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CHEMO-STRATIGRAPHIC DIVISIONS WITHIN THE ABITIBI VOLCANIC BELT, ROUYN-NORANDA DISTRICT, QUEBEC

EXPLORATION GÉOLOGIQUE

MINISTÈRE
DES RICHESSES
NATURELLES
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ABSTRACT

Following Dimroth et al. (1973), volcanic rocks from the Rouyn-Noranda region of the Abitibi Belt can be divided into the Kinojevis (older) and Blake River Groups. The chemistry of the meta-volcanics in these Groups permits a chemo-stratigraphic division to be superposed on the broad field classification such that the Kinojevis Group can be suvdivided into the Hunter Mine, Deguisier tholeiitic, and Destor tholeiitic series. The Deguisier tholeiitic series comprises a monotonous sequence of meta-basalt and minor meta-andesite flows displaying two cycles of Fe-enrichment. The Destor tholeiitic series is characterized by ultramafic lavas and high Mg basalt within meta-basalt and meta-andesite, minor meta-rhyolite and intrusive equivalents of the meta-volcanics.

The Blake River Group can be subdivided (from the lower stratigraphic sections upward) into the Duparquet-Destor-Manneville tholeiitic series, the Rouyn-Noranda tholeiitic series, the Reneault and Dufault calc-alkaline series and the Dufresnoy tholeiitic series. The tholeiitic series consist mostly of meta-basalt and meta-andesite flows with minor meta-rhyolite, while the calc-alkaline series consist mostly of meta-andesite and meta-rhyolite. All series display a compositional gap between 64 and 71 percent SiO_2.

The most plausible model for the Archean tectonic environment leading to the formation of the Abitibi pile is that of a continental island-arc similar in many respects to the Pleistocene volcanism of the Taupo province, New-Zealand. This model is compatible with such features as the common quartz-normative state of almost all tholeiites analyzed, even in the Kinojevis Group, and the abundance of meta-rhyo- litesin the upper stratigraphic sections. Evidence exists to suggest that most of the volcanics were derived from shallow depths most proba- bly less than 50 kilometers and in all possibility less than 20 kilometers.

CONTENTS

FIGURES

TABLES

PLATE

INTRODUCTION

Although rocks of volcanic derivation make up some 30% of the area of the Archaean shield of Canada which in turn makes up more than half of the sub-continent, only in the last ten years has significant work been done on the interpretation of these mildly metamorphosed but unquestionably volcanic rocks. Wilson *et al.* (1965) chemically analysed more than 200 samples from volcanic belts of Manitoba and Ontario and showed them to consist of basalts, andesites, dacites and both sodic and potassic rhyolites. They concluded that Archaean volcanics were similar to those of modern calc-alkaline series of island-arcs. Since that study, these ancient meta-volcanics, and most particularly the meta-basalts, have been found to show some similarities with modern-day volcanics originating in other tectonic settings. For instance Glikson (1970) stressed the similarity between tholeiitic metabasalts from Australia, Africa and Canada and modern sea-floor basalts.

We are hence presented with conflicting data and, hypothesis for the origin of the Archean meta-volcanics; they may be summarized as follows:

a) the monotonous, pillowed, metabasalts represent ancient sea-floor basalts, and the basalt-andesite-rhyolite horizons represent superposed island-arc material.

b) The pillowed metabasalts are primitive island-arc tholeiites of the type described by Jakĕs and Gill from Fiji (1970). The basalt-andesite-rhyolite superstructure would be again superposed on more mature island-arc material.

c) The rocks are continental island-arc series resting on sialic crust much like the New-Zealand, Japan and Peru examples.

d) The pillow basalts are continental flood basalts resting on a sialic base and result from continental rifting.

e) The Archean sequence is unique, and no directly comparable modern equivalent exists.

Recently, considerable progress has been made in distinguishing between these possibilities for more recent rocks by the use of certain trace-elements which are resistant to secondary modification (e.g. the Ti, Zr, Y, Nb studies of Pearce and Cann (1973), Floyd and Winchester (1975)). Nonetheless the fact remains that major-elements have been used to subdivide volcanic rocks into broad associations such as tholeiitic and calc-alkaline (following Kuno (1968) and Miyashiro (1974)). The almost complete restriction of the latter association to orogenic, island-arc settings is in itself a type of major-element fingerprint. With this possibility in mind, we initiated a detailed investigation of the petrography and major-element chemistry of Archean volcanics along a sampling traverse north and south of Rouyn-Noranda, Québec (figure 1), with the aim of firstly characterizing the main volcanic associations and secondly distinguishing the most plausible tectonic environment responsible for their formation.

In this paper we present the results of this investigation and show that despite pervasive alteration and secondary mineralogies, we can distinguish both tholeiitic and calc-alkaline associations along our sampling traverse and that these distinct volcanic associations permit a chemically-based stratigraphic division of this part of the Abitibi volcanic pile. The most plausible tectonic environment describing these Archean volcanics is an ancient analogue of a modern-day, continental island-arc.

GEOLOGICAL OUTLINE

The southern part of the Superior Province contains east-trending metavolcanic belts, alternating with meta-sedimentary belts. The metavolcanic belts are typically arcuate and complexely deformed, with lenticular granitic rocks intruded along antiforms. The Abitibi volcanic belt (Goodwin and Ridler, 1970) in the eastern part of the Superior Province is one of the most extensive of these Archean belts and from size consideration alone it is unique even when compared to South African and Australian examples. The belt is complexely folded about generally east-west trending axes, and the diagnostic and traceable ultramafic, mafic and volcano-sedimentary horizons are

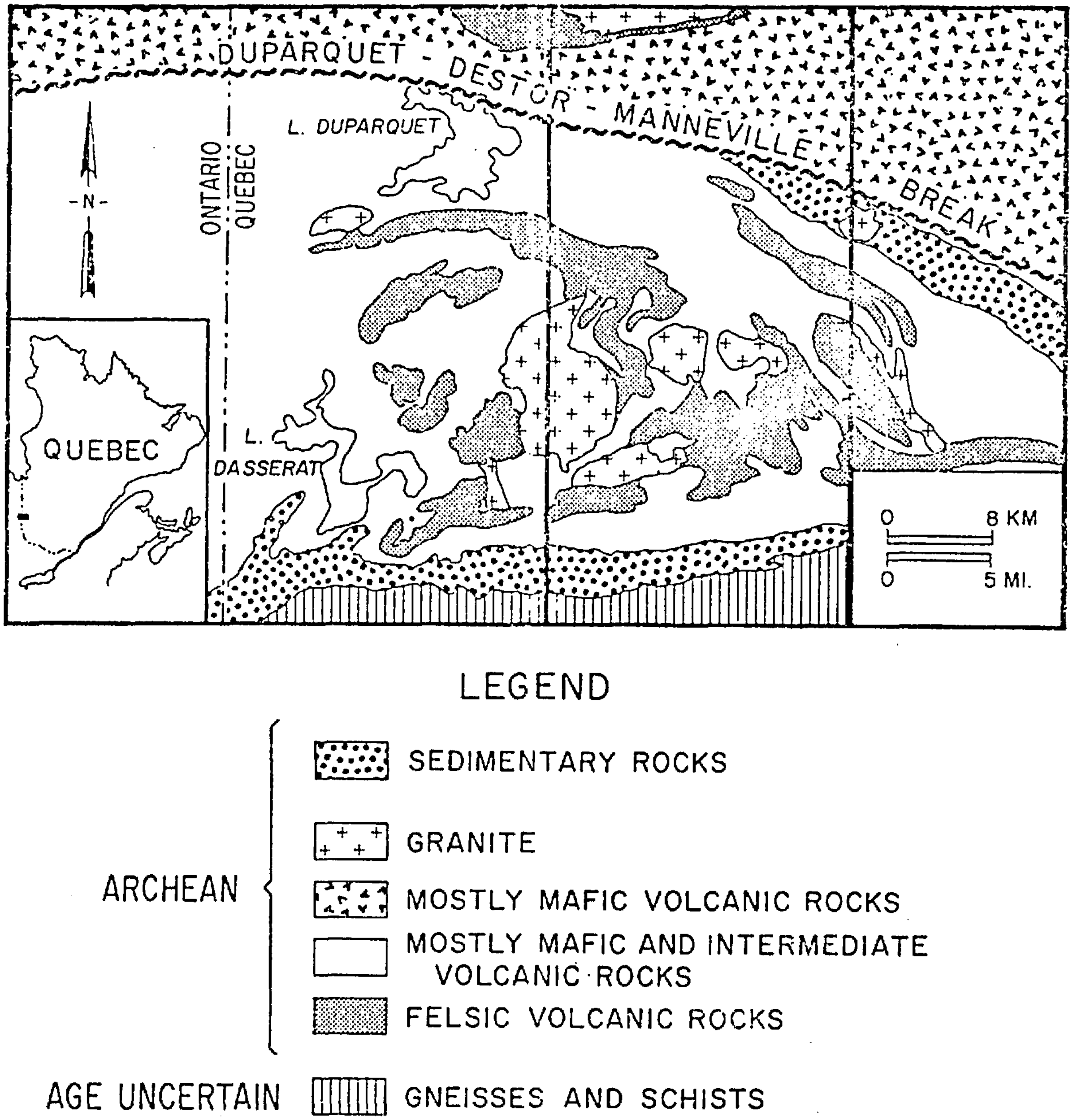

FIGURE 1 - Regional geology of the Abitibi Belt in the vicinity of Rouyn-Noranda; the heavy lines limit the boundaries of the detailed map figure 2.

oriented mostly east-west. Our traverse within the Abitibi belt was oriented north-south, in order to intersect the dominant trends within the belt.

The belt contains large scale isoclinal folds generally displaying two superposed schistosities and subvertical minorfolds (Dimroth, et al., 1973). The intensity of deformation within the belt varies considerably, and certain strongly deformed zones have been used to structurally segment it. One such zone of deformation termed the "Duparquet-Destor-Manneville break" (Dimroth, et al. 1973; hereafter the 'DDM break') intersects our line of traverse. The overall metamorphic grade of this belt is prehnite-pumpellyite to low-greenschist facies, a feature we attribute to the thermal buffering effect of considerable thickness of volcanic rocks during post-formational regional metamorphism. Delicate and ornamental quench textures preserved in many of the meta-basalts and meta-andesites have already been described (Gélinas and Brooks, 1974) as have the variolites of the Rouyn-Noranda district (Gélinas et al., 1975).

Following Dimroth et al. (1973) the meta-volcanic rocks of the Abitibi belt are divided into two Groups, the Kinojevis Group and the Blake River Group (figure 2). The former is located north of the DDM Break and can be subdivided on field criterion alone. Three divisions are recognized: the Hunter Mine, Deguisier and Destor series, where the term "series" has a magmatic differentiation conotation rather than a stratigraphic one, although both aspects are implied. The Blake River

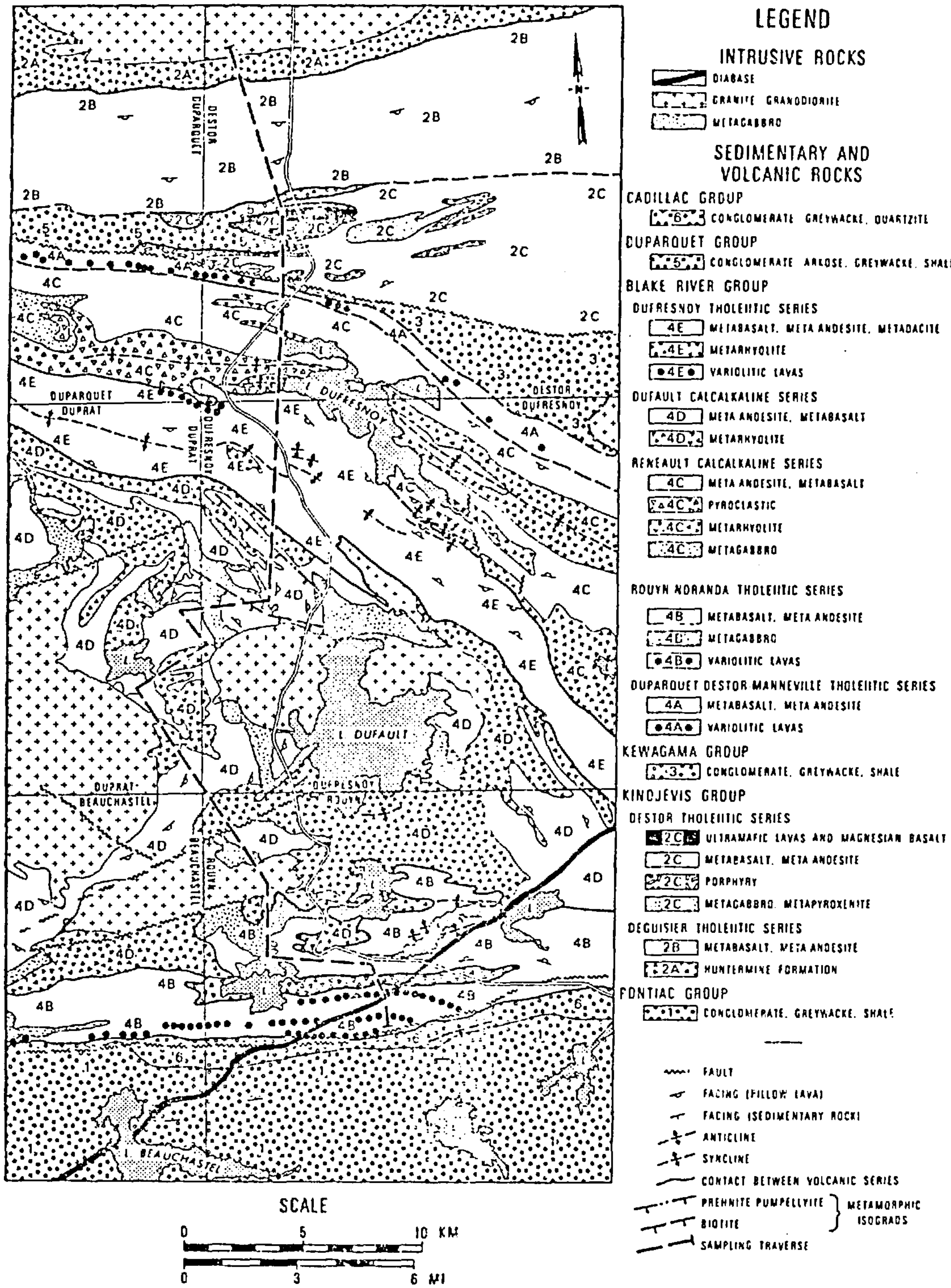

FIGURE 2 - Geological map of the Rouyn-Noranda district showing the chemo-stratigraphic divisions established in this study.

