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PETROGRAPHY AND GEOCHEMISTRY OF SEDIMENTARY ROCKS
OF THE YELLOWKNIFE SUPERGROUP (ARCHEAN),
SLAVE PROVINCE, NORTHWEST TERRITORIES

by

GORDON RODERICK PEELING, B.Sc. (HONOURS)

A thesis submitted to the Faculty of Graduate
Studies in partial fulfilment of the degree of
Master of Science

Carleton University
Ottawa, Ontario.
May, 1974

The undersigned hereby recommend to the Faculty of Graduate
Studies acceptance of this thesis, submitted by Gordon Roderick
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ABSTRACT

Modal analyses of samples from the lower, middle and upper parts of the Burwash Formation, Yellowknife Supergroup, at Yellowknife Bay, indicate an increase upwards in the amount of components derived from silicic volcanic and plutonic rocks. An accompanying decrease in abundance of mafic volcanic clasts upwards in the Burwash Formation, with none being present in the overlying Walsh Formation, suggests a waning in importance of mafic volcanics as a source for detritus. A high quartz content and a relative increase in plutonic rock fragments in the Walsh Formation suggest that deposition of the Walsh Formation coincided with unroofing of a silicic pluton in the source area. This plutonic body is interpreted to be the "western granodiorite" which crops out west of Yellowknife Bay.

The geochemistry of the Burwash and Walsh Formations indicates that the Walsh Formation sediments are high in silica and soda and low in potash, compared to the Burwash Formation sediments. Secular chemical trends in the Burwash Formation are cyclic, with the lower and upper parts of the formation being similar chemically. Bouma-cycle trends within the Burwash Formation appear to be consistent, showing an increase in abundance of phyllosilicates in the finer grained units. The chemistry of the B, C and D units of the Bouma cycle is intermediate to that of the end member units (A and E). Trace element data suggest that a mixed terrane of volcanic and plutonic rocks supplied detritus for the sediments of the Burwash and Walsh Formations.

The secular chemical trends within the Burwash Formation, and from the Burwash Formation to the Walsh Formation, are similar to those within the Yellowknife volcanic pile. The similarity in trends is interpreted as indicating that the Yellowknife volcanic pile and/or its lateral extension over the "western granodiorite" was a major source of detritus for the Burwash and Walsh Formation sediments.

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INTRODUCTION

INTRODUCTION

During late May and early June of 1972, the author spent seven days collecting samples from three localities in the Burwash Formation and one locality in the Walsh Formation of the Yellowknife Supergroup at Yellowknife Bay in the Northwest Territories. One hundred and forty-two samples were collected from the Burwash Formation and ten samples from the Walsh Formation.

The purpose of this study is to describe the mineralogy and chemistry of the sedimentary rocks of the Yellowknife Supergroup in an attempt to provide useful criteria for correlation with similar supracrustal sequences in the Slave Province; to understand better the history of the Archean crust at Yellowknife; to determine secular petrographic and geochemical trends upwards in the Burwash Formation; and, to evaluate geochemical trends in Bouma cycles in the Burwash Formation.

For this study, point-count modal analyses have been used as a basis for comparison of petrographic parameters involving quartz, feldspar and lithic fragments, with emphasis on ratios of composite quartz grains to total quartz, plagioclase to total feldspar, and volcanic lithic fragments to total lithic fragments. In addition, individual chemical analyses have been related to the petrographic results in an attempt better to delineate chemical and petrographic trends in the Burwash Formation and from the Burwash Formation to the Walsh Formation.

Studies of Archean rocks, using similar methods, have been carried out by Donaldson and Jackson (1965), Goodwin and Shklanka (1967), Condie (1967), Condie et al (1970), Walker and Pettijohn (1971), and Ojakangas (1972) to determine the nature of source terrane.

Donaldson and Jackson (1965) determined that Archean sedimentary rocks in the North Spirit Lake area of northwestern Ontario have a high quartz content and therefore probably were derived from a sedimentary or granitoid source area rather than a volcanic one. Goodwin and Shklanka (1967) concluded that sediments of the Bee

Lake area of northern Ontario had been deposited in a trough behind a volcanic uplift and had been derived in part from an adjacent granitic upland. In a study of early Precambrian graywackes from Wyoming, Condie (1967) determined, on the basis of modal and chemical compositions, that the source area was composed of quartz-rich meta-sedimentary rocks with lesser amounts of granitic rock. Relatively high amounts of Fe, Mg, and Ni, and a high Mg/Fe ratio suggest a minor mafic component in the source area.

Graywackes of the Fig Tree Group in South Africa are inferred to have been derived from a diverse source area composed principally of chert, volcanics, granitic-metamorphic rocks, and some ultramafics (Condie et al 1970). A progressive upward increase in granitic debris in the graywackes suggests a gradual unroofing of a granitic metamorphic terrane which was initially covered by a thick sequence of volcanic rocks. The granitic detritus in the graywackes indirectly records one or more pre-Fig Tree (>3400 m.y.) granite-forming events in Southern Africa (Condie et al 1970).

Walker and Pettijohn (1971) have identified four main facies in the East Bay area of Minnitaki Lake of northern Ontario. A quartz-porphyry at the eastern end of the basin has been identified as the source area for the arkosic conglomerates. Quartz-rich graywackes and granite-bearing conglomerates indicate a granite or granite-gneiss source area, devoid of greenstone cover. The gradual increase in quartz during basin filling suggests progressive uplift of the terrane bordering the trough.

Archean graywackes of the Vermilion district, northeastern Minnesota, were derived from felsic-intermediate volcanic accumulations within the depositional basin. Minor granitic detritus can be traced to the Saganaga Granite, which appears to have intruded the sequence during volcanism and sedimentation (Ofakangas 1972).

The studies of Archean sedimentary rocks in the Superior Province of the Canadian Shield (Donaldson and Jackson 1965; Goodwin

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and Shklanka 1967; Walker and Pettijohn 1971; and Ojakangas 1972) in Wyoming (Condie 1967), and in South Africa (Condie et al 1970) have shown that on the basis of petrography and chemistry of the sedimentary rocks, pre-sedimentary granitic sources can be convincingly demonstrated and the evolution of provenance of the sediments determined. The present study was initiated with the hope that a study of the only identified basin in the Slave Province (J.B. Henderson 1970a) would yield similar results.

CHAPTER I

DESCRIPTION OF THE SUPRACRUSTAL ROCKS OF THE SLAVE PROVINCE

INTRODUCTION

The Slave Province (Figure 1) underlies some 75,000 square miles of the northwestern part of the Canadian Shield (McGlynn and Henderson 1970) and the rocks are mostly Archean in age. The last major event to affect the Slave Province was the Kenoran event at 2480 m.y. (Stockwell 1968). Summaries of the geology of the Slave Province can be found in McGlynn (1970), McGlynn and Henderson (1970, 1972), and J.B. Henderson (1970a). The following description of the supracrustal rocks is taken from McGlynn (1970) and McGlynn and Henderson (1970).

SUPRACRUSTAL ROCKS

About 40% of the Slave Province is underlain by Archean supracrustal rocks of the Yellowknife Supergroup. Of this, more than three-quarters are of sedimentary origin, in various degrees of preservation, and the rest volcanic (Figure 1). All the Archean stratified rocks of the Slave Province belong to the Yellowknife Supergroup (J.B. Henderson 1970b). The succession is broadly similar throughout the Province and is similar to that of Archean stratified rocks throughout the world. It consists of a thick sequence of predominantly mafic volcanics at the base followed by graywackes and shales. Minor amounts of conglomerate, more mature sandstones, limestones and tuffaceous sediments may occur in the transition zone between these two major lithologic divisions.

The volcanic rocks are mainly basic flows of subaqueous origin. Intermediate to acidic flows, tuffs, and breccias are common in the upper part of the volcanic sequence but these rocks form less than 15% of the total volcanic sequence. Chemically, the magma type is tholeiitic basalt with some calc-alkaline characteristics which Baragar (1966) attributes to contamination by sialic material. Minor bodies of diorite and gabbro are common within the volcanics.

Overlying the volcanic sequence is a thick monotonous succession of quartzose and feldspathic graywackes and interbedded

Figure 1. Generalized geological map of the Slave Province (from McGlynn and Henderson 1972).

- A. Predominantly granitic rocks.
- B. Mixed granitic and metasedimentary and metavolcanic rocks.
- C. Volcanic rocks of the Yellowknife Supergroup.
- D. Sedimentary rocks of the Yellowknife Supergroup.
- E. Aphebian cover on the Slave Province.

shales and argillites. The sediments are typically conformable with the volcanics and many thin flows and tuffaceous units are interbedded with the sediments. Conglomerates and carbonates are common in the transition zone. The graywackes are typically graded, and although average bedding thickness is less than 10 cm., more massive units several meters thick are common. Calc-silicate layers and lenses are common in the sandy portions of some beds. Primary structures are: graded bedding, groove casts, convolute laminations, flame structures, and parallel and ripple laminations (Plates I and II). They are characteristic of Bouma cycles and indicative of turbidity current deposition. Local thin beds of limestone and dolomite and dolomite breccia within the sedimentary sequence where the volcanic division thins may have been deposited in shallow water around centers of volcanic activity. The quartz-rich character of the graywackes and the presence of granitic cobbles and vein quartz in the conglomerates suggest a source area consisting in part of granitic rocks.

YELLOWKNIFE SUPERGROUP TYPE SECTION

The type area of the Yellowknife Supergroup is Yellowknife Bay. The geology was first described by R. Bell (1900) and subsequently by Camsell and Malcolm (1919), J.M. Bell (1929), Stockwell (1933), J.F. Henderson (1938), Jolliffe (1936, 1938, 1942, and 1946), and J.F. Henderson and Brown (1948, 1950, and 1966). Baragar (1966) described the chemistry of the volcanic rocks, Brown (1955) the faults, J.B. Henderson (1970a, 1970b, and 1972) the petrography, stratigraphy and primary structures of the sedimentary rocks, and Ramsay (1973), the nature of biotite chemistry in the sediments.

J.B. Henderson (1970b) defined the Yellowknife Supergroup, comprising the Beaulieu Group and the Duncan Lake Group (Figure 2). The Kam and Duck Formations make up the Beaulieu Group and the Burwash, Walsh, and Jackson Lake Formations make up the Duncan Lake Group. The Banting Formation has not been assigned to either group.

STRATIGRAPHY OF THE YELLOWKNIFE SUPERGROUP AT YELLOWKNIFE, N.W.T.

Figure 2. Stratigraphy of the Yellowknife Supergroup at Yellowknife (after J.B. Henderson 1970b).

* not assigned to either group

WEST SIDE YELLOWKNIFE BAY

Kam Formation

The Kam Formation crops out on the west side of Yellowknife Bay and comprises about 9,000 meters of basaltic to andesitic flows, massive and pillowed (Figure 3). The flow units range from a meter to 150 meters in thickness. There also are interbedded tuffs, agglomerates, breccias, few porphyritic flows, and 360 meters of metadacite. The succession has been intruded by sills and dykes and irregular bodies of gabbro. The base is an intrusive contact with the western granodiorite and the top has been eroded.

Jackson Lake Formation

This Formation unconformably overlies the Kam Formation. The basal unit is a conglomerate with coarse angular blocks of mafic volcanics. Upwards, the clasts are smaller, more rounded, and show an increase in felsic content. Granitic boulders occur in this unit to the south. The conglomerate is overlain by crossbedded sandstone with thin interbeds of siltstone to black shale. The top is either unexposed or faulted out against the Banting Formation.

EAST SIDE YELLOWKNIFE BAY

Duck Formation

Intermediate volcanic flows that make up the Duck Formation may represent the eastern extension of the Kam Formation. The Duck Formation appears to be conformably overlain by the Burwash Formation.

Burwash Formation

The Burwash Formation, about 4,500 meters thick, consists of graywackes and shales that show features characteristic of turbidity current deposition and Bouma cycles. The graywacke predominates over shale except near the top of the section. The framework components of the graywackes are quartz, volcanic rock fragments, and

West side of Yellowknife Bay

East side of Yellowknife Bay

Fault.....

Syncline, anticline.....

Figure 3. Geology of the Yellowknife Bay area (after Henderson 1972).

plagioclase in decreasing order of abundance.

Banting Formation

This is a volcanic succession about 1,200 meters thick, of porphyritic dacite flows, felsic agglomerates, pillowed andesites and crystal tuffs. The clasts are streaked due to shearing. A conglomerate occurs at the top, west of Yellowknife River.

Walsh Formation

This Formation is made up of graywackes and argillites and overlies the Banting Formation. It differs from the Burwash Formation in that there is a much higher proportion of shale relative to siltstone and graywacke. It is exposed along the axis of the syncline north of Yellowknife Bay (Figure 3), and is highly deformed.

