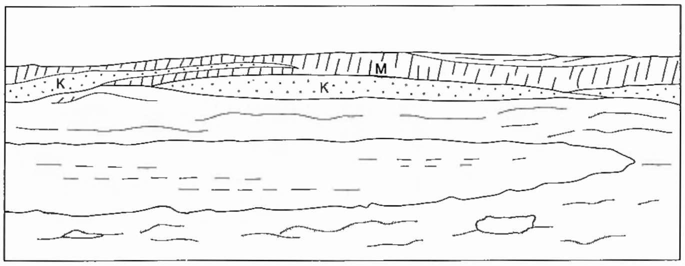


Figure 11. Sills of Martell Syenite (M) intruding arkose of the Kazan Formation (K) near Martell Lake, MacQuoid Lake map area.

The uranium and associated mineralization probably took place during Dubawnt Group time. This is suggested firstly by a U-Pb date of 1813 Ma (Miller, pers. comm., 1978) on pitchblende from a fracture-filling in basement rocks near Kazan Falls, and secondly, by the several occurrences of uranium mineralization in thermally metamorphosed arkose of the Kazan Formation. The latter mineralization almost certainly took place at the time of metamorphism, when the arkose was intruded by Dubawnt dykes. However, much of the mineralization subsequently migrated to new sites, as it now occurs in fracture systems that postdate the Dubawnt Group.

The Dubawnt volcanic rocks are relatively rich in uranium, and may be the primary source for the mineralization. Over fifty samples of the volcanics have been analyzed for uranium by delayed neutron activation, and many of these have 5-10 ppm U (Tables 5-7). This compares with less than 2 ppm U typically present in the basement rocks. Uranium originally held in the volcanic rocks may have been released into the groundwater during devitrification and propylitic alteration, and was concentrated later within fracture systems and zones of high reducing potential. (Supporting evidence for this is given by the few analyses available of highly altered (propylitized) volcanic rocks: some of these have less than 5 ppm U, i.e., have been partly leached.)

DUBAWNT GROUP VOLCANICS IN THE TULEMALU LAKE MAP AREA

In the Tulemalu Lake map area (Fig. 12) there are two large areas of Dubawnt Group rocks, one in the south trending east-northeast between Angikuni Lake and Yathkyed Lake, and one to the north trending northeast between Angikuni Lake and Nutarawit Lake. These are termed the main southern and main northern outcrop areas, respectively. The Dubawnt Group rocks here appear to have been laid down in two large valleys within a mountainous terrain formed of crystalline basement rocks. There are also two much smaller outcrop areas of Dubawnt rocks, west and southwest of Tulemalu Lake, which are parts of large outcrop areas in adjoining map areas, and there are some small outliers on the northwest side of Angikuni Lake and on an island in this lake. In all these outcrop areas the Dubawnt Group consists predominantly of volcanic rocks. A gabbro dyke of the Mackenzie swarm cuts across both the main outcrop areas; it is poorly exposed but forms a prominent aeromagnetic feature.

Main southern outcrop area

In this area low exposures of Dubawnt Group rocks, all mapped as Christopher Island Formation, are separated by broad expanses covered by lakes and unconsolidated Quaternary sediments (mainly glacial). The Dubawnt rocks are mostly flat-lying to gently dipping, and may have a maximum thickness of less than 100 m. Although some shearing is evident locally, only one major fault has been found either within or partly bounding the outcrop area (Fig. 12); this is in marked contrast to the main northern outcrop area. The irregular contact between Dubawnt and basement rocks in the northeast reflects the irregular topography that existed during Dubawnt Group time.

The Christopher Island Formation in the northeast part of the area is at least 70 m thick. It consists of a basal conglomerate overlain by partly volcaniclastic sandstone containing intercalations of mafic trachyte lava, tuff, agglomerate, and conglomerate. The basal conglomerate, which probably represents alluvial fan deposits, contains rounded to angular clasts, some over 50 cm across. Most clasts are of basement rocks but there are also some of Dubawnt sedimentary and volcanic rocks. In places a regolith, consisting of red Dubawnt sandstone filling fractures in red altered granite, is present beneath the conglomerate. The overlying sandstone, probably a fluvial deposit, is mainly thin bedded to laminated, and shows ripple marks, crossbedding, desiccation cracks, scour and fill structures, crude graded bedding, intraformational breccias, and scattered pebbles of basement rocks. Thick bedded to massive tuff and agglomerate occur locally within the sandstone sequence, and in places are over 10 m thick.

In the central part of the outcrop area most exposures are of massive, medium- to coarse-grained tuff. Some coarser fragmental rocks are present locally, in particular at the site of a probable eruptive centre in the north, where a vent breccia-agglomerate contains blocks of basement and volcanic rocks up to 3 m across. South of this centre there are exposures of thin bedded to laminated red sandstone, which is probably partly tuffaceous, and also exposures of mafic and felsic trachyte lava. In the far south a boulder conglomerate at least 12 m thick overlies unweathered basement granodiorite; this conglomerate contains some fragments of Dubawnt volcanics and includes some thin beds and lenses of red arkose.

Exposures of lava flows predominate in the southwest. The lavas are mainly mafic trachytes, although some felsic trachyte lava may be present in the east. Fine- to medium-grained tuff, lapilli tuff and agglomerate are exposed in the southeast and far west. In the west these pyroclastic rocks consist almost entirely of mafic trachyte fragments, and although they appear to be generally massive, they locally show steep banding like that found in many vent agglomerates; this indicates the likely presence of an eruptive site. Arkose and conglomerate overlying the basement are exposed to the southeast; these probable fluvial deposits contain a few fragments of Dubawnt volcanic and sedimentary rocks in addition to basement detritus.

Table 5

Chemical composition of mafic trachyte and lamprophyre Christopher Island Formation, Tulemalu Lake map area
(For sample number and rock type see Table 2)

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Major element content (weight %)																		
SiO_2	45.4	46.3	47.0	52.1	52.6	53.3	54.3	54.9	55.0	55.2	55.4	55.7	55.4	56.2	56.5	58.2	59.2	59.8
TiO_2	0.39	0.78	0.77	0.62	0.62	0.59	0.61	0.70	0.71	0.48	0.64	0.67	0.66	0.57	0.59	0.60	0.54	0.55
Al_2O_3	9.8	9.30	10.7	11.0	12.9	11.4	12.7	14.3	11.7	12.1	12.1	11.2	13.7	11.6	12.1	13.4	13.4	12.3
Fe_2O_3	5.3	4.4	4.3	5.4	5.3	2.5	4.8	2.8	4.3	3.2	2.9	3.2	3.6	3.3	3.6	2.1	3.9	3.6
FeO	0.2	1.7	1.9	0.9	1.4	3.4	2.0	3.0	2.3	0.9	2.5	1.6	2.9	2.5	2.0	3.8	1.0	0.3
MnO	0.12	0.10	0.10	0.11	0.10	0.11	0.13	0.07	0.09	0.07	0.12	0.07	0.11	0.10	0.11	0.11	0.09	0.06
MgO	10.4	10.6	10.7	9.61	10.9	7.44	5.87	6.13	7.28	5.59	7.48	7.03	6.42	6.27	5.87	5.57	3.45	3.83
CaO	8.90	9.18	8.82	6.79	6.30	7.37	6.43	5.57	5.94	4.60	5.09	4.76	5.69	6.63	6.01	5.28	4.77	3.79
Na_2O	4.15	4.78	4.79	2.25	3.10	2.76	3.18	3.27	2.64	3.01	2.64	3.26	3.17	3.10	3.01	3.01	4.84	3.36
K_2O	0.17	2.60	2.40	6.68	5.13	5.74	6.03	4.36	6.51	6.05	7.35	6.25	6.20	6.65	6.86	6.01	4.81	5.46
P_2O_5	0.89	0.74	0.82	1.1	0.76	1.4	1.0	0.68	1.0	0.64	1.1	0.91	1.2	1.2	1.0	1.0	0.74	0.64
H_2OT	1.9	1.7	1.3	1.1	0.8	1.3	0.8	1.7	1.4	0.9	1.3	1.2	0.7	0.9	1.2	1.2	0.6	0.2
CO_2	12.6	6.5	6.2	2.6	0.0	3.2	1.5	1.5	1.4	6.7	1.3	2.4	0.0	0.7	1.8	0.1	2.2	4.8
S	0.17	0.33	0.13	0.06	0.02	0.04	0.13	0.15	0.03	0.22	0.15	0.19	0.03	0.04	0.05	0.13	0.04	0.15
Total	100.4	99.0	99.9	100.3	99.9	100.6	99.5	99.1	100.3	99.7	100.1	98.4	99.8	99.8	100.7	100.5	99.6	98.8
Trace element content (weight %)																		
Zr	0.004	0.025	0.026	0.007	0.007	0.018	0.015	0.011	0.020	0.024	0.019	0.024	0.014	0.028	0.025	0.017	0.033	0.017
Sr	0.054	0.25	0.22	0.079	0.15	0.22	0.13	0.13	0.085	0.16	0.088	0.18	0.13	0.22	0.22	0.11	0.14	0.18
Zn	0.005	0.014	0.031	0.008	0.010	0.009	0.011	0.007	0.009	0.006	0.012	0.007	0.006	0.009	0.007	0.007	0.007	0.002
Ni	0.021	0.026	0.037	0.028	0.031	0.012	0.011	0.015	0.012	0.014	0.018	0.019	0.015	0.007	0.008	0.007	0.010	0.015
Ba	0.48	0.48	0.35	0.17	0.27	0.36	0.24	0.18	0.27	0.31	0.29	0.28	0.23	0.40	0.38	0.19	0.28	0.46
Rb	0.000	-	-	0.054	0.032	0.025	0.028	-	0.036	-	0.045	-	0.043	0.025	0.024	0.036	0.024	0.019
U	0.00051	-	0.00060	0.00085	0.00037	0.00082	0.00083	-	0.00065	-	0.00126	-	0.00104	0.00062	0.00096	0.00077	0.00109	0.00033
K_2O+Na_2O	4.32	7.38	7.19	8.93	8.23	8.50	9.21	7.63	9.15	9.06	9.99	9.51	9.37	9.75	9.87	9.02	9.65	8.82
K_2O/Na_2O	0.04	0.54	0.50	2.97	1.65	2.08	1.90	1.33	2.47	2.00	2.78	1.92	1.96	2.15	2.28	2.00	0.99	1.63
CIPW norm																		
Q				-	-	0.58	-	3.81	0.55		-	2.85	-	-	1.50	2.15	7.23	
co				-	-	-	-	-	-		-	-	-	-	-	-	-	
or				39.69	30.50	34.10	36.06	36.39	38.82		43.89	37.84	36.89	39.66	40.66	35.72	28.73	
ab				19.14	20.81	23.47	27.23	28.34	22.54		21.54	23.37	27.01	22.85	24.12	25.62	39.68	
an				0.19	6.17	1.77	2.60	11.74	0.86		-	-	4.87	-	-	5.33	1.55	
ne				-	3.02	-	-	-	-		-	-	-	-	-	-	-	
ac				-	-	-	-	-	-		0.91	4.31	-	3.19	1.26	-	-	
mgdi				8.00	16.21	4.23	10.87	1.91	10.82		7.78	2.44	11.78	15.38	9.78	8.97	3.11	
fedi				-	-	0.67	-	0.20	-		0.48	-	0.89	1.67	0.12	2.37	-	
en				9.74	-	16.67	9.38	14.75	13.28		9.30	16.81	2.71	4.57	10.13	9.79	7.24	
fs				-	-	3.02	-	1.75	-		0.66	-	0.23	0.57	0.14	2.97	-	
fo				7.44	13.87	-	0.26	-	-		4.15	-	5.55	2.84	-	-	-	
fa				-	-	-	-	-	-		0.32	-	0.53	0.39	-	-	-	
mt				1.24	2.97	3.64	4.72	4.16	5.61		3.79	2.54	5.26	3.23	4.61	3.06	1.86	
il				1.18	1.18	1.13	1.17	1.36	1.36		1.23	1.30	1.26	1.09	1.12	1.15	1.04	
hm				4.57	3.28	-	1.60	-	0.47		-	0.03	-	-	-	-	2.66	
ru				-	-	-	-	-	-		-	-	-	-	-	-	-	
ap				2.62	1.81	3.33	2.40	1.65	2.39		2.63	2.21	2.86	2.87	2.38	2.38	1.77	
pr				0.11	0.04	0.08	0.25	0.29	0.06		0.28	0.36	0.06	0.08	0.09	0.24	0.08	
cc				5.95	-	7.32	3.45	3.49	3.21		2.99	5.99	-	1.61	4.11	0.23	5.06	
DI				58.83	54.33	58.15	63.29	58.55	61.90		65.43	64.09	63.89	62.51	66.27	63.49	75.64	

Note: Analyses by Analytical Chemistry Section, Geological Survey of Canada.

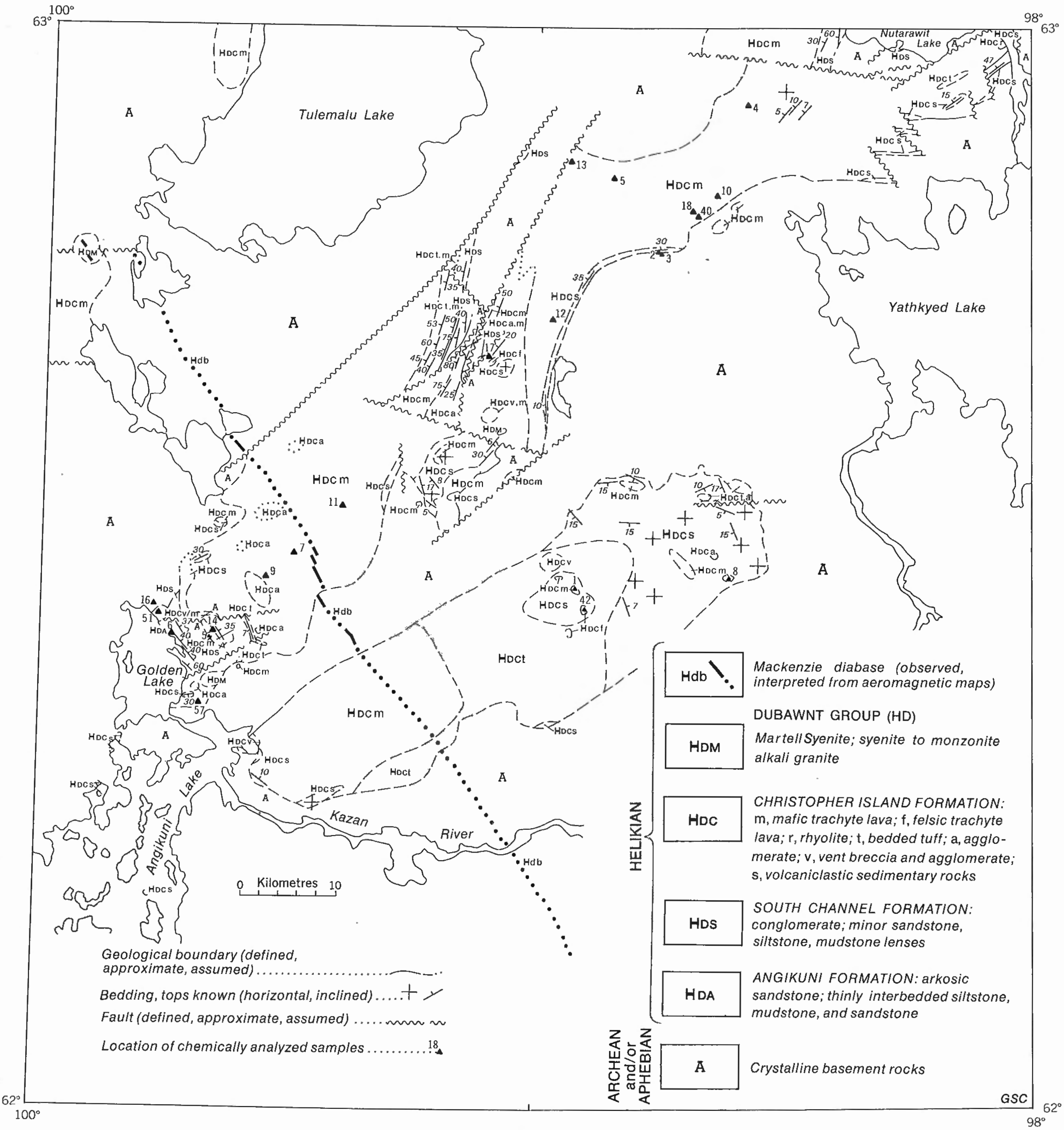


Figure 12. Dubawnt Group, Tulemalu Lake map area.