Group however cannot be subdivided solely on the basis of field observation, and a combination of field and chemical data are necessary to effect this. The resulting subdivision from the lower stratigraphic sections upward is: the DDM tholeiitic series (south of the DDM break), the Rouyn-Noranda tholeiitic series (south of Rouyn) both tholeiitic series are believed to form the base of the Blake River Group; the Reneault and Dufault calc-alkaline series (overlying the basal tholeiitic series); and the Dufresnoy tholeiitic series (believed to be the youngest volcanic series found in this part of the Abitibi volcanic belt). A detailed account of each of these volcanic series is given in the section entitled chemical stratigraphy.

MINERALOGY AND PETROGRAPHY

Because of the secondary nature of most of the minerals found in the metavolcanics we cannot overlook the mineralogy and petrography of the rocks. We will not belabor this section however with a detailed written account, but instead we have summarized the pertinent observations in two tables. The first table (Table No I) presents the observed mineralogical assemblages within the prehnite-pumpellyite zone of metamorphism as well as the assemblages from the biotite zone of metamorphism. We cannot distinguish in the field the usual intermediate subfacies between them (chlorite zone) due to the steep thermal gradient in the vicinity of bathöliths, however an approximation of this zone is recognized from the disappearance of prehnite-pumpellyite and primary augite to the first appearance of biotite (figure 2).

Unlike the observations of Jolly (1975; and this volume) we have not observed under the microscope any fresh calcic plagioclase anywhere along our line of traverse or in the adjacent areas. Neither have we observed fresh olivine or orthopyroxene in mafic meta-volcanics from the Rouyn-Noranda region (we have observed fresh olivine in ultramafics.) In order to be absolutely sure of our microscopic identifications (or absences of identifications) we completed a large number of X-ray powder diffraction and microprobe analysis on thin-sections of the rocks, and the results completely confirmed the microscopic observations, namely total absence of primary mineralogies save for the presence of clinopyroxene.

Despite the fact that the mineralogies are almost totally secondary in nature there are many igneous textures preserved within the rocks. They have been the subject of earlier publication (Gélinas and Brooks, 1974) and we have summarized the observations in Table II.

Examination of the pseudomorphed primary minerals and their textures leads to reconstruction of the primary sequence of

TABLE I

Resume of textures and related mineralogy for the ultramafic and mafic meta-volcanics

Rouyn-Noranda traverse

PRIMARY MINERALS	MINERAL PSEUDOMORPHS	TEXTURES	ROCK TYPES
CALCIC PLAGIOCLASE	Limpid Albite	Skeletal, Porphyritic	Tholeiitic Basalt Tholeiitic Andesite Calc-alkaline Andesite
	Albite-Clinozoisite; Albite-Prehnite	Porphyritic	Tholeiitic Basalt Tholeiitic Andesite Calc-alkaline Andesite
CLINOPYROXENE	Relics of Primary Minerals; Actinolite with or without Chlorite; Chlorite-Epidote-Carbonate	Skeletal, Dendritic, Spherulitic	Komatiite, Mg - Tholeiite
		Subophitic	Tholeiitic Basalt Tholeiitic Andesite Calc-alkaline Andesite
ORTHOPYROXENE	Talc-Carbonate	Porphyritic (Rare)	Tholeiitic Basalt
	Chlorite-Actinolite	Skeletal (Common)	Variolitic Lava
OLIVINE	Chlorite-Actinolite	Skeletal (Common)	Mg - Tholeiite Variolitic Lava
	Chlorite or Quartz	Porphyritic (Rare)	Ol - Tholeiite
	Serpentine-Magnetite; or Quartz	Porphyritic (Rare)	Komatiite Mg-Tholeiite
		Skeletal	Komatiite, Mg-Tholeiite

TABLE II

Mineral assemblages in mafic and intermediate meta-volcanic rocks of the Kinojevis and Blake River Groups, Rouyn-Noranda traverse

A. PREHNITE-PUMPELLYITE ZONE

QUARTZ-ALBITE-CHLORITE*

Clinozoisite																		X	X	X	X	X	X	X
Prehnite	X							X			X					X					X		X	
Pumpellyite			X		X		X		X			X					X				X			
Epidote	X	X	X	X			X		X	X			X	X	X		X	X	X			X	X	X
Actinolite	X	X	X	X	X	X													X			X		
Carbonate	X	X	X		X	X	X			X	X	X	X	X		X	X	X	X				X	X
Clinopyroxene	X	X	X	X	X	X	X	X	X	X	X	X							X	X	X			
Hydrogrossular								X																
Stilpnomelane													X	X	X	X	X	X						

QUARTZ-ALBITE#

Clinozoisite	X	X	X	X	X	X	X	X
Prehnite			X			X	X	
Pumpellyite			X	X		X		X
Epidote		X	X	X	X	X	X	
Actinolite	X	X						
Carbonate	X		X	X	X			
Clinopyroxene	X		X	X	X	X	X	X

B. BIOTITE ZONE

QUARTZ-ALBITE-CHLORITE*

Clinozoisite					X	X	X	X	X	X	X	X
Epidote	X	X	X	X	X	X					X	X
Actinolite	X		X		X	X	X		X			
Carbonate	X	X				X	X	X				X

QUARTZ-ALBITE#

Clinozoisite	X		X		X			
Epidote	X	X		X	X	X	X	X
Actinolite	X	X	X	X	X		X	X
Chlorite				X	X	X	X	
Biotite				X	X	X	X	X
Carbonate								

* Phases common to all the mineral assemblages listed below.

\# Mineral assemblage with or without the primary phase clinopyroxene.

crystallization. For tholeiitic rocks, the magnesian meta-basalts (1) have olivine (Plate I-A) or clinopyroxene (Plate I-B) as the liquidus minerals, followed by plagioclase. The olivine tholeiites have olivine as the liquidus mineral followed by plagioclase and clinopyroxene. The meta-basalts and meta-andesites of the tholeiitic and calc-alkaline series have plagioclase as the liquidus phase followed by clinopyroxene (Plate I-C, I-D). These observations based primarly on skeletal textures are summarized in figure 3. As previously noted (Gélinas and Brooks 1974) we can adequately describe these rocks with the terminology of Miyashiro *et al.* (1969), in which the type of basalt is tagged with the name of the first mineral to crystallise. Our observations indicate the PL-tholeiite is much more common along our traverse than OL-tholeiite.

CHEMICAL STRATIGRAPHY-PRELIMINARY CONSIDERATIONS

Fundamental aspects:

The chemical characterization of the meta-volcanic rocks in the study area was largely carried out by rapid routine instrumental

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(1) The terminology used is as follows:

Basalt <	54% SiO_2	(volatile free),
andesite	54-62% SiO_2	(volatile free),
dacite	62-67% SiO_2	(volatile free),
rhyodacite	67-71% SiO_2	(volatile free),
rhyolite >	71% SiO_2	(volatile free),

High magnesium meta-basalt: > 8% MgO (volatile free). Tholeiitic olivine metabasalt: containing normative olivine-diopside-hypersthene. Tholeiitic meta-basalt: containing normative diopside-hypersthene-quartz. High-alumina metabasalt: following Kuno's (1960) classification. Tholeiitic metaandesite and calcalkaline metaandesites: using Irvine and Baragar's (1971) division line on the AFM diagram.

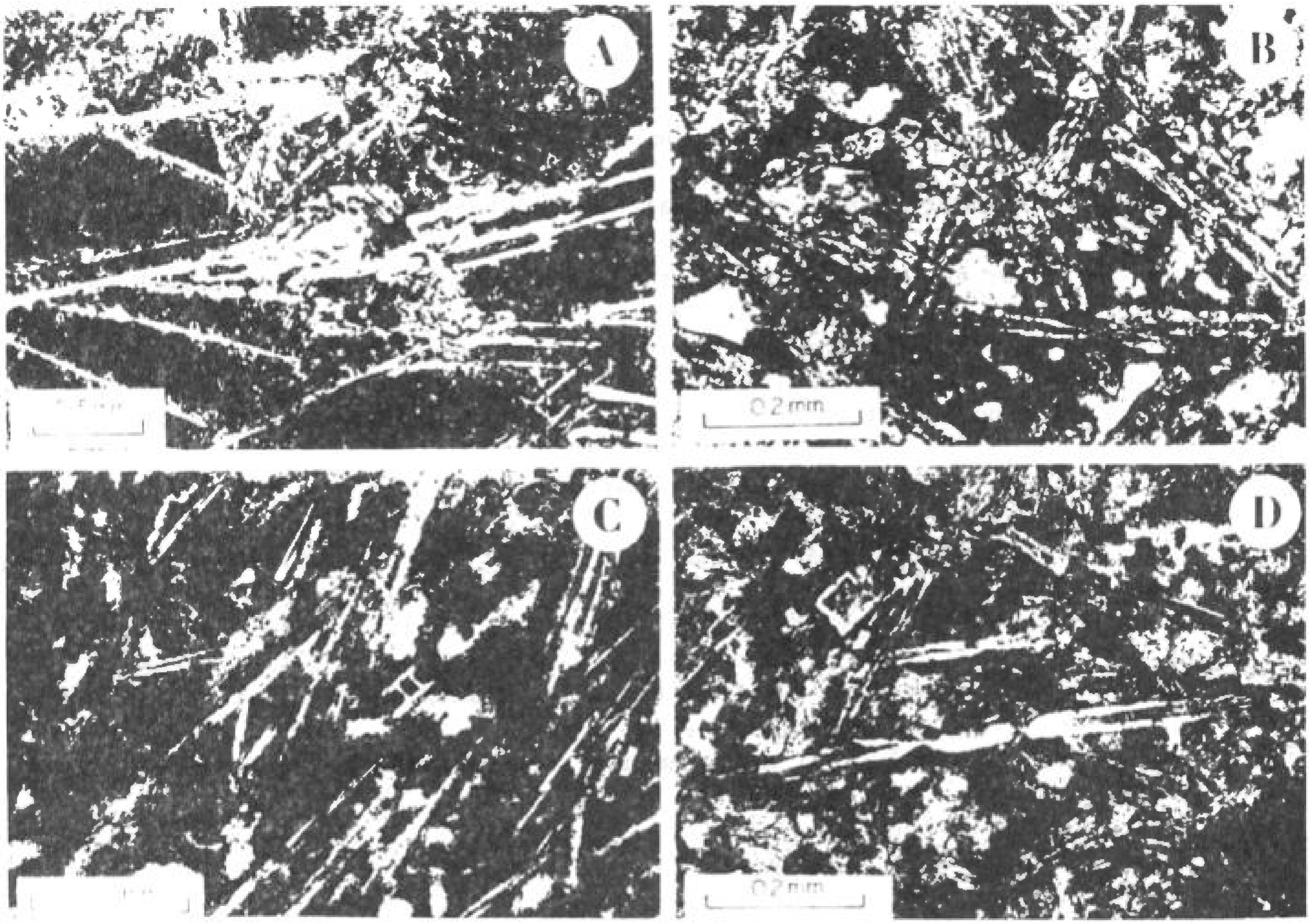

PLATE I - A - Mg-Basalt with skeletal olivine replaced by microcrystalline quartz aggregates; spherulitic clinopyroxenes in groundmass are partly replaced by actinolite.

B - Mg-Basalt with skeletal clinopyroxene (high relief) partly replaced by actinolite.

C - Tholeiitic basalt with skeletal plagioclase of limpid albite (e.g. belt-buckle type in the centre field).

D - Calc-alkaline andesite with skeletal plagioclase of limpid albite.

techniques (principally X-ray fluorescence). To better appreciate the data, we have prepared the following statement on the precision and accuracy of the determinations:

1- Precision: throughout the analytical work, we intermittently submitted two rock samples, prepared accurately and in sufficient quantity, to our laboratory under different specimen numbers. One rock was a metarhyolite and the other was a meta-basalt. We believe that deviations obtained for these two samples truly represent an all inclusive measure of precision; instrumental, sample preparation and technician errors are necessarily all included in this appreciation of precision. The data are summarized in Table 3 and require little additionnal comment. We conclude that the petrological interpretation derived from the analytical measurements are well within the limits of the precision of the data.