AGE RELATIONS

The last major thermal event to affect the Yellowknife area of the Slave Province was associated with the Kenoran Orogeny at 2480 m.y. (Stockwell 1970). All the rocks of the Yellowknife Supergroup are Archean in age. Using Rb-Sr whole rock methods, Green et al (1968) dated the volcanics at 2625 ± 160 m.y. The volcanic sequence is intruded by two synkinematic to late kinematic batholiths at 2610 ± 58 m.y. (southeast granodiorite) and 2590 ± 90 m.y. (western granodiorite). A large body of muscovite granite at Prosperous Lake gives a date of 2575 ± 25 m.y. Green and Baadsgaard (1971) have refined these dates using zircon, Rb-Sr whole rock, and K-Ar values. The volcanics are 2650 m.y. The southeast granodiorite is 2620-2640 m.y. and the western granodiorite is 2610 ± 58 m.y. Thorpe (1971) gives a date of 2685 m.y. for the sediments based on a Pb-Pb value from zircons. The western granodiorite gives a date of 2690 ± 20 m.y. and the southeast granodiorite 2610 ± 10 m.y. Green and Baadsgaard (1971) also suggest that zircons from boulders in the Jackson Lake Formation conglomerate have Pb-Pb ages similar to those from the southeast granodiorite and that the southeast granodiorite was a partial source for the Jackson Lake Formation and overlying sediments.

CONGLOMERATES OF THE YELLOWKNIFE SUPERGROUP

There are a number of excellent occurrences of conglomerates in Slave Province. The most notable ones crop out at Yellowknife, Ross Lake, and Point Lake (Figure 4). Unfortunately, all previous observations in these localities have been qualitative, and no detailed studies in the manner recommended by Donaldson and Jackson (1965) have been yet undertaken. The following descriptions are taken from the original work and the qualitative nature of the observations is evident.

Yellowknife Bay

The conglomerate that crops out on the west side of Yellowknife Bay, Walsh Lake, Jolliffe Is., and the Sub Islands has been described by Jolliffe (1938), J.F. Henderson and Brown (1948), and J.B. Henderson (1970a, 1970b, and 1972). At Yellowknife Bay this conglomerate has been assigned to the Jackson Lake Formation (J.B. Henderson 1970b).

The transition within the Yellowknife Supergroup from volcanics to sediments is marked at Yellowknife Bay by a conglomerate which rests unconformably on the underlying volcanics. An erosional surface with up to 60 meters of relief can be traced from Jackson Lake north of Yellowknife Bay, west to Walsh Lake, and south along the west side of Yellowknife Bay. This basal conglomerate also crops out on Jolliffe Is. and on the Sub Islands to the south.

Most boulders in the conglomerate are volcanic rocks of local derivation. The clasts are boulder size at the base of the conglomerate and decrease in size upwards. There is also an upward trend from an abundance of mafic volcanic clasts to an abundance of felsic volcanic clasts. Clast types that have been noted are: pink granite, granitic, quartz, and vein quartz, chert porphyry, ferruginous carbonate, arkosic grit, 'green rock', felsic volcanic, and mafic volcanic. The matrix ranges from ferruginous carbonate to graywacke. Well-rounded granitic boulders are particularly abundant on the Sub Islands.

Figure 4. Localities of conglomerates and basement rocks in the Slave Province. From McGlynn and Henderson (1972) with localities added.

1. Yellowknife area.
2. Ross Lake area.
3. Benjamin Lake area.
4. Arseno Lake area.
5. Point Lake area.
6. Courageous Lake area.
7. Indin Lake area.
8. Beaulieu River area.

Legend same as in Figure 1.

Ross Lake Area

The conglomerate at Ross Lake has been described by J.F. Henderson (1938 and 1939) and Fortier (1947). Clast types noted are: granite, quartzite, greenstone, and felsite. The matrix is a limy sandstone to limy grit. East of Ross Lake the conglomerate has a crystalline matrix, altered in many places to lime-silicate minerals. The unit grades, from the contact on the east with a granodiorite, westward into a conglomerate composed of only volcanic material. At Ross Lake the conglomerate is separated from sedimentary strata to the west by a heterogeneous group of rocks including rhyolite, breccia, chert, slate, sericite schists, and bands of limestone. Farther south, the conglomerate occurs where the volcanics thin and is conformable with the sediments to the west. To the east, it is intruded by granodiorite, but to the north, altered basic lavas are exposed between the granodiorite and conglomerate.

Courageous Lake Area

The conglomerate north of Courageous Lake has been described by Folinsbee (1947) and Mobre (1951 and 1956). Interbedded with the volcanics, it forms a unit 1,500 meters long and up to 45 meters wide. Pebbles up to 3 cm. in length are elongated and well rounded. Clasts noted are: quartz, chert, rhyolite, amygdaloidal lava, mafic volcanics, quartz-feldspar-hornblende-chlorite-epidote clasts, shale, and graywacke. This conglomerate is well sorted and of aqueous origin.

Point Lake Area

Stockwell (1933) and Bostock (1967) have described a conglomerate at Point Lake that is interbedded with volcanics just east of Richardson Bay. In this locality the conglomerate outcrop belt is approximately 1,200 meters wide but narrows and ends along strike within 1.6 km.

On the north shore is another conglomerate belt which extends for at least 5 km. and is 900 meters wide. It lies between the contact of volcanic rocks and a sequence of slate-argillite-graywacke. The

conglomerate is composed of rounded boulders, cobbles, and pebbles, chiefly of vein quartz and granitic rocks in a greenish schistose matrix. Granitic gneiss and quartzite clasts are represented locally and there also are light and dark green ovoid volcanic bombs, lenses of carbonte, and rare cobbles of diorite and amphibolite.

A K-Ar determination on muscovite from a boulder indicates an age of 2660 ± 75 m.y. A third body of conglomerate crops out on the first point west of Richardson Bay and is about 2 km. long and is bordered on its southeast side by granite.

There also is a narrow band of conglomerate that crops out on a creek flowing from Wray Lake (now called Starvation Lake on G.S.C. compilation map 1055A - by Brown 1958) to Point Lake. It is bordered on the east by sedimentary gneiss and on the west by granite. Pebbles of squeezed grey granite and quartz in a biotite gneiss matrix are reported for this locality.

Arseno Lake Area

McGlynn and Ross (1963) have described a paraconglomerate which conformably overlies the volcanic rocks in the southeast part of the Arseno Lake area. Ranging in thickness from about one meter to 450 meters, it consists of a variety of pebbles from 3 to 30 cm. in size in a matrix of indistinct layers of aligned hornblende crystals alternated with quartz-and plagioclase-rich bands. Biotite, minor epidote and sulphides are also present. Chlorite is the chief mafic mineral, but hornblende forms up to 30% of the matrix. Pebbles, rarely in contact with one another, compose as little as 1% but locally as much as 25% of the rock. Near the associated volcanic rocks, pebbles are mostly angular volcanic fragments. Higher in the section, the diversity is greater and includes rounded cobbles of granitic rock, diorite, quartz, fine-grained felsitic rock, and angular pebbles of graywacke and shale. The pebbles are stretched parallel to the crush zones which in turn are parallel to fold axes (McGlynn and Ross 1963). These rocks are conformably overlain by feldspathic graywacke and shale.

Conclusion

Except for the Yellowknife Bay locality, conglomerates in Slave

Province are everywhere conformable with associated rocks. At Point Lake and Courageous Lake the conglomerate is interbedded with the volcanics. J.B. Henderson (1970a and 1970b) and McGlynn and Henderson (1970 and 1972) do not regard the unconformity at Yellowknife as a major break, interpreting the conglomerate to have been deposited contemporaneously with late volcanism.

The interesting thing to note is that granitic clasts, invariably well rounded, and/or quartz, vein quartz and chert occur in all conglomerates, even those conglomerates that are interbedded with the volcanics. The well-rounded granitic clasts, as compared to the angular volcanic and sedimentary clasts in the conglomerates, suggest that granitic sources were exposed during and after volcanism, but were more distant than other sources of components in sedimentary rocks of the Yellowknife Supergroup.

BASEMENT ROCKS TO THE YELLOWKNIFE SUPERGROUP

See Figure 4 for localities:

Beaulieu River Area

J.F. Henderson (1938), Baragar (1966) and J.B. Henderson (1973) have described a chloritized granite body that may be basement to the Yellowknife Supergroup rocks. This highly altered granite has been intruded by other granitic bodies that also cut the Yellowknife sediments. Clearly defined intrusive contacts between the granite body and the volcanic belt are not seen. Mafic dykes, compositionally and texturally similar to some of the Yellowknife volcanic flows, intrude the granite body and the volcanic belt. If the mafic dykes are related to the volcanic flows, the granitic body must predate the Yellowknife supracrustal rocks (Baragar 1966).

Benjamin Lake Area

Davidson (1967) and Heywood and Davidson (1969) have mapped a leucocratic to mesocratic biotite metatonalite at Brislane Lake in the Benjamin Lake area that may be basement to the Yellowknife Supergroup rocks. The body exhibits no cross-cutting relationships. The Yellowknife volcanics surround the body on the north, west, and south sides. A thin wedge of banded rock separates the body from the mafic volcanics on the east side. There is no evidence of a contact aureole. Amphibolite dykes which cut the metatonalite may be feeders to the Yellowknife volcanic rocks. On the west side of Brislane Lake, it is not certain whether the amphibolite dykes are older than the Yellowknife volcanics, or are simply an intrusive equivalent of the lower part of the Yellowknife Supergroup.

Indin Lake Area

Frith et al (1974) have suggested that granitic rocks along the western margin of the supracrustal belt may represent basement to the Yellowknife Supergroup rocks in the Indin Lake area. A biotite granite gneiss, part of the "basement" sequence, has been

dated at 3002 m.y. in the Grenville Lake area (Frith et al 1974). Also part of the "basement" sequence is a hornblende metagabbroic gneiss and a metasomatized quartz dioritic gneiss. Similar rocks also occur to the south at Truce Lake, a distance of 15 km., as migmatites.

Point Lake Area

A body of chloritized granite at Point Lake is probably older than the nearby assemblage of conglomerate, volcanics and schist (Stockwell 1933). The granite body contains inclusions of dark green schist, remnants of the country rock, which the granite intruded. The granite body is also cut by younger granite bodies which cut also the Yellowknife volcanics and sediments. The conglomerate on the first point west of Richardson Bay rests against the granite body and dips away from the granite. The conglomerate shows no evidence of contact metamorphism and contains many boulders identical to the granite. Basic dykes closely resembling the lavas overlying the conglomerate are intruded into the conglomerate and cut the granite but do not appear to cut younger granites in the area. Stockwell (1933) suggests that these dykes are feeders to the Yellowknife volcanics.

Conclusion

In all the above mentioned cases, the granitic "basement" rocks are highly altered. The bodies are close to or part of large granodiorite batholiths and at, or close to, margins of supracrustal outcrop areas. This last fact has lead J.B. Henderson (1972), and McGlynn and Henderson (1970 and 1972) to conclude that these areas of supracrustal rocks represent basins of accumulation and are not just structurally preserved downfoldings of an originally much more extensive area. If this is true, present basin margins are close approximations to original depositional margins.

CHAPTER II

PETROGRAPHY OF THE BURWASH AND WALSH FORMATIONS

INTRODUCTION

One hundred and fifty-two samples were collected from the Burwash and Walsh Formations along the east side of Yellowknife Bay (Figure 5). The Burwash Formation has been sampled at three localities, stratigraphically corresponding to the lower, middle and upper parts of the Formation. The sample locality in the Walsh Formation is at the head of Yellowknife Bay, but because of the structural complexity of the area, the stratigraphic position in the formation is unknown. The lower section in the Burwash Formation was sampled over a distance of 100 meters, and the middle and upper sections over 80 meters each. The section in the Walsh Formation was sampled over a distance of 20 meters.

After preliminary examination of thin sections of all samples, eighteen were selected for detailed petrographic and chemical analysis. Seven additional samples were selected for detailed point-count modal analysis, thereby reducing the possibility of erroneous conclusions being drawn on the basis of atypical graywackes.

In point counting the thin sections, the author used the clast classification described by J.B. Henderson (1972) to allow sound comparison of the results of this work with those of Henderson.

The value and reliability of point-count modal analysis has been discussed by Van der Plas and Tobi (1965), Welsh (1967) and Kalsbeck (1969). Given the grain size of the specimens, the chart of Kalsbeck shows that a systematic count of 700 points for the coarser units would result in at least 580 individual grain counts with a precision of $\pm 4\%$. An estimate of the reliability, as determined from the chart of Kalsbeck, is: quartz, matrix and total rock fragments - $\pm 3.5\%$; feldspar - $\pm 3\%$; and all other classifications - $\pm 2\%$. The values quoted in Table I should be read as, quartz 29% $\pm 3.5\%$.

Figure 5. Location of sample localities in the Burwash and Walsh Formations at Yellowknife Bay. Sections 1, 2 and 3 correspond to the lower, middle and upper parts of the Burwash Formation. 4 is the section locality in the Walsh Fm.