Table 6

Chemical composition of mafic trachyte and lamprophyre, Christopher Island Formation, Thirty Mile Lake and MacQuoid Lake map areas
(For sample numbers and rock types see Table 2)

No.	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Major element content (Weight %)																		
SiO_2	46.9	52.1	52.3	52.3	52.7	53.7	53.7	54.1	54.3	55.1	55.6	55.7	55.7	56.6	56.9	57.0	57.1	57.3
TiO_2	0.61	0.60	0.63	0.59	0.71	0.57	0.59	0.63	0.73	0.58	0.73	0.64	0.72	0.58	0.57	0.55	0.66	0.59
Al_2O_3	11.9	12.2	13.7	12.5	14.5	14.2	14.7	13.5	15.2	14.5	16.1	13.9	15.2	14.5	12.8	15.0	14.8	15.9
Fe_2O_3	3.7	4.9	4.2	4.9	3.9	3.7	2.8	6.8	3.5	3.4	2.1	4.5	2.2	2.0	2.7	4.5	2.2	3.3
FeO	1.8	0.7	3.0	2.4	4.7	0.5	3.6	1.3	3.5	2.7	5.0	2.6	4.5	3.1	1.8	0.4	4.4	1.4
MnO	0.10	0.08	0.09	0.12	0.16	0.10	0.10	0.13	0.12	0.11	0.12	0.11	0.11	0.13	0.09	0.06	0.11	0.09
MgO	10.3	5.64	8.75	6.98	6.45	4.56	6.45	5.87	6.34	5.80	4.41	6.55	5.01	6.55	6.42	3.13	5.03	6.13
CaO	5.71	8.54	6.06	7.67	5.01	4.32	6.04	5.75	6.45	6.95	5.21	5.59	5.35	4.63	5.71	4.63	4.37	2.88
Na_2O	3.84	3.03	1.78	2.45	3.77	4.20	2.85	2.58	3.00	2.81	3.46	2.52	3.20	2.94	2.71	4.86	3.50	2.85
K_2O	4.81	5.36	7.02	5.52	4.27	4.50	5.48	6.67	4.67	4.72	5.04	5.56	5.96	5.90	5.41	3.85	4.96	5.09
P_2O_5	0.80	0.94	0.56	0.87	0.83	0.61	0.67	1.1	0.81	0.85	0.70	0.85	0.56	0.70	0.68	0.74	0.70	0.56
H_2OT	2.7	1.1	1.9	1.5	2.2	1.2	1.6	1.3	1.8	1.0	0.6	1.5	0.6	1.6	1.6	1.5	1.4	2.4
CO_2	7.2	4.9	0.4	1.0	0.6	5.4	0.9	0.5	0.3	0.4	0.0	0.1	0.0	0.1	1.8	2.9	0.3	1.0
S	0.00	0.00	0.07	0.07	0.00	0.33	0.00	0.00	0.03	0.08	0.00	0.00	0.04	0.00	0.00	0.15	0.15	0.03
Total	100.4	100.1	100.5	98.9	99.8	97.9	99.5	100.2	100.8	99.0	99.1	100.1	99.2	99.3	99.2	99.3	99.7	99.5
Trace element content (weight %)																		
Zr	0.015	0.017	0.011	0.011	0.014	0.011	0.009	0.019	0.021	0.015	0.016	0.017	0.011	0.012	0.022	0.027	0.013	0.010
Sr	0.14	0.22	0.18	0.18	0.065	0.078	0.13	0.11	0.14	0.13	0.12	0.14	0.12	0.11	0.13	0.057	0.096	0.079
Zn	0.003	0.007	0.010	0.010	0.012	0.006	0.009	0.008	0.010	0.006	0.010	0.009	0.009	0.011	0.008	0.005	0.008	0.008
Ni	0.016	0.022	0.028	0.028	0.004	0.026	0.011	0.006	0.008	0.009	0.004	0.007	0.006	0.014	0.014	0.009	0.007	0.005
Ba	0.27	0.35	0.21	0.21	0.26	0.72	0.20	0.22	0.20	0.23	0.14	0.20	0.21	0.21	0.27	0.35	0.18	0.18
Rb	0.011	0.020	0.034	0.034	0.021	0.029	0.030	0.039	0.028	0.028	0.030	0.044	0.029	0.030	0.032	0.018	0.027	0.026
U	0.00082	0.00041	0.00052	0.00052	0.00131	0.00065	0.00076	0.00043	0.00069	0.00071	0.00061	0.00095	0.00046	0.00093	0.00122	0.00088	0.00071	0.0062
Na_2O+K_2O	8.65	8.39	8.80	7.97	8.04	8.70	8.33	9.25	7.67	7.53	8.50	0.08	9.16	8.84	8.12	8.71	3.46	7.94
K_2O/Na_2O	1.25	1.77	1.25	3.94	2.25	1.13	1.92	2.59	1.56	1.68	1.46	2.21	1.86	2.01	2.00	0.79	1.42	1.79
CIPW norm																		
Q			-	-	-		-	-	-	2.94	-	3.00	-	-	6.59	9.31	2.46	10.38
co			-	-	-		-	-	-	-	-	-	-	-	-	2.71	-	4.10
or			42.00	33.44	25.81		33.04	39.82	27.85	28.41	30.21	33.27	35.70	35.61	32.69	23.23	29.8	30.94
ab			14.21	21.25	32.63		24.60	22.05	25.62	24.22	29.70	21.59	27.44	25.41	23.45	41.99	30.11	24.80
an			8.77	6.98	10.26		11.36	5.61	14.35	13.25	13.71	10.32	9.64	9.13	6.94	0.52	10.19	4.80
ne			0.56	-	-		-	-	-	-	-	-	-	-	-	-	-	-
ac			-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
mgdi			11.90	15.87	4.02		6.24	10.28	7.70	10.33	4.39	9.17	8.19	6.36	4.92	-	3.35	-
fedi			0.48	-	0.99		1.19	-	1.07	0.75	2.26	0.11	3.09	1.13	0.08	-	1.19	-
en			-	8.02	6.39		8.09	8.64	11.99	9.92	6.98	12.27	1.90	13.08	14.07	7.96	11.18	15.70
fs			-	-	1.81		1.77	-	1.90	0.83	4.12	0.17	0.82	2.67	0.27	-	4.54	-
fo			11.59	1.71	5.73		3.79	0.95	0.26	-	1.49	-	4.87	0.44	-	-	-	-
fa			0.59	-	1.79		0.92	-	0.05	-	0.97	-	2.32	0.10	-	-	-	-
mt			6.17	6.35	5.78		4.14	2.52	5.12	5.02	3.09	6.61	3.23	2.96	4.00	-	3.24	3.10
il			1.21	1.15	1.38		1.14	1.21	1.40	1.12	1.41	1.23	1.39	1.13	1.11	0.65	1.27	1.15
hm			-	0.64	-		-	5.13	-	-	-	-	-	-	-	4.60	-	1.25
ru			-	-	-		-	-	-	-	-	-	-	-	-	0.22	-	-
ap			1.34	2.11	2.01		1.62	2.63	1.94	2.05	1.68	2.04	1.34	1.69	1.65	1.79	1.69	1.36
pr			0.13	0.13	-		-	-	0.06	0.15	-	-	0.08	-	-	0.29	0.29	0.06
cc			0.92	2.33	1.40		2.09	1.15	0.69	0.93	-	0.23	-	0.23	4.19	6.74	0.69	2.34
DI			56.77	54.69	58.44		57.65	61.87	53.47	55.57	59.91	57.86	63.14	61.02	62.73	77.24	62.37	70.22

Note: Analyses by Analytical Chemistry Section, Geological Survey of Canada.

Main northern outcrop area

This area of Dubawnt Group rocks is larger and more complex than the southern area, and is crossed and partly bounded by several major faults (Fig. 2, 7, 12). It includes outcrops of Angikuni Formation, South Channel Formation and Martell Syenite, but consists mainly of Christopher Island Formation.

In the northeast part the South Channel Formation is exposed only in the vicinity of Nutarawit Lake. It is at least 1000 m thick, and is overlain, probably conformably, by mafic trachyte lava flows of the Christopher Island Formation. The lavas and older rocks here are intruded by several lamprophyre dykes. To the south, on the north side of Yathkyed Lake, northerly dipping, partly volcaniclastic conglomerate, sandstone and siltstone of the Christopher Island Formation lie directly on basement. This sequence is generally less than 10 m thick, but is at least 1000 m thick in the extreme east, where it includes some thick layers of rhyolitic tuff. Mafic trachyte lavas overlie the sedimentary sequence, and overlap onto basement rocks to the west. Flows of felsic trachyte are present locally within the lava succession, and a rhyolite body is exposed within it in the east; the latter contains phenocrysts of feldspar and quartz and is locally pyritic. Agglomerate, tuff, and fine- to coarse-grained volcaniclastic sedimentary rocks, in places several metres thick, are locally interlayered with the lavas.

In the central part of the outcrop area the Dubawnt Group is also represented by the South Channel Formation and Christopher Island Formation. The South Channel Formation is present in the north, mainly northwest of a major northeast trending fault (labelled 'A', Fig. 7). Here it is up to 100 m or more thick and dips steeply west beneath conformably overlying volcanics of the Christopher Island Formation. These volcanics comprise a lower sequence at least 1600 m thick (labelled HDCt,m in Fig. 7) of fine- to coarse-grained bedded tuffs, some containing scoriaceous lava bombs, and subordinate interlayered mafic trachyte lavas, and an upper sequence over 400 m (labelled HDCm) thick of mainly mafic trachyte lava. A somewhat similar succession is exposed to the south and east, on the southeast side of the 'A' fault, but here the lower part of the volcanic succession consists mainly of massive agglomerate (labelled HDCa, in Fig. 7). This agglomerate may lie within the central core of a large volcano; if so the 200 m thick volcanic pile to the northwest may be part of the western flank succession of this volcano.

To the south the Christopher Island Formation consists of flat-lying to gently dipping agglomerate, tuff, mafic and felsic trachyte lava, volcaniclastic conglomerate and sandstone, and volcanic breccia. There is also an outcrop of Martell Syenite. The site of a volcanic vent (HDCv,m, Fig. 12) in this part of the area is indicated by an area of agglomerate, tuff, volcanic breccia, and richly xenolithic felsic to mafic trachyte lava. A zone of abundant secondary carbonate and chert on the southeast side of this vent may be the result of fumarolic activity. Syenite is exposed to the south, intruding interlayered tuff and mafic trachyte lava. Farther south, conglomerate and mafic trachyte lava lie on an irregularly eroded basement surface on which a fossil regolith consisting of reddened altered granitic rock, is locally preserved.

In the southwest part of the main northern outcrop area the Dubawnt Group is represented by sedimentary rocks of the Angikuni and South Channel formations, volcanic rocks of the Christopher Island Formation, and medium grained intrusive rocks mapped as Martell Syenite. Most of the Dubawnt rocks, except for those of the Angikuni Formation, appear to be flat-lying to gently dipping. The Angikuni Formation is confined to the far southwest (Fig. 2), where it dips steeply northeast and is at least 1900 m thick. Its outcrop is bounded by faults on the north, east and south sides, and by 'Golden Lake' to the west. Conglomerate assigned to the South Channel Formation is exposed north and east of the Angikuni Formation, where it appears to be overlain conformably by volcanics of the Christopher Island Formation, the main unit in the area. The volcanics comprise mafic trachyte lava, vent agglomerate and breccia, massive agglomerate and tuff, bedded tuffaceous and volcaniclastic sandstone and conglomerate, and lamprophyre intrusions. Best exposed are massive lavas; these give rise to steep-sided low hills and ridges, some of which are flat-topped and resemble mesas.

Three volcanic vents are present on the east side of 'Golden Lake', and two probable former craters, now filled with mafic trachyte lava, occur to the east (Fig. 2). Other eruptive centres may be represented by outcrops of massive agglomerate. The three volcanic vents are aligned north-northwest. They contain agglomerate, breccia, and lava, and coincide with concentrations of minor intrusions. The two southerly vents, which could be part of a single complex vent, are situated within the outcrop area of the Angikuni Formation. Both appear to be less than 500 m across. In one of these two vents, that to the north, mainly agglomerate is exposed, whereas in the other vent xenolithic lava predominates. The agglomerate and lava both contain sub-angular to angular blocks, some over 1 m across, of crystalline basement rocks, sedimentary rocks derived from the Angikuni Formation, and contemporaneous mafic trachyte. The vent agglomerate and lava are surface or near surface rock types, and as they cut sedimentary rocks which lie at least 1600 m stratigraphically below the top of the Angikuni Formation, a unit which does not contain any volcanic material, they indicate that the two vents were formed after the Angikuni Formation had been tilted, faulted, and eroded to more or less the level of the present land surface. The third and most northerly vent is about 1500 m across, and has fractured conglomerate of the South Channel Formation exposed on its east side. It contains mainly breccia formed of basement rocks (granitic and chloritic gneiss, amphibolite, quartzite) and minor quartz arenite, mafic trachyte and felsic trachyte fragments enclosed in a medium- to fine-grained matrix consisting partly of altered volcanic glass. Some massive mafic trachyte lava is present in the centre of the vent. This lava is cut by curved chloritic veinlets, which probably developed along either flowage features or cooling joints, and it contains actinolite pseudomorphically replacing pyroxene phenocrysts and filling vesicles; the chlorite and actinolite are attributed to hydrothermal metamorphism associated with the volcanicity.

The two circular probable craters filled with massive mafic trachyte lava 20 or more metres thick are situated at 62°26'N, 99°39'W and 62°24'N, 99°36'W (Fig. 2). The lava in the more southerly crater contains basement xenoliths and shows swirl-like flow features.

Microsyenite and syenite intrusions, and a single body of partly granophyric alkali granite (at 62°27'N, 99°37'W), all mapped as Martell Syenite, cut rocks of the Christopher Island, South Channel, and Angikuni formations and the basement. One of the best exposed intrusions is a sill of porphyritic microsyenite (sample no. 6 in Tables 2, 5) over 100 m thick and 2 km long within the Angikuni Formation on the northeast side of 'Golden Lake' (Fig. 2).

Table 7

Chemical composition of felsic trachyte and rhyolite, Christopher Island Formation (CIF) and Pitz Formation (PF), and of Martell Syenite.
(For sample numbers and rock types see Tables 3 and 4)

	Felsic trachyte (CIF)								Rhyolite (CIF)		Rhyolite (PF)	
No.	37	38	39	40	41	42	43	44	45	46	47	48
Major element content (weight %)												
SiO_2	59.9	59.9	61.2	61.8	63.3	63.6	65.6	69.4	75.7	75.8	66.3	70.8
TiO_2	0.32	0.45	0.44	0.26	0.29	0.54	0.13	0.57	0.16	0.07	0.93	0.58
Al_2O_3	14.9	14.2	13.3	15.9	17.5	12.3	16.3	15.3	14.8	11.0	14.4	18.6
Fe_2O_3	1.8	3.5	1.8	4.0	1.0	3.3	1.1	4.8	0.4	0.0	1.5	2.6
FeO	0.1	1.2	2.8	0.0	1.7	0.3	0.2	0.0	0.0	0.4	1.3	0.3
MnO	0.07	0.08	0.08	0.06	0.08	0.05	0.06	0.00	0.01	0.02	0.08	0.02
MgO	0.62	4.40	5.67	1.81	1.25	3.64	0.63	0.20	0.06	0.30	1.85	0.11
CaO	5.67	2.88	4.31	2.33	2.80	3.16	2.72	0.47	0.06	0.33	2.09	0.04
Na_2O	5.86	3.16	3.03	3.30	4.06	5.14	3.75	8.22	3.53	0.15	3.20	0.13
K_2O	3.13	6.12	3.97	7.94	5.63	2.83	6.88	0.31	6.21	9.73	5.37	0.99
P_2O_5	0.22	0.52	0.39	0.32	0.21	0.51	0.12	0.37	0.05	0.05	0.33	0.18
H_2OT	0.5	1.4	1.8	0.8	1.3	0.4	0.8	1.0	0.4	0.5	1.5	3.9
CO_2	5.0	1.1	0.1	1.7	2.2	3.6	2.2	0.0	0.0	0.3	1.4	0.0
S	0.21	0.00	0.05	0.03	0.00	0.24	0.00	0.17	0.00	0.07	0.00	0.05
Total	98.3	98.9	98.9	100.3	101.3	99.6	100.5	100.8	101.4	98.7	100.3	98.3
Trace element content (weight %)												
Zr	0.030	0.019	0.010	0.018	0.017	0.023	0.019	0.012	0.017	0.002	0.061	0.054
Sr	0.049	0.091	0.072	0.099	0.080	0.098	0.015	0.004	0.009	0.004	0.009	0.053
Zn	0.001	0.009	0.009	0.005	0.008	0.002	0.003	0.000	0.002	0.001	0.005	0.001
Ni	0.001	0.005	0.012	0.008	0.02	0.008	0.001	0.003	0.001	0.001	0.002	0.002
Ba	0.64	0.18	0.13	0.13	0.22	0.24	0.055	0.048	0.077	0.022	0.11	0.016
Rb	0.006	0.040	0.021	0.050	0.027	-	0.041	-	0.027	0.031	0.021	0.002
U	0.00030	0.00131	0.00090	0.00080	0.00091	-	0.00056	-	0.00057	0.00043	0.00032	0.00028
Na_2O+K_2O	8.99	9.28	7.00	11.24	9.69	7.97	10.63	8.53	9.74	9.88	8.57	1.02
K_2O/Na_2O	0.53	1.94	1.31	2.41	1.39	0.55	1.83	0.04	1.76	64.87	1.68	7.62
CIPW norm												
Q		9.92	12.57	9.59	15.39	17.84	16.60		30.94		24.69	
co		0.82	-	1.89	4.73	0.80	2.70		2.20		3.37	
or		37.05	24.12	47.22	33.28	17.10	40.84		36.33		32.14	
ab		27.39	26.36	28.10	34.36	44.46	31.87		29.57		27.42	
an		4.40	11.27	-	-	-	-		0.13		-	
ne		-	-	-	-	-	-		-		-	
ac		-	-	-	-	-	-		-		-	
mgdi		-	5.18	-	-	-	-		-		-	
fedi		-	0.95	-	-	-	-		-		-	
en		11.23	12.12	4.54	3.11	9.27	1.58		0.15		4.67	
fs		-	2.54	-	1.97	-	-		-		-	
fo		-	-	-	-	-	-		-		-	
fa		-	-	-	-	-	-		-		-	
mt		2.92	2.68	-	1.45	-	0.47		-		1.78	
il		0.88	0.86	0.08	0.55	0.10	0.25		0.02		1.79	
hm		1.57	-	4.03	-	3.37	0.78		0.40		0.29	
ru		-	-	0.22	-	0.50	-		0.15		-	
ap		1.26	0.95	0.76	0.50	1.24	0.29		0.12		0.79	
pr		-	0.10	0.06	-	0.46	-		-		-	
cc		2.56	0.23	3.53	4.67	4.72	4.63		-		3.07	
DI		75.18	63.04	86.79	87.75	80.20	92.01		99.04		87.61	

Table 7 (cont.)