2- Accuracy: periodically, calibration curves were established using well documented international reference materials. We used 16 such reference materials:

2.1 The United State Geological Survey materials:
basalt BCR-1, peridotite PCC-1, granite G-2, dunite DTS-1, granodiorite GSP-1 and andesite AG V-1.

2.2 The Centre de Recherche pétrologique et géochimique materials (Nancy, France):
serpentine VB-N, granite GH, basalt BR, granite GA

TABLE III

Precision and accuracy

of analytical data

OXYDES	RHYOLITE		BASALT		CALIBRATION CURVES
	$\bar{x}$ n = 14	σ_x	$\bar{x}$ n = 13	σ_x	Sx
SiO_2	74.59	0.38	47.54	0.50	0.23
Al_2O_3	11.80	0.16	13.78	0.15	0.19
b Fe_2O_3	0.61	0.21	5.21	0.33	
a FeO	2.71	0.18	10.48	0.31	0.09
MgO	0.63	0.02	5.73	0.11	0.18
CaO	0.36	0.01	9.69	0.13	0.07
c Na_2O	2.35	0.02	1.57	0.02	
K_2O	5.06	0.09	0.07	0.04	0.04
TiO_2	0.26	0.02	1.86	0.03	0.03
d P_2O_5	0.07	0.03	0.11	0.07	
e CO_2	0.22	0.14	0.21	0.14	
e S	0.22	0.06	0.14	0.04	
f H_2O +	1.17	0.09	3.67	0.22	
g H_2O –	0.06	0.02	0.14	0.05	
h TOTAL	100.11		100.20		

a – Wet chemical analysis
b – $Fe_2O_3 = (Fe_{tot.} - FeO \times .7773)/0.6994$
c – Atomic absorption spectrophotometry
d – Calorimetric methods
e – Volumetric analysis
f – Penfield technique
g – Gravimetry

h – Analysis is declared acceptable if total lies between 99.30 and 100.70

and diorite DRN.

2.3 The Canadian Standard Reference Materials Project: gabbro MRG-1, syenite rock S-3, and ultramafics VM-1, VM-2 and VM-4.

Our own three internal standards (basalt, dacite and rhyolite) fitted these calibration curves well and were used for the routine runs.

We propose that the error of estimation obtained from the calibration curves using these 16 reference materials reflects roughly the accuracy of our analytical data. We propose that although it is an imperfect measure, it does have some useful meaning. These errors of estimation where available are given in Table 3 (last column).

The basis for treating the data obtained was the AFM diagram in which a division into tholeiitic and calc-alkaline association can be made (following Kuno, 1968; Irvine and Baragar, 1971). In this paper rocks that plot within the field of tholeiites and show clear trends towards iron-enrichment are considered to be true tholeiites, while those plotting within the calc-alkaline field with clear trends toward alkali-enrichment (or following Miyashiro (1974) iron-depletion trends) are accepted as true calc-alkaline rocks.

In order to support the separation of volcanic series based on the AFM diagram (and especially for those series which showed limited range in SiO_2) we have also treated the data according to Miyashiro (1974). The data when plotted on the $\Sigma FeO/MgO$ versus SiO_2 and versus ΣFeO diagrams (ΣFeO refers to the sum of $FeO + Fe_2O_3$ express as FeO) confirm the broad chemical divisions based on alkalis, iron and magnesium (the diagrams are not reproduced in this paper but are available on request). A further study to support the chemo-stratigraphic divisions revealed on the AFM diagram was made on the Dufresnoy tholeiitic series. It will be shown later that this predominantly tholeiitic series contains a section of calc-alkaline affinity exposed on each limb of a syncline. A number of additional traverses were made some distance from the main traverse in order to examine the persistence of the chemical variation along strike. In each case the chemical identity was consistent along a strike distance of nearly 10 kilometers thereby lending confidence that the chemo-stratigraphic divisions as established are primary properties of the volcanics and ones that describe both lateral and vertical variations in the pile.

Role of alteration:

Throughout this study we were faced with the pervasive secondary modification that characterises the Archean sections. Clearly, any assumption that Archean total-rock, major-element analysis reflect primary parameters is a gross over-simplification that cannot be made without considerable preliminary treatment of the alteration patterns observed. Our experience with Archean sections both in Quebec and elsewhere suggests that even the freshest metavolcanics have been subject to minor modification and special care must be exercised in the appraisal. To minimize the secondary effect in interpreting Archean meta-volcanic data, we have developed a series of criteria with which we identify and reject from further consideration, those rocks whose chemistry is anomalous. The full treatment of chemical alteration of these meta-volcanic rocks will be reported in near future, but the main highlights of the rejection package as applied to mafic and intermediate rocks are follows.

In order of application the criteria are:

(1) Limpid albite in mafic rocks. This contrasts with the usual intergrowth of albite and clinozoisite, or albite and prehnite, both intergrowths of which pseudomorph calcic plagioclases. The presence of limpid albite (one of the petrographic indexes for spilite) does not necessarly mean that sodium has been introduced into the rock but usually means that calcium has been removed with the deficit being taken up by volume adjustement or the introduction of other elements (e.g. SiO_2, K_2O).

(2) Volatile contents. A cut-off of 3.8% total H_2O and CO_2 is applied to all data. Rejection based on this criterion and at similar cut-off levels is not new (e.g. Wilson et al. 1965,; Brooks et al., 1969), and is justified since much of the CO_2 occurring in the metavolcanics and H_2O have been introduced from outside sources (Brooks et al. loc. cit.).

(3) Abnormal normative minerals. The existence of normative (CIPW) corundum, nepheline and wollastonite in subalkaline metavolcanics is indicative of considerable alteration. The pertinent details accompanying the existence of these minerals in the CIPW norm for these rocks are as follows: corundum - indicative of a peraluminous composition due to escape of calcium; (re: criterion 1) nepheline - indicative of introduction of SiO_2 and Na_2O; wollastonite - indicative of addition of calcium and the presence of abnormally high iron contents (figure 4).

(4) Total alkali content. If the metavolcanics plot within the alkali field of MacDonald and Katsura (1964), they show alkaline affinity even although they may have normative olivine, and hypersthene or olivine and quartz. On this basis they are rejected.

(5) Potash content. Using the Irvine and Baragar (1971) diagram for normative anorthite, albite and othoclase we reject data that plot within the potassic field of sub-alkaline rocks.

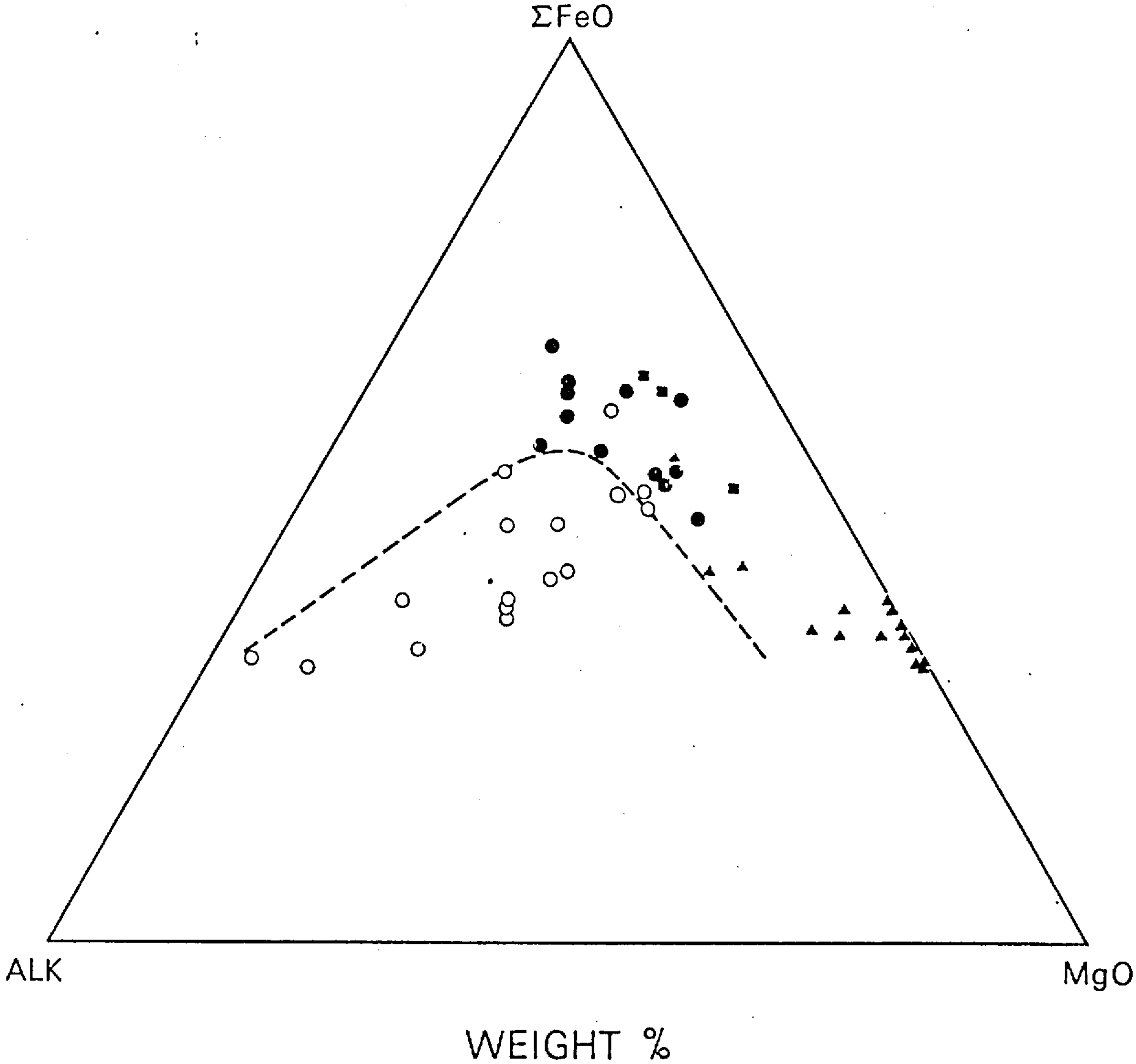

FIGURE 3 - AFM diagram of Kinojevis and Blake River Groups summarizing sketetal crystal occurence, grouped according to volcanic association.

The liquidus minerals and association are as follows:

open circle - plagioclase, calc-alkaline series

close circle - plagioclase, tholeiitic series

closed square- clinopyroxene, tholeiitic series

closed triangles olivine, tholeiitic series.

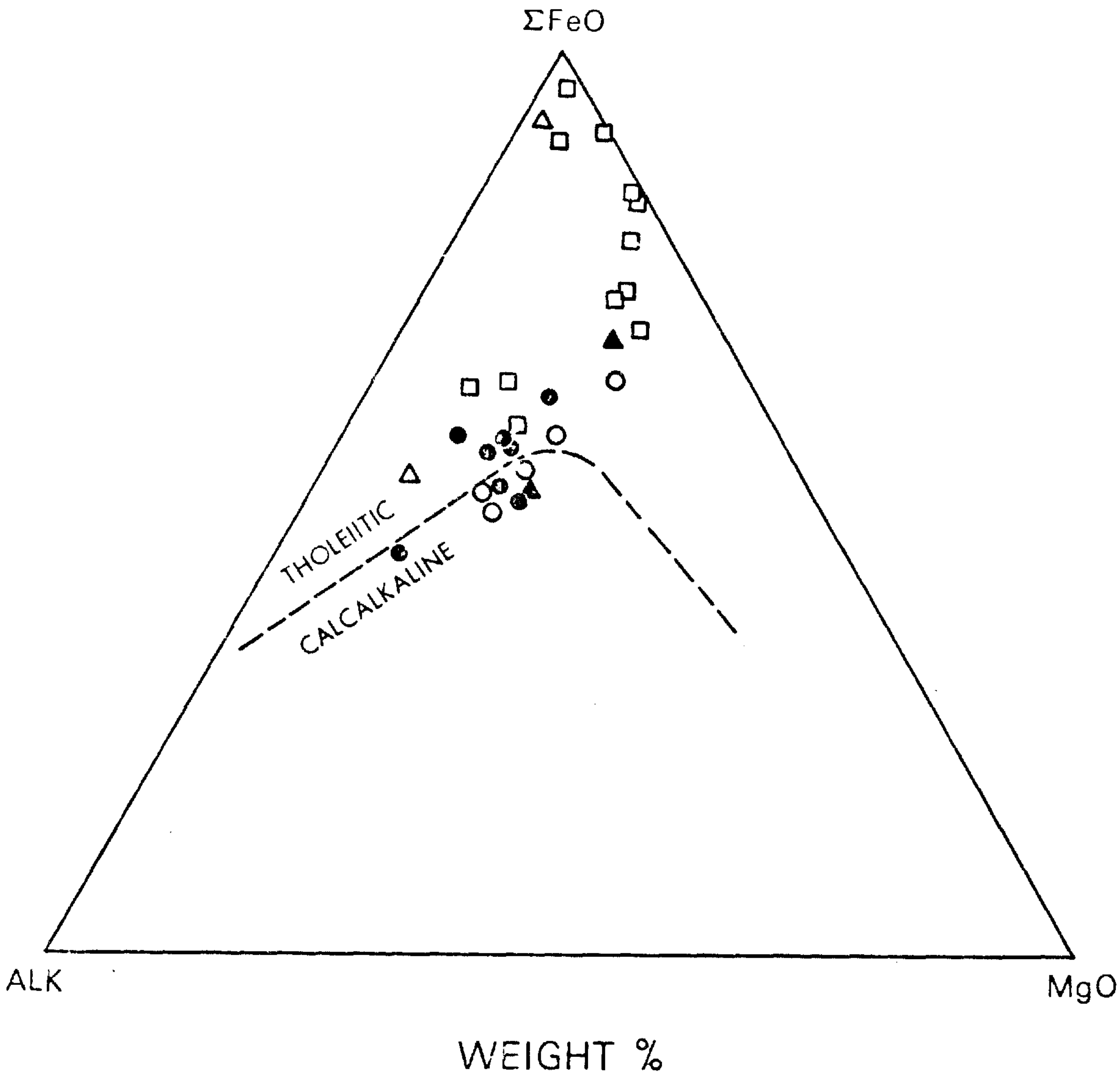

FIGURE 4 - AFM diagram showing the anomalous composition of altered basic lavas with respect to their CIPW index mineralogy (basic data from Smith 1968). (solid circle-nepheline normative, open circle corundum normative, closed triangle-nepheline and corundum normative, open triangle nepheline and wollastonite normative, open square-wollastonite normative).