Petrography

The sandstone units weather light gray to dark greenish gray to black. The grain size is typically medium sand or finer (J.B. Henderson 1972); coarser material is confined to the bottom of A units (Bouma cycle A, B, C, D and E designation of Bouma 1962, is used throughout for individual bed descriptions - see Figure 6), but grain size greater than medium sand size is rare. Individual units grade upwards from medium to fine sand to siltstone to mudstone. The A units typically are of medium sand size at the base and grade to fine sand. The B units are fine sand to silty; most C units are slightly coarser than the B units with fine sand size predominating. The D units tend to be siltstone and of slightly finer average grain size compared to the B units. The E units are mudstones and those beds that grade directly from A to E (B, C and D absent) are mudstones at the top.

The coarse units of the Burwash Formation are graywackes (Pettijohn 1957). The framework components are quartz, rock fragments and plagioclase in an abundant matrix of chlorite, muscovite and fine-grained quartzo-feldspathic material.

The graywackes are typically homogeneous on thin-section scale. Maximum grain size ranges from 0.9 mm. to 1.9 mm., with modes falling between 0.4 and 0.7 mm. Continuous gradation from maximum size through to matrix (less than 0.02 mm.) and smaller is present in all graywackes. Quartz typically is the coarsest framework component although some volcanic fragments are larger and some intraformational sedimentary fragments are of pebble size. Most grains are angular (roundness has been estimated visually using the chart of Pettijohn 1957) and much of the quartz has serrated edges which is probably a metamorphic effect (J.B. Henderson 1972). The feldspar is angular, occurring as euhedral to subhedral grains. Rock fragments, however, show a complete gradation from angular to well-rounded grains (Plates II and IV). Granitic fragments commonly show the best rounding. Boundaries of rock fragments show a gradation from

Figure 6. A complete Bouma cycle.

sharply defined to diffuse, merging with the matrix. The latter most commonly are mafic and intermediate volcanic fragments (Plates IV and VI).

The graywackes are mineralogically, chemically (Table III) and texturally immature as shown by the abundance of unstable rock fragments and feldspar, the low ratio of alumina to soda which is an index of chemical maturity (the value for these samples varies from 3.5 to about 5 as compared to 10 for a mature sandstone; Pettijohn 1957), the angular nature of the coarser fraction and by the abundance of matrix (this last point is somewhat misleading and will be discussed in the section on matrix). These results are in agreement with the observations of J.B. Henderson (1972).

Quartz

The average quartz content of the Burwash Formation is 26% and of the Walsh Formation is 29% (Table I). The quartz has been subdivided into single-domain grains, those with two or more but less than six domains, and those grains with greater than six domains. See Plates II and IV for examples of quartz types. Blatt (1967) has suggested that those grains with more than six domains are likely to have been derived from a metamorphic terrane. No genetic significance has been placed on the divisions used in this report. Most of the grains with greater than six domains do not have the internal morphology described by Krynine (1946) as being typical of metamorphic quartz. Very rare grains do have internal elongate boundaries and a bimodal size distribution of domains. Virtually all grains of quartz show undulatory extinction which is probably a result of metamorphism. Some very angular and shard-like grains may be devitrified glass which has been replaced during diagenesis and metamorphism by quartz. A few quartz grains that show resorption quite likely are of volcanic origin but for the most part the quartz provenance is indeterminate.

Feldspar

The Burwash and Walsh Formations average 13% and 22% feldspar respectively. All feldspar is plagioclase of albite-oligoclase composition. No grains of microcline or orthoclase were revealed by staining sections using the Bailey and Stevens two-stage method (Allman and Lawrence 1972). The thin sections were examined after the cobaltinitrite stage and no K-feldspar was noted, although muscovite took up the stain. The second stage gave poor results because the samples are very fine grained and the rhodizonate coated the slide, obscuring grain relationships.

The feldspar is easily divided into twinned and untwinned groups. The untwinned plagioclase appears dusty (Plate VI), a common characteristic of albitized plagioclase (Crook 1960; Dickinson et al 1969). Most of the twinned feldspar is smaller in size and ranges from very fresh grains with distinct twinning to highly altered grains that show almost totally obscured twinning. Albite, pericline and carlsbad twins were noted, with albite twinning being the most common. The destruction of twins might be a result of the regional grade of metamorphism (Ramsay 1973). Only two plagioclase grains showing possible zoning were seen (Plate VII) but the grains were so badly altered that a firm identification could not be made. Both twinned and untwinned plagioclase is of albite-oligoclase composition which is probably a function of regional greenschist grade of metamorphism. The two types may reflect the dual nature of the source area (J.B. Henderson 1972).

The lack of K-feldspar is characteristic of Archean graywackes of the Canadian Shield (Donaldson and Jackson 1965; Walker and Pettijohn 1972; Ojakangas 1972). Henderson (1972) also noted the lack of K-feldspar in the Burwash Formation but Ramsay (1973) mentions the presence of K-feldspar in both the Burwash and Walsh Formations (although he gives no detail on abundance or characteristics of the feldspar). Because granitic rock fragments are a small but important component of the graywackes, it would seem that grains of K-feldspar must have been present at one time, but in view of the

TABLE I

MODAL ANALYSES* OF SEDIMENTS FROM THE BURWASH AND WALSH FORMATIONS

Sample No. **	1-1	1-18	1-33	1-41	1-44	1-62	1-70	2-1	2-5	2-17	2-19	2-20	2-21
Boima Designation	A	A	A	B	E	A	A	A	A	A	B	C	D
QUARTZ	20.7	24.3	24.6	24.5		22.1	25.8	28.4	27.6	31.5	18.6	18.7	6.6
1 d	69.0	69.4	57.0	71.9		57.0	73.5	60.3	43.6	69.6	78.3	69.5	78.3
2 < d ≤ 6	20.0	19.4	29.6	21.2		25.9	18.8	27.4	34.2	20.7	24.6	28.2	17.4
d > 6	11.0	11.2	13.4	6.9		17.1	7.7	12.3	22.2	9.7	3.1	2.3	4.3
FELDSPAR	9.3	10.8	15.3	11.7		13.4	9.9	13.6	12.4	15.4	7.2	12.6	2.3
twinned	64.6	69.7	56.1	74.7		61.8	69.6	74.5	63.3	71.2	68.0	62.5	50.0
untwinned	35.4	30.3	43.9	25.3		38.2	30.4	25.5	36.7	28.8	32.0	37.5	50.0
ROCK FRAGMENTS	36.8	32.1	20.7	25.1		30.9	26.6	23.4	18.8	18.1	7.7	10.3	12.0
plutonic	5.8	5.3	12.4	5.0		8.1	7.5	5.9	10.2	9.2	5.6	5.6	7.1
silt. volcanic	9.3	4.9	6.2	4.5		16.7	8.1	20.8	19.2	13.1	7.4	11.1	25.0
int. volcanic	52.6	54.7	42.1	63.5		41.0	48.4	44.1	55.7	37.7	33.4	25.0	
mafic volcanic	11.3	14.2	14.5	7.9		14.1	4.8	0.6	3.0		3.6	11.1	
sedimentary	12.8	9.8	13.1	9.0		8.6	15.6	25.0	11.9	8.5	50.0	45.8	67.9
unidentified	8.2	11.1	11.7	10.1		11.5	15.6	25.0	11.9	31.5	50.6	45.4	76.3
MATRIX	26.7	25.4	33.8	28.8		21.9	30.9	30.0	29.6	28.9	43.1	38.7	34.6
qtz-fs	54.6	43.2	46.9	37.7		32.5	21.8	60.2	75.9	63.0	56.9	61.3	65.4
micaceous	45.4	56.8	53.1	62.3		67.5	78.2	39.8	24.1	27.0	tr		
CARBONATE	2.4	1.4	1.5	7.5		8.9	2.7	0.4	0.3	0.4	tr		
EPIDOTE	2.0	1.0	0.7	0.4		1.3	2.0	1.5	1.6	1.9	1.6	1.3	2.5
OPAQUES	1.0	1.4	0.6	0.8		1.1	0.4	0.4	1.4	0.7	0.7	0.9	0.3
META-BIO-CHL	1.1	2.7	1.8	0.5		0.3	1.7	2.3	3.7	3.1	13.6	10.8	
APATITE	tr						tr		tr		tr		
AMPHIBOLE		0.8		0.7	tr								
ZIRCON		0.1											
TOURNALINE													
Q"	31	36	41	40		34	41	43	47	48	55	45	
F	14	16	25	19		20	16	21	21	24	21	30	
L	55	48	34	41		46	43	37	32	28	24	25	
G/Q	0.3	0.3	0.3	0.3		0.4	0.3	0.4	0.6	0.3	0.3	0.3	
P/F	1	1	1	1		1	1	1	1	1	1	1	
V/L	0.8	0.8	0.8	0.8		0.8	0.7	0.9	0.9	0.8	0.7	0.8	

* 700 points per thin section
" explained in text** Sample number 1-18 designates sample 18
of section 1

TABLE I (CONTINUED)

Sample No.	2-22	2-31	2-36	3-1	3-3	3-12	3-17	3-18	3-26	4-5	4-8	4-9	4-10
Bouma Designation	E	A	A	A	A	A	A	B	A	A	A	A	E
QUARTZ													
1 d													
2<d≤6													
d>6													
FELDSPAR													
twinned													
un-twinned													
ROCK FRAGMENTS													
plutonic													
sil. volcanic													
int. volcanic													
mafic volcanic													
sedimentary													
unidentified													
MATRIX	100.0												
qtz-fs	44.0												
micaceous	56.0												
CARBONATE	tr												
EPIDOTE	tr												
OPAQUES	tr												
META-BIO-CHL	tr												
APATITE													
AMPHIBOLE													
ZIRCON													
TOURNALINE													
Q	39	42	35	42	40	44	44	57	44	55	45	45	
F	25	23	20	15	20	20	17	17	20	28	43	30	
L	36	35	45	43	40	40	39	26	36	17	12	17	
C/Q	0.4	0.5	0.3	0.4	0.3	0.3	0.5	0.4	0.3	0.5	0.3	0.4	
P/F	1	1	1	1	1	1	1	1	1	1	1	1	
V/L	0.8	0.8	0.8	0.9	0.8	0.8	0.9	1	0.9	0.8	0.8	0.9	

observations of J.B. Henderson and Ramsay, the K-feldspar was only a minor component. J.B. Henderson (1972) has suggested that breakdown of the K-feldspar may be promoted by reaction with sea water. Gluskoter (1964) has explained the lack of K-feldspar in parts of the Franciscan graywackes of California as being due to secondary breakdown. K-feldspar in the Burwash and Walsh Formations may have been similarly altered to clay minerals and other matrix components.

The feldspar grains in the Burwash and Walsh Formations appear to have been derived mainly from a volcanic terrane. Intermediate and felsic volcanic rock fragments occur in various states of preservation in the graywackes. Thin section evidence suggests that breakdown of volcanic clasts into matrix and individual feldspar grains (Plates V and VI) may have resulted in those feldspar grains being counted as individual framework feldspar grains.

Feldspar in Yellowknife sediments of other areas in the Slave Province have been recorded as follows: Stockwell (1933), Great Slave Lake-Coppermine River area, oligoclase; Tremblay (1950), northeast part of Giaque Lake area, andesine-albite; Tremblay (1952), Giaque Lake area, andesine; Tremblay (1971), Beechey Lake area, mentions the presence of potassic feldspar along with plagioclase but no description of its nature is given; Moore (1956), Courageous Lake-Matthews Lake area, albite and perhaps some orthoclase.

Rock Fragments

Rock fragments average 26% in the Burwash Formation and 9% in the Walsh Formation. Rock fragment abundance varies with metamorphic grade. In the Burwash and Walsh Formations, as biotite becomes more abundant, apparent rock fragment abundance decreases due to breakdown into matrix-like material (J.B. Henderson 1972). This process together with changing source conditions probably are the main reasons for the paucity of rock fragments in the Walsh Formation. In descriptions of graywackes from other parts of the Slave Province, no mention of rock fragments is ever made. This probably is a direct

result of metamorphism (J.B. Henderson, personal communication 1973).

The following rock types can be recognized as sand-sized clasts in thin section (see also Plates II to VII for examples of clast types):

Plutonic: These fragments are of fine to medium sand size and are moderately well-rounded interlocking aggregates of 2 or 3 grains of quartz and feldspar.

Silicic Volcanic: These clasts range from well rounded to very angular, and from fine sand to coarse sand. They have the appearance of recrystallized chert, but their volcanic nature can be discerned on closer inspection.

Intermediate Volcanic: Most are of medium sand size and are angular to well rounded. They have a very fine-grained groundmass of small plagioclase laths and quartz, and phenocrysts of plagioclase.

Mafic Volcanic: These clasts typically consist of felty masses of plagioclase laths with some epidote and rare altered pyroxene. Most of these grains are quite well rounded. The epidote probably results from the alteration of ferromagnesian minerals, resulting in the formation of quartz along with epidote (Plate VII). The textures and compositions are typical of Archean basalts and andesites (Moorhouse 1970).