	Martell Syenite														
No.	49	50	51	52*	53	54	55	56	57	58	59	60	61	62	63
	Major element content (weight %))														
SiO_2	50.1	52.1	52.9	53.2	54.0	54.5	54.4	55.0	55.3	55.9	56.7	57.3	57.9	58.8	63.2
TiO_2	0.54	0.77	0.79	0.60	0.76	0.71	0.52	0.67	0.72	0.60	0.47	0.54	0.70	0.72	0.69
Al_2O_3	13.3	14.4	14.2	11.1	14.6	15.4	14.9	11.3	14.1	15.4	13.7	13.9	16.9	14.8	16.6
Fe_2O_3	2.6	3.2	2.6	1.6	1.7	3.8	2.0	2.2	1.9	1.1	2.2	1.6	3.9	2.7	3.3
FeO	5.5	4.1	5.1	2.8	5.6	4.3	4.0	3.2	5.4	4.8	3.9	4.1	3.3	3.7	1.5
MnO	0.13	0.09	0.13	0.08	0.12	0.15	0.12	0.12	0.11	0.09	0.10	0.10	0.13	0.11	0.05
MgO	9.14	4.65	5.71	8.03	5.51	6.52	5.25	7.97	6.00	6.07	6.21	5.85	3.61	4.00	2.24
CaO	6.62	4.87	6.10	7.50	5.77	6.32	5.10	6.02	5.11	5.37	5.32	4.91	3.89	4.05	1.86
Na_2O	2.40	3.53	3.30	2.72	3.24	3.25	3.44	2.59	2.78	3.20	3.48	3.35	2.79	3.48	3.75
K_2O	4.77	4.65	4.43	5.67	4.64	4.81	5.98	6.65	6.24	5.61	5.80	5.47	5.29	5.33	6.25
P_2O_5	0.59	0.57	0.64	1.90	0.70	0.48	0.93	1.40	0.67	0.59	0.94	0.67	0.71	0.71	0.47
H_2OT	2.7	2.2	1.2	1.3	1.7	1.4	0.5	1.7	1.2	0.4	0.7	0.9	1.1	1.0	1.0
CO_2	0.2	2.6	1.0	1.9	0.0	0.0	0.6	1.3	0.0	0.3	0.0	0.5	0.0	0.5	0.0
S	0.06	0.13	0.09	0.20	0.03	0.07	0.06	0.16	0.05	0.00	0.02	0.06	0.00	0.16	0.00
Total	98.7	97.9	98.2	98.7	98.6	101.7	98.3	100.3	99.6	99.4	99.5	99.3	100.2	100.1	100.9
	Trace element content (weight %)														
Zr	0.007	0.012	0.006	0.028	0.011	0.008	0.009	0.029	0.012	0.008	0.026	0.023	0.052	0.025	0.14
Sr	0.11	0.081	0.10	0.15	0.11	0.098	0.19	0.12	0.11	0.13	0.14	0.12	0.10	0.12	0.060
Zn	0.009	0.011	0.008	0.006	0.006	0.008	0.009	0.014	0.009	0.008	0.007	0.007	0.011	0.007	0.007
Ni	0.011	0.005	0.006	0.016	0.004	0.005	0.007	0.019	0.006	0.013	0.013	0.010	0.004	0.007	0.004
Ba	0.13	0.15	0.16	0.52	0.15	0.18	0.30	0.31	0.19	0.23	0.17	0.16	0.16	0.24	0.15
Rb	0.029	0.021	0.024	0.012	0.025	0.025	0.029	0.037	0.043	0.038	0.033	0.026	0.033	0.028	0.061
U	0.00026	0.00060	0.00042	0.00053	0.00046	0.00047	0.00079	0.00158	0.00071	0.00044	0.00095	0.00042	0.00127	0.00078	0.00282
Na_2O+K_2O	7.17	8.18	7.73	8.39	7.88	8.06	9.42	9.24	9.02	8.81	9.28	8.82	8.08	8.81	10.00
K_2O/Na_2O	1.99	1.32	1.34	2.08	1.43	1.48	1.74	2.57	2.24	1.75	1.67	1.63	1.90	1.53	1.67
	CIPW norm														
Q	-	3.53	-	-	-	-	-	-	-	-	-	0.57	3.19	6.06	11.34
co	-	2.07	-	-	-	-	-	-	-	-	-	-	-	-	1.30
or	29.32	28.70	26.95	34.34	28.31	28.31	36.24	39.79	37.44	33.42	34.61	32.82	31.19	31.76	36.93
ab	19.21	31.20	28.75	23.58	28.31	27.39	29.85	21.36	23.88	27.29	29.74	28.78	31.99	29.69	31.73
an	11.89	4.50	11.17	1.37	11.97	13.17	7.75	-	7.68	11.18	4.68	6.84	13.45	9.10	6.46
ne	1.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ac	-	-	-	-	-	-	-	0.73	-	-	-	-	-	-	-
mgdi	10.84	-	5.62	9.07	7.18	10.13	5.26	9.26	7.95	5.94	10.19	6.43	1.01	2.36	-
fedi	2.95	-	2.05	1.03	3.53	2.03	1.73	1.25	3.38	2.43	2.70	2.06	0.19	0.68	-
en	-	12.10	9.05	13.96	5.77	2.25	1.24	11.43	3.44	3.89	3.82	11.81	8.50	8.95	5.58
fs	-	3.69	3.78	1.82	3.25	0.52	0.47	1.78	1.68	1.82	1.16	4.35	1.84	2.94	-
fo	13.07	-	2.09	1.63	3.56	6.46	6.82	3.07	5.64	6.02	4.96	-	-	-	-
fa	4.49	-	0.96	0.23	2.21	1.64	2.83	0.53	3.03	3.11	1.66	-	-	-	-
mt	3.92	4.85	3.88	2.38	2.55	5.49	2.97	2.87	2.80	1.61	3.22	2.36	5.64	3.95	3.03
il	1.07	1.53	1.54	1.17	1.49	1.34	1.01	1.29	1.39	1.15	0.90	1.04	1.33	1.38	1.31
hm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.21
ru	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ap	1.45	1.41	1.56	4.61	1.71	1.13	2.26	3.36	1.61	1.41	2.25	1.61	1.68	1.70	1.11
pr	0.12	0.25	0.17	0.38	0.06	0.13	0.12	0.30	0.09	-	0.04	0.11	-	0.30	-
cc	0.47	6.18	2.34	4.43	-	-	1.40	2.99	-	0.69	-	1.15	-	1.15	-
DI	49.56	65.50	55.70	57.92	56.62	55.70	66.10	61.15	61.32	60.71	64.35	62.18	66.37	67.51	81.29

Note: Analyses by Analytical Chemistry Section, Geological Survey of Canada. * Lamprophyre dyke

Outcrop areas west and southwest of Tulemalu Lake

Mafic trachyte lavas of the Christopher Island Formation predominate in both the Dubawnt outcrop area west of Tulemalu Lake and that to the southwest. The latter area also includes, in the north, a syenitic intrusive complex mapped as possible Martell Syenite. This complex is made up of foliated medium- to coarse-grained hornblende syenite to syenodiorite cut by veins of aplite and dykes of microsyenite, biotite lamprophyre and gabbro. The gabbro intrusions may belong to the Mackenzie dyke swarm.

Angikuni Lake outliers

Three small outliers of Christopher Island Formation are present on the northwest side of Angikuni Lake and another forms part of a small island within the lake to the south-southeast (Fig. 12). The northwestern outliers consist of partly volcaniclastic conglomerate and sandstone. The island outlier is formed of breccia containing basement and volcanic fragments up to 50 cm across. The breccia, a probable scree deposit, overlies red altered gneiss which may represent a paleosol. The contact between the breccia and the gneiss appears flat-lying in the north and nearly vertical in the south.

DUBAWNT GROUP VOLCANICS IN THE THIRTY MILE LAKE (EAST HALF) AND MACQUOID LAKE (WEST HALF) MAP AREAS

Dubawnt Group rocks are confined to the northern part of these areas, occupying the southern part of a basin which has its main axis trending east-northeast across Pitz Lake and along the southern side of Baker Lake (Fig. 4). Six of the formally named units of the Dubawnt Group are present. Shallow water fluvial sediments and subaerial volcanics are exposed in the south whereas to the north many of the sediments may be deeper water deposits, and there are some subaqueous volcanic rocks.

The redbeds of the lower part of the Dubawnt succession are more extensive in this area than in the Tulemalu Lake map area. The conglomeratic South Channel Formation, mainly representing alluvial fan deposits, is exposed in the south, unconformably overlying basement rocks. Irregularities in the unconformity (Fig. 4) are due partly to the basement surface having a considerable relief, and partly to offsets along faults. The South Channel Formation ranges in thickness from 0 to about 1800 m, and dips northwards. Steep dips (45° to 80°) in the west are attributed to tilting associated with penecontemporaneous faulting, probably along an east-northeast trending fault south of and roughly parallel to the Dubawnt unconformity in this part of the area (LeCheminant et al., 1977).

The conformably overlying Kazan Formation, consisting predominantly of crossbedded arkose, dips mainly gently northwards. It is thickest in the east, north of Bissett Lake, where it is probably at least 1000 m thick. In the west, north of Thirty Mile Lake, it is thin and locally absent. Conglomerate lenses occur locally, the largest being a band about 5 km long and 200 m thick, 15 km northeast of Kazan Falls (Fig. 4). This band dips north at 75°-80°, presumably due to tilting along a penecontemporaneous fault on its south side, downthrown to the north.

The main outcrop area of Dubawnt volcanic rocks is north of Thirty Mile Lake and west of the Kazan River downstream from Kazan Falls, mainly in the Thirty Mile Lake map area. Here the Christopher Island and Pitz formations are exposed, and the sedimentary Thelon Formation. All three formations in this area are cut by basic dykes of the Mackenzie swarm, one of which intrudes South Channel Formation and basement rocks to the southeast.

A partly fault-bounded exposure of Christopher Island Formation outcrops between Kazan Falls and Bissett Lake, and a lens of volcaniclastic rocks mapped as Christopher Island Formation occurs within the Kazan Formation to the north, on the northeast side of Martell Lake.

Intrusions of Martell Syenite are confined mainly to the MacQuoid Lake map area, where they occur within outcrops of basement rocks, Kazan Formation, and Christopher Island Formation.

Outcrop area north of Thirty Mile Lake and west of the Kazan River

Christopher Island Formation

The Christopher Island Formation here is made up of lava (mafic trachyte and minor felsic trachyte and rhyolite), agglomerate, tuff, volcaniclastic sedimentary rocks, and lamprophyre and feldspar porphyry dykes. Because trachyte and rhyolite lavas being highly viscous, are unlikely to have travelled far from their emission sources, probable and possible eruptive sites are marked by outcrops of these lavas. The sites are also marked by occurrences of coarse agglomerate and richly xenolithic lava.

Mafic trachyte lava flows are widespread, and are thought to be mainly subaerial. Interlayered pyroclastics and volcaniclastic sedimentary rocks indicate that the lavas have mainly gentle to moderate dips (up to 35°), and may locally retain their original attitudes. In the northeast, mafic trachyte flows at the base of the formation interfinger with Kazan arkose. In a cliff section at 63°56'N, 95°36'W (Fig. 13), Kazan arkose is separated from a conformably overlying mafic lava flow by 2 m of bedded waterlain tuff; to the north this flow is overlain by Kazan arkose. North of the eastern half of Thirty Mile Lake mafic lavas appear to lie directly on basement rocks and also to interfinger in places with South Channel conglomerate and Kazan arkose (Fig. 4). These apparent relationships could be due to local faulting.

Mafic trachyte exposed 22 km north of Kazan Falls may represent a vent-filling lava. It contains abundant xenoliths, mainly volcanic, in a porphyritic lava-type (Fig. 14).

Not all extrusions of mafic trachyte appear to have been subaerial. For instance, in the extreme west, about 10 km north of Kazan River, between two bodies of felsic trachyte, the upper part of one mafic trachyte lava consists of an altered palagonite-type breccia, indicating possible subaqueous volcanicity. In this breccia irregular fragments of dark brown trachyte are enclosed in a pinkish, fine grained, silicified sandstone made up predominantly of grains of altered volcanic glass; the breccia passes down into massive lava which overlies bedded waterlain tuffs.

Subaqueous volcanic eruptions are also thought to have taken place in the northwest corner of the area (Fig. 9), where volcanics of the Christopher Island Formation form the southern flank succession of what was probably an underwater volcanic cone. The oldest rock exposed is a highly altered, massive to brecciated and agglomeratic trachyte lava. It is overlain to the south by agglomerate, several metres thick, containing scoriaceous lava fragments. Above the agglomerate is a sequence of about 1000 m of bedded waterlain sediments which become generally finer grained upwards. This sequence is mainly interbedded volcaniclastic rocks; thin bedded to laminated, fine- to coarse-grained, highly tuffaceous sandstone containing clasts of altered volcanic glass and abundant angular white grains that are probably altered feldspar; conglomerate, especially near the base of the sequence, formed of subangular to subrounded mafic trachyte clasts; thin bedded to laminated and commonly brecciated hematitic tuffaceous mudstone and muddy sandstone; and brecciated chert probably representing very fine grained silicified tuff. The sequence also includes some interbeds of pink arkosic and quartzose sandstone containing little or no volcanic material. Most of the volcaniclastic rocks are regarded as hyaloclastites.

Felsic trachyte lavas have been found at only a few localities. Their main occurrence is in the west, where four separate felsic trachyte lavas, interpreted as cumulodomes occupying former craters (which were probably breached), are exposed, 17 to 20 km southwest of Pitz Lake (Fig. 4). These form broad hills which are surrounded by low lying exposures of less resistant mafic lava flows, tuff, and agglomerate. The cumulodome in the northwest dips northwest at about 25° (assuming that the regular close jointing present is parallel to its base). A marshy depression, possibly along a fault line, separates this cumulodome from one to the south, around which mafic lavas and interlayered tuffs dip up to 35° northwest and west-northwest. To the east is a third cumulodome, which is flanked by outwardly dipping mafic lavas; on its southeast side this cumulodome has a near-vertical crosscutting contact with the mafic lavas, the contact being the wall of the crater filled by the felsic trachyte (Fig. 15). The fourth cumulodome lies to the east-southeast; the volcanic sequence to the south of it includes a microsyenite intrusion.

Rhyolite extrusions are present in the northeast of the MacQuoid Lake map area. The main body is a partly exhumed cumulodome forming a prominent, dome-shaped hill, about 150 m high, 30 km north of Kazan Falls. Most of this cumulodome lies in the adjoining Baker Lake map area. The rhyolite here shows contorted flow-banding and internal breccia zones. At its base, exposed in the east, flow-banded rhyolite passes down into brecciated rhyolite, several metres thick, which overlies bedded tuffs. On its west side the cumulodome is intruded by a lamprophyre dyke.