Typically more than one criterion will lead to rejection of an altered sample and the most common combination for rejection was, volatiles greater than 3.8% coupled with corundum in the norm.

In the Kinojevis Group, the meta-basalts and meta-andesites show local evidences of sea-floor metamorphism, with the occurrences of limpid albite in intimate association with chlorite and either primary clinopyroxene or its mineral pseudomorphs, chlorite-actinolite. In the mafic metavolcanics displaying quench textures, the evidence of spilitization is ubiquitous; skeletal primary calcic plagioclase grains are always replaced by a very fine mosaic of limpid albite grains, as shown in Table I. A rapid glance at the photomicrographs in Amstutz (1974) confirms the intimate relationship between the rapid cooling rate of mafic volcanics and their subsequent mode of alteration to spilite. Similar observations are noted for the mafic metavolcanics of the tholeiitic series of the Blake River Group; however, the calc-alkaline meta-andesites of the Dufault series, in the vicinity of ore bodies and rhyolitic domes display intense spilitization on a regional scale. The degree of alteration of the mafic meta-volcanics in the various series of both the Kinojevis and Blake River Groups are given in Table IV.

In Tables V and VI we report average data for the different rock types encountered in each chemo-stratigraphic series. This data is

TABLE IV

Percentage of altered mafic meta-volcanics in the various series according to the criteria given in the text

SERIES	% ALTERED ROCKS
Deguisier tholeiitic series, cycle I	31%
Deguisier tholeiitic series, cycle II	50%
Dufresnoy tholeiitic series	65%
Rouyn-Noranda tholeiitic series	72%
Reneault calc-alkaline series	73%
Destor tholeiitic series (Lavas)	75%
Dufault calc-alkaline series	77%

TABLE V

Weighted mean chemical analysis of the Kinojevis Group

Kinojevis Group

SERIES	DEGUISIER tholeiitic series (cycle 1)			DEGUISIER tholeiitic series (cycle 2)				DESTOR tholeiitic series (lavas)			
N	22			12				6			
	Mg-Basalt	Basalt	Andesite	Mg-Basalt	Olivine Basalt	Basalt	Andesite	Mg Basalt	Basalt	Andesite	Dacite
n	7	11	4	1	3	4	4	1	1	2	2
SiO_2	51.51[a]	51.54	55.35	47.57	51.00	52.23	58.46	53.27	53.73	60.63	63.56
Al_2O_3	15.09	14.97	14.58	16.12	15.40	24.64	15.25	15.19	15.38	14.75	13.99
Fe_2O_3	1.70	2.25	1.61	2.69	2.25	3.03	2.30	0.74	3.15	2.39	2.53
FeO	9.79	10.59	8.75	10.18	10.53	10.55	8.09	9.23	9.76	7.36	6.86
MgO	8.41	6.73	7.10	8.10	6.86	4.83	4.51	8.70	4.05	3.44	2.23
CaO	9.82	10.42	9.21	11.23	8.77	9.45	6.25	8.12	7.83	4.36	4.46
Na_2O	2.07	2.04	2.10	2.11	3.59	3.24	3.36	2.56	3.58	5.25	5.07
K_2O	0.33	0.15	0.16	0.77	0.26	0.17	0.51	1.34	0.24	0.23	0.11
TiO_2	0.91	1.01	0.51	1.11	1.15	1.48	1.09	0.71	1.60	1.09	0.97
P_2O_5	0.03	0.04	0.03	0.10	0.06	0.18	0.14	0.08	0.44	0.24	0.20
CO_2	0.18	0.23	0.23	0.31	0.47	0.60	0.38	0.40	0.10	0.37	1.62
H_2O	3.86	3.29	3.36	3.63	2.95	2.52	3.36	3.50	2.66	3.18	2.03
	C.I.P.W. Norm – % Cation equivalents[b]										
Qz	2.20	4.28	9.87	0.00	0.00	4.53	13.78	0.00	7.11	12.37	21.70
Or	1.95	0.89	0.95	4.55	1.54	1.00	3.01	7.92	1.42	1.36	0.65
An	30.91	31.25	29.88	32.24	25.14	24.90	25.02	26.00	25.19	16.00	10.58
Ab	17.52	17.26	17.77	17.85	30.38	27.42	28.43	21.66	30.29	44.42	42.90
Di	8.29	8.46	6.99	10.46	6.90	6.92	1.18	5.69	4.04	0.72	–
He	5.20	7.01	4.62	6.62	5.48	7.24	1.02	3.50	4.43	0.71	–
En	17.10	12.84	14.44	4.95	9.36	8.82	10.68	18.33	8.21	8.23	5.55
Fs	12.31	12.19	10.94	3.59	8.53	10.58	10.61	12.91	10.32	9.36	6.91
Fo	–	–	–	7.27	3.17	–	–	0.49	–	–	–
Fa	–	–	–	5.92	3.19	–	–	0.39	–	–	–
Mt	2.46	3.26	2.33	3.90	3.26	4.39	3.33	1.07	4.57	3.47	3.67
Il	1.73	1.92	1.54	2.11	2.18	2.81	2.05	1.35	3.04	2.07	1.84
Ap	0.07	0.09	0.07	0.24	0.14	0.43	0.33	0.19	1.04	0.57	0.47
Cc	0.41	0.52	0.52	0.71	1.07	1.36	0.86	0.91	0.23	0.84	3.68
C :	–	–	–	–	–	–	–	–	–	–	1.65

(a) Values are recalculated, volatile free, major element compositions.

(b) C.I.P.W. Norm of recalculated chemical analysis to 100% without H_2O and CO_2; with an upper limit on Fe_2O_3 set according to the following equation: $\%Fe_2O_3 = \%TiO_2 + 1.5$; the excess of Fe_2O_3 is converted to FeO (Irvine and Baragar, 1971).

TABLE VI

Weighted mean chemical analysis of the Blake River Group

Blake River Group

SERIES	DUFRESNOY tholeiitic series						ROUYN-NORANDA tholeiitic series				
N	32						32				
	Olivine Basalt	Basalt	Tholeiitic Andesite	Calc-alkaline Andesite	Rhyodacite	Rhyolite	Mg-Basalt	Olivine Basalt	Basalt	Andesite	Rhyolite
n	1	7	10	4	3	7	2	3	6	4	17
SiO_2	49.41 (a)	52.08	56.08	58.31	70.17	74.57	49.51	48.92	52.35	58.04	76.53
Al_2O_3	15.04	16.17	14.78	17.43	14.98	13.51	16.57	16.72	15.28	16.70	12.03
Fe_2O_3	3.23	3.14	3.15	1.61	0.96	1.23	1.74	2.76	2.39	1.89	0.73
FeO	10.24	9.97	9.36	5.68	3.72	1.90	8.20	10.37	9.74	6.64	2.96
MgO	5.53	4.91	4.08	4.36	1.06	0.64	9.06	6.51	5.33	3.56	0.59
CaO	10.24	9.22	7.38	6.11	2.21	1.79	12.07	10.54	10.78	7.94	1.36
Na_2O	3.39	2.55	3.01	4.83	5.37	5.38	1.58	2.40	2.28	3.13	3.56
K_2O	0.29	0.12	0.13	0.35	0.90	0.60	0.03	0.10	0.11	0.66	1.24
TiO_2	1.65	1.58	1.65	1.03	0.48	0.29	0.50	1.44	1.39	1.20	0.37
P_2O_5	0.39	0.22	0.15	0.17	0.11	0.07	0.04	0.10	0.10	0.20	0.05
CO_2	0.47	0.31	0.41	0.34	0.35	0.52	0.17	0.22	0.33	0.36	1.22
H_2O	3.08	3.45	3.25	2.98	1.55	0.93	3.69	3.26	2.74	2.34	1.39
	C.I.P.W. Norm - % cation equivalents (b)										
Qz	0.00	7.38	13.75	7.51	28.05	36.89	0.54	0.0	6.84	13.94	47.76
Or	1.71	0.71	0.77	2.07	5.32	3.55	0.18	0.59	0.65	3.90	7.33
An	24.96	32.32	26.43	24.58	8.03	5.14	39.03	34.55	31.13	29.57	1.19
Ab	28.69	21.58	25.47	41.38	45.44	45.52	13.37	20.31	19.29	26.49	30.12
Di	9.10	4.30	2.72	1.27	-	-	11.29	7.29	8.57	2.79	-
He	7.69	4.02	2.77	0.75	-	-	5.36	5.64	7.66	2.37	-
En	7.79	10.24	8.90	10.27	2.64	1.59	17.33	12.83	9.30	7.57	1.47
Fs	7.56	10.97	10.39	7.00	5.25	2.01	9.45	11.39	9.54	7.39	4.22
Fo	1.24	-	-	-	-	-	-	-	-	-	-
Fa	1.32	-	-	-	-	-	-	-	-	-	-
Mt	4.68	4.55	4.57	2.33	1.39	1.78	2.52	4.00	3.47	2.74	1.06
Il	3.19	3.00	3.13	1.96	0.91	0.53	1.52	2.73	2.65	2.28	0.70
Ap	0.92	0.52	0.36	0.40	0.26	0.17	0.09	0.24	0.24	0.47	0.12
Cc	1.07	0.71	0.93	0.77	0.80	1.18	0.39	0.50	0.75	0.82	2.77
Cc	-	-	-	-	2.23	2.13	-	-	-	-	4.40

SERIES	RENEAULT calc-alkaline series			DUFAULT calc-alkaline series				
N	11			24				
	Tholeiitic Andesite	Calc-alkaline Andesite	Rhyolite	Mg-Basalt	Olivine Basalt	Basalt	Andesite	Rhyolite
n	1	9	1	1	1	2	10	10
SiO_2	56.92	57.94	79.42	51.73	50.53	53.00	57.84	76.27
Al_2O_3	15.93	17.13	10.76	16.13	15.75	16.33	16.30	12.07
Fe_2O_3	2.09	1.74	1.04	1.26	2.35	1.35	1.35	0.65
FeO	7.77	5.89	1.02	7.85	8.22	8.87	6.70	3.01
MgO	5.02	4.04	0.87	8.05	6.79	7.61	4.64	1.52
CaO	7.59	6.84	2.93	10.42	11.05	7.74	7.08	1.14
Na_2O	2.87	4.22	3.70	2.97	3.10	3.37	4.01	3.65
K_2O	0.38	0.38	0.12	0.45	0.21	0.37	0.73	1.29
TiO_2	1.36	1.36	0.08	1.01	1.76	1.20	1.18	0.33
P_2O_5	0.05	0.21	0.05	0.11	0.24	0.13	0.15	0.05
CO_2	0.14	0.36	0.10	0.26	0.33	0.09	0.21	0.58
H_2O	3.44	3.02	1.00	2.73	1.93	3.11	2.36	1.55
	C.I.P.W. Norm - % Cation equivalents (b)							
Qz	12.37	10.37	50.13	0.00	0.00	0.52	8.26	45.09
Or	2.25	2.25	0.71	2.66	1.24	2.19	4.31	7.62
An	29.46	26.68	12.40	29.35	28.44	28.34	24.32	1.66
Ab	24.29	35.71	31.31	25.13	26.23	28.52	33.93	30.89
Di	3.34	1.83	0.70	10.77	12.11	4.40	4.11	-
He	2.40	1.13	0.25	5.48	5.40	2.67	2.87	-
En	10.95	9.22	1.84	11.38	10.65	16.91	9.65	3.79
Fs	9.02	6.53	0.75	6.64	6.45	11.77	7.72	4.45
Fo	-	-	-	2.58	0.46	-	-	-
Fa	-	-	-	1.66	0.30	-	-	-
Mt	3.03	2.52	1.51	1.83	3.41	1.96	1.96	0.94
Il	2.58	2.58	0.15	1.92	3.34	2.29	2.24	0.63
Ap	0.12	0.50	0.12	0.26	0.57	0.31	0.36	0.12
Cc	0.32	0.82	0.21	0.59	0.75	0.20	0.45	1.32
Co	-	-	-	-	-	-	-	4.06

(a) Values are recalculated, volatile free, major element compositions.