Sedimentary: These fragments, interpreted as intraformational in origin, are siltstones and mudstones that consist of micaceous masses intergrown with fine-grained quartzo-feldspathic material. Most are angular and resemble both the E units and typical matrix of the A units (Plate II).

Unidentified: Fragments of this category are so extensively deformed and altered or so gradational with the matrix that it is impossible to determine their original nature. In some units this is the dominant category of grains classified as rock fragments (Table I).

Averages of the various rock types for the two formations are as follows (the Burwash Formation averages are given first and the Walsh Formation averages are parenthesized): Plutonic 8.4 (10.2);

Silicic Volcanic 13.9 (27.0); Intermediate Volcanic 47.7 (26.5); Mafic Volcanic 6.6 (0); Sedimentary 6.8 (0.7); Unidentified 15.2 (31.9).

There is a major decline in abundance of rock fragments from the Burwash to the Walsh Formation. This decline is probably of multiple origin, arising from changing source conditions, texture (the Walsh Formation being finer grained), increased structural deformation and slightly higher grade of metamorphism in the Walsh Formation. Plutonic and silicic volcanic fragments show a relative increase in the Walsh Formation compared to the Burwash Formation, with mafic volcanics absent and intermediate volcanics greatly decreased. The matrix in the Walsh Formation is less micaceous (i.e. mainly quartzo-feldspathic) and thus the breakdown of all mafic volcanics into matrix does not seem to provide an adequate explanation for their absence.

Several important conclusions can be drawn from the nature and abundance of rock fragments. The clasts, particularly the mafic and intermediate volcanic fragments, are probably an important source for in situ production of matrix. A certain percentage of feldspar grains in the framework also can be explained by the breakdown of intermediate volcanic clasts, thus leaving the phenocrysts as individual framework grains. The sedimentary rock fragments are commonly squeezed, elongate and gradational with the matrix, and thus they also may be an important source of matrix.

Accessory Framework Minerals

Minor constituents occurring in the Burwash Formation as detrital grains are: biotite and traces of muscovite (Plate IV), mainly as large ragged cleavage flakes which are different in size and texture from the metamorphic biotite and muscovite; zoned zircon; rounded grains of detrital epidote which contrasts with granular masses of secondary epidote; ragged detrital hornblende; apatite; rare tourmaline; and possibly some grains of sulphides, which could also be of diagenetic origin.

Carbonate is an important accessory but appears to be entirely of secondary origin. Condie (1967) has suggested that the following reaction takes place between calcic plagioclase and interstitial water during diagenesis:

This reaction could explain the presence of carbonate and the albization of the plagioclase.

The Walsh Formation contains detrital grains of apatite, zircon, and epidote. Opaques occur as a secondary mineral along with carbonate. The latter is a minor constituent that occurs only in the fine-grained mudstones.

Most biotite and muscovite is diagenetic and metamorphic, embaying and penetrating clastic grains. Chlorite is common as a replacement of biotite, and also appears to have replaced some mafic volcanic clasts (Plates II and IV).

Matrix

Matrix is the most abundant component of the graywackes, averaging 29.5% in the Burwash Formation and 37.7% in the Walsh Formation. Because of its abundance, its origin is important. The production of matrix in sandstones during diagenesis and subsequent metamorphism has been studied by many workers in the last ten years. Cummins (1962) first brought the problem of matrix origin to the attention of geologists. Experimental work on volcanogenic sediments by Hawkins and Whetten (1969) and Whetten and Hawkins (1970) suggests that post-depositional matrix is produced at temperature and pressure equivalent of 3,000-4,500 meters of burial. Brenchley (1969) has described matrix of authigenic origin in Ordovician graywackes of the Berwyn Hills, North Wales, and Lovell (1972) has provided petrographic evidence that at least part of the matrix in two eugeosynclinal flysch sequences is of post-depositional origin. In particular, he described the authigenic growth of phyllosilicates and the replacement of mafic volcanic clasts by pasty chlorite, interspersed with quartz and calcite. Buller and McManus (1973) used textural analysis to conclude that diagenetic disintegration

of about 30% of the sand-sized minerals would convert a typical modern turbidite into graywacke. Galloway (1974) has shown that several stages of matrix authigenesis occur in buried sandstones.

The matrix in the Burwash and Walsh Formations completely surrounds detrital grains. The division between matrix and grains, especially rock fragments, is subjective (Welsh 1967). There is complete gradation between sharply bordered unaltered clasts to highly altered clasts with indistinct boundaries.

The matrix shows a gradation between quartzo-feldspathic and micaceous varieties. The former is mainly a recrystallized fine interlocking mosaic of quartz and feldspar, whereas the latter is mainly a meshed intergrowth of muscovite and chlorite with only minor amounts of quartzo-feldspathic material. The muscovite is by far the dominant micaceous mineral.

Formation of the quartzo-feldspathic matrix is most likely a result of breakdown of felsic and silicic volcanic fragments, the micaceous matrix is most likely the result of breakdown of sedimentary fragments (J.B. Henderson 1972). From the textural evidence, this seems to be the most important source of matrix in the Burwash Formation (Plate VI). The Walsh Formation, however, is notable for a scarcity of micaceous matrix compared to the Burwash Formation. In the Walsh Formation, it would appear that silicic volcanic and granitic components were more abundant relative to mafic, intermediate volcanic, and sedimentary rocks. The strength of these conclusions must be tempered by the fact that fewer samples of Walsh Formation graywackes were examined.

INTERPRETATION

Crook (1960) and Dickinson (1970 and 1971) have described a method of interpreting detrital modes of graywacke and arkose using six basic parameters which are: Q-total quartz, F-total feldspar, L-total unstable lithic fragments, C/Q-composite quartz grains to total quartz, P/F-plagioclase to total feldspar, and V/L-volcanic fragments to total lithic fragments. Subquartzose sandstones have

Q less than 75 and further divisions in this category are: feldspathic (F/L greater than 3), lithofeldspathic (F/L less than 3 but greater than one), and lithic (L/F greater than 3). These parameters for the Burwash and Walsh Formation graywackes are given in Table I. Using these subdivisions, the Burwash Formation graywackes are subquartzose feldspatholithic sandstones and those of the Walsh Formation are subquartzose lithofeldspathic sandstones.

TABLE II
PARAMETERS TYPICAL OF VOLCANIC, PLUTONIC, AND TECTONIC
PROVENANCES WITHIN OROGENIC BELTS (DICKINSON 1970)

	Volcanic	Plutonic	Tectonic
Q	low (<25)	high (50±25)	moderate (25-50)
F	moderate (25-50)	high (~50)	low (25)
L	high (50-75)	low (~25)	moderate (~50)
C/Q	low (near 0)	low (near 0)	high (>0.5)
P/F	high (1.0-.75)	variable	variable
V/L	high (near 1.0)	variable	moderate (~0.5)
Special	pyriboles	mica	'chert-grain'

Subquartzose sandstones derived exclusively from a volcanic provenance typically have P/F near unity, a high V/L ratio, and a low value of Q (see Table II). The sands are typically feldspatholithic. The Burwash Formation graywackes are feldspatholithic but are unusually quartz-rich, with Q about 40 (Table I). This value of Q is typical of both plutonic and tectonic provenances but very few grains show the characteristics of metamorphic quartz. It therefore seems more likely, considering the ubiquitous presence of granitic fragments in both the graywackes and conglomerates, as well as the nature of pre-Yellowknife rocks, that a sialic plutonic source was present, although possibly it was only a minor source. The Walsh Formation graywackes are lithofeldspathic and all parameters are characteristic of a volcanic provenance except for quartz. The change from feldspatholithic in the Burwash to lithofeldspathic in

the Walsh plus an increase in quartz in the Walsh is suggestive of a waning in importance of the mafic volcanic source and a probable relative increase in importance of a plutonic source. This suggests that as deposition took place, a sialic source, which was remote and initially of minor importance as a supplier of detritus, was gradually being unroofed. The detrital amphibole and mica (Table I) are also indicative of a mixed volcano-plutonic source. No chert-grains are seen.

At Yellowknife, the associated volcanic pile is not regarded as a major contributor to the sediments by J.B. Henderson (1972) and McGlynn and Henderson (1970 and 1972). The new data presented here suggests that a lateral extension of the Yellowknife volcanic pile that must have extended over the western granodiorite was a major source for the sediments. If this is true, two problems can now be explained. Most volcanic rocks of the Slave Province appear to be of subaqueous origin, with pillowed flows being common (Baragar 1966; Baragar and Goodwin 1969; McGlynn and Henderson 1970, 1972). Perhaps the paucity of mafic volcanic fragments in the sediments is partly a result of early burial of mafic portions of the volcanic pile by acid volcanics, with the pile only being exposed to erosion when it was built up above wave base. The synkinematic southeast granodiorite contributed detritus to the conglomerate at Yellowknife (Green and Baadsgaard 1971) and probably to the overlying sediments as well. The western granodiorite, also synkinematic (Green and Baadsgaard 1971), would be unroofed and contribute detritus to the sediments as it was stripped of its volcanic cover. The western granodiorite would then be a supplier of plutonic detritus that became of increasing importance as erosion continued. Paleocurrent data of J.B. Henderson (1972) confirms the source to be in the west. This is from the direction of the volcanic pile and the western granodiorite. It appears that major unroofing of the western granodiorite coincided with the deposition of the Walsh Formation. This plutonic source, being farther away, explains the finer grain size and the better rounding of the granitic fragments in the graywackes. It would also be a partial explanation for the increase in quartz in the Walsh Formation. This change between the Burwash and Walsh.

Formations can be seen clearly in a QFL plot (Figure 7). Thus the Yellowknife volcanic pile and/or its lateral extension over the western granodiorite would be the major source for the volcanic detrital constituents in the sediments and the western and southeast granodiorites would be a source for the quartz and plutonic fragments.

Figure 7. QFL diagram of Burwash and Walsh Formation graywackes. I, II and III represent the lower, middle and upper sections of the Burwash Formation respectively.

CHAPTER III

GEOCHEMISTRY OF THE BURWASH AND WALSH FORMATIONS

INTRODUCTION

After preliminary thin section analysis, 16 samples from the Burwash Formation and 2 samples from the Walsh Formation were chosen for detailed chemical analysis. Examination of the thin sections ensured selection of representative samples, showing minimum secondary alteration, for analysis. Of the Burwash Formation samples, 9 are A units, 3 are B units, 1 is a C unit, 1 is a D unit, and 2 are E units. One A unit and one mudstone were selected from the Walsh Formation. The localities are shown in Figure 5. The samples were analysed by the author at the X-ray fluorescence facilities of Dr. B.M. Gunn at the University of Montreal. The method of preparation of samples has been described by Gunn and Watkins (1969), Gunn (1971), and Watkins et al (1970). The author used glass buttons and powder pellets to analyse for the following elements: Si, Al, Ti, Fe, Mn, Mg, Ca, Na, K, P, Rb, Sr, Cr, and Ni. The results are given in Table III. The samples were analysed for FeO and total volatiles in the geochemical laboratory of the Carleton University Geology Department. The analyst was C. Murray, using the method of Hounslow and Moore (1966).