Figure 13. Conformable contact between arkose of the Kazan Formation and overlying bedded tuff and cliff-forming mafic trachyte lava of the Christopher Island Formation, 13 km northwest of Martell Lake, MacQuoid Lake map area. (GSC 203324-D)

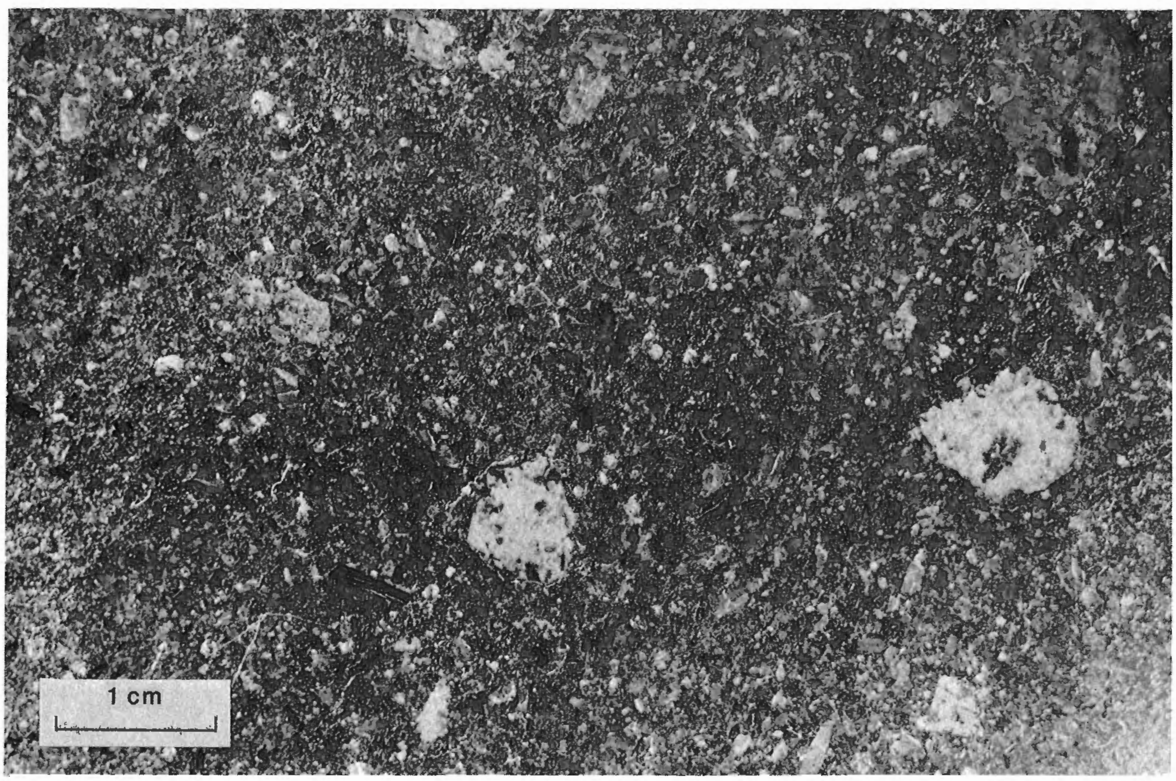


Figure 14. Xenolithic mafic trachyte, a possible vent filling lava 22 km north of Kazan Falls, MacQuoid Lake map area. (GSC 203350)

Similar rhyolite associated with bedded tuffaceous sedimentary rocks and intruded by Martell Syenite is exposed 5 km to the southwest. Another body of rhyolite is present 50 km to the east, in the east half of the MacQuoid Lake map area (Fig. 4). All these rhyolite extrusions occur near the base of the Christopher Island Formation.

Agglomerate and tuff are commonly interlayered with lava flows, and they also form separate masses which may mark eruptive sites. One probable eruptive site, 13 km northwest of Martell Lake, appears to have been active while Kazan arkose was being deposited nearby. Here a circular structure less than 1 km in diameter and thought to represent a volcanic vent, has moderate to steep inward dips. The outer part of the structure in the east consists of arkose similar to that of the surrounding Kazan Formation except that it contains scattered small angular volcanic fragments. The arkose passes inwards into mainly coarse grained, poorly sorted, bedded tuffs which grade into a central core formed of massive agglomerate. Inward dips of the bedded rocks range from 10° on the outer, eastern side to vertical on the north side of the structure.

Volcaniclastic sedimentary rocks southwest of Pitz Lake overlie and interfinger with mafic trachyte lava flows to the south, and are overlapped by Thelon sandstone to the north. The thickness of the volcaniclastic sequence here probably exceeds one hundred metres, and consists mainly of conglomerate and coarse- to fine-grained sandstone made up almost entirely of volcanic detritus. The conglomerate and sandstone commonly show crossbedding. At its easternmost exposure, a stream section just south of Pitz Lake, this sequence also includes interbeds of thin bedded to laminated siltstone which show ripple marks, desiccation cracks, rain prints, heavy mineral laminae, and flute casts; these sedimentary features together indicate very shallow water deposition, possibly in ephemeral lakes.

The volcaniclastic sequence in the northwest of the MacQuoid Lake map area consists of sandstone, siltstone, mudstone and conglomerate, and may have a maximum thickness of more than 1000 m. It interfingers with and overlies Kazan arkose, and is overlain by, and also interfingers with, lava flows. North of the MacQuoid Lake map area, in the southest corner of the Baker Lake map area, it passes upwards into poorly sorted and locally agglomeratic bedded tuffaceous rocks that may represent air-fall deposits. In the far south, 8 km northwest of Kazan Falls, the sedimentary sequence is about 100 m thick and is sandwiched between two flows of mafic trachyte lava. Here it consists mainly of medium to thin beds of crossbedded sandstone between which are mudstone laminae showing ripple marks and desiccation cracks, but it also includes conglomerate beds near the base and thin bedded to finely laminated hematitic and calcareous siltstone and mudstone, which are probably lacustrine deposits, near the top. The volcaniclastic sequence at this locality has been updomed by two laccolithic intrusions of Martell Syenite, the roof contacts of which are exposed (Fig. 10).

Dykes are exposed locally within the main outcrop of Dubawnt volcanics, but are more common to the east, intruding Kazan arkose, and to the south, intruding basement rocks south of the Dubawnt unconformity. Most of the dykes are of lamprophyre, but some felsic types are present in the east.

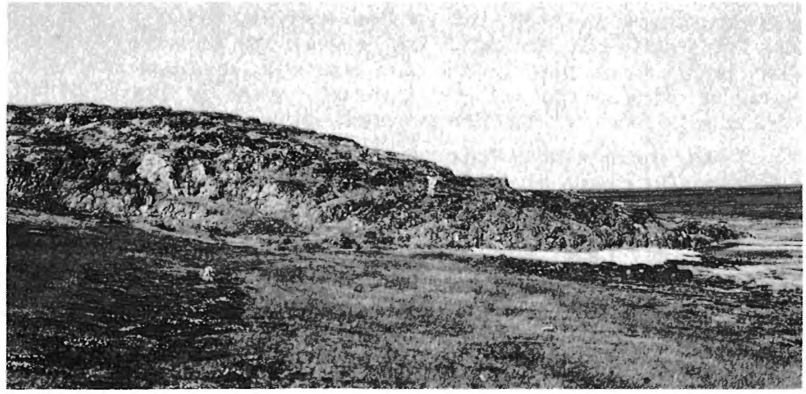


Figure 15. Crater-filling cumulodome of felsic trachyte flanked by outwardly dipping older flows of mafic trachyte. Exposure southwest of the Pitz Lake, Thirty Mile Lake map area. (GSC 203324-C)

Figure 16. Autobrecciated porphyritic rhyolite of the Pitz Formation, Thirty Mile Lake map area. (GSC 203324-A)

Pitz Formation

The Pitz Formation is represented by two separate lavas exposed in the northwest of the area. The main flow forms a series of lobes which have a maximum thickness of about 100 m. The lobes appear to have gentle dips, which may more or less correspond to their original attitudes, and they form rounded to flat-topped ridges with steep sides, partly reflecting their original shapes.

In the north the main lava overlies volcanics of the Christopher Island Formation, apparently conformably, (Fig. 9), and to the southwest it appears to overlie the other Pitz lava, which in this area is of considerably lesser extent. Both lavas are overlapped by clastic sediments of the Thelon Formation, which originally filled the depressions between the steep-sided lava lobes.

Although massive in places, the main lava is brecciated at most exposures. This is because it has extensively autobrecciated margins, including tops, which are intimately mixed with red, pink and orange chert, siltstone, and sandstone consisting mainly of altered volcanic glass and phenocryst fragments (Fig. 16). The marginal breccias and associated sediments are together interpreted as hyaloclastites, and indicate that the lava was probably erupted under water. The associated sediments fill irregular cracks and crevices in the inner and more massive parts of the flow margins and form a sparse to abundant matrix enclosing angular lava fragments in the outer parts. Locally these sediments can be seen to pass laterally outwards and conformably upwards into sandstone of the Thelon Formation, showing that there was essentially no time break between the emplacement of the lava lobes and the deposition of the Thelon Formation.

Good exposures through part of the main flow can be seen in a gorge near the western edge of the area, at 63°53'N, 96°58'W. In a cliff face (Fig. 17), a deep red to maroon, arcuate lensoid zone up to 5 m thick is exposed between paler porphyry lava above and below. The lensoid zone consists largely of spherulites which attain a width of 5 cm in the upper part but are generally less than 5 mm in the lower part. The zone is not sharply bounded; instead it grades into the massive lava above and below over a distance of a few centimetres. Both it and the massive lava are crossed by several thin, irregular veinlets of white clay. A possible interpretation for the lensoid zone is that it represents hydration resulting from the trapping of water within the lava flow during subaqueous extrusion: water, converted to steam and under pressure, became trapped in the lava, which as it chilled, formed a more hydrated glass than elsewhere; subsequent devitrification of this glass resulted in the formation of spherulites. Along the gorge to the northwest of this cliff the steep, possibly faulted, side of the main flow is exposed alongside fanglomerate made up entirely of subangular to subrounded clasts derived from the flow. The fanglomerate, which may be a subaqueous avalanche deposit, dips gently northwest and is overlain conformably by Thelon sandstone which contains an appreciable amount of volcanic detritus.

The main lava of the Pitz Formation has abundant phenocrysts up to 2 cm across of feldspar pseudomorphically replaced by kaolinite, and subordinate smaller phenocrysts of altered ferromagnesian minerals and partly resorbed quartz. A modal analysis of a sample from this lava is given in Table 3 (No. 48). The phenocrysts are set in a very fine grained, iron-stained, siliceous matrix representing altered volcanic glass. Intense silica and carbonate veining is present locally, possibly resulting from contemporaneous fumarolic activity. In the other lava (Table 3, No. 47) the phenocrysts are up to 1 cm across and form 30 to 40 per cent of the total rock: phenocrysts of generally little altered plagioclase and alkali feldspar predominate. This lava differs from the main lava in three respects: it does not appear to be associated with hyaloclastites, its phenocrysts commonly occur in clots rather than singly, and it contains little altered feldspar. The contrast in alteration of the feldspar phenocrysts in the two lavas indicates that the kaolinite in the main lava was probably formed hydrothermally during or immediately after extrusion of this lava, rather than during any subsequent weathering.

Outcrop area between Kazan Falls and Bissett Lake

The Dubawnt volcanics in this area are represented by the Christopher Island Formation, which here consists of mafic trachyte lava, volcaniclastic sedimentary rocks, agglomerate, tuff, and a few lamprophyre dykes. The formation overlies Kazan arkose to the north, apparently conformably, and it is faulted against basement rocks to the southwest.

In the west a sequence about 200 m thick of gently dipping volcaniclastic sandstone, conglomerate, and minor ripple marked siltstone and mudstone is exposed on the north side of a broad hill, overlying Kazan arkose. To the south this sequence is overlain conformably by a series of mafic trachyte lava flows with some interlayered agglomerate and, in the west, a pink felsic tuff bed about 10 m thick. The tuff, which may be an ignimbritic deposit, contains devitrified glass shards (now silica), phenocrystic quartz, potassic feldspar, and sodic plagioclase, and subrounded clasts of vesicular mafic trachyte.

The eastern exposures consist of mafic trachyte lava and minor agglomerate.

Outcrop on northeast side of Martell Lake

A sequence more than 100 m thick of interbedded volcaniclastic conglomerate and sandstone is exposed on two hills close to the northeast tip of Martell Lake, apparently forming a lens surrounded by Kazan arkose. The volcaniclastic rocks are mainly medium bedded and show large scale, low-angle crossbedding, with sets many metres thick and many tens of metres long. This crossbedding suggests that the sequence may represent a series of coalescing fan deposits, perhaps on the flanks of a hidden or eroded volcano.

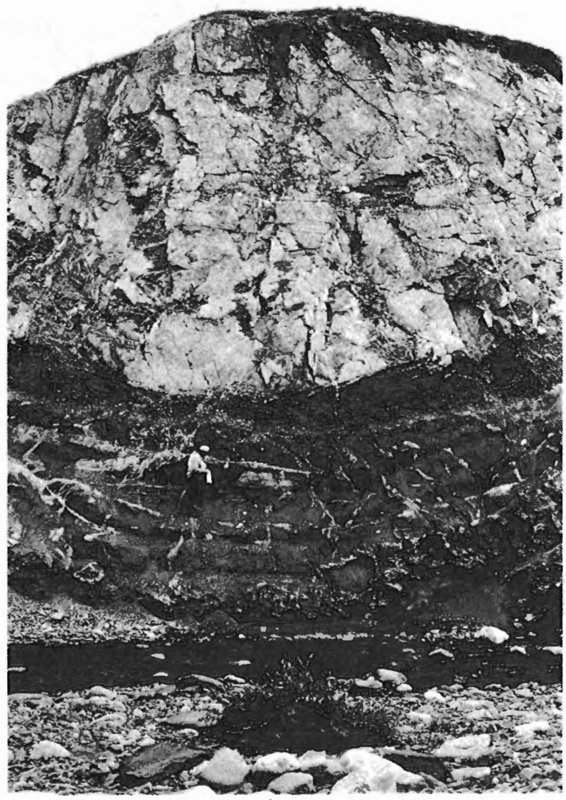


Figure 17. Cliff exposure of porphyritic rhyolite, Pitz Formation, showing lensoid spherulitic zone. Gorge near western edge of the Thirty Mile Lake (east half) map area. (GSC 203324-B)

The conglomerate beds consist predominantly of angular to rounded clasts up to 15 cm across of scoriaceous mafic trachyte which has a green mineral, possibly celadonite, in vesicles. These clasts must be locally derived, and indicate that there was an active volcanic centre nearby when the volcaniclastic sequence was deposited.

Martell Syenite intrusions

Bodies of Martell Syenite occur mainly in the east, in the MacQuoid Lake map area (Fig. 4). They intrude rocks of the Christopher Island Formation, Kazan Formation, and basement, and are themselves cut by a few lamprophyre dykes. Being relatively resistant to erosion, they generally form hills. Most are composite or multiple intrusions formed of two or more sharply bounded rock types. At least some of the larger bodies are laccolithic. These include two bodies updoming volcaniclastic sediments of the Christopher Island Formation 8 km northwest of Kazan Falls (Fig. 10); another body 4 km to the north; the main intrusions north of Martell Lake, the bottoms of which are more or less concordant with bedding in underlying Kazan arkose; and a large body in the northwest intruding Christopher Island Formation.

The smaller intrusions of Martell Syenite are mainly sills and dykes. Sills several metres thick (Fig. 11) are well exposed on hills northeast and northwest of Martell Lake, within Kazan arkose. Some elongate dyke-like bodies 100 m or more thick intrude Kazan arkose northeast of Bissett Lake.

DUBAWNT GROUP VOLCANICS ON CHRISTOPHER ISLAND

The Dubawnt Group is represented on Christopher Island (Fig. 18) by conglomerate of the South Channel Formation, arkose of the Kazan Formation, volcanics of the Christopher Island Formation, and high level intrusions mapped as Martell Syenite. These rocks are cut by one major fault, which trends northwest along the island, and by several smaller faults.