(b) C.I.P.W. Norm of recalculated chemical analysis to 100% without H_2O and CO_2; with an upper limit on Fe_2O_3 set according to the following equation: $\%Fe_2O_3 = \%TiO_2 + 1.5$; the excess of Fe_2O_3 is converted to FeO (Irvine and Baragar, 1971).

for those analyses ("fresh") remaining after rejection of "altered" rocks. This identification is maintained throughout the diagrams used in this paper. The main result from using the rejection package was not the identification of trends that were hidden when all data was used, but in almost all cases use of the package eliminated outliers, reduced data dispersion and considerably refined and highlighted trends already in evidence. For instance, based on this package, we can confidently say that the calc-alkaline metavolcanic trend cannot be produced by secondary modification of tholeiitic series rocks; we firmly believe that the analytical data reported in this paper are as close to primary metavolcanic chemistry's as can be reached with current techniques and levels of understanding. However, when such data will be correlated with less mobile minor and trace-element data (e.g. Nb, Y, Zr etc), further refinement may well be possible.

CHEMICAL STRATIGRAPHY - RESULTS

Kinojevis Group

Hunter Mine series:

Because of poor exposure we have limited knowledge of the chemistry of the Hunter Mine series, the basal series within the Kinojevis Group. It appears to be mostly an association of meta-rhyolite with minor meta-andesite and meta-basalt and clearly indicates that the Kinojevis Group does possess some markedly differentiated rock types (cf Jolly 1975).

Deguisier tholeiitic series:

This series which overlies the Hunter Mine series consists of a monotonous sequence of meta-basalt with minor meta-andesite flows, and beds of chert and tuff. In progressing upward from the base of the section, the Deguisier series displays two cycles of iron-enrichment. The cycles are very similar with exception that the first one commences with a meta-basalt containing skeletal clinopyroxenes set in a strongly chloritized matrix, while the second commences with a cumulus olivine basalt. This is the only occurrence of skeletal pyroxenes in either of the two cycles of iron-enrichment. Although skeletal crystals of plagioclase are common throughout the two cycles, the skeletal clinopyroxene occurrence at the base of the first cycle is unique, and as such it can be used to define a stratigraphic marker. The chemical variation of ΣFeO, MgO, SiO_2, Al_2O_3, CaO and TiO_2, with stratigraphic position is shown in figure 5. The two cycles are most clearly evident for ΣFeO, MgO, SiO_2 and TiO_2. Other major-elements are less convincing, and CaO especially, shows a wide dispersion of data-points, a feature we attribute to secondary processes.

The meta-volcanics of the two cycles when plotted on the AFM diagram (figure 6) show strong iron-enrichment, and can be clearly termed tholeiites following the convention adopted in this paper. The meta-volcanics are mostly quartz tholeiites with only a few being olivine tholeiites (figure 7). Some of the meta-basalts show strong iron-enrichment ($SiO_2 = 49$, $\Sigma FeO = 17.9$): they are anomalously high when compared to similar rocks from the Tonga-Kermadec volcanic arc (e.g. for $SiO_2 = 52.5$ $\Sigma FeO = 15.9$; cf Brothers and Searle 1970).

Destor tholeiitic series:

This series which occurs in the vicinity of the DDM break, is characterized by ultramafic lavas intimately associated with high Mg-basalt containing relicts of skeletal olivines. These ultramafic flows occur within meta-basalt and meta-andesite of tholeiitic affinity (figure 8). Meta-rhyolite flows are of minor importance in this sequence (there is no volcanic representatives between 64 and 73 percent SiO_2) although intrusive rocks are relatively common. These intrusive rocks plot in the same general locations on the AFM diagram as the extrusive rocks, indicating that they may be metavolcanic equivalents of the extrusives (figure 8).

The ultramafic lavas in this series plot (figure 9), on the CaO - MgO - Al_2O_3 diagram in or near the Geluk field of basaltic komatiite (Viljoen and Viljoen, 1969). These rocks are not chemically within the limits of komatiite as given by Brooks and Hart (1974) but do

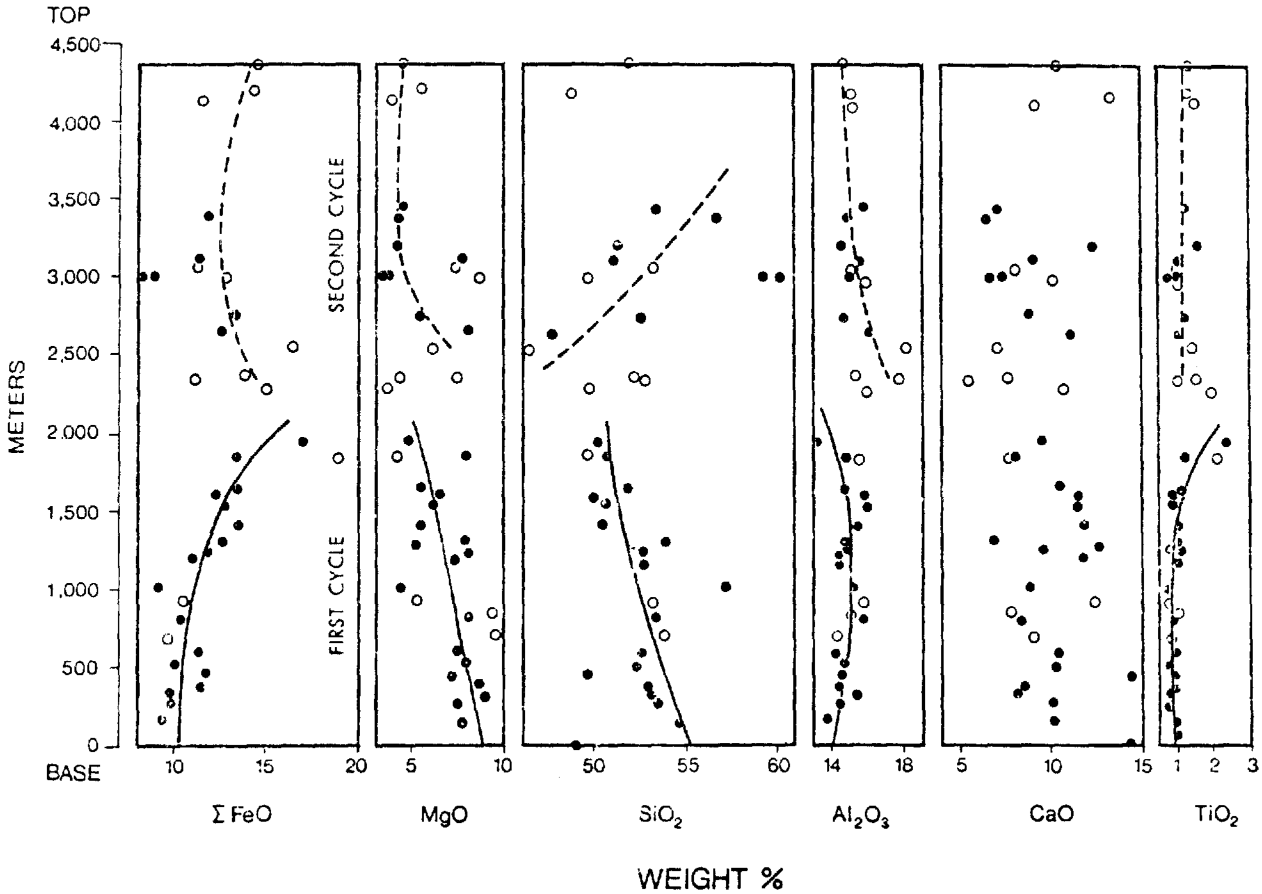

FIGURE 5 - Stratigraphic variation diagram for Deguisier tholeiitic series showing internal division into two cycles. Closed circles represent least altered rocks, open circles rocks rejected following application of rejection criteria (see text), crosses represent average data for the different rock types from each chemo-stratigraphic series, Tables V and VI. This figure legend applies to all AFM diagrams in this paper.

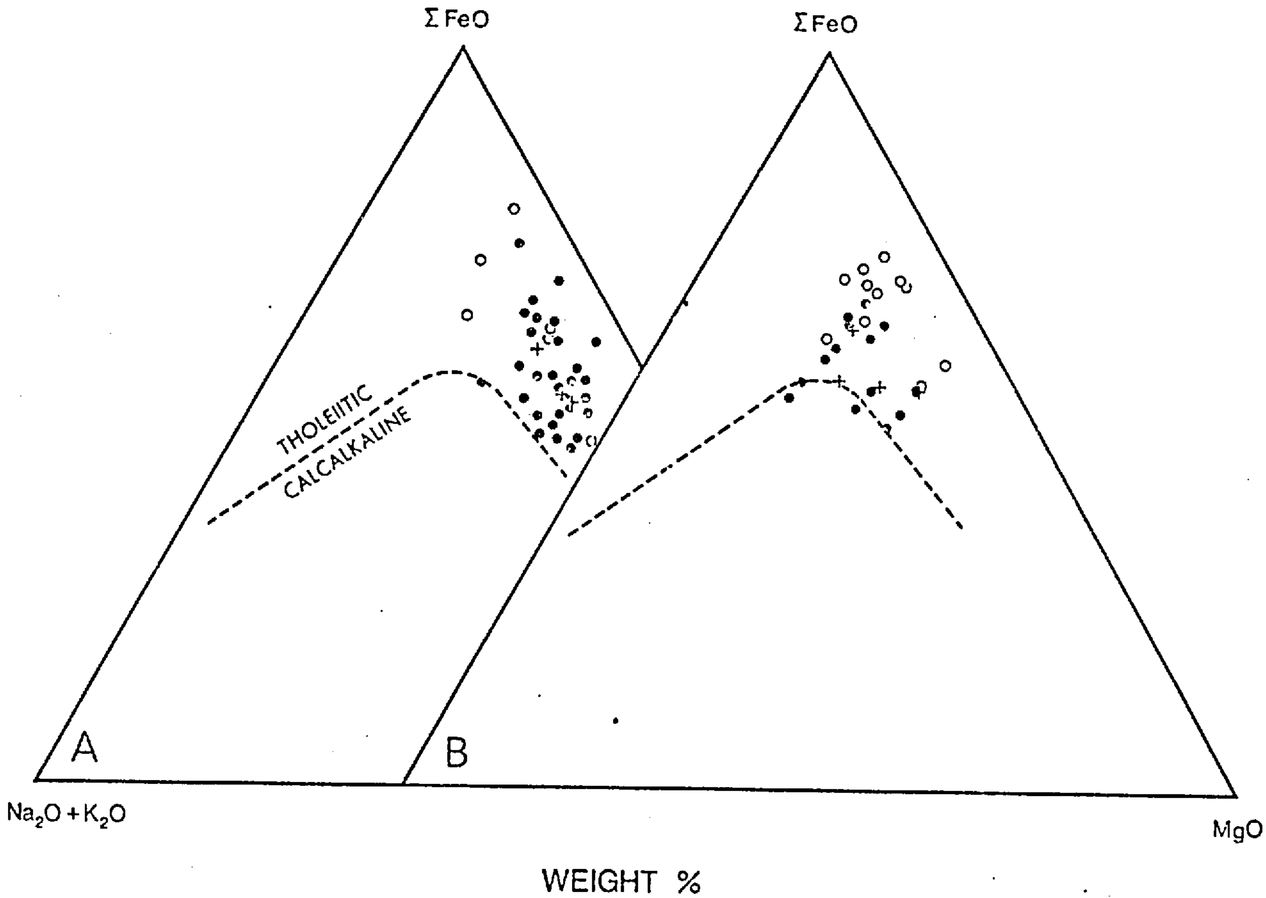

FIGURE 6 - AFM diagrams for the Kinojevis Group Deguisier tholeiitic series, (5A - first cycle, 5B - second cycle) showing trends towards iron-enrichment. The broken dividing line between tholeiitic and calc-alkaline fields is after Irvine and Baragar (1971).