The precision quoted for analyses done on standards at the facilities in Montreal is a maximum $\pm 0.3\%$ (SiO_2) to $\pm 0.002\%$ (MnO), and from a maximum ± 5 ppm (Cr) to ± 0.8 ppm (Rb), at the 95% confidence limit for replicate determinations (Watkins et al 1970). With respect to accuracy, any duplicate measurement not agreeing within the 95% confidence level is rejected by the computer and the analysis is repeated a third time (Watkins et al 1970). To ensure this standard of accuracy, the author made several duplicate buttons and powder pellets. Not only were the duplicate samples analysed, but samples were replicated every fourth analysis and three standards were also analysed at the beginning and end of each run (USGS standards analysed were AGV-1, W-1, and GSP-1). It was possible to reproduce the precision quoted for the analyses of the standards, but samples showed more variation in duplicate and replicate analyses. Although uncertainty is hard to determine, an acceptable accuracy appears to be $\pm 2\%$ of the quoted values (in the tables) for

TABLE III
CHEMICAL ANALYSES* OF SEDIMENTS OF THE BURWASH AND WALSH FORMATIONS

BURWASH FORMATION: SECTION 1 AND SECTION 2												
Sample No.	1-18	1-33	1-41	1-44	1-62	2-5	2-19	2-20	2-21	2-22	2-31	2-36
Bouma Unit	A	A	B	E	A	A	B	C	D	E	A	A
SiO ₂	56.64	58.63	60.36	56.85	57.23	64.93	59.14	63.06	51.26	51.01	63.16	62.00
Al ₂ O ₃	15.38	14.09	15.85	15.21	11.22	14.80	16.79	16.93	20.22	23.27	16.40	16.63
TiO ₂	0.82	0.68	0.82	0.75	0.37	0.63	0.71	0.72	0.91	0.97	0.70	0.65
Fe ₂ O ₃ **	8.04	7.80	6.82	8.71	4.69	6.53	7.51	7.01	9.30	10.37	7.08	6.84
MnO	0.08	0.07	0.09	0.11	0.10	0.06	0.08	0.07	0.10	0.12	0.07	0.07
MgO	3.45	3.09	2.61	3.79	1.81	2.42	2.89	2.84	4.00	4.66	2.93	2.81
CaO	1.85	1.24	3.48	1.47	6.51	1.39	1.77	1.50	1.72	1.93	1.16	1.23
Na ₂ O	4.13	4.10	3.92	3.12	3.30	3.15	3.07	2.96	2.23	2.09	3.25	3.25
K ₂ O	2.36	1.84	2.48	2.29	1.97	2.52	2.77	2.91	3.63	3.69	2.49	2.48
P ₂ O ₅	0.24	0.19	0.23	0.18	0.12	0.12	0.11	0.15	0.20	0.19	0.13	0.10
Volatiles	2.92	3.70	4.21	4.51	5.70	1.85	2.68	2.59	3.82	4.83	2.84	3.03
FeO	5.67	5.58	6.36	6.47	3.64	4.75	7.04	5.06	6.88	7.99	6.13	5.18
Rb	77	58	92	74	77	56	97	101	90	89	81	73
Sr	380	374	460	305	408	337	273	228	228	237	219	205
Cr	273	279	285	272	182	224	243	238	281	310	258	242
Ni	77	85	91	108	61	69	105	104	111	137	98	83
Total	95.81	95.08	99.87	96.99	93.02	98.40	97.42	100.74	97.39	103.13	100.21	99.09
Al ₂ O ₃ /Na ₂ O	3.8	3.5	4.0	5.0	3.3	4.6	5.4	5.7	8.8	9.8	5.0	5.1
Na ₂ O/K ₂ O	1.8	2.2	1.6	1.4	1.7	1.2	1.1	1.0	0.6	0.6	1.3	1.3
Rb/Sr	0.20	0.15	0.20	0.24	0.19	0.17	0.35	0.44	0.39	0.38	0.37	0.36
Cr/Ni	3.6	3.3	3.1	1.5	3.0	3.3	2.3	2.2	2.5	2.3	2.6	2.9

* oxides in weight %; trace elements in ppm

** determined as total iron
determined separately

TABLE III (CONTINUED)

Sample No.	BURWASH FORMATION					WALSH FORMATION		AVERAGES				
	SECTION 3							A	B	C	D	E
	3-3	3-12	3-17	3-18	4-5	4-10						
Bourne unit	A	A	A	B	A	E						
SiO ₂	63.25	63.80	68.32	54.86	70.55	50.76	65.27	61.19	64.39	55.64	57.44	
Al ₂ O ₃	14.76	16.17	14.37	19.02	11.60	24.31	15.86	18.13	17.38	21.53	20.12	
TiO ₂	0.58	0.67	0.62	0.84	0.53	1.08	.64	.80	.71	.92	.85	
Fe ₂ O ₃	5.82	6.65	6.19	8.44	5.71	7.08	6.72	7.70	6.88	9.54	9.53	
MnO	0.07	0.07	0.08	0.09	0.06	0.08	.07	.08	.07	.10	.11	
MgO	2.30	2.71	2.31	3.46	1.93	2.99	2.70	3.01	2.76	4.00	3.42	
CaO	2.67	1.72	2.51	1.95	1.21	0.41	2.44	2.51	1.55	1.83	1.75	
Na ₂ O	4.10	3.42	3.56	2.56	4.06	3.29	3.83	3.35	3.06	2.44	2.80	
K ₂ O	1.50	2.25	1.56	3.37	.19	4.63	2.28	3.03	3.04	3.82	3.08	
P ₂ O ₅	0.11	0.13	0.11	0.14	0.06	0.10	.14	.17	.15	.21	.18	
Volatiles	2.29	2.13	1.67	3.03	1.62	3.94						
FeO	4.95	5.15	5.43	6.52	4.24	5.57	5.13	6.64	5.06	6.88	7.23	
Rb	99	76	55	104	2	159	71	98	101	90	82	
Sr	255	306	352	284	236	131	315	339	228	228	271	
Cr	260	315	327	296	244	276	262	275	238	281	291	
Ni	80	82	74	109	69	95	80	102	104	111	123	
Total	97.45	99.72	101.30	97.76	97.52	98.65						
Al ₂ O ₃ /Na ₂ O	3.6	4.7	4.0	7.3	2.9	7.5	4.1	5.4	5.7	8.8	7.2	
Na ₂ O/K ₂ O	2.7	1.5	2.2	0.8	20.8	0.7	1.7	1.1	1.0	0.6	0.9	
Rb/Sr	0.39	0.25	0.16	0.37	0.08	1.2	0.22	0.28	0.44	0.39	0.30	
Cr/Ni	3.3	3.8	4.4	2.7	3.5	2.9	3.3	2.7	2.3	2.5	2.4	

major elements at the 95% confidence level. For the trace elements, a reasonable estimate of accuracy from duplicate and replicate analyses is Rb $\pm 3\%$, Sr $\pm 2\%$, Cr $\pm 6\%$, and Ni $\pm 5\%$ at the 95% confidence level. The accuracy of the determinations of FeO is about $\pm 5\%$.

Results

The Burwash Formation sandstones qualify chemically as well as petrographically for designation as graywackes (Table IV). Compared to average graywacke composition (Table IV -- column 9), they are high in alumina, total iron, and soda and magnesia. The ratio of $\text{Na}_2\text{O}/\text{K}_2\text{O}$ is typical of graywackes (i.e. greater than one). The mudstones (E units, Table III) have a chemistry which in general reflects an increased content of biotite, chlorite and muscovite over quartz and feldspar (see Table I) as shown by the lower SiO_2 values and the increased Fe_2O_3 , MnO, MgO, TiO_2 , and Al_2O_3 . The $\text{Na}_2\text{O}/\text{K}_2\text{O}$ ratio is less than unity for most of the mudstones. The $\text{Al}_2\text{O}_3/\text{Na}_2\text{O}$ ratio for the section averages of the Burwash Formation falls between 3 and 5, and is a measure of the immaturity of the graywackes (Pettijohn 1957, a mature sandstone would have a ratio of about 10). Note that for the mudstones, sample 1-44 has a chemistry which is similar to the graywackes in section 1. The reasons for this similarity are not readily discernable from the petrography of the sample.

The analyses in this report do not differ significantly from those of J.B. Henderson (1972) (Table IV), or of Ramsay (1973) for the Burwash Formation. A chemical analysis of siliceous graywacke from the Yellowknife Supergroup within the Gjaque Lake area, 90 km. north of Yellowknife, (Tremblay 1952), is also similar to the values for the Burwash Formation (see Table IV, column 6). Results for the Walsh Formation show more variation when compared with the results of Ramsay (Table IV, column 8). The results obtained for the present study are higher in CaO and Na_2O , and lower in magnesia, potash and the alumina/soda ratio. The results of both studies (the present

TABLE IV
GRAYWACKE CHEMICAL COMPOSITIONS IN THE SLAVE PROVINCE^a (OXIDES IN WEIGHT %)

	1	2	3	4	5	6	7	8	9
SiO ₂	63.41	65.62	66.78	66.24	65.9	65.76	73.33	71.0	66.75
Al ₂ O ₃	15.19	16.68	15.72	15.28	15.3	17.79	12.53	13.4	13.54
TiO ₂	.66	.66	0.62	0.64	0.6	0.53	.53	0.5	.63
Fe ₂ O ₃	7.29	6.75	6.14	0.70	1.2	0.32	5.64	0.7	1.60
FeO	4.96	5.35	5.07	4.53	4.7	4.68	4.24	5.0	3.54
MnO	.09	.07	.08	0.06	0.1		0.06	0.1	.12
MgO	2.94	2.73	2.42	2.74	2.8	2.97	1.99	2.6	2.15
CaO	3.62	1.32	2.38	1.70	1.5	1.90	1.28	0.3	2.54
Na ₂ O	4.28	3.37	3.84	3.12	2.9	4.48	4.36	2.5	2.93
K ₂ O	2.30	2.66	1.88	1.91	2.0	0.75	0.21	1.2	1.99
P ₂ O ₅	.19	.12	0.12	0.12			.07		.16
Other*	4.10	2.57	2.03	2.95	2.2	1.58	1.62	2.9	4.21
FeO/Fe ₂ O ₃	2.1	3.8	4.7	6.5	3.9	10.5	3.0	7.1	2.2
Na ₂ O/K ₂ O	1.9	1.3	2.0	1.6	1.5	6.0	20.8	2.1	1.5
Al ₂ O ₃ /Na ₂ O	3.5	4.9	4.1	4.0	5.3	4.0	2.9	5.4	4.5

1. Graywacke average: section 1 of Burwash Formation, this report.
2. Graywacke average: section 2 of Burwash Formation, this report.
3. Graywacke average: section 3 of Burwash Formation, this report.
4. Burwash Formation, J.B. Henderson (1972).
5. Burwash Formation, C.R. Ramsay (1973).
6. Siliceous graywacke, Gjaque Lake area, L.P. Tremblay (1952).
7. Graywacke, Walsh Formation, this report.
8. Graywacke, Walsh Formation, C.R. Ramsay (1973).
9. Average graywacke (Pettijohn 1972).

^a Total iron as Fe₂O₃

" determined separately

* loss of ignition: CO₂, H₂O⁺, and H₂O⁻

one and Ramsay's) show a high silica content for the Walsh Formation compared to the Burwash Formation. Caution must be used in comparing results for the Walsh Formation because only one graywacke has been analysed by this author and only one has been analysed by Ramsay. Nonetheless, differences between the Walsh and Burwash values for graywackes are striking (i.e. higher SiO_2 , Na_2O , and lower K_2O).

Table V shows analyses of graywackes from several Precambrian areas: the Burwash Formation at Yellowknife in the Slave Province, the Precambrian graywackes of Wyoming, and the Archean graywackes of the Sheba Formation and Belvue Road Formation of the Fig Tree Group in South Africa. The Fig Tree Group graywackes are high in magnesia and low in alumina, soda and potash compared to the Wyoming and Burwash graywackes, but the soda/potash ratios are similar except for the low value for the Sheba Formation (also see Figures 8 and 9). The silica (except for the Belvue Road Formation which is low) and total iron values are very similar for all graywackes, and overall, they are quite similar to the Burwash Formation values. Figure 8, a potash-versus-soda plot of the graywackes from Table V with the Walsh Formation values added shows also the similarity of the Wyoming and Yellowknife sediments. Figure 9 is a plot of CaO - Na_2O - K_2O with the fields of several common rock types plotted for comparison. Both the Wyoming and Yellowknife rocks (the Walsh Formation values being slightly separated) occupy the same field and one Burwash Formation value plots in the field of quartz diorite. Again the similarity of the Yellowknife and Wyoming graywackes are noted.

Trace Elements

The samples were analysed for Rb, Sr, Cr and Ni using X-ray fluorescence spectrometry and the individual results are shown in Table III and the averages in Table VI. The average for the Wyoming graywackes (Table VI - column 4) is high in Sr (424) compared to the Burwash average (315 - for graywackes), and the Fig Tree Group

TABLE V
MAJOR ELEMENT COMPOSITION OF ARCHEAN GRAYWACKES

	1	2	3	4	5	6
SiO ₂	63.41	65.62	66.78	66.2	59.8	64.43
Al ₂ O ₃	15.19	16.68	15.72	10.2	12.9	15.48
TiO ₂	.66	0.66	0.62	0.52	0.55	0.62
Fe ₂ O ₃	7.29	6.75	6.14	7.01	6.56	6.54
MnO	.09	0.07	.08	0.07	0.07	
MgO	2.94	2.73	2.42	4.50	4.44	3.12
CaO	3.62	1.32	2.38	1.97	4.69	2.22
Na ₂ O	4.28	3.37	3.84	1.80	2.41	3.74
K ₂ O	2.30	2.66	1.88	1.58	1.57	2.44
P ₂ O ₅	.19	.12	.12			
Na ₂ O/K ₂ O	1.9	1.3	2.0	3.1	1.5	1.5

1. Graywacke average, section 1, Burwash Formation, this report.
2. Graywacke average, section 2, Burwash Formation, this report.
3. Graywacke average, section 3, Burwash Formation, this report.
4. Graywacke, Archean Sheba Formation (Condle et al 1970).
5. Graywacke, Archean Belvue Road Formation (Condle et al 1970).
6. Graywacke average for Precambrian of Wyoming (Condle 1967).

Figure 8. K_2O versus Na_2O for Archean graywackes from Yellowknife, South Africa and Wyoming. Diagram from Condie et al (1970) with data from this report and Ramsay (1973) added.