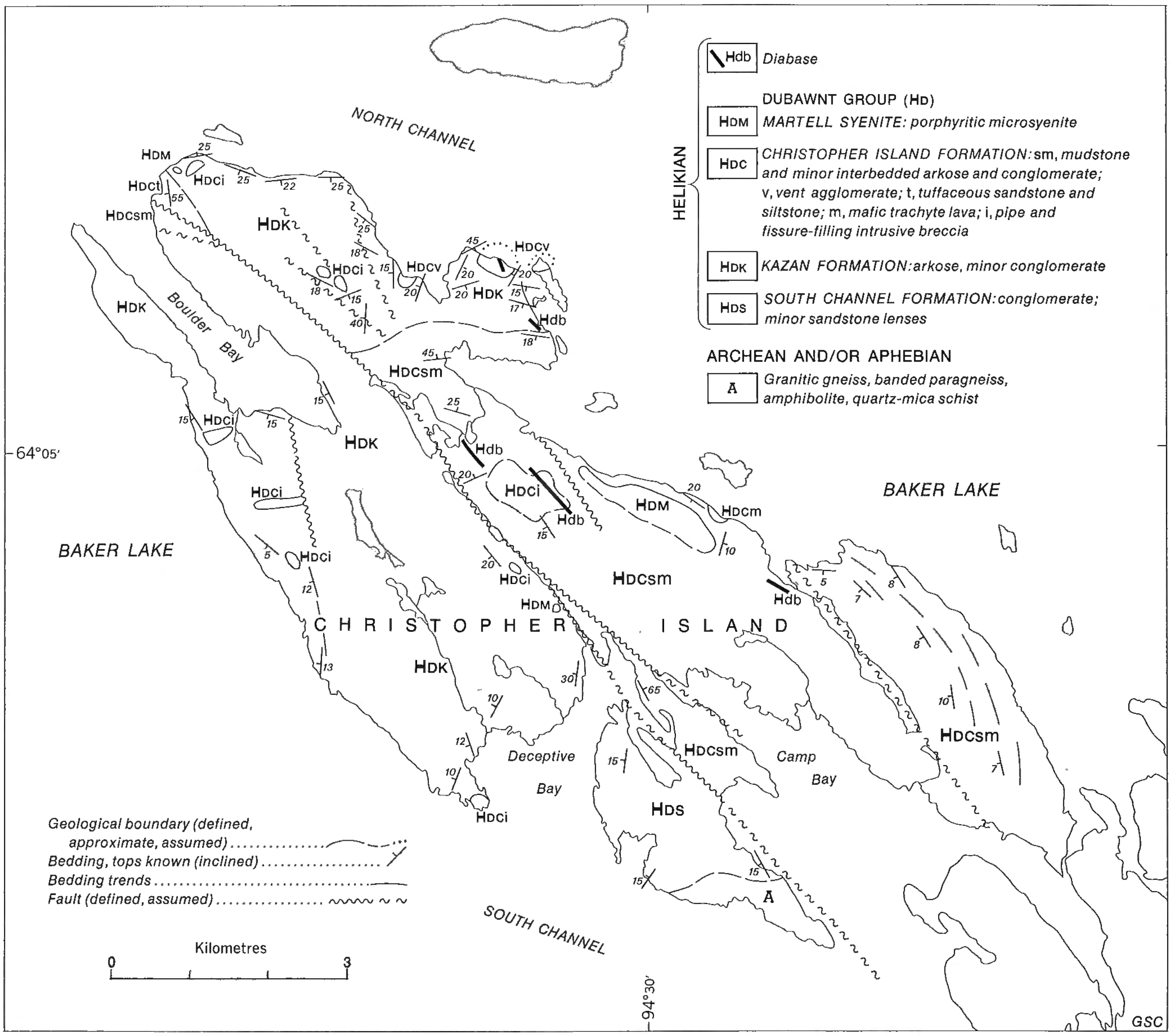


Figure 18. Geological map of Christopher Island (geology by D.H. Blake and A.R. Miller).

Basement rocks are exposed only on the southern end of a peninsula in the south of the island. They consist of granitic gneiss, banded paragneiss, amphibolite, and quartz-mica schist. The South Channel conglomerate (Fig. 5) is confined to the same peninsula, unconformably overlying basement rocks to the south. It is about 500 m thick and dips westwards at around 15°. It is inferred to be overlain conformably by Kazan arkose to the north.

The Kazan Formation is exposed in the western and northern parts of Christopher Island, and probably reaches a thickness of more than 1000 m. It is overlain conformably by volcaniclastic rocks of the Christopher Island Formation and is cut by lamprophyre and microsyenite intrusions, by pipes and fissures filled with volcanic breccia, and, in the east, by diabase. Medium bedded arkose, the predominant rock type of the Kazan Formation, shows laminar banding, crossbedding, ripple marks, mudstone and siltstone laminae with desiccation cracks, mudstone and siltstone chips on some bedding planes, scattered angular to rounded pebbles of basement rocks, slump structures, and intraformational breccias. Crossbedding is commonly the broad low-angle type, but there are some large scale high-angle sets. Some lenses of conglomerate similar to that of the South Channel Formation occur in places.

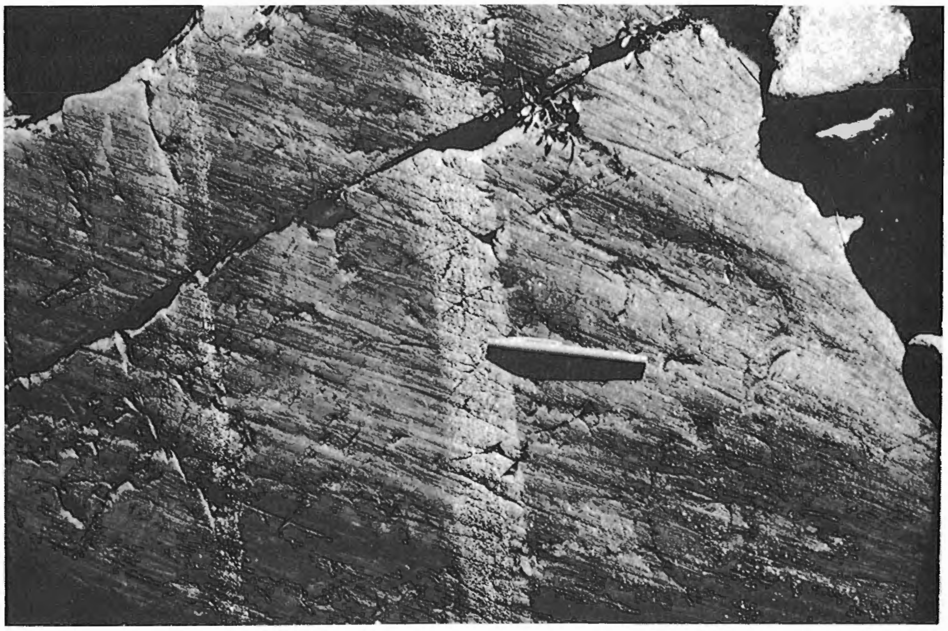


Figure 19. Mudstone unit of the Christopher Island Formation on Christopher Island. Glacially striated surface showing mudstone with thin sandstone laminae. (GSC 203366-G)

Following Macey (1973), the Kazan Formation is regarded as a mainly braided river deposit, whereas the South Channel Formation was probably deposited as an alluvial fan.

Christopher Island Formation

On Christopher Island this formation is represented by a unit of mudstone with minor interbedded arkose and conglomerate, and by vent agglomerate, tuffaceous sandstone and siltstone, mafic trachyte lava, intrusive volcanic breccia, and lamprophyre dykes and sills. It is intruded by microsyenite bodies mapped as Martell Syenite and by diabase dykes. It is at least 200 m thick in the southern part of the island. Conformable contacts with underlying Kazan Formation are exposed in the northeast, where arkose is thinly interbedded with mudstone and some laminated dolomitic sandstone.

The most extensive unit of the Christopher Island Formation on the island is mudstone and minor interbedded arkose and conglomerate (Figs. 18, 19, 20). This unit forms most of the eastern part of the island and is also exposed in a small fault block in the northwest. It is conformable on Kazan arkose in the northeast. The unit ranges from massive to finely laminated, but is mainly thick bedded, especially in the southeast, where it is 200 m or more thick. The mudstone component is a reddish maroon rock made up of angular, fine to coarse, sand-size grains enclosed in an abundant, very fine grained hematitic matrix which probably consists largely of altered volcanic dust. Most of the sand grains are of quartz and feldspar, but some of fine grained trachyte and of carbonate possibly representing altered pumice are also present. Larger trachyte clasts occur only on the east shore where the mudstone overlaps trachyte lava.

Figure 20. Slump breccia in the mudstone unit of the Christopher Island Formation on Christopher Island. (GSC 203366-H)

In many thick beds the sand grains tend to be concentrated along poorly defined planes forming a three-dimensional polygonal framework which on flat surfaces resembles chicken wire in overall pattern and dimensions. Bedding planes with desiccation cracks of similar shape and size occur locally within the unit, indicating very shallow water and periodic drying during the deposition of the mudstone. In such an environment, wind blown sand grains may have become trapped in open desiccation cracks during dry periods, and this could account for the polygonal framework of sand grains present in many mudstone beds. Thin beds and laminae of arkose are present locally, and a bed about 1 m thick of conglomerate containing basement clasts and flakes of mudstone occurs in the east, above the trachyte lava.

Many beds within the unit show evidence of slumping and brecciation (Fig. 20), features which could be triggered by earthquake activity associated with contemporaneous volcanism.

The mudstone unit is interpreted as a largely low energy fluvial floodplain or lacustrine deposit formed partly of volcanic dust. The interbeds of sandstone and conglomerate may represent the deposits of braided rivers which now and then invaded the low energy environment, perhaps as a result of nearby volcanic activity. The change from Kazan arkose to Christopher Island mudstone deposition coincided with the onset of volcanic activity in the area.

Vent agglomerate is exposed in the northeast (Fig. 18), occupying the central parts of three funnel-shaped collapse structures, interpreted as subaqueous volcanic vents, near the base of the Christopher Island Formation. The largest of these is about 500 m across. At each one, arkose of the Kazan Formation is overlain conformably by a sequence a few metres thick of thin bedded to laminated tuffaceous mudstone and muddy sandstone dipping radially inwards at up to 60°. Beds in the upper part of this sequence (Fig. 21) contain abundant angular to flattened fragments, mainly up to lapilli size, of pale trachyte 'pumice' now largely altered to carbonate but with phenocryst and vesicle outlines, and apatite microphenocrysts, preserved. The bedded sequence passes inwards, through a zone of breccia, into agglomerate (Fig. 22) containing blocks of basement rocks, Kazan arkose, maroon mudstone, and mafic trachyte; these are mainly less than 10 cm in diameter, although some are more than 10 m across. The blocks are enclosed in an abundant matrix of brownish to purplish maroon mudstone which in places shows an irregular and generally steep laminar banding. Many of the trachyte inclusions are lensoid and scoriaceous and show concentric colour and textural zoning, indicating that they are probably volcanic bombs. Similar agglomerate is also exposed near the northwest tip of the island.

Maroon tuffaceous sandstone and siltstone are restricted to a small area in the northwest, where they overlie Kazan arkose, probably conformably. They dip 50° to 60° west and pass westwards into massive agglomerate which may be occupying another volcanic vent.

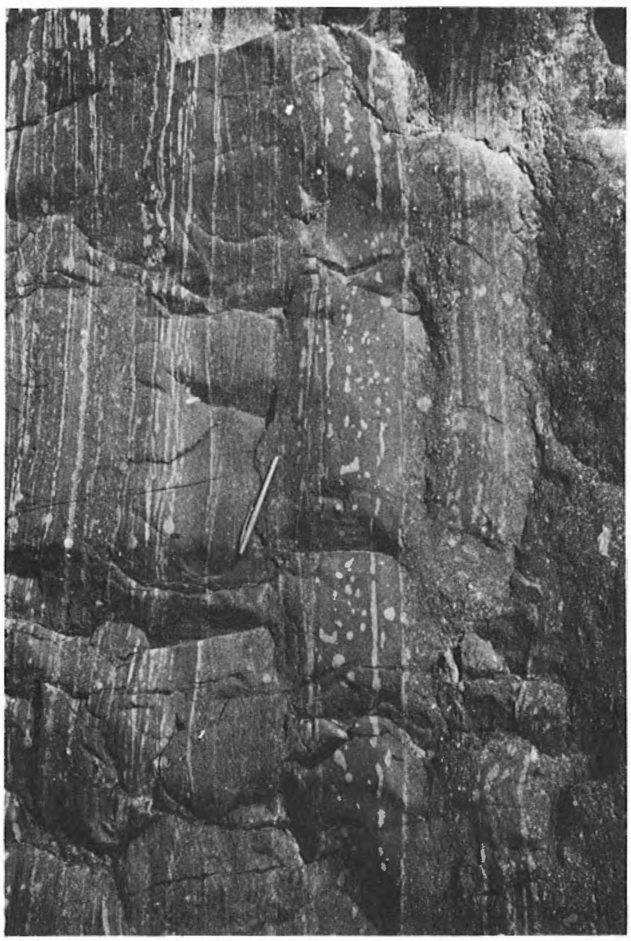


Figure 21. Steeply dipping tuffaceus mudstone and muddy sandstone with pale pumice fragments as well as reduction spots and streaks, Christopher Island Formation, Christopher Island. (GSC 203366-E)

Figure 22. Agglomerate of the Christopher Island Formation in central part of a volcanic vent on Christopher Island. (GSC 203366-F)

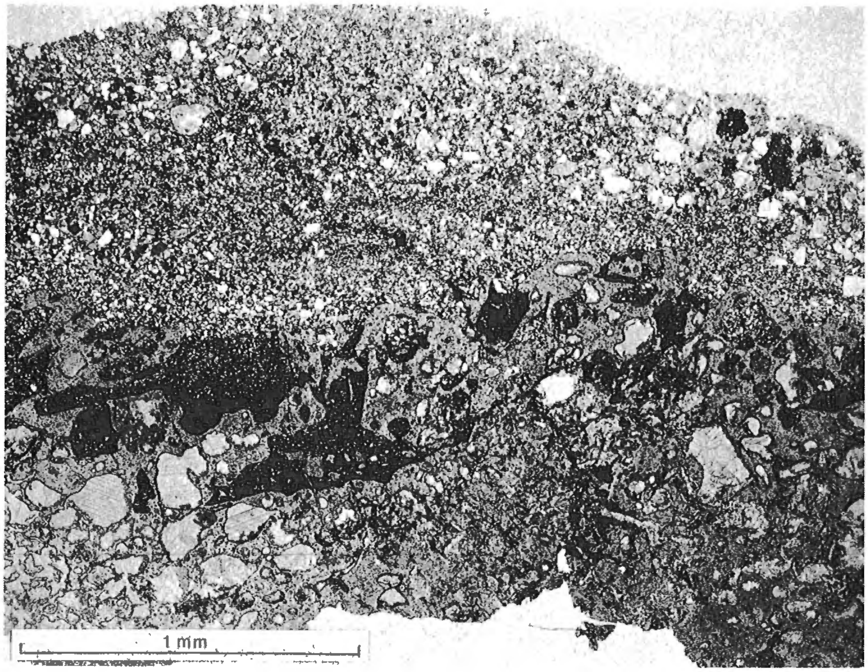


Figure 23. Photomicrograph of contact between vesicular mafic trachyte lava (l) and overlapping hematitic mudstone (m), Christopher Island Formation, east side of Christopher Island. (GSC 203172-E)

The top of a mafic trachyte lava is exposed on the shore on the east side of the island, where it is overlapped by maroon mudstone. The lava is scoriaceous and autobrecciated, and shows some poorly defined, pillow-like structures. It has a sharp but highly irregular contact with the mudstone, which fills crevices and vesicles in the lava at the contact surface (Fig. 23). The lava does not appear to have been weathered or eroded before being covered by mudstone, and its delicately irregular surface is considered to be a primary feature. Fragments of the trachyte in the surrounding mudstone were probably incorporated at the time of lava extrusion. The suggestion put forward here is that the lava was extruded, probably into shallow water, at the same time as the adjacent mudstone was being deposited.

Intrusive volcanic breccia fills near-vertical pipes and fissures cutting through arkose of the Kazan Formation and mudstone of the Christopher Island Formation. The pipes and fissures probably reached the surface to form eruptive sites. Most are cut by small lamprophyre and microsyenite intrusions and are bounded by brecciated country rock. The infilling breccia is brownish to purplish maroon in overall colour, and consists of angular fragments of all sizes up to 1 m across of basement rocks, arkose, mudstone and mafic trachyte, in various proportions.

Dykes of lamprophyre intrude rocks of the Kazan and Christopher Island formations, and a lamprophyre sill about 1 m thick occurs in a sandstone bed within the South Channel Formation on the island.

Martell Syenite

Several small bodies of porphyritic microsyenite mapped as Martell Syenite are present on Christopher Island, intruding Kazan Formation and Christopher Island Formation, mainly in the vicinity of pipes and fissures. The largest body of microsyenite, at least 30 m thick, occurs within the mudstone unit of the Christopher Island Formation on the east side of the island, where it forms a prominent ridge. This body has irregularly bulbous basal and side contacts, indicating that it was probably emplaced while the enclosing mudstone was still soft.

Diabase intrusions

Northwest trending diabase dykes, some with sill-like apophyses, are exposed in the central and eastern parts of the island, where they intrude arkose of the Kazan Formation and mudstone, vent agglomerate and volcanic breccia of the Christopher Island Formation. These dykes may be related to the about 1200-Ma-old Mackenzie swarm (Patchett, et al. 1978), although they are much smaller and less continuous than the typical dykes of this swarm. Alternatively, they may be unrelated to the Mackenzie swarm, and instead could be responsible for a thermal event at about 1510 Ma – Rb-Sr whole rock isochron age given by some samples of mudstone from Christopher Island (Bell; Carleton Univ., Ottawa; pers. comm., 1977).

PETROLOGY OF THE VOLCANIC ROCKS

Thin section petrography

More than 200 samples of lavas and intrusive rocks and 60 samples of pyroclastic and volcaniclastic sedimentary rocks from the Dubawnt Group have been examined in thin section. Modal analyses of chemically analyzed rocks are shown in Tables 2, 3, and 4, together with the main secondary minerals present.

Almost all the lavas and many of the intrusions are porphyritic. The phenocrysts generally make up between 10 and 40 per cent of the total rock, and range in maximum size in different samples from 1 mm to more than 10 mm. Many specimens contain small cognate and other xenoliths. Most lava specimens examined have secondary vesicle-filling minerals.