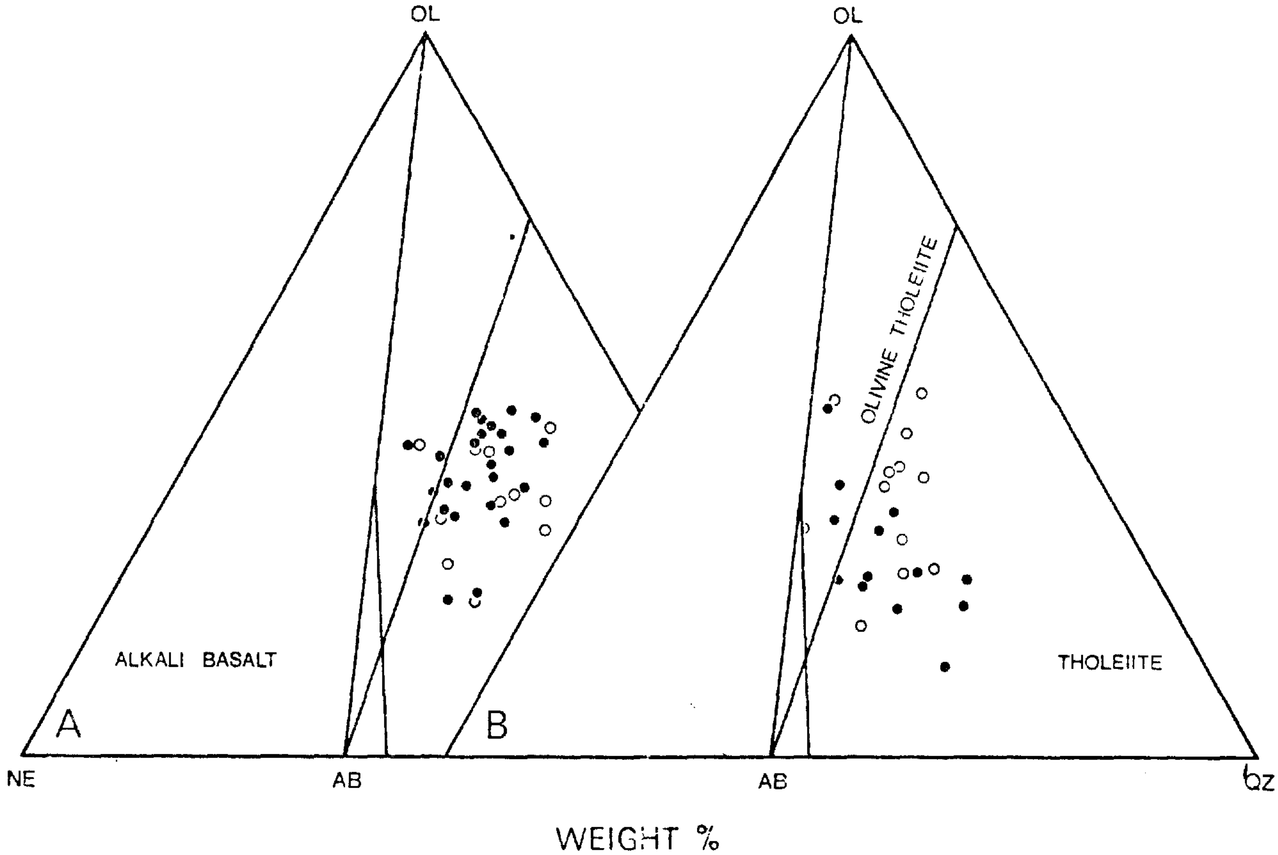

FIGURE 7 - Nepheline - olivine - quartz normative diagrams for the Deguisier tholeiitic series (5A - the first cycle, 6B - second cycle) showing the abundance of quartz-tholeiite basalt in this "primitive" series.

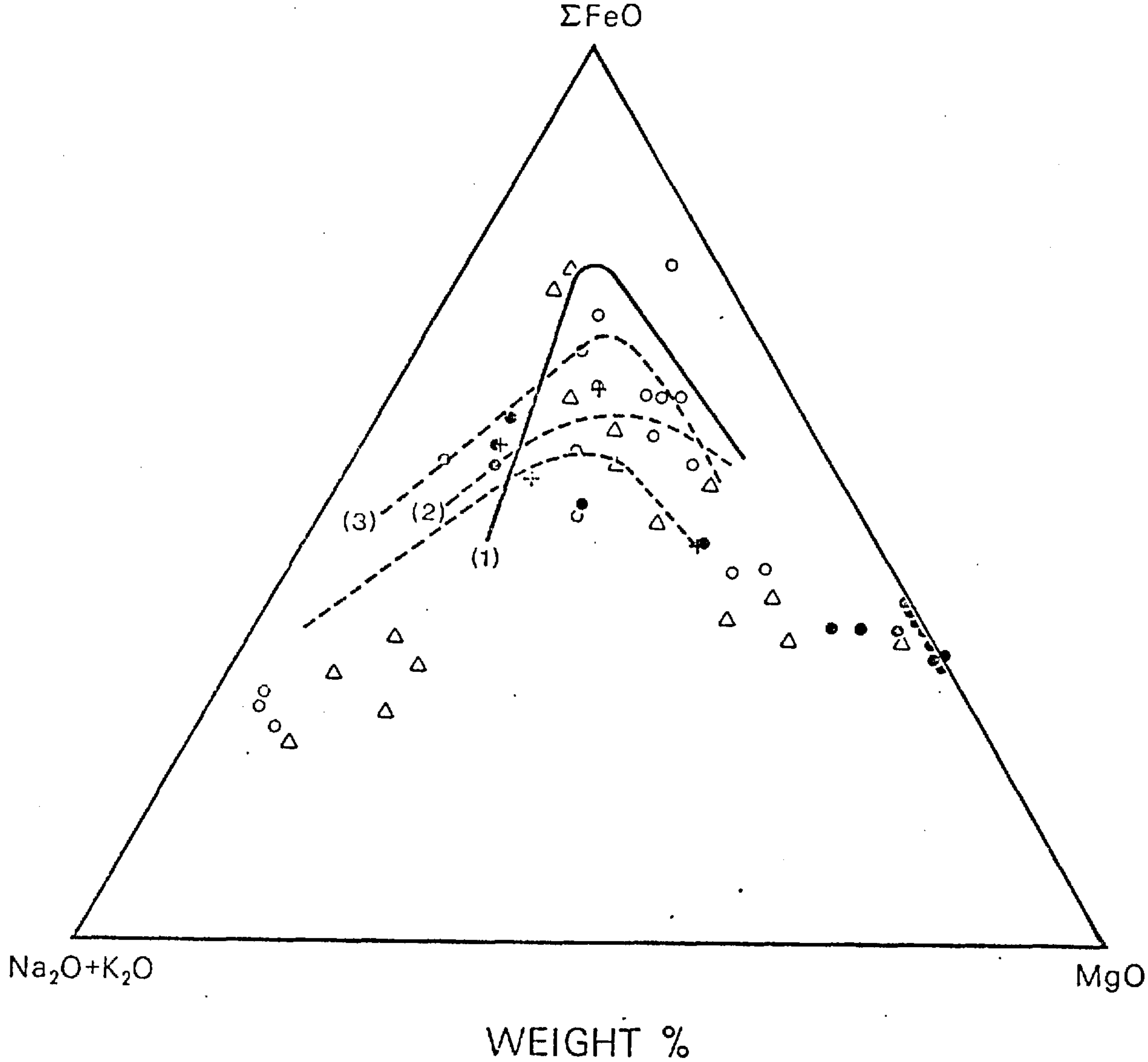

FIGURE 8 - AFM diagram for the Kinojevis Group, Destor tholeiitic series which includes komatiites, meta-basalts, meta-andesites and meta-rhyolites (closed and open circles, see figure 4), as well as intrusive equivalents (open triangles). The superposed chemical trends are as follows (1) Raoul Islands, (Brothers and Searle, 1970), (2) Tonga Islands, (Bryan *et al.*, 1972) both from the Kermadec Group, Western Pacific; (3) Nasu tholeiitic series, Japan (Kawano *et al.*, 1961). The unnumbered broken line is the dividing line of figure 5.

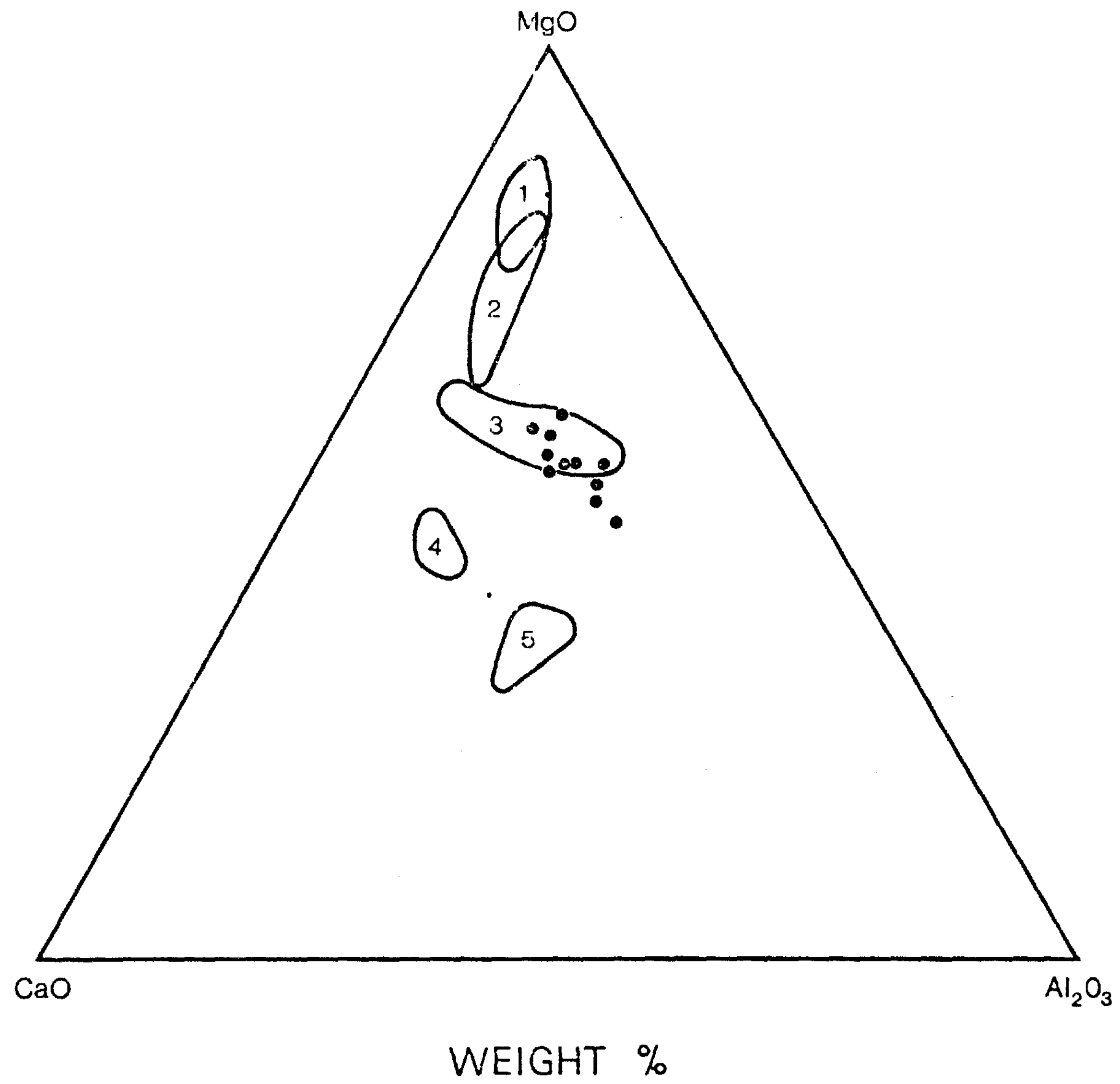

FIGURE 9 - CaO - MgO - Al_2O_3 diagram showing the komatiites of the Destor tholeiitic series with respect to the South Africa fields (Viljoen and Viljoen, 1969). Fields are 1, 2 peridotitic komatiites, 3, 4 and 5 basaltic komatiites (Geluk, Badplaas, and Barberton types respectively).

qualify if the less rigid chemical criteria of Arndt (1976) is adopted, specifically with regard to the CaO/Al_2O_3 ratio.

Comparison of the Destor and Deguisier tholeiitic series reveals that the younger series (Destor) is more differentiated than the older series but because the older series crops out over a much bigger area than the younger, the impression one gains is that the Kinojevis Group is largely a monotonous sequence of mafic meta-volcanics.

Blake River Group

Duparquet-Destor-Manneville tholeiitic series:

This series consists of meta-basalt and meta-andesite flows with minor amounts of meta-rhyolite. We have no chemical information on this series which is extremely thin and not well exposed in the region of traverse (maximum thickness of about 3,000 ft.). Further along strike in either direction from the line of traverse, variolitic horizons of tholeiitic affinity occur, and because of this occurrence and because such variolites are entirely restricted to tholeiitic series in the Rouyn-Noranda district, we make a preliminary identification of the Duparquet-Destor-Manneville series as tholeiitic. Dimroth (written communication) indicates that this terminology may not exactly describe this sequence of rocks since they are not in evidence in the township of Manneville, but only developed between Hébécourt Lake and Reneault.

Hence this series may have to be revised in the future.

Rouyn-Noranda tholeiite series:

This series is believed to be the stratigraphic equivalent of the Duparquet-Destor-Manneville series. It consist mostly of meta-basalt and meta-andesite with minor meta-rhyolite, and contains three horizons of variolite which can be traced for many tens of kilometers. These variolites have been linked to immiscible processes in tholeiitic volcanism (Gélinas et al. 1975). There is a compositional gap between 64 and 71 percent SiO_2.

The data for this series plot as a zone that straddles the dividing line between the calc-alkaline and tholeiitic fields (figure 10B). Because the meta-basalts shows a moderate trend of iron-enrichment we have termed them tholeiitic, however they could in all likelihood be also termed primitive calc-alkaline series since some data points fall in the field of calc-alkaline rocks. Our bias is towards the iron-enrichment trend, and here we refer to the series as tholeiitic (cf Jolly, this volume).