- I. Sheba Formation, South Africa.
- II. Belvue Road Formation, South Africa.
- III. Precambrian Wyoming graywackes.
- IV. Burwash Formation (this report).
- ▲ Walsh Formation (this report).
- Walsh Formation (Ramsay 1973).

Figure 9. $\text{CaO-Na}_2\text{O-K}_2\text{O}$ diagram for igneous rock types and for the Burwash and Walsh Formations. Data from this report added to diagram from Condie (1967).

graywackes (columns 2 and 3) contain two to four times as much Ni compared to the Burwash Formation. The Burwash Formation graywackes are very high in Cr compared to an average for the Canadian Shield (column 7), to an average for the basalts at Yellowknife (column 8), and to basalts of the Superior Province (column 9). The nickel content of the Burwash Formation graywackes is similar to basalts from the Superior Province, similar to Precambrian graywackes from Wyoming, similar to average crust, but is higher than values for granodiorite. The rubidium is quite high compared to basic volcanics from various areas in the Superior Province (columns 11 and 13), but is typical of the granodiorite to quartz diorite range of rocks. The Rb/Sr and K/Rb ratios are similar to the values give by Tarney (1972) for average crust. The chrome/nickel ratio of the graywackes of the Burwash Formation is intermediate between the value of an average metabasalt from the Superior Province (column 9) and average crust as given by Tarney (column 6). Thus it seems that mafic volcanics must have contributed detritus to the sediments to give rise to the high Cr and Ni values for the Burwash Formation graywackes. Figure 10 shows that the Yellowknife sediments when compared to certain average rock types are similar to basic rocks in Ni-Cr content. A plot of Ni versus Rb (Figure 14) on the other hand shows the values for the sediments to be similar to average crust. Thus it seems that both mafic volcanics and sialic plutonic rocks acted as a supplier for the Yellowknife sediments.

Discussion of the Geochemistry

Figures 12, 13, 14, and 15 show that there are trends (although slight) in the chemical composition of the Burwash Formation : (1) from A to E within the Bouma cycle units, (2) secular trends upwards in the Burwash Formation, and (3) from the Burwash Formation to the Walsh Formation. Figure 12, a plot of potash versus soda, shows an increasing potash/soda ratio from A to E, and a secular trend of increased potash/soda ratio from section 1 to section 2 in the Burwash Formation and then a decreased ratio from section 2 to section 3, with section 3 being closer to section 1 in composition.

TABLE VI

TRACE ELEMENTS OF IGNEOUS ROCKS AND ARCHEAN SEDIMENTS

	1	2	3	4	5	6	7	8	9	10	11	12	13
Rb	71	54	90	88	—	90				75-110			
Sr	315	98	354	424		375	320	117	124	200-400	5	34	6
Cr	262				213	100	59	161	175		146	167	175
Ni	80	290	160	91	108	75	18	110	85	10-25			
Rb/Sr	.22	.64	.27	.23		.24				.37-.27	.03	.20	
K/Rb	257	216	204	230		232					580	295	360
Cr/Ni	3.3				2.0	1.3	3.2	1.5	4.8				

1. Burwash Formation, this report.
2. Sheba Formation (Condie et al 1970).
3. Belvue Road Formation (Condie et al 1970).
4. Average Wyoming Precambrian graywacke (Condie 1967).
5. Average of 29 Canadian Precambrian graywackes (MacPherson 1958).
6. Average crust (Tamey et al 1972).
7. Average composition of Canadian Shield (Eade and Fahrig 1971).
8. Average of 61 metabasalts from Yellowknife (Baragar and Goodwin 1969).
9. Average of 85 metabasalts from Superior Province (Baragar and Goodwin).
10. Granodiorite-Quartz diorite (Condie 1967).
11. Average basalt Vermilion District Minnesota (Jahn 1974).
12. Average intermediate to felsic volcanic, Vermilion District Minnesota (Jahn 1974).
13. Average of 70 basic volcanics from the Superior Province (Hart et al 1970).

Figure 10. Ni versus Cr for average rock types and Yellowknife Supergroup sediments. Diagram from Glikson (1971) with data from this report added.

1. Average olivine-normative tholeiite.
2. Average quartz-normative tholeiite.
3. Average of 10 oceanic tholeiites.
4. Average of 38 mid-Atlantic ridge basalts.
5. Average granite, post-Archean.
6. Average granodiorite.
7. Field of Burwash and Walsh sedimentary rocks (.....).
- + Average Archean granites and porphyries.
- X Average metabasalts from Archean basic-ultrabasic assemblages.
- Average metabasalts from Archean calc-alkaline volcanic sequences.

Figure 11. Ni versus Rb for average rock types, Wyoming graywackes and Yellowknife graywackes. Diagram from Condie et al (1970) with data from this report added.

- I. Granites
- II. Andesites
- III. Continental tholeiites
- IV. Submarine tholeiites
- V. Ultramafic rocks
- VI. Fig Tree Group graywackes
- VII. Wyoming graywackes
- Burwash Formation
- ▲ Walsh Formation

□ Average Crust

Figure 12. Potash versus soda for the Burwash and Walsh Formations. Letters designate the unit of the Bouma cycle and the sample plots at that point. W-A designates a Walsh Formation A unit and the sample plots at the A site. The arrow shows the A to E trend with the point of the arrow indicating the E direction. I, II and III indicate the respective fields of Burwash Formation graywackes from sections 1, 2 and 3. Correlation coefficient is -0.63 ; standard error of estimate is 0.77 .

The Walsh Formation values show a strong separation from the Burwash Formation values with a very high ratio for the mudstone and a very low ratio for the graywacke.

Figure 13, showing potash versus silica, displays several trends. In going from A to E, as SiO_2 decreases, K_2O increases resulting in an increase in the ratio of potash/silica. In going from section 1 to section 2, both potash and silica increase but in section 3 there is a decrease in potash. There is a strong negative linear correlation between potash and silica (coefficient $-.89$). There is also a striking separation of the values for the Walsh Formation compared to the Burwash Formation.

In Figure 14, the A to E trend is well developed, with K_2O and Al_2O_3 increasing simultaneously to maintain a relatively constant ratio. The secular trend is slight in the Burwash Formation, but there is an increase in potash in section 2. Again the Walsh Formation shows a strong separation from the Burwash values.

Figure 15, a plot of soda versus alumina, shows an A to E trend that is linear with a negative slope showing a decrease in soda correlating to an increase in alumina. The secular trend, in going from section 1 to section 2 in the Burwash Formation, is a decrease in soda in section 2, followed by an increase in soda (to a value similar to that of section 1) in section 3 (the ratio of soda/alumina remaining relatively constant). The Walsh Formation sediments do not show much separation in this plot.

There is a strong A to E trend, with TiO_2 increasing with Al_2O_3 to maintain a (relatively constant ratio (Figure 16). There is no discernable secular trend nor a separation of the Walsh and Burwash values.

Figures 17 and 18, ternary plots of iron-magnesia-alkalies and alkalies-ferromagnesia-alumina respectively, show that there is little variation in bulk chemistry of these constituents for the Burwash and Walsh Formation sediments.

In the iron versus magnesia plot (Figure 19), the only trend evident is an A to E trend. There is a strong linear correlation (coefficient $.92$) between the two components with both increasing proportionately in going from A to E to maintain a constant ratio.

Figure 13. K₂O versus SiO₂ for Burwash and Walsh Formation sediments. Symbols are the same as in Figure 12. Linear correlation coefficient is -0.89 ; standard error of estimate is 0.46 .

Figure 14. K_2O versus Al_2O_3 for the Burwash and Walsh Formations. Symbols are the same as in Figure 12. Linear correlation coefficient is .89; standard error of estimate is 0.45.

Figure 15. Na_2O versus Al_2O_3 for the Burwash and Walsh Formations. Symbols are the same as in Figure 12. Linear correlation coefficient is $-.65$; standard error of estimate is 0.54 .

Figure 16. TiO_2 versus Al_2O_3 for the Burwash and Walsh Formations. Symbols are the same as in Figure 12. Linear correlation coefficient is .81; standard error of estimate is 0.10.
 — encloses all Burwash and Walsh A units.

Figure 17. Iron-alkalies-magnesia diagram for the Burwash and Walsh Formations.

* individual samples
2 and 3 correspond to the number of samples that plot at that point.

Figure 18. Alkalies-ferromagnesia-alumina diagram for the Burwash and Walsh Formations.

* individual samples
2 and 4 correspond to the number of samples that plot at that point

Figure 19. Total iron (as Fe_2O_3) versus MgO for the Burwash and Walsh Formations. Symbols are the same as in Figure 12. Linear correlation coefficient is .92; standard error of estimate is 0.53.

Figure 20 shows an expected strong linear correlation between nickel and magnesia in going from A to E in the Bouma cycle. Figure 21 shows a poorly defined trend for Cr and MgO in going from A to E, with both components increasing.

The plots of Sr versus CaO and Rb versus potash (Figures 22 and 23 respectively) show an expected (but poorly developed) correlation of increased content of Sr with increased CaO and similar increased Rb with increased potash. The nickel versus chromium plot (Figure 24) shows no trends.

Conclusions

The geochemistry of the Burwash and Walsh Formation graywackes show several interesting trends. The Walsh sediments, on the basis of certain chemical elements (see Table IV), appear to be quite different from the Burwash sediments (the Walsh sediments have a high silica, soda, and low potash content, and these differences are evident in Figures 11, 12 and 13: the plots of potash versus soda; potash versus silica; and potash versus alumina). Petrographically the changes are borne out by an increase in quartz and feldspar, both in the framework and matrix of the Walsh Formation. The chrome and nickel values for the Walsh Formation are also low compared to the Burwash. These chemical and petrographic changes would be consistent with an increase in importance of silicic volcanics and sialic plutonic rocks and a decrease in importance of mafic volcanic rocks as a source for the detritus in the sediments of the Walsh Formation. Secular trends within the Burwash Formation are not as distinct and appear to be cyclical. Chemical changes that are evident in section 2 of the Burwash Formation as compared to section 1 are as follows: an increase in K_2O/Na_2O ; and increase in both potash and silica with the ratio about the same as in section 1; an increase in both K_2O and Al_2O_3 , again with a ratio similar to section 1; and a lower Na_2O/Al_2O_3 ratio with alumina content relatively constant. The petrographic changes are as follows: an increase in quartz and feldspar,

Figure 20. Ni versus MgO for the Burwash and Walsh Formations. Symbols are the same as in Figure 12. Linear correlation coefficient is .86; standard error of estimate is 10.01.

Figure 21. Cr versus MgO for the Burwash and Walsh Formations. Symbols are the same as in Figure 12. Linear correlation coefficient is .47; standard error of estimate is 27.78.

Figure 22. Sr versus CaO for the Burwash and Walsh Formations. Symbols are the same as in Figure 12. Linear correlation coefficient is .67; standard error of estimate is 90.01. The numeral 2 indicates that 2 samples plot at that site (the Bouma unit designation for the two samples is written to the upper right and lower right of the numeral).

Figure 23. Rb versus K_2O for the Burwash and Walsh Formations. Symbols are the same as in Figure 12. Linear correlation coefficient is .87; standard error of estimate is 14.81.

Figure 24. Ni versus Cr for the Burwash and Walsh Formations. Symbols are the same as in Figure 12. Linear correlation coefficient is .46; standard error of estimate is 17.37.

both in framework and matrix; and a relative increase in silicic volcanic rock fragments, and a relative decrease in mafic volcanic rock fragments.

Section 3 of the Burwash Formation, compared to section 2, shows the following chemical differences: a decrease in K_2O and Na_2O , but similar to section I values; a decrease in K_2O ; decrease in both K_2O and Al_2O_3 but with a relatively constant ratio; and an increase in Na_2O and Cr. The petrographic changes in section 3 with respect to section 2 are as follows: decrease in quartz in the framework (very slight) and decrease in feldspar in the framework. The petrographic changes between sections 3 and 2 are slight yet the chemical differences are quite distinct on the K_2O vs Na_2O , K_2O vs SiO_2 , K_2O vs Al_2O_3 , Na_2O vs Al_2O_3 , and Cr vs MgO plots. Section 3 appears to be chemically similar to section I with the secular trend seeming to indicate a change in source conditions between sections 2 and I and then a change back to conditions similar to I in section 3.

The Bouma cycle trends within the Burwash Formation are probably consistent with the chemical variations associated with an increase in abundance of phyllosilicates in the finer grained units. Units B, C and D are intermediate to the end members A and E both petrographically and chemically. Table III and Table VII show the major element chemistry and trace element chemistry respectively of the Bouma cycle. In going from A to E in the cycle there is a decrease in SiO_2 and in the soda/potash ratio. The Rb/Sr ratio shows a normal distribution about C and Rb also shows this normal distribution.