Christopher Island Formation

Mafic trachyte lavas

All samples of mafic trachyte examined contain phenocrysts of clinopyroxene and almost all contain phenocrysts of biotite-phlogopite (Table 2; Fig. 24, 25). Many samples also contain pseudomorphs after olivine phenocrysts, especially those in the Thirty Mile Lake-MacQuoid Lake area, and microphenocrysts of apatite. Sodic plagioclase and K-feldspar occur as phenocrysts in some samples, as also do equant opaque microphenocrysts, and a few samples have sparse partly resorbed quartz 'xenocrysts'.

The phenocrysts are set in a fine to very fine grained groundmass consisting mainly of K-feldspar and sodic plagioclase, but also including opaque granules, interstitial quartz (in the more silicic types), and clinopyroxene ± olivine (pseudomorphed) ± amphibol ± mica ± chloritic altered glass (in the less silicic types). Much of the groundmass feldspar, especially sodic plagioclase, forms small flow-aligned laths generally less than 0.1 mm long. Vesicles are filled with carbonate ± chlorite ± feldspar ± amphibole ± mica ± quartz. Amphibole and mica are present as groundmass and vesicle minerals only in samples from the Tulemalu Lake map-area.

Lamprophyre dykes and sills

These are similar in mineralogy and overall texture to the mafic trachyte lavas (Table 2). However, their groundmass is generally coarser grained and the feldspar laths within it are not normally flow aligned (Fig. 26).

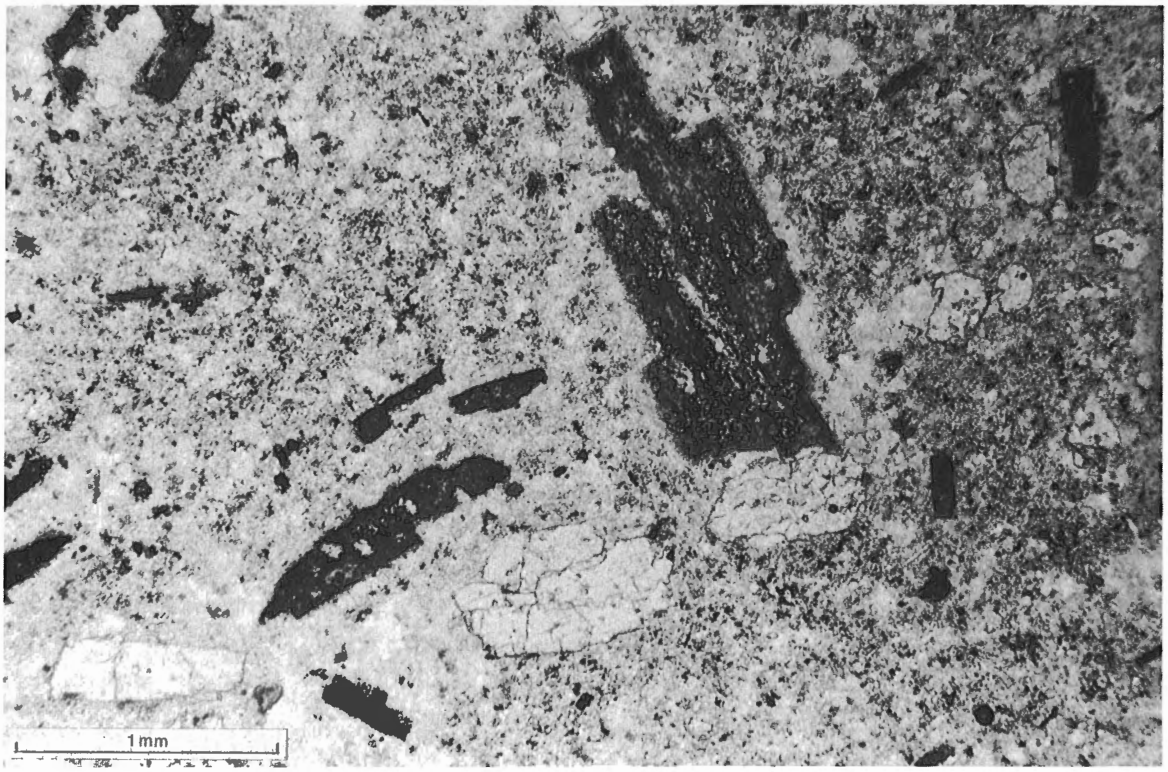


Figure 24. *Mafic trachyte, Christopher Island Formation. Phenocrysts of pale clinopyroxene and dark biotite (largely replaced by opaque granules) enclosed in a very fine grained groundmass of K feldspar, sodic plagioclase, and minor clinopyroxene, opaque granules, and interstitial quartz. Plane polarized light. (GSC 203366-K)*

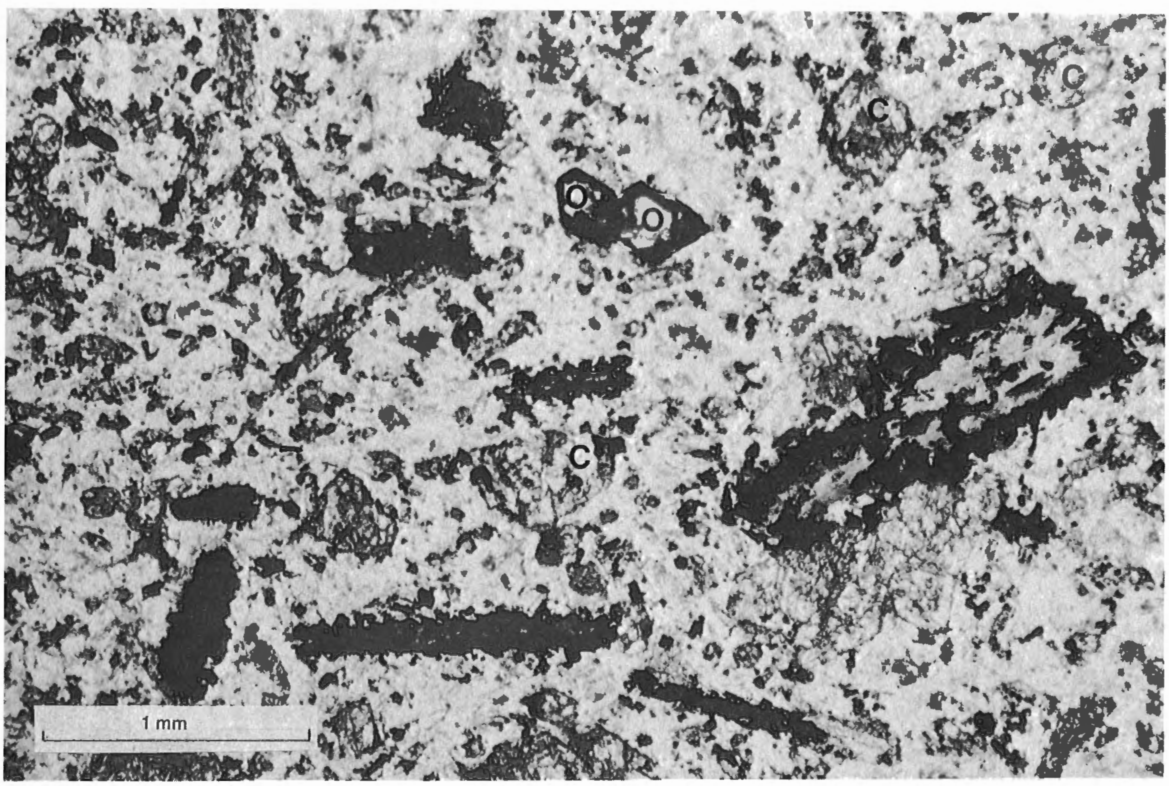


Figure 25. *Mafic trachyte, Christopher Island Formation. Phenocrysts of biotite partly altered to opaque granules, clinopyroxene (c) largely replaced by calcite, and olivine (o) pseudomorphed by calcite and opaques, enclosed in a fine grained groundmass of clear K-feldspar, faintly turbid albite, clinopyroxene, and opaque granules. Plane polarized light. (GSC 203366-A)*

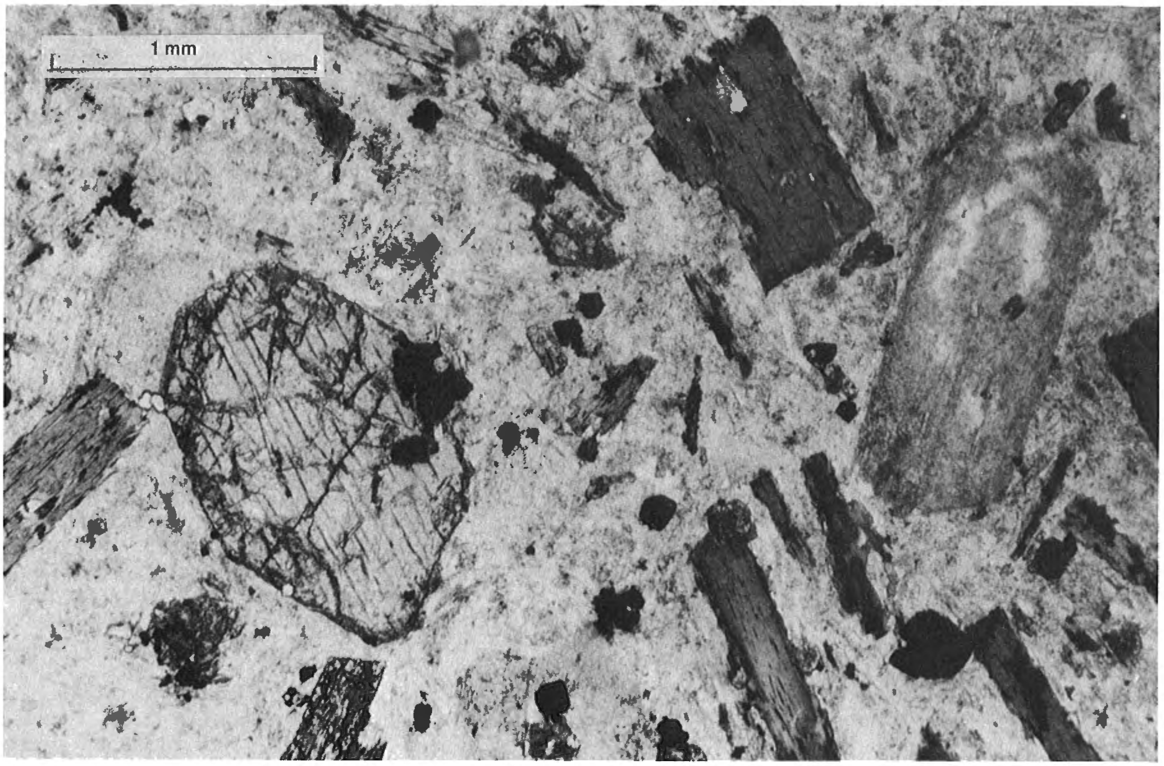


Figure 26. *Lamprophyre. Phenocrysts of augite, biotite and turbid plagioclase in a fine-grained groundmass of faintly turbid alkali feldspar, clear quartz, and minor equant opaques. Plane polarized light. (GSC 203366-D)*

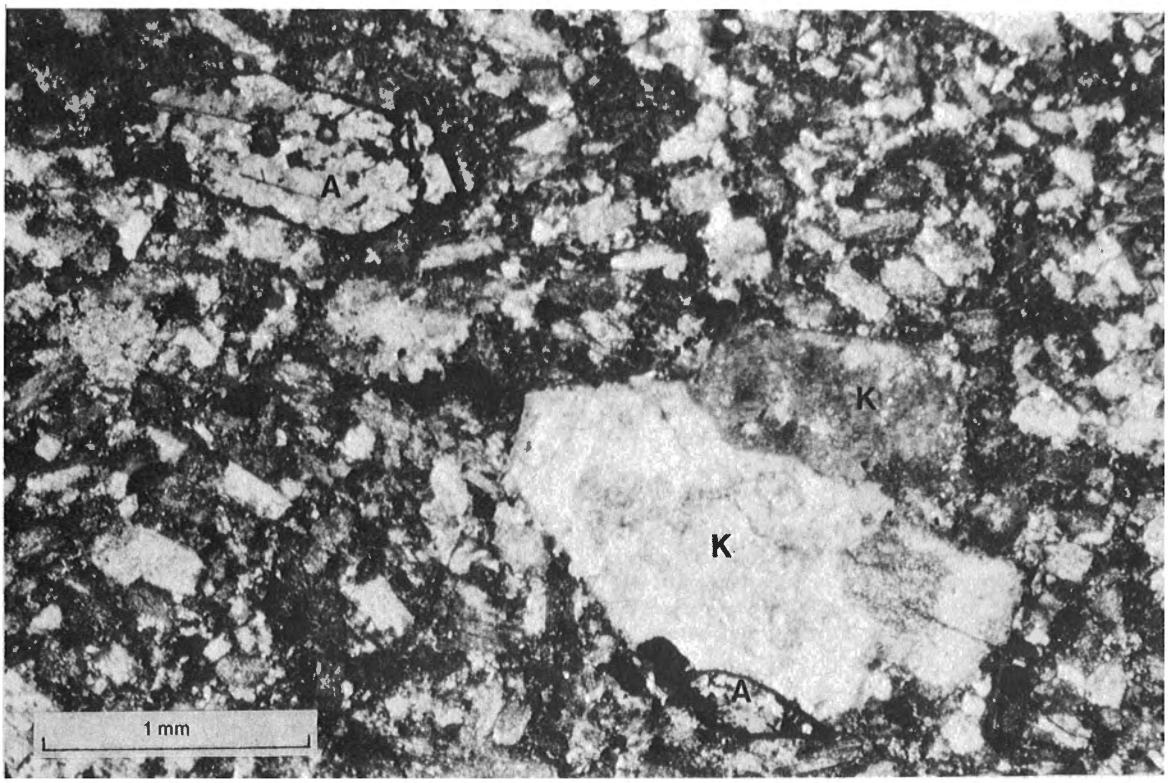


Figure 27. *Felsic trachyte, Christopher Island Formation. Phenocrysts of K-feldspar (K) and amphibole (A) pseudomorphed by calcite and opaques set in a groundmass of K-feldspar and albite crystals, opaque granules, and interstitial very fine intergrowths of K-feldspar and quartz. Crossed polarizers. (GSC 203366-C)*

Felsic trachyte lavas

In the samples of felsic trachyte examined (e.g., Fig. 27) feldspar phenocrysts make up 10 per cent or more of the total rock and generally predominate over phenocrysts of biotite-phlogopite ± clinopyroxene ± amphibole ± olivine (pseudomorphed) ± rare orthopyroxene (Table 3). Most samples also contain apatite and opaque microphenocrysts and a few have sparse quartz phenocrysts. These lie in a very fine grained quartzofeldspathic mosaic (devitrified glass) which includes some opaque granules and dust and, in a few cases, small feldspar laths.

Rhyolite lavas

Rhyolite forming the cumulodome 30 km north of Kazan Falls is nonporphyritic (No. 46, Table 3) whereas that exposed 5 km to the southwest contains some plagioclase and K-feldspar phenocrysts (No. 45, Table 3). Rhyolite in the northeast part of the main Dubawnt outcrop in the Tulemalu Lake map area contains quartz as well as feldspar phenocrysts. The groundmass of the rhyolite extrusions is a very fine grained quartzofeldspathic mosaic, representing devitrified glass. It shows flow banding and, in some samples, perlitic structures (Fig. 28).

Pyroclastics

Tuffs consist of vesicular lava fragments together with whole and broken phenocrysts and minor basement-derived clasts. Hematite, carbonate and chlorite are generally abundant as secondary minerals. Lava fragments are typically highly irregular in shape and consist largely of altered glass; some are flattened and have frayed ends, evidently representing squashed pumice. Agglomerates are generally similar, but are coarser and commonly contain some recognizable fragments of Dubawnt sedimentary rocks.

Hyaloclastites

These are represented by massive to thin bedded and laminated clastic rocks west of Pitz Lake and by breccia 30 km to the south. The clastic rocks are poorly sorted deposits ranging from very fine grained and cherty to coarse grained and conglomeratic. They consist largely of angular to rounded clasts of trachyte, shard-like fragments of altered volcanic glass, and subhedral feldspar grains pseudomorphed by white clay, enclosed in an abundant, fine grained, iron-stained matrix. Some also contain chips of hematitic mudstone. Basement-derived clasts, mainly quartz and quartzite grains, are locally a major constitutent.

The breccia to the south is made up of angular fragments of pale and dark brown mafic tracyte in a matrix of rounded to angular sand-sized grains of altered volcanic glass and minor quartz and feldspar.

Volcaniclastic sedimentary rocks

These range from mudstone through siltstone and sandstone to conglomerate. They are typically poorly sorted, and contain both volcanic and basement clasts, either of which may predominate, in a fine grained calcareous and hematitic matrix (e.g., Fig. 8).