Reneault calc-alkaline series:

This series consists mostly of meta-andesite flows and andesitic

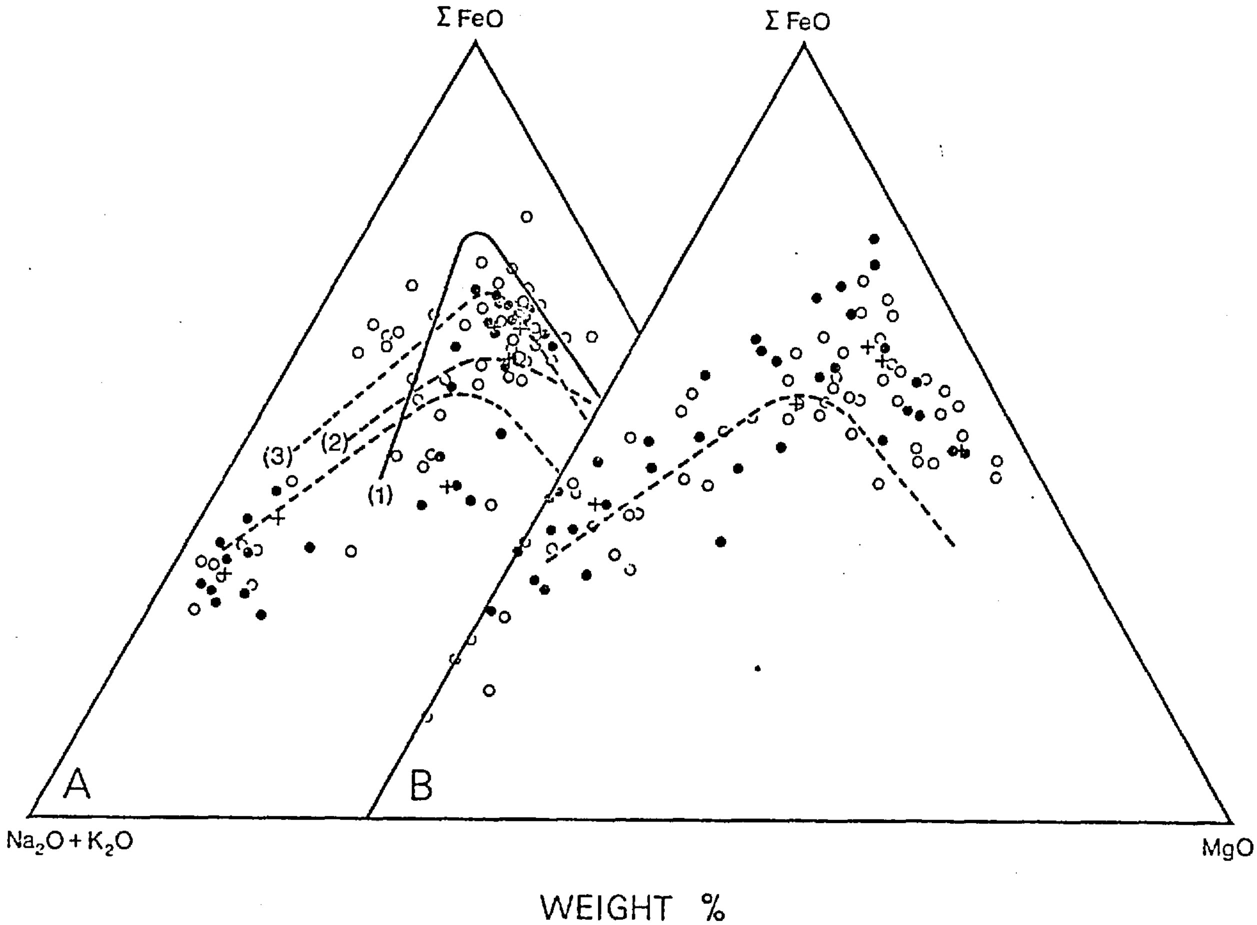

FIGURE 10 - AFM diagrams for the Blake River Group tholeiitic series, viz, Dufresnoy (9A) and Rouyn-Noranda (10B) showing iron-enrichment in the mafic members. The numbered trends in 10A are those of figure 8.

to dacitic pyroclastics, with minor metabasalt. The rocks plot on the AFM diagram within the calc-alkaline field and show a clear trend towards alkali enrichment (figure 11 A).

Dufault calc-alkaline series:

This series is either younger than or equivalent in age to the Reneault series. It consists mostly of meta-andesite flows but unlike the Reneault series the more differentiated members are rhyolitic and appear to be primarily pyroclastics with subordinate flows. A compositional gap is observed within this series: no dacites or rhyodacites (SiO_2 between 64 and 71%) were encountered.

On the AFM diagram (figure 11B) the data define a trend towards alkali enrichment within the calc-alkaline field. No evidence of an iron enrichment trend is observed.

In figure 12A, we have plotted the meta-rhyolites from the Dufault calc-alkaline series in the system anorthite-albite-orthoclase - SiO_2, an inspection of this diagram reveals that the meta-rhyolites plot within the quartz field and define a tight trend. By comparison the meta-rhyolites from the Rouyn-Noranda tholeiite series (figure 12B) plot either close to the cotectic for .5 kb of water pressure, or within the plagioclase field. Only 4 of the calc-alkaline meta-rhyolites plot

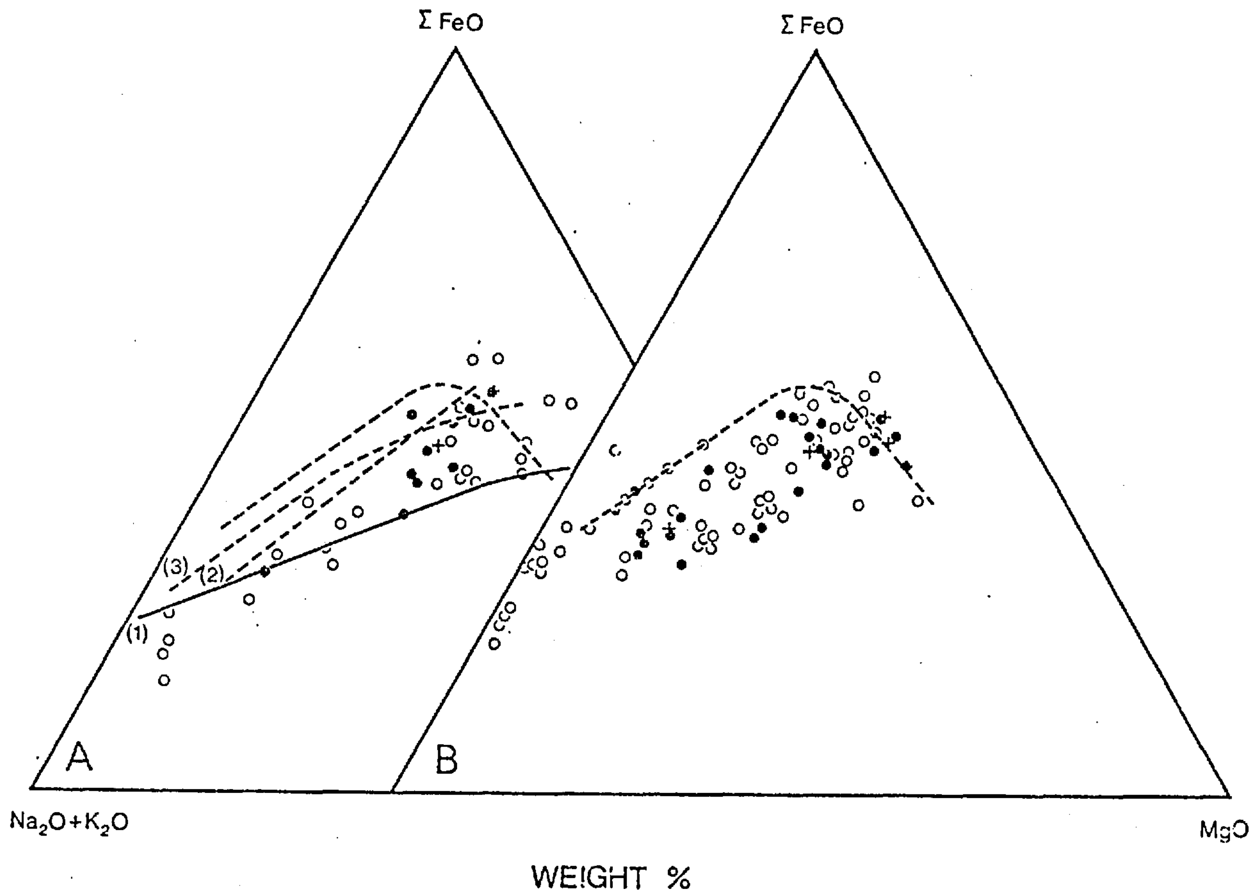

FIGURE 11 - AFM diagrams for the Blake River Group calc-alkaline series, viz, Reneault (11A) and Dufault (11B), showing alkali-enrichment and iron-depletion trends. The numbered trends in 11A are

1 - Cascades (Smith and Carmichael, 1968),

2 - Calc-alkaline trend of Turner of Verhoogen (1960), and

3 - The Nasu calc-alkaline trend (Kawano, *et al.*, 1961).

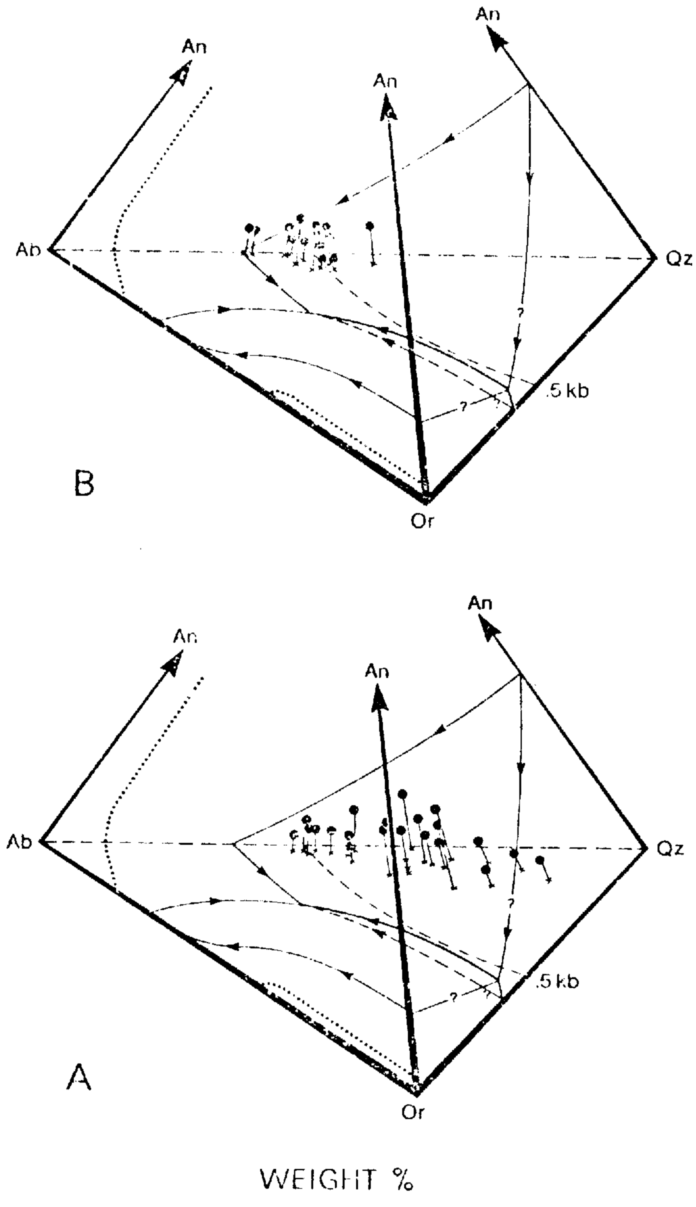

FIGURE 12 - Truncated anorthite-albite - orthoclase - quartz tetrahedron with cotectic planes for 10 Kb P_{H_2O} and the cotectic line for 0.5 Kb P_{H_2O} shown. 12A is for Blake River Group calc-alkaline rhyolites. 12B for Blake River Group tholeiitic rhyolites. Circles are the analyses seen in three dimensions, and the crosses their projection from the anorthite pole. The calc-alkaline rhyolites plot well within the quartz field whereas the tholeiitic rhyolites plot in the vicinity of the 0.5 Kb P_{H_2O} cotectic line.

in a similar location and this implies a fundamental difference in the P_{H_2O} conditions existing during the formation of the rhyolite of the two series. The P_{H_2O} in the acidic magma of the Dufault series must have been significantly greater than that for the Rouyn-Noranda series. It could be argued that the meta-rhyolites of the Dufault series have been modified by sea-floor metamorphism which led to increase in the relative SiO_2 contents, however it is unlikely that the two series, which contain similar evidences of submarine volcanism (mafic pillows etc), were subjected to markedly different histories while on the sea-floor. Hence we tentatively view the trend shown in figure 12A as primary, reflecting variations associated with magmatism.

Dufresnoy tholeiitic series:

This series consists mostly of meta-basalt and meta-andesite with minor meta-rhyolite; there is no dacite, 62 - 67% SiO_2 or rhyodacite, 67 - 71% SiO_2). The series is the youngest of the Blake River Group and it occupies a syncline flanked by the two calc-alkaline series of the Group. Like the other tholeiitic series it contains a variolite horizon although in this series it is more discontinuous than those in the older series.

When plotted on the AFM diagram the data for this series are seen to fall within both the calc-alkaline and tholeiitic fields (figure 10A). This dispersed picture becomes rapidly clarified however when stratigraphic position is considered. The data plotting within the calc-alkaline field comes from a restricted and stratigraphically related section on both flanks of the syncline. The former shows a trend of increasing iron-enrichment with decreasing age (figure 13). While we have termed the series tholeiitic (based on the dominent rock type) it should not be forgotten that the series is a mixed one. The field boundary (figure 2) between the Dufresnoy series and the subjacent series is evident only where rocks of contrasting mineralogy are juxtaposed in the field. Where the adjacent series rocks are both mafic volcanics, the contact is only approximate and usually drawn as an "along strike" extrapolation of a more obvious field contact.