TABLE VII
TRACE ELEMENTS COMPOSITION OF YELLOWKNIFE AREA ROCKS

	1	2	3	4	5	6	7	8	9	10	11	12
Rb	71	98	101	90	82	2	2	5	34	6	56	127
Sr	315	339	228	228	271	236	117	146	167	153	288	98
Cr	261	275	238	281	291	244	161					
Ni	80	102	104	111	123	69	110					
Rb/Sr	23	.29	.44	.39	.30	.01		.04	.20	.04	.19	1.3
K/Rb	257							580	295	370		

1. A-units, Burwash Formation, this report.
2. B-units, Burwash Formation, this report.
3. C-units, Burwash Formation, this report.
4. D-units, Burwash Formation, this report.
5. E-units, Burwash Formation, this report.
6. Nalst Formation graywacke, this report.
7. Yellowknife volcanics (Baragar and Goodwin 1969).
8. Average basalt, Vermilion District (Jahn 1974).
9. Average intermediate to felsic volcanic, Vermilion District (Jahn 1974).
10. Average of 499 Archean basalts, Canadian and Western Australian Shields (Jahn 1974).
11. Southeast granodiorite, Yellowknife area (Green and Baadsgaard 1971).
12. Ross Lake granodiorite, Yellowknife area (Green and Baadsgaard 1971).

CHAPTER IV
SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

J.B. Henderson (1972) has defined an Archean basin of deposition at Yellowknife Bay in the Slave Province of the Canadian Shield. Paleocurrent directions within this basin indicate that the sediment source was from the west, in the outcrop area of both the Yellowknife volcanic pile and the western granodiorite.

The general stratigraphy within the basin is that of a basic volcanic pile at the base, with two cycles of magma generation, overlain by sedimentary rocks. The first volcanic trend is tholeiitic, ending with minor production of silicic volcanics, and the second trend is a calc-alkaline one, again terminated by silicic volcanism. Baragar (1966) has suggested that the change in trends was caused by silicic contamination of the magma. The volcanics are overlain, with slight angular unconformity, by a conglomerate containing mostly locally derived volcanic pebbles and boulders, but also some well-rounded granitic boulders. McGlynn and Henderson (1970) are of the opinion that the unconformity and erosional surface do not mark a significant time break. J.B. Henderson (1970a, and 1972) has concluded that the volcanic pile at Yellowknife could not be a source for the associated sediments because of the high quartz content of the sediments. Green and Baadsgaard (1971) have noted that the southeast granodiorite was exposed and contributing material to the conglomerates in the Yellowknife area at the time of deposition of the graywackes. They have also suggested that the western granodiorite was formed and intruded into the volcanic pile while volcanism was still taking place.

The data in this thesis have established secular chemical trends upwards in the Burwash Formation and from the Burwash Formation to the Walsh Formation. These trends are a reflection of the petrography of the sediments. The general petrographic trends are (Table III), comparing section 2 to section 1: an increase in quartz and feldspar in both the framework and matrix, a relative increase in silicic volcanic fragments, and a decrease in relative abundance of

mafic fragments; and in comparing section 3 to section 1: the feldspar content is similar, but there is a relative decrease in mafic volcanic fragments, and an increased abundance of quartzo-feldspathic matrix. There also is a relative increase in plutonic fragments in going from section 1 to section 2 to section 3, but in absolute terms (i.e. number of point counts), the difference is minimal. The Walsh Formation is very quartz and feldspar rich compared to the Burwash Formation. There are no mafic volcanic fragments, and the relative increase in silicic volcanic fragments is large. In determining a source of the Burwash and Walsh Formation sediments, it is interesting to study the Yellowknife volcanic pile. The chemistry of the pile is cyclic. If it is assumed that volcanism, intrusion of the western and southeast granodiorites, and deposition of the sediments is roughly synchronous with formation of the basin (Green and Baadsgaard 1971, have proposed a similar model for the Yellowknife area), then a comparison of the chemical trends in the sediments to the chemical trends in the volcanic sequence may confirm whether the volcanic pile is a likely source of detritus for the sediments.

Table VIII is a comparison of the chemical trends in the sediments with chemical trends in the volcanics. I have made the assumption that the basal parts of both successions are the equivalent points to which comparisons are made. This seems reasonable for the Burwash Formation sediments because the lower section shows the highest aggregate of mafic and intermediate volcanic clasts and the chemical analyses show that it is the least siliceous. Table VIII shows that the trends in the sediments and the trends in the volcanics are quite similar. Dissimilar trends in the upper sections and the Walsh Formation are probably the result of an increase in importance of a silicic source. The deposition of the Walsh Formation appears to coincide with the unroofing of the western granodiorite and a return to silicic volcanism in the volcanic pile. This would explain the high quartz content, high plutonic-fragment content and

TABLE VIII

COMPARISON OF CHEMICAL TRENDS IN THE BURWASH AND WALSH FORMATIONS WITH THOSE IN THE YELLOWKNIFE VOLCANIC PILE

	1	2	3	4	5	6
SiO ₂	+	+	-	X	+	+
Al ₂ O ₃	+	+	X	X	X	+
TiO ₂	-	-	-	-	X	X
Fe ₂ O ₃	X	X	X	+	X	X
MnO	-	-	-	-	-	-
MgO	X	X	X	+	X	X
CaO	X	X	+	+	X	X
Na ₂ O	+	+	+	X	+	+
K ₂ O	+	+	X	X	X	+
Na ₂ O/K ₂ O	X	X	+	+	+	X

1. Middle section, Burwash Formation compared to lower section.
2. First acidic layer of volcanic rocks (end of tholeiitic trend) compared to the base in the volcanic pile.
3. Upper section, Burwash Formation compared to middle section.
4. Basic unit of volcanism (beginning of calc-alkaline trend) compared to first acidic layer.
5. Walsh Formation compared to the Upper Burwash Formation.
6. Last acidic layer (end of calc-alkaline trend) compared to the basic unit of calc-alkaline volcanic rocks.

- no trend
+ increase
X decrease

Figure 25. Model of evolution for the Yellowknife Supergroup sediments at Yellowknife Bay.

high silicic-volcanic fragment content relative to the upper section of the Burwash Formation. It seems reasonable to suggest a relationship to unroofing of the western granodiorite, given the work of Green and Baadsgaard (1971). The southeast granodiorite was intruded first and had already contributed detritus to the conglomerate at the base of the sedimentary succession. The western granodiorite was intruded into the volcanic pile later than the southeast granodiorite but it was still synkinematic (Green and Baadsgaard 1971).

Figure 25 shows the various stages in a model for the evolution of the sedimentary succession at Yellowknife Bay.

The trends as outlined in this model are obscured by metamorphism and by breakdown of framework clasts during diagenesis and metamorphism. These two processes have obscured the trends, and made interpretation of detrital modes difficult. The probable breakdown of K-feldspar makes it impossible to determine more than an absolute minimum quantity for material of granitic origin. Mafic clasts seem to break down into matrix readily and thus their importance as an indicator of source is also hard to determine. A more continuous sampling of the middle part of the Burwash Formation is needed to better delineate its nature and extent. The same is true of the Walsh Formation. The samples described here and the samples of the Walsh Formation described by Ramsay (1973) provide only a first step in defining the differences between the Walsh Formation and the Burwash Formation. Other basins in the Slave Province need to be studied but only areas of low-grade metamorphism can be expected to be studied fruitfully, because rock fragments break down extensively, even at medium greenschist grade. Macroscopic features suggest that evolution of the supracrustal rocks in the Slave Province was similar everywhere, but only when detailed petrographic and chemical analysis of the sediments is extended to other basins and the results compared with the results for the Yellowknife basin, will this be known with any certainty. It is hoped that the model presented in this thesis will provide a useful basis for comparison throughout the Slave Province.

REFERENCES

REFERENCES

- Allman, M., and Lawrence, D.F., 1972. Geological laboratory techniques. Blandford Press, London, 335 p.
- Baragar, W.R.A., 1966. Geochemistry of the Yellowknife volcanic rocks. Can. Jour. Earth Sci. 3, p. 9-30.
- _____, and Goodwin, A.M., 1969. Andesites and Archean volcanism in the Canadian Shield, in: Proceedings of the Andesite Conference. Oregon Dept. Geol. and Min. Indust. 65, p. 121-141.
- Bell, J.M., 1929. Great Slave Lake. Roy. Soc. Can. 23, sec. 4, p. 5-38.
- Bell, R., 1900. Mackenzie District. Geol. Surv. Can. Annual Rept. 12, p. 103A-110A.
- Blatt, H., 1967. Original characteristics of clastic quartz grains. Jour. Sed. Pet. 37, p. 401-424.
- Bostock, H.H., 1967. Geological notes Itchen Lake map-area, District of Mackenzie, part of 76E and 86H. Geol. Surv. Can., Paper 66-24.
- Bouma, A.H., 1962. Sedimentology of some flysch deposits. Elsevier, Amsterdam, 159 p.
- Brenchley, P.J., 1969. Origin of matrix in Ordovician graywackes, Berwyn Hills, North Wales. Jour. Sed. Pet. 39, p. 1297-1301.
- Brown, I.C., 1955. Late faults in the Yellowknife area. Proc. Geol. Assoc. Can. 7, Pt. 1, p. 123-138.
- _____, 1958. Geological map of the District of Mackenzie, Northwest Territories. Geol. Surv. Can., Map 1055A.
- Buller, A.T., and McManus, J., 1973. Modes of turbidite deposition deduced from grain-size analyses. Geol. Mag. 109, p. 491-500.
- Camsell, C., and Malcolm, W., 1919. The Mackenzie River Basin. Geol. Surv. Can., Mem. 108, 154 p.
- Condie, K.C., 1967. Geochemistry of early Precambrian graywackes from Wyoming. Geochim. et Cosmochim. Acta 31, p. 2135-2149.

- Condie, K.C., Macke, J.E., and Reimer, T.O., 1970. Petrology and geochemistry of Early Precambrian graywackes from the Fig Tree Group, South Africa. *Geol. Soc. Am. Bull.* 81, p. 2759-2776.
- Crook, K.W., 1960. Petrology of Tamworth Group, Lower and Middle Devonian, Tamworth Nundle District, New South Wales. *Jour. Sed. Pet.* 30, p. 353-369.
- Cummins, W.A., 1962. The graywacke problem. *Liverpool and Manchester Geol. Jour.* 3, p. 51-72.
- Davidson, A., 1967. Metamorphism and intrusion in the Benjamin Lake map-area, Northwest Territories. Unpubl. Ph.D. thesis, Univ. British Columbia.
- Dickinson, W.R., Ojakangas, R.W., and Stewart, R.J., 1969. Burial metamorphism of the late Mesozoic Great Valley Sequence, Cache Creek, California. *Geol. Soc. Am. Bull.* 80, p. 519-526.
- _____, 1970. Interpreting detrital modes of graywacke and arkose. *Jour. Sed. Pet.* 40, p. 695-707.
- _____, 1971. Detrital modes of New Zealand graywackes. *Sediment. Geol.* 5, p. 37-56.
- Donaldson, J.A., and Jackson, G.D., 1965. Archean sedimentary rocks of the North Spirit Lake area, Northwestern Ontario. *Can. Jour. Earth Sci.* 2, p. 622-647.
- Eade, K.E., and Fahrig, W.F., 1971. Geochemical evolutionary trends of continental plates - a preliminary study of the Canadian Shield. *Geol. Surv. Can., Bull.* 179, 51 p.
- Folinsbee, R.E., 1947. Lac de Gras, Northwest Territories, preliminary map. *Geol. Surv. Can., Paper* 47-5.
- Fortier, Y.O., 1947. Ross Lake, Northwest Territories. *Geol. Surv. Can., Paper* 47-16, 4 p.
- Frith, R.A., Frith, R., Helmsteadt, H., Hill, J., and Leatherbarrow, R., 1974. Geology of the Indian Lake area (86B) District of Mackenzie. *Geol. Surv. Can., Paper* 74-1, Part A, p. 165-171.
- Galloway, W.E., 1974. Deposition and diagenetic alteration of sandstone in Northeast Pacific arc-related basins: Implications for graywacke genesis. *Geol. Soc. Am. Bull.* 85, p. 379-390.
- Glikson, A.Y., 1971. Primitive Archean element distribution patterns: chemical evidence and geotectonic significance. *Earth Planet. Sci. Lett.* 12, p. 309-320.