Pitz Formation

In the rhyolite lavas of the Pitz Formation abundant phenocrysts of feldspar generally at least 5 mm across and smaller subordinate phenocrysts of partly resorbed quartz and pseudomorphed ferromagnesian minerals are enclosed in a fine grained, quartzofeldspathic groundmass. The feldspar in the main lava (No. 48, Table 3) is pseudomorphically replaced by kaolinite and quartz (Fig. 29), but is little altered in the other lava (No. 47, Table 3), which contains both K-feldspar and oligoclase-andesine as phenocrysts. The main lava is relatively rich in zircon microphenocrysts.

The Pitz hyaloclastites are partly laminated sandy mudstone and partly autobrecciated lava in which angular fragments of Pitz rhyolite lie in a cherty to sandy mudstone matrix. The mudstone beds and breccia matrix are poorly sorted and consist largely of quartz, hematite, and kaolinite.

Martell Syenite

The Martell Syenite intrusives range from fine grained and mainly porphyritic to medium grained and mainly nonporphyritic. They consist predominantly of feldspar, with K-feldspar in excess of plagioclase, and have reddish to yellowish brown biotite or pale greenish to colourless augite or both as the main ferromagnesian minerals (Fig. 30). Green to greenish brown hornblende or olivine (almost invariably pseudomorphed) or both are also commonly present, as also is some interstitial quartz. A few samples contain some faintly pleochroic orthopyroxene. The K-feldspar, either or both orthoclase and microcline, is generally anhedral and in some samples forms large poiklitic anhedral crystals. The plagioclase tends to be subhedral and is mainly oligoclase or andesine. Quartz occurs as an interstitial mineral and in myrmekitic intergrowths with plagioclase, but is an essential mineral only in the alkali granite in the Tulemalu Lake map area, where it occurs in micrographic intergrowths with K-feldspar. The alkali granite consists of microcline (about 40%), quartz (about 20%), calcite probably pseudomorphing pyroxene (about 20%), phlogopite partly altered to chlorite (about 10%), and oligoclase (about 10%). Accessory minerals present in the intrusives include apatite, opaques, and less commonly sphene and metamict ?allanite and ?zircon.

Phenocryst mineralogy

Biotite-phlogopite form euhedral phenocrysts which in a few samples are bent. The phenocrysts range in colour from brown, greenish brown or reddish brown (biotite) to pale yellowish brown or colourless (phlogopite, confirmed by electron probe studies). They commonly show colour and compositional zoning, from relatively pale cores to darker margins. In most samples the phenocrysts have opaque rims which in some cases are embayed and apparently corroded. Very commonly the phenocrysts are partly or completely replaced by secondary minerals. Two types of mica phenocrysts are present in some mafic trachyte lavas: little altered phlogopite with opaque rims and completely pseudomorphed 'biotite' without such rims.

Clinopyroxene forms euhedral phenocrysts which are colourless to very pale greenish or greenish brown. Like those of biotite-phlogopite, they are darkest at their margins, indicating compositional zoning. Electron probe studies show that the phenocrysts range in composition mainly from diopside to salite, but a few analyses lie in the endiopside and augite compositional fields (LeCheminant, pers. comm., 1978). Part to complete alteration to secondary minerals is very common. Possible orthopyroxene phenocrysts, pseudomorphed by chlorite, are present in felsic trachyte exposed 12 km southeast of Pitz Lake, where they are subordinate to unaltered clinopyroxene phenocrysts.

Olivine phenocrysts are always pseudomorphed by secondary minerals, mainly opaques, carbonate, chlorite, ?serpentine, ?bowlingite, and quartz. They are euhedral to subhedral, and are rimmed and internally veined by opaque material.

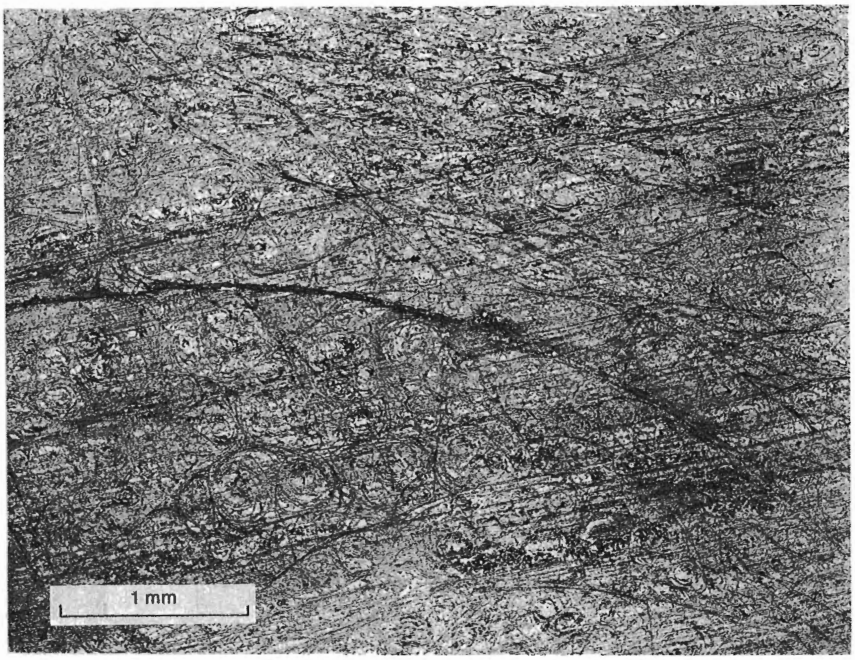


Figure 28

Rhyolite, Christopher Island Formation. Perlitic structures in nonporphyritic flow-banded rhyolite. Plane polarized light. (GSC 203172-R)

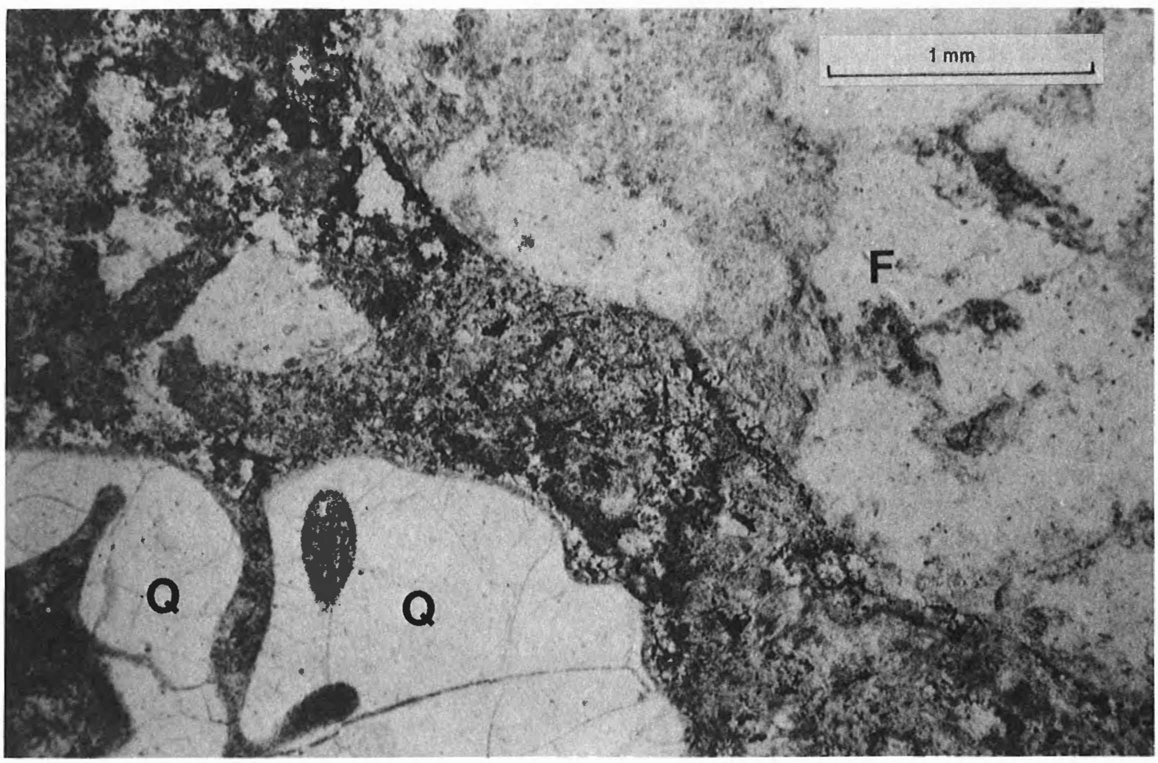


Figure 29. *Main porphyry lava, Pitz Formation. Large phenocrysts of feldspar (F), pseudomorphed by kaolinite and quartz, and partly resorbed quartz (Q) in a fine grained partly vesicular groundmass now consisting of quartz, kaolinite, and iron oxide. Plane polarized light. (GSC 203366-B)*

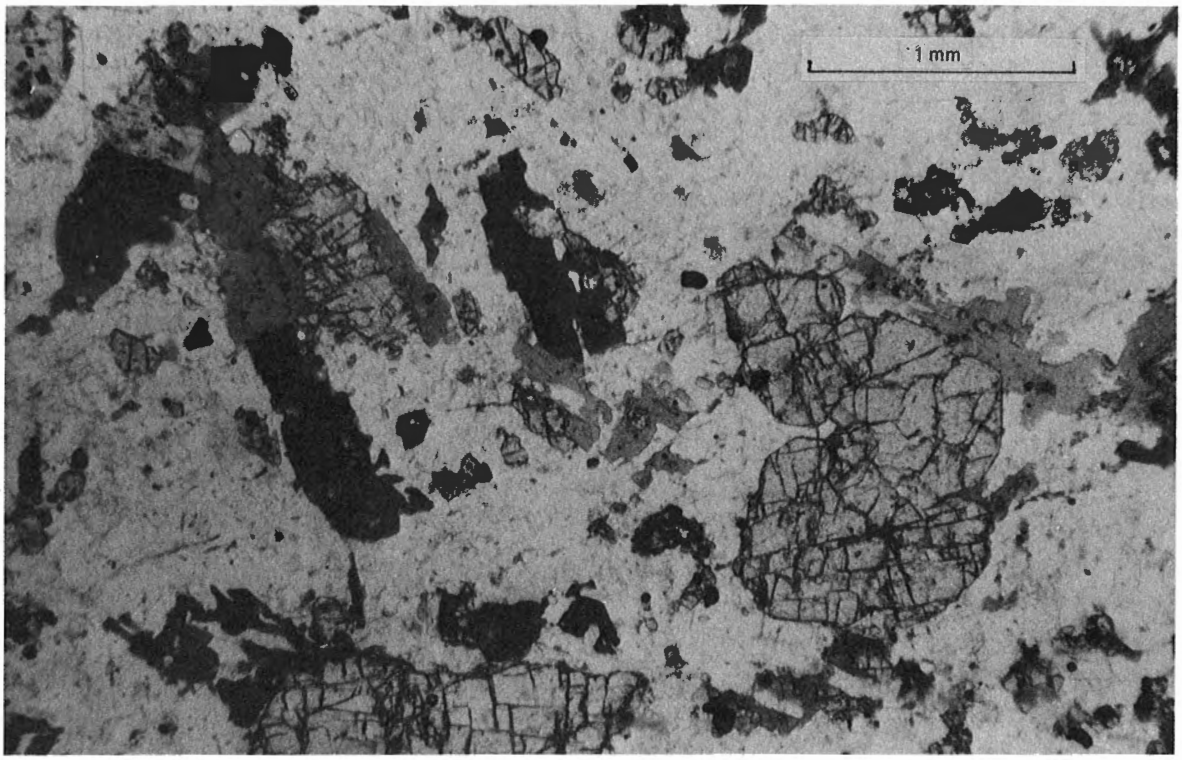


Figure 30. *Medium- to fine-grained syenite, Martell Syenite. Rock consists mainly of augite, strongly pleochroic biotite, and white K-feldspar. Plane polarized light. (GSC 203366)*

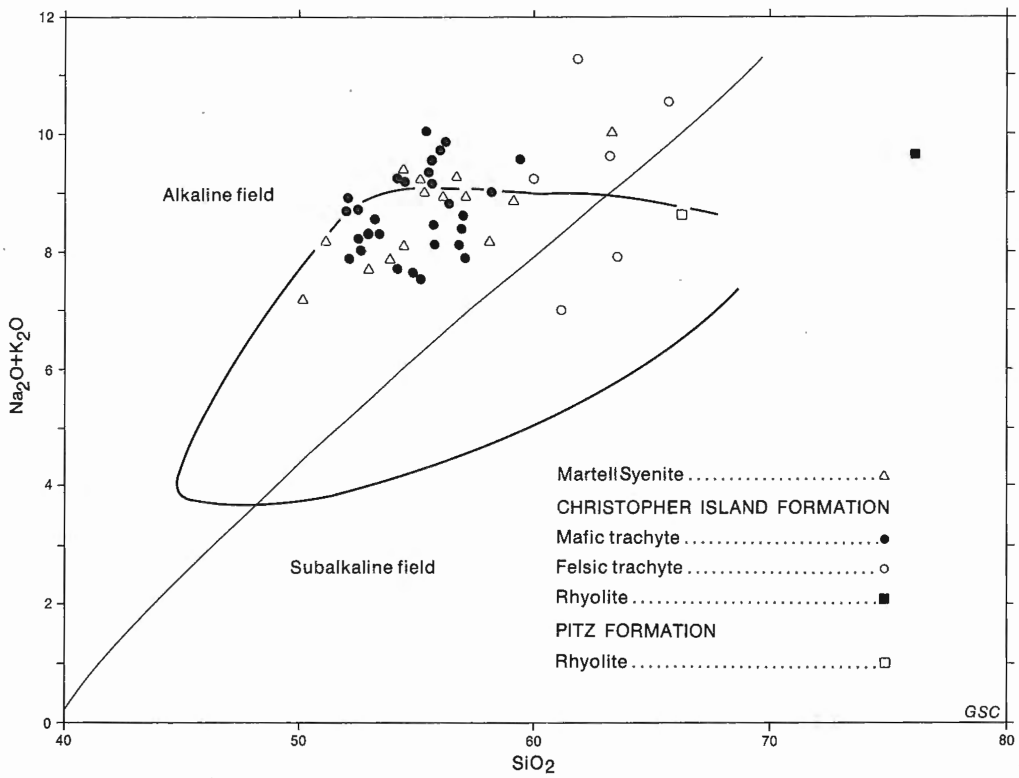


Figure 31

Na_2O+K_2O/SiO_2 relationship for the Dubawnt Group volcanic rocks. Alkaline and subalkaline fields from Irvine and Baragar (1971). Field of late Cenozoic volcanics from southeast Papua (from Smith and Davies, 1976) shown by heavy solid line.

Euhedral amphibole phenocrysts are restricted to felsic trachyte and more acid lavas. They are almost invariably pseudomorphically replaced, but can be distinguished by their characteristic shape and cleavage. Like most other ferromagnesian phenocrysts they have opaque rims.

Plagioclase phenocrysts are euhedral and predominantly of oligoclase to andesine composition. They show lamellar twinning and normal zoning. K-feldspar phenocrysts are generally subhedral to partly resorbed. Some show complex twinning and exsolution features, but most show only simple twinning. 2V estimates indicate orthoclase and less commonly sanidine compositions. Some feldspar phenocrysts are partly altered to chlorite, sericite, carbonate, and epidote. In general K-feldspar phenocrysts are less altered than those of plagioclase.

Quartz phenocrysts are subhedral to anhedral, and are partly resorbed.

Secondary minerals

In all volcanic samples examined, including those chemically analyzed, secondary minerals are present, in some cases forming more than 50 per cent of the total rock. The most common and abundant secondary minerals are carbonates (either calcite or dolomite, distinguished by X-ray methods), chlorite, opaques (including hematite), quartz, and alkali feldspar (Tables 2, 3, and 4). These minerals fill vesicles, partly or completely pseudomorphically replace ferromagnesian minerals, and also partly replace primary feldspar. Less widespread secondary minerals include sericite (after plagioclase), kaolinite (after feldspar, especially in Pitz lavas), epidote, sphene, serpentine and 'bowlingite' (after olivine), barite (in vesicles), ?zeolites (in vesicles, pseudomorphed by quartz), red biotite (in syenite), and, in the Tulemalu Lake map area, amphibole, talc and phlogopite.

Two amphiboles are present in many mafic trachytes of the Tulemalu Lake map area, a sodium-rich variety, which may be a primary constituent, and tremolite-actinolite. The Na-amphibole forms small elongate prisms which are pleochroic from colourless to various shades of pink, yellow, brown, reddish brown, violet, blue, and green. It has a low birefringence with strongly anomalous colours, and inclined extinction. Electron probe analyses show that in one sample (No. 14, Table 2) the Na-amphibole is strongly zoned from richterite to ferrorichterite (LeCheminant, pers. comm., 1978). Tremolite-actinolite, together with talc and phlogopite, partly or completely replace ferromagnesian phenocrysts and also form vesicle fillings. The secondary phlogopite in the Tulemalu Lake lavas occurs as radiating clusters of small, mainly yellowish brown flakes.

Chemistry

Major and trace element analyses of 63 volcanic rocks from the Dubawnt Group are presented in Tables 5-7. The samples were analyzed by the Analytical Chemistry Section, Geological Survey of Canada, mainly by XRF. Sodium was determined by atomic absorption, uranium by neutron activation.