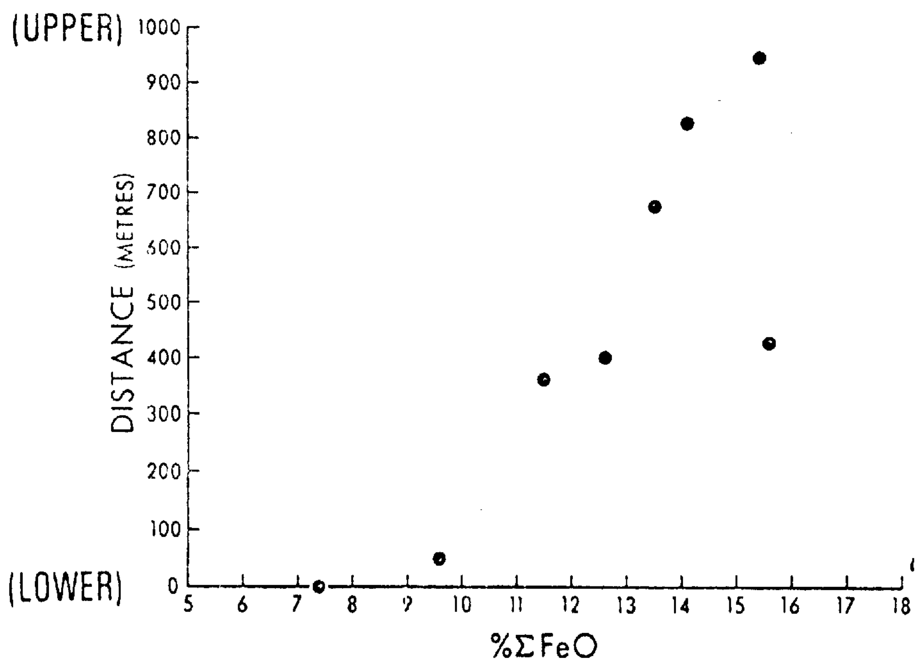

FIGURE 13 - Stratigraphic variation diagram of total iron in the Dufresnoy tholeiitic series.

DISCUSSION AND CONCLUSIONS

The main highlight of the chemo-stratigraphic division of the Abitibi belt north and south of Rouyn-Noranda is the identification of (a) a mafic basal section (Kinojevis Group) in which the metavolcanics show pronounced tholeiitic affinity, and (b) a younger sequence of tholeiitic and calc-alkaline lavas (Blake River Group). These relationships are summarized in Figure 14. The intermingled tholeiitic and calc-alkaline lavas are not randomly associated but occur in definite stratigraphic position such that individual volcanic series can be identified. Even in one of the series which shows an intermingling of associations (Dufresnoy), the calc-alkaline rocks are stratigraphically isolated from the tholeiitic rocks. This, of course, has important implications in any regional compilation of data from the Abitibi belt, in which the chemically distinct associations are not separated, and individually assessed (see Table 1). Such compilations will obviously obscure the fundamental petrogenetic relationships essential to the understanding of Archean volcanism.

On first appraisal, the results of the geochemical investigation of the metavolcanics of the Abitibi belt, Rouyn-Noranda District would seem to confirm the previous suggestions of Gélinas and Brooks (1974) in which an analogy is drawn between the Blake River and

Kinojevis Groups on the one hand an island-arc superstructure overlying sea-floor material on the other. Such an appraisal would be in accord with previous and current regional compilations, but however it does not adequately account for the new data from along the line of traverse. The ocean floor analogy postulated to explain the monotonous pillowed mafic sections of the Kinojevis Group must provide for the fact that,

(a) modern sea-floor volcanics are olivine and hypersthene normative while the Kinojevis rocks are almost exclusively quartz-normative (indicating that even the more monotonous Archean mafic sections, are not as "primitive" as modern sea-floor volcanics),

(b) the degree of iron-enrichment in the Kinojevis Group mafics, (Deguisier series) is much greater than modern sea-floor volcanics, indicating again that the most primitive of Archean rocks are much more differentiated than modern sea-floor volcanics, and

(c) the Kinojevis Group basalts and andesites have TiO_2 contents much lower than modern sea-floor basalts. The only modern rocks with comparable TiO_2 values are the low-K tholeiites of similar $\Sigma FeO/MgO$ from island-arcs (Miyashiro, et al., 1974; and written communication).

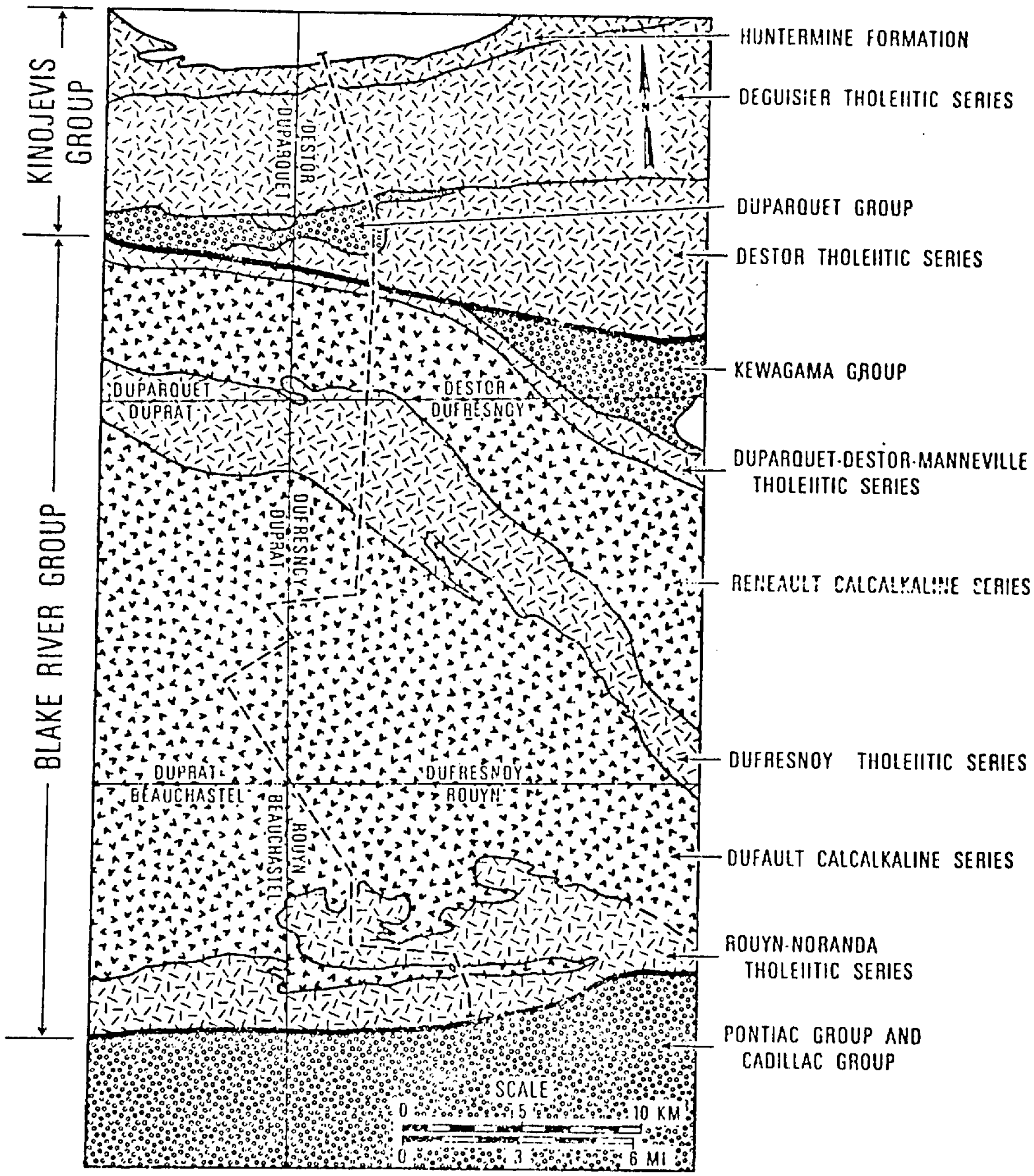

FIGURE 14 - Simplified summary of the chemo-stratigraphic divisions within the Rouyn-Noranda District of the Abitibi belt, Quebec.

Similarly, the island-arc analogy postulated to explain the Blake River Group metavolcanics must account for the following properties of the Group:

(a) The differentiation trends of the tholeiitic series of the Blake River Group are explained adequately by a simple model of crystal fractionation of a basaltic parent under low oxidation; the crystallization of titaniferous magnetite is delayed, resulting in the enrichment in ΣFeO of the residual magma (Osborn, 1957; Presnall, 1966). Their early chemical evolution (figures 9A, 9B) is similar to that of low-K tholeiitic island arcs such as the Tonga Kermadec arc (Tonga Islands, Bryan et al. 1972; Raoul Island, Brothers and Searle, 1970), the Nasu Zone, Japan (Kawano et al., 1961) and the South Sandwich Islands, Scotia arcs (Baker, 1968). The late trend of differentiation seems to be controled by liquid immiscibility; one of the liquids has a normal low-K rhyolite composition similar to the abundant rhyolites of the region and the other liquid is more ferruginous than most previously analysed volcanics of similar SiO_2 content (Gélinas et al., 1975).

(b) All mafic rocks (even those with calc-alkaline affinity) have K contents lower than modern island-arc suites save for the most primitive low-K tholeiite suites adjacent to the trenches (see figures 9A, 10A).

(c) No high-alumina basalt or andesite (following Kuno, 1960) occurs in the calc-alkaline volcanic series of the Group, despite the peraluminous nature of many of the volcanics.

(d) In the Dufault calc-alkaline series, the volumetric abundance of both the meta-andesite (54-62% SiO_2, volatile free) and the rhyolite (> 71% SiO_2, volatile free) and the paucity of associated meta-basalt are not explained adequately with the hypothesis of crystal fractionation.

(e) Because plagioclase is the ubiquitous liquidus phase of calc-alkaline andesite of the Dufault series, there is little evidence for the presence of excessive amounts of water in the andesitic magmas.

The available experimental evidences for calc-alkaline andesite submitted to various water pressures indicate that the liquidus phase plagioclase is restricted to low total pressures (Green, 1972; Eggler, 1972). According to Eggler (op.cit.), plagioclase is the liquidus phase of the Paricutin calc-alkaline andesite when water contents in the liquid are less than 2.0 weight percent and when the total pressure is less than 5 Kb. (15 - 20 depth Km).

The most plausible model accounting for these observations is notone implicating modern sea-floor analogues. The Kinojevis and the Blake River Groups most plausibly resemble successive sequences of an ancient island-arc. The Kinojevis Group could only be sea-floor, if the Archean sea-floor volcanism was quite different from the modern equivalent. There are some indications that certain aspects of Archean volcanism were indeed unique (e.g. peridotitic komatiites, Brooks and Hart, 1974),but we are not ready, as yet, to extrapolate this to a general rule embracing large extents of volcanics, as would be implicated in an ancient, sea-floor model.

On pursuing the island-arc analogy for the Archean section we have studied, we find that our data provide some contraints on the type of magmatism. We have information suggesting that the Archean volcanics were derived from "shallow" depth (based on TiO_2 and K_2O and the presence of plagioclase on the liquidus of andesite). Hart et al. (1970) in their trace-element model for Archean mafic volcanism invoke magma derivation from depths of less than 50 Km by high degrees (> 30%) of partial melting. The abundance of rhyolite in the higher stratigraphic sections of the Archean pile, (Dufault calc-alkaline and Dufresnoy tholeiitic series) suggests that the island arc was of a continental rather than oceanic type (following Miyashiro, 1974). Independant evidence from other parts of the Superior Province, and specifically from north of Chibougamau (Brooks, unpub. data) indicates that acidic continental-type material was in existence prior to the development of the Abitibi metavolcanic-pile. Thus if the island-arc anolcgy is valid, the Abitibi volcanics most probably formed as a continental island-arc similar in many respects to the Pleistocene volcanism of the Taupo province, New-Zealand (Carmichael et al., 1974). The Archean arc was, however, much more primitive at all stages of its development than the more nature continental arcs such as Peru (James et al., 1975). This could be linked to thinner lithospheric conditions prevailing in the Precambrian as a result of radioactive heat production being approximately twice the value at present. The Dufault calc-alkaline and Dufresnoy tholeiitic rhyolites could have been the direct result of the accumulation of mafic, (quartz-normative) tholeiites of both, the Kinojevis and Blake River Groups, under submarine conditions, either directly upon or overlapping sialic crust.

Crustal downwarping would have depressed the sialic crust into a region where participation in magma generation was possible. Alternative models for the generation of excess rhyolites above that normally resulting from differentiation are discussed by Miyashiro (1974).

We are currently pursuing many of the lines of inquiry stimulated by our findings and both trace-element and isotopic analysis studies are being completed. Hopefully, the results will further clarify the interpretation presented here, and will allow a much more definitive model to be outlined, one involving perhaps the orientation and development of Archean plate-boundaries related to the proposed island-arc system.

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