- Gluskoter, H.J., 1964. Orthoclase distribution and authigenesis in the Franciscan Formation of a portion of Western Marin County, California. *Jour. Sed. Pet.* 34, p. 335-343.
- Goodwin, A.M., and Shklanka, R., 1967. Archean volcanic-tectonic basins: form and pattern. *Can. Jour. Earth Sci.* 4, p. 777-795.
- Green, D.C., Baadsgaard, H., and Cumming, G.L., 1968. Geochronology of the Yellowknife area, N.W.T., Canada. *Can. Jour. Earth Sci.* 5, p. 725-735.
- _____, and Baadsgaard, H., 1971. Temporal evolution and petrogenesis of an Archean crustal segment at Yellowknife, N.W.T., Canada. *Jour. of Petrol.* 12, p. 177-217.
- Gunn, B.M., 1971. Trace element partition during olivine fractionation of Hawaiian basalts, *Chem. Geol.* 8, p. 1-13.
- _____, and Watkins, N.D., 1969. The petrochemical effect of the simultaneous cooling of adjoining basaltic and rhyolitic magmas. *Geochim. et Cosmochim. Acta* 33, p. 341-356.
- Hart, S.R., Brooks, C., Krogh, J.E., Davis, G.L., and Nava, D., 1970. Ancient and modern volcanic rocks: A trace element model. *Earth and Planet. Sci. Lett.* 10, p. 17-28.
- Hawkins, J.W. Jr., and Whetten, J.T., 1969. Graywacke matrix minerals: hydrothermal reactions with Columbia River sediments. *Science* 166, p. 868-870.
- Henderson, J.B., 1970a. Petrology and origin of the Yellowknife Supergroup (Archean), Yellowknife, District of Mackenzie, Canada. Unpubl. Ph.D. thesis, The John Hopkins Univ.
- _____, 1970b. Stratigraphy of the Archean Yellowknife Supergroup, Yellowknife Bay-Prosperous Lake area, District of Mackenzie. *Geol. Surv. Can.*, Paper 70-26, 12 p.
- _____, 1972. Sedimentology of Archean turbidites at Yellowknife, Northwest Territories. *Can. Jour. Earth Sci.* 9, p. 882-902.
- _____, Lambert, M.B., and Peeling, G.R., 1973. Yellowknife and Hearne Lake map areas, District of Mackenzie. *Geol. Surv. Can.*, Paper 73-1, p. 148-151.
- Henderson, J.F., 1938. Beaulieu River area, Northwest Territories. *Geol. Surv. Can.*, Paper 38-1.

- Henderson, J.F., 1939. Beaulieu River area, Northwest Territories. Geol. Surv. Can., Paper 39-1.
- _____, and Brown, I.C., 1948. Preliminary map, Yellowknife Northwest Territories. Geol. Surv. Can., Paper 48-17, 6 p.
- _____, 1950. Preliminary map Yellowknife Northwest Territories. Geol. Surv. Can., Paper 50-34.
- _____, 1966. Geology and structure of the Yellowknife greenstone belt, District of Mackenzie. Geol. Surv. Can., Bull. 141, 87 p.
- Heywood, W.W., and Davidson, A., 1969. Geology of Benjamin Lake map-area, District of Mackenzie (75 M/2). Geol. Surv. Can., Mem. 361, 35 p.
- Hounslow, A.W., and Moore, J.M.Jr., 1966. Preparation and analysis of silicate rocks and minerals. Carleton Univ., Geol. Paper 66-1, p. 42-44.
- Jahn, B-M., Shih, C., and Murthy, V.R., 1974. Trace element geochemistry of Archean volcanic rocks. Geochim. et Cosmochim. Acta 38, p. 611-627.
- Jolliffe, A.W., 1936. Yellowknife River area, Northwest Territories. Geol. Surv. Can., Paper 36-5.
- _____, 1938. Yellowknife Bay-Prosperous Lake area, Northwest Territories. Geol. Surv. Can., Paper 38-21, 41 p.
- _____, 1942. Yellowknife Bay, District of Mackenzie Northwest Territories. Geol. Surv. Can., Map 709A.
- _____, 1946. Prosperous Lake, District of Mackenzie, Northwest Territories. Geol. Surv. Can., Map 868A.
- Kalsbeck, F., 1969. Note on the reliability of point counter analysis. N. Jb. Miner. Mh., H.1, p. 1-6.
- Krynine, P.D., 1946. Microscopic morphology of quartz types. Annals Second Panamerican Congress of Mining and Geological Engineering 3, p. 35-49.
- Lovell, J.P.B., 1972. Diagenetic origin of graywacke matrix minerals: a discussion. Sedimentology 19, p. 141-143.
- MacPherson, H.G., 1958. A chemical and petrographic study of Precambrian sediments. Geochim. et Cosmochim. Acta 14, p. 79-92.

- McGlynn, J.C., 1970. Slave Province, in: Douglas, R.J.W., ed., *Geology and economic minerals of Canada*. Geol. Surv. Can., Econ. Geol. Rept. no. 1, 5th ed., p.71-76.
- _____, and Henderson, J.B., 1970. Archean volcanism and sedimentation in the Slave Structural Province, in: Baer, A.J., ed., *Basins and geosynclines of the Canadian Shield*. Geol. Surv. Can., Paper 70-40, p. 31-44.
- _____, 1972. The Slave Province, in: Price, R.A., and Douglas, R.J.W., ed., *Variations in tectonic styles in Canada*. Geol. Assoc. Can., Spec. Paper 11, p. 506-526.
- _____, and Ross, J.V., 1963. Arseno Lake map-area; District of Mackenzie 86B/12, Geol. Surv. Can., Paper 63-26, 7 p.
- Moore, J.C.G., 1951. Courageous Lake, Northwest Territories. Geol. Surv. Can., Paper 51-14.
- _____, 1956. Courageous Lake-Matthews Lake area, District of Mackenzie, N.W.T. Geol. Surv. Can., Mem. 283, 52 p.
- Moorhouse, W.W., 1970. A comparative atlas of textures of Archean and younger volcanic rocks, (J.J. Fawcett, ed.). Geol. Assoc. Can., Spec. Paper 8.
- Ojakangas, R.W., 1972. Archean volcanogenic graywackes of the Vermilion District, Northeastern Minnesota. Geol. Soc. Am. Bull. 83, p. 429-442.
- Pettijohn, F.J., 1957. *Sedimentary rocks*. Harper Bros., New York, 718 p.
- _____, 1972. The Archean of the Canadian Shield: a résumé. Geol. Soc. Am., Mem. 135, p. 131-149.
- Ramsay, C.R., 1973. Controls of biotite zone mineral chemistry in Archean meta-sediments near Yellowknife, Northwest Territories, Canada. Jour. of Petrol. 14, p. 467-488.
- Stockwell, C.H., 1933. Great Slave Lake - Coppermine River area, Northwest Territories. Geol. Surv. Can., Sum. Rept. 1932, Part C, p. 37-63.
- _____, 1968. Geochronology of stratified rocks of the Canadian Shield. Can. Jour. Earth Sci. 5, p. 693-698.
- _____, 1970. Geology of the Canadian Shield, in: Douglas, R.J.W., ed., *Geology and economic minerals of Canada*. Econ. Geol. Rept., no. 1, 5th ed., p. 43-54.

Tarney, J., Shinner, A.C., and Sheraton, J.W., 1972. A geochemical comparison of major Archean gneiss units from Northwest Scotland and East Greenland. 24th Int. Geol. Cong., sect. 1, p. 162-174.

Thorpe, R.I., 1971. Comments on rock ages in the Yellowknife area, District of Mackenzie, Geol. Surv. Can., Paper 71-1, Part B, p. 76-79.

Tremblay, L.P., 1950. Northeast part of Giaque Lake map-area, Northwest Territories. Geol. Surv. Can., Paper 50-18, 37 p.

_____, 1952. Giaque Lake map-area. Geol. Surv. Can., Mem. 266, 74 p.

_____, 1971. Geology of the Beechey Lake map-area, District of Mackenzie: a part of the western Canadian Shield. Geol. Surv. Can., Mem. 365, 56 p.

Van der Plas, and Tobi, A.C., 1965. A chart for judging the reliability of point counting results. Amer. Jour. Sci. 263, p. 84-90.

Walker, R.G., and Pettijohn, F.J., 1971. Archean sedimentation: analysis of the Minnitaki basin, Northwestern Ontario, Canada. Geol. Soc. Am. Bull. 82, p. 2099-2130.

Watkins, N.D., Gunn, B.M., and Coy-yll, R., 1970. Major and trace element variations during the initial cooling of an Icelandic lava. Amer. Jour. Sci. 268, p. 24-49.

Welsh, W., 1967. The value of point-count modal analysis of graywackes. Scott. Jour. Geol. 3, p. 318-328.

Whetten, J.T., and Hawkins, J.W.Jr., 1970. Diagenetic origin of graywacke matrix minerals. Sedimentology 15, p. 347-361.

PLATES

PLATE I

- a) Interbedded graywacke-mudstones, Burwash Formation (G.S.C. photograph 11-15-72).
- b) Scour at base of A unit, Burwash Formation (G.S.C. photograph 11-17-72).
- c) Load and flame structures at base of graded A unit. The A unit overlies a parallel laminated D unit, Burwash Formation (G.S.C. photograph 8-1-72).
- d) Refraction of cleavage from a coarse A unit to a mudstone, Burwash Formation (G.S.C. photograph 11-8-72).
- e) Complete Bouma cycle with A unit at bottom grading into parallel laminated B with C-rippled and D and E units above, Burwash Formation (G.S.C. photograph 11-9-72).
- f) Thinly interbedded graywacke-mudstones, Walsh Formation (G.S.C. photograph 11-13-72).

PLATE I

PLATE II

- a) Rippled C unit, Burwash Formation (G.S.C. photograph 11-11-72).
- b) Thin-bedded siliceous graywacke, Burwash Formation (G.S.C. photograph 11-5-72).

Photomicrographs c, d, e and f: field of view is 1.35 mm. wide, 28X.

- c) Granitic clast at center. Sample 1-1, crossed-nicols.
- d) Polycrystalline quartz (>6 domains). 3-1, crossed-nicols.
- e) Polycrystalline quartz with detrital (?) muscovite in the lower left corner. 1-18, crossed-nicols.
- f) Large intraformational mudstone clast. Note its internal texture and compare with fine-grained units in Plate III. Plane light, 4-1.

PLATE II

PLATE III

The field of view for all photomicrographs is 4.35 mm wide at 28X.

- a) A unit, 2-17, note the abundant angular single and polycrystalline quartz, crossed nicols.
- b) B unit, 2-19, crossed nicols.
- c) ~~C~~ unit, 2-20, crossed nicols.
- d) D unit, 2-21, parallel laminations are vague but run approximately left-right, plane light.
- e) E unit, 2-22, very finely laminated, plane light.
- f) E unit, 1-44, very fine grained, plane light.

2 2
OF/DE

PLATE III

PLATE IV

Field of view is 1.35 mm. wide for all photomicrographs.

- a) Intermediate volcanic fragment at center of view, plane light, 1-41.
- b) Same sample as (a), crossed-nicols. Note difficulty in determining boundaries of the clast in crossed-nicols. There is a sedimentary fragment at bottom center. 1-41.
- c) Large polycrystalline quartz grain. The large feldspar to the northeast appears to exhibit anti-perthite texture. 3-17, crossed-nicols.
- d) Detrital (?) muscovite in center of field of view. 3-1, crossed-nicols.
- e) Resorbed quartz grain. 3-1, crossed-nicols.
- f) Large chlorite clot, right center, replacing (?) mafic volcanic fragment. 3-26, plane light.

PLATE IV

PLATE V

Field of view for all photomicrographs 1.35 mm. wide.

- a) Large granitic fragment or volcanic (?). 1-41, plane light.
- b) Same clast, crossed-nicols, light grey is quartz, black is plagioclase.
- c) Large granitic clast. 1-21, crossed-nicols.
- d) Large granitic clast, well rounded. 3-1, crossed-nicols.
- e) Mafic volcanic clast showing felty texture of plagioclase. 1-70, plane light.
- f) Intermediate volcanic fragment with large feldspar phenocryst in fine-grained groundmass. The borders of the clast are very diffuse. 1-18, plane light.

PLATE V

PLATE VI

Field of view for all photomicrographs is 1.35 mm. wide.

- a) Intermediate volcanic clast with large feldspar phenocryst. 1-18, plane light.
- b) Same clast: note gradational nature of boundary of the clast with the matrix. 1-18, crossed-nicols.
- c) Intermediate volcanic clast. 1-1, plane light.
- d) Same clast. 1-1, crossed-nicols.
- e) Dusty nature of feldspar - a result of albitization (also see (a) of this plate). 1-33, plane light.
- f) Large sedimentary fragment, grading into matrix on the left side. 1-41, crossed-nicols.

PLATE VI

PLATE VII

Field of view for all photomicrographs is 0.45 mm. wide and magnification is 80X.

- a) Close up of a mafic volcanic clast showing products of breakdown of ferromagnesian minerals: p = plagioclase; q = quartz; and e = epidote. 1-1, crossed-nicols.
- b) Internal texture of intermediate volcanic clast with small feldspar phenocryst in a groundmass of feldspar and quartz. 1-1, crossed-nicols.
- c) Zoned(?) plagioclase. 3-17, crossed-nicols.
- d) Internal texture of a mafic volcanic clast showing felty mass of plagioclase laths. 1-70, crossed-nicols.
- e) Mafic volcanic clast with large epidote grains. 1-70, crossed-nicols.
- f) Resorbed quartz, volcanic origin. 1-70, plane light.

PLATE VII

END

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FIN