The amount of secondary alteration in the samples can be assessed in part from their CO_2, H_2O, and FeO/Fe_2O_3 values. All samples show some alteration, although only 12 are altered to such a degree that their analyses are unlikely to reflect in the main their original composition. These 12 samples have either more than 4 per cent CO_2 and/or H_2O, or K_2O/Na_2O values greater than 10 or less than 0.1; they have been omitted from Figures 32, 33 and 34, and are not considered in the following discussion.

The analyzed Dubawnt volcanics show a range in silica composition from 52 to 76 wt. per cent. Their most obvious chemical characteristic is their overall high alkali content, especially potassium (Figs. 32, 33). The samples plot as alkaline in the total alkalis versus silica diagram, and are appreciably more potassic than typical calcalkaline and tholeiitic rocks. They are also generally richer in total alkalis and K_2O than, for example, most of the potassium-rich late Cenozoic volcanics of southeast Papua. Other noteworthy chemical features are high P_2O_5 and Ba contents compared with most other volcanic rocks, variable but generally high Sr and U, and low TiO_2 and total iron.

CIPW norms of the 51 least altered analyzed samples of Dubawnt volcanics are also shown in Tables 5-7. Of the 43 mafic trachyte and Martell Syenite samples, 18 have normative quartz; normative corundum, nepheline and acmite are present in four samples, each. The eight felsic trachyte and rhyolite samples have over 9 per cent normative quartz, and all but one have normative corundum. The samples show a range in Differentiation Index (the sum of normative salic constituents – Thornton and Tuttle, 1960) from 53 to 99.

The Dubawnt volcanics do not fit readily into any one classification scheme. According to that of Irvine and Baragar (1971), they range from peralkaline rocks to trachybasalt and trachyandesite (potassic alkaline series), tholeiitic andesite, calcalkaline (high alumina) andesite, calcalkaline dacite and rhyolite. Using the scheme of Johnson et al. (1978a, Figure 8) for volcanic rocks of convergent plate boundaries, they lie mainly within the trachybasalt-trachyandesite-trachyte field (Fig. 33).

Discussion

The Dubawnt volcanic rocks show the characteristic features of the shoshonite association of Joplin (1968) and the shoshonite series of Carmichael et al. (1974): presence of K-feldspar as well as plagioclase, even in the most mafic rocks; high $K_2O + Na_2O$ and K_2O/Na_2O; more than 50 per cent SiO_2; normative hypersthene in most rocks. Rocks of the shoshonite association are typically associated with post-orogenic uplift. They are found, for example, in the Late Cenozoic of Papua New Guinea, where they are situated close to plate boundaries and major faults, but are not, apparently, directly related to active subduction zones (Johnson et al., 1978b).

ENVIRONMENT AT THE TIME OF DUBAWNT VOLCANISM

The lavas and pyroclastics of the Dubawnt Group were erupted from numerous volcanic centres, several of which have now been located. Many centres may have been small volcanoes formed during single eruptions lasting only about one year, but some, such as those southeast of Tulemalu Lake and west of Pitz Lake, were probably large complex stratovolcanoes formed by multiple eruptions during many years. Most eruptions were probably subaerial, although at least some took place under water. The associated tuffaceous and volcaniclastic sediments represent fluvial (including alluvial fan), lacustrine and possibly shallow marine deposits. The lamprophyre and feldspar porphyry dykes, sills and sheets and the bodies of Martell Syenite are high-level subvolcanic intrusions, and their field relations, mineralogy and chemistry indicate that they were comagmatic with the extrusives.

The volcanism took place within and close to mountainous areas of crystalline basement. The available isotopic data indicate that this volcanism occurred shortly after the Hudsonian Orogeny, and it was probably associated in time and space with large scale faulting.

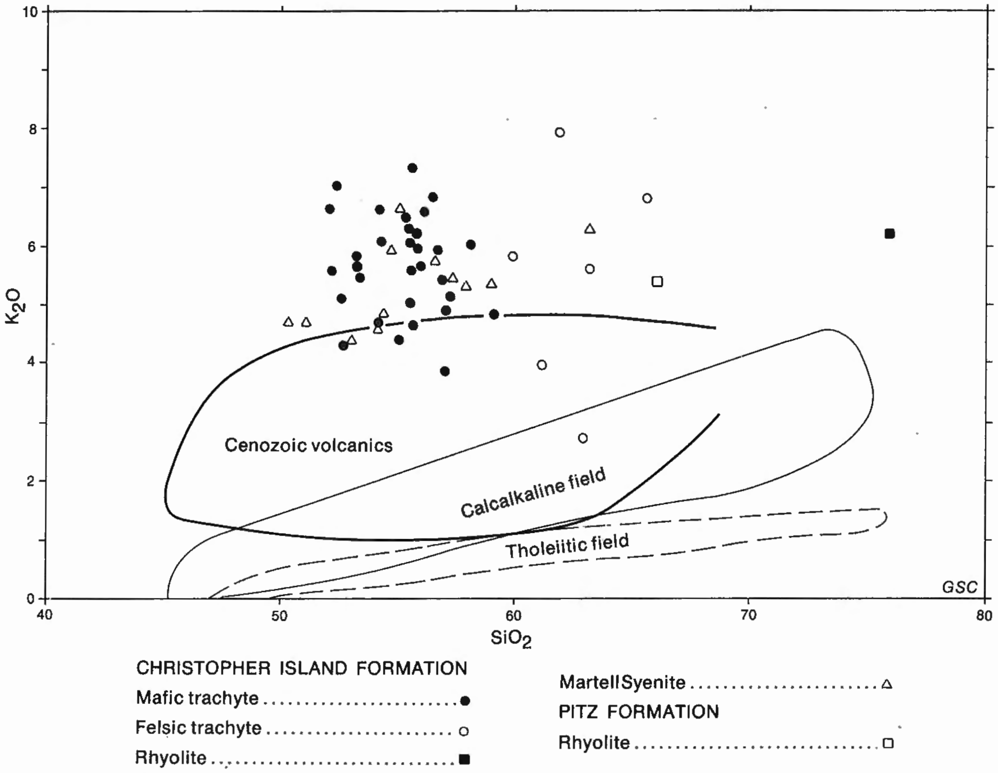


Figure 32. *K_2O/SiO_2 relationship for the Dubawnt Group volcanic rocks. Also shown are the field of late Cenozoic volcanics from southeast Papua (heavy solid line, from Smith and Davies, 1976), and the generalized calcalkaline and tholeiitic fields of Jakes and Gill (1970).*

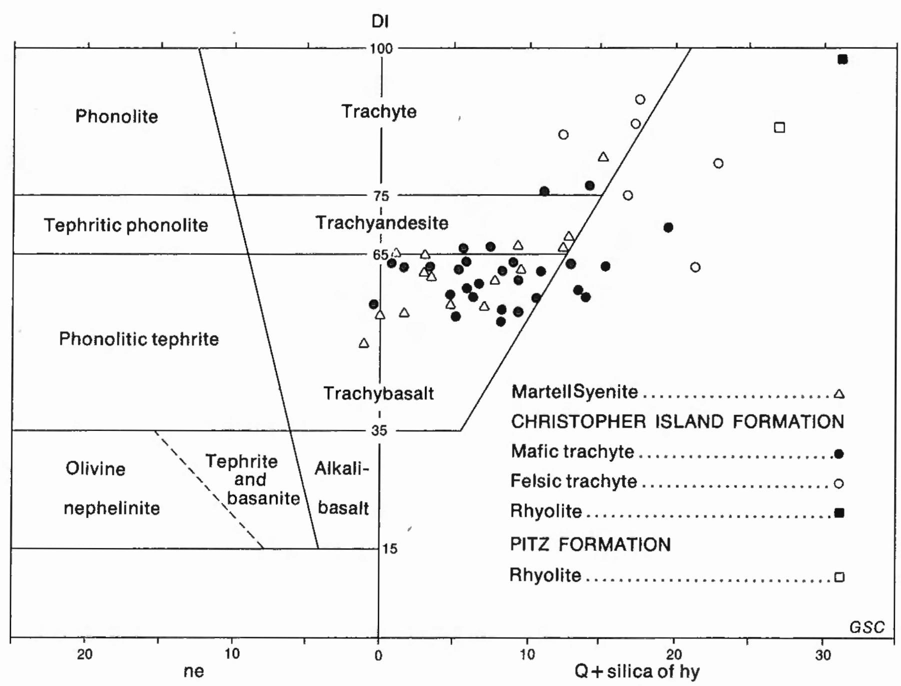


Figure 33. *Plot of Dubawnt Group volcanic rocks, using the classification scheme of Johnson et al. (1978a), based on Differentiation Index (DI) and degree of silica saturation (normative nepheline or normative quartz and silica of normative hypersthene).*

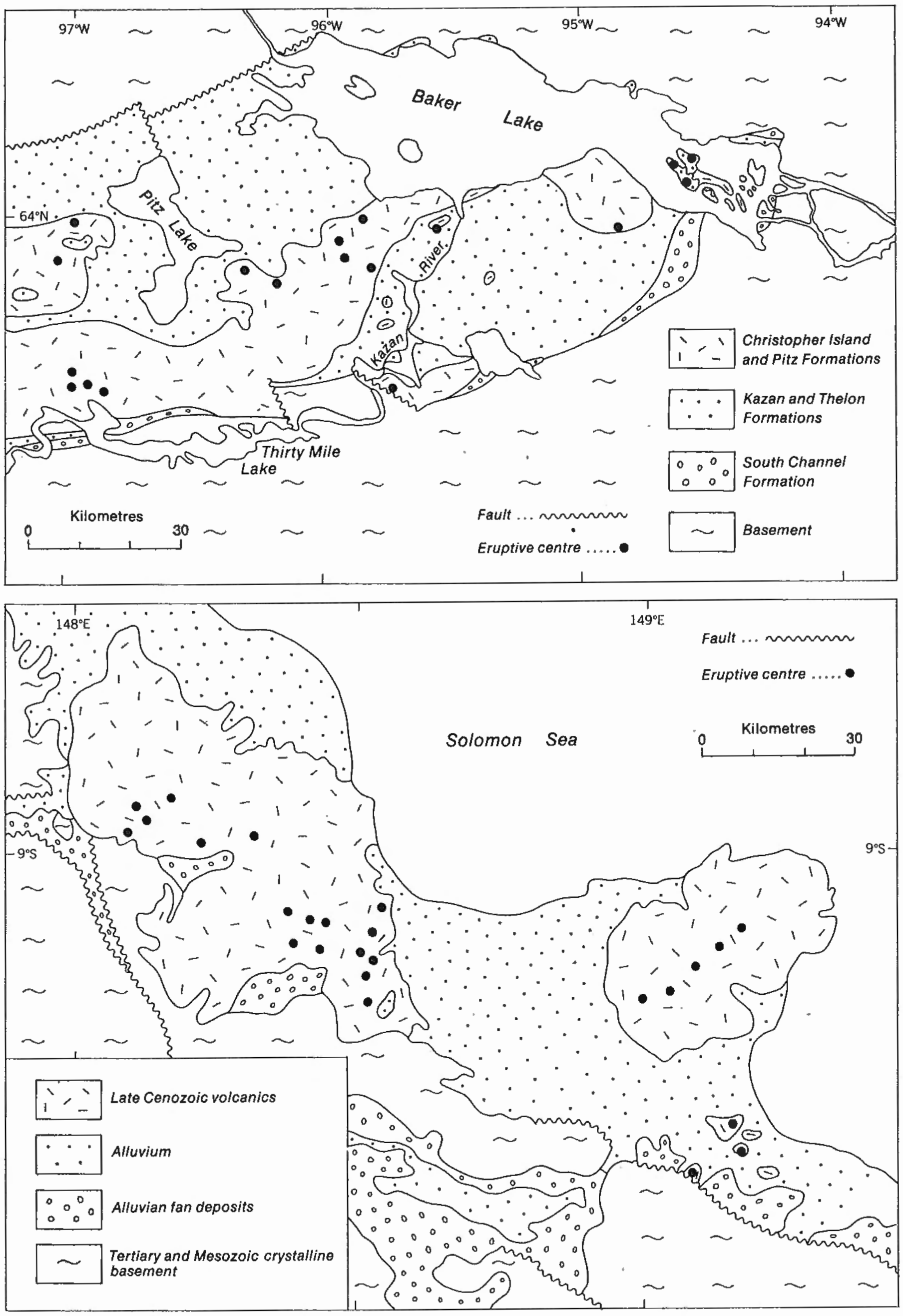


Figure 34. Baker Lake region and part of southeastern Papua.

The depositional and tectonic environment in the area at the time of the volcanism shows many similarities to that existing at the present time in the volcanic area of southeast Papua, Papua New Guinea, near the eastern end of the island of New Guinea (Davies and Smith, 1971; Blake, et al. 1973; Smith and Davies, 1976). In southeast Papua a high mountain range formed largely of Mesozoic and Tertiary metamorphic and igneous rocks, is bounded to the northeast by a broad fluvial plain (Fig. 34). Along the mountain front, which is marked by major faults, there are numerous alluvial fans. Many small and a few large Quaternary volcanoes are situated on the fluvial plain, and there are also some volcanoes within the mountain ranges. On the plain the volcanic rocks interfinger with alluvium. The volcanism and sedimentation closely followed the main period of tectonism and mountain building, which culminated during the Pliocene. The volcanic rocks forming many of the volcanoes are potassic alkaline types, like those of the Dubawnt Group, and they include lavas almost identical in mineralogical and chemical composition to the Dubawnt trachytes. Neither the southeast Papuan volcanics nor the Dubawnt volcanics appear to be directly related to subduction.

SUMMARY OF CONCLUSIONS

1. The Dubawnt Group was laid down unconformably on an irregular surface developed on Archean and Aphebian crystalline basement rocks, forming a mainly flat-lying to gently dipping cratonic cover.

2. The group comprises the sedimentary Angikuni, South Channel, Kazan, and Thelon formations, the volcanic Christopher Island and Pitz formations, and the intrusive

Martell Syenite. The rocks of these units retain their original sedimentary and igneous textures. However, primary minerals in the volcanic rocks are commonly altered, mainly to carbonate, chlorite, and hematite; this alteration is attributed to the Dubawnt volcanism, and not to any subsequent regional metamorphism.

3. The Dubawnt Group is Paleohelikian, slightly younger than the Hudsonian Orogeny. Volcanics from the group have been dated by the Rb-Sr whole-rock isochron method at 1786 ± 26 Ma (using $1.42 \times 10^{-11} y^{-1}$ as the decay constant of ^{87}Rb), initial $^{87}Sr/^{86}Sr$ = 0.7059 ± 0.0001 (Wanless and Loveridge, 1972).

4. The Christopher Island Formation consists of mafic trachyte, felsic trachyte, and minor rhyolite lavas; pyroclastics; associated sedimentary rocks; hyaloclastites; intrusive breccias; and lamprophyre and feldspar porphyry dykes and sills. In the Tulemalu Lake map area it postdates the Angikuni Formation and overlies South Channel conglomerate conformably. In the Baker Lake region it interfingers with and overlies Kazan arkose.

5. The Pitz Formation, which is not present in the Tulemalu Lake map area, consists of rhyolite lava lobes and associated hyaloclastites. It overlies Christopher Island volcanics, apparently concordantly, and is thought to be contemporaneous with the older part of the Thelon Formation, which abuts against and overlies it. The main lava flow exposed was probably erupted under water.

6. The Martell Syenite comprises subvolcanic syenite and monzonitic intrusives. Field relations, mineralogy, and chemistry indicate that these intrusives were comagmatic with the Christopher Island volcanics.

7. The Christopher Island Formation and older rocks are hosts to uranium and minor associated base and precious metal mineralization. The volcanics of the Christopher Island Formation are relatively rich in uranium, and may be the primary source for this mineralization.

8. Several probable and possible eruptive centres for the Dubawnt volcanics have been located. These are marked by outcrops of vent agglomerate and lava, intrusive breccia (on Christopher Island), and coarse pyroclastics.

9. The trachyte lavas and lamprophyre of the Christopher Island Formation are potassium-rich alkaline rocks containing phenocrysts of biotite-phlogopite, clinopyroxene, and less commonly plagioclase, feldspar, olivine (pseudomorphed), quartz, and amphibole; the dominant groundmass phase is alkali feldspar.

10. The rhyolite lavas of the Pitz Formation contain abundant large phenocrysts of feldspar and subordinate smaller phenocrysts of quartz and ferromagnesian minerals. The feldspar in the main lava is pseudomorphed by kaolinite.

11. Chemically, the Christopher Island volcanics and the Martell Syenite intrusives show features characteristic of the shoshonite association of Joplin (1968) rocks of which are typically associated with uplift immediately following orogenesis.

12. Environmental conditions at the time of Dubawnt volcanism may have been similar in many ways to those of present day southeast Papua, Papua New Guinea: the volcanoes of southeast Papua are situated on a broad fluvial plain flanking a high young mountain range, and to a lesser extent within this range, and their products include potassium-rich alkaline lavas similar mineralogically and chemically to the Dubawnt trachytes.

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