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PROTOLITH, MINERALOGY, AND GOLD DISTRIBUTION

OF CARBONATE RICH ROCKS OF THE

LARDER LAKE BREAK, AT MISEMA RIVER, ONTARIO

Protolith, Mineralogy, and Gold Distribution  
of Carbonate Rich Rocks  
of the  
Larder Lake Break, at Misema River, Ontario

by  
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## ABSTRACT

The Larder Lake Break (LLB) is one of the structures controlling the location of gold deposits in the Kirland Lake camp. This intensely carbonated and often strongly foliated zone is part of the Larder Lake Group as defined by Downs (1980). Protoliths at the LLB are problematical.

Misema River is a well exposed occurrence of the LLB, showing chlorite schist, pervasively fuchsite quartz carbonate and syenite dyke material. It is divided into three sections. Section I samples indicate an ultramafic protolith as suggested by Jensen Cation plots, and the section is interpreted as komatiitic flow(s). Section II is well foliated and shows both ultramafic and calc-alkalic components which decrease and increase in intensity respectively away from the section I-section II contact. Section II is interpreted as a polymodal sediment. Section III is similar chemically and texturally to section I, and is therefore a komatiitic flow(s).

The intrusion of syenite dykes into section I occurred after initial carbonatization and deformation of the flows and associated sediments.

Radiochemical neutron activation analysis shows all but one of the syenite dyke samples to contain greater than 10 ppb gold whereas the other rock types averages approximately 2 ppb. A peak

content of 64 ppb occurred at a dyke contact. The high gold contents clearly originate from the syenite dykes, which also provide a heat source for a second period of carbonatization.

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## TABLE OF CONTENTS

	page
Chapter 1 Introduction and Background	1
1.1 Introduction	1
1.2 Location and Geological Setting	1
1.3 Larder Lake Break	7
1.4 Gold Mineralization	8
Chapter 2 Sampling and Analytical Methods	10
2.1 Sample Collecting and Preparation	10
2.2 X-Ray Fluorescence	10
2.3 X-Ray Diffraction	11
2.4 CO <sub>2</sub> and Lithium Analysis	11
2.5 Gold Analysis	11
Chapter 3 Observations and Results	14
3.1 Field Observations	14
3.2 Mineralogy and Petrography	23
3.2.1 Whole Rock X-Ray Diffraction and X-Ray Fluorescence Analysis	23
3.2.2 Textural Descriptions	30
3.2.2.1 Sections I and III	30
3.2.2.2 Carbonate Minerals	30
3.2.2.3 Syenite Dykes	30

	page
3.2.2.4 Section II	31
3.3 Opaque Mineralogy	31
3.4 CO <sub>2</sub> and Lithium Analysis	47
3.5 Gold	47
Chapter 4 Discussion and Interpretation	51
4.1 Inferred Primary Lithologies	51
4.2 Model of Origin	54
4.3 Carbonates	56
4.4 Gold Mineralization	57
Chapter 5 Conclusions	59
Appendix I Experimental Results	61
Appendix II Radiochemical Neutron Activation Analysis Procedure	65
References	70



## LIST OF FIGURES

	page
Figure 1 General location of the study	2
Figure 2 The Kirkland Lake-Larder Lake Gold Camp	4
Figure 3 General stratigraphy and structure of the Timmins-Kirkland Lake area	5
Figure 4 Distribution of major units, discordances, and minor fold axis azimuths	6
Figure 5 Position and intensity of the diagnostic peaks of the major rock forming minerals	12
Figure 6 Misema River Road Cut, North Face	17
Figure 7 Nickel versus chromium	29
Figure 8 Distribution of gold in the different sample groupings	50
Figure 9 Jensen cation plot	52

## LIST OF TABLES

	page
Table 1 Approximate modal percentages, as estimated by thin section examination	24
Table 2 Mineralogy (X-Ray Diffraction)	26
Table 3 Average bulk composition of sample groupings	27
Table 4 CO <sub>2</sub> content (% by wt.)	48
Table 5 Lithium content of ten samples	49

## LIST OF PLATES

	page
Plate 1 The Misema River Road Cut, North Face	15
Plate 2 The Misema River Road Cut, North Face	16
Plate 3 Breccia at edge of syenitic dyke	21
Plate 4 Spinifex texture	22
Plate 5 Cross cutting carbonate vein	33
Plate 6 Fuchsitic quartz-carbonate	34
Plate 7 Fuchsitic quartz-carbonate	34
Plate 8 Larger albite grain	35
Plate 9 Polycrystalline quartz	36
Plate 10 Syenite dyke	37
Plate 11 Syenite dyke near contact	38
Plate 12 Chill margin at dyke-country rock contact	39
Plate 13 Chlorite schist	40
Plate 14 Chlorite schist and deformed carbonate vein	41
Plate 15 Well foliated quartz carbonate	42
Plate 16 Well foliated fuchsitic quartz-carbonate and cataclastic pyrite	43
Plate 17 Well foliated quartz-carbonate with carbonate vein	44
Plate 18 High pyrite content of sample 16	45
Plate 19 Leucoxene	46

## CHAPTER 1

### Introduction and Background

#### 1.1 Introduction

The Kirkland Lake-Larder Lake gold camp has historically been one of the more important gold producing camps in Canada. As of the end of 1976, this camp had produced 36% of the total Ontario gold (Gordon *et al.*, 1979). From the two still active mines, Kerr Addison and Wilroy Mines (Macassa Division), 1978 production is listed as 4280 kg (150 972.6 oz.) (Hogan, 1979). This gold camp is presently ranked third behind Timmins and Red Lake in yearly production. However, the precise source of the gold, the timing of the mineralization event(s?) and the nature of the host rocks particularly those associated with the Larder Lake Break (LLB) are debatable.

This thesis is a detailed study of the gold distribution using the carbonate rocks of the Larder Lake Break at one specific locality. The major objectives are to obtain a better understanding of pre-alteration lithologies on the Larder Lake Break and whether gold distribution is related to specific rock types.

#### 1.2 Location and Geological Study

The study area is situated immediately to the east of the Highway 66 bridge over the Misema River in the far southeast corner of Gauthier Township, District of Timiskaming, Northeastern Ontario (Fig. 1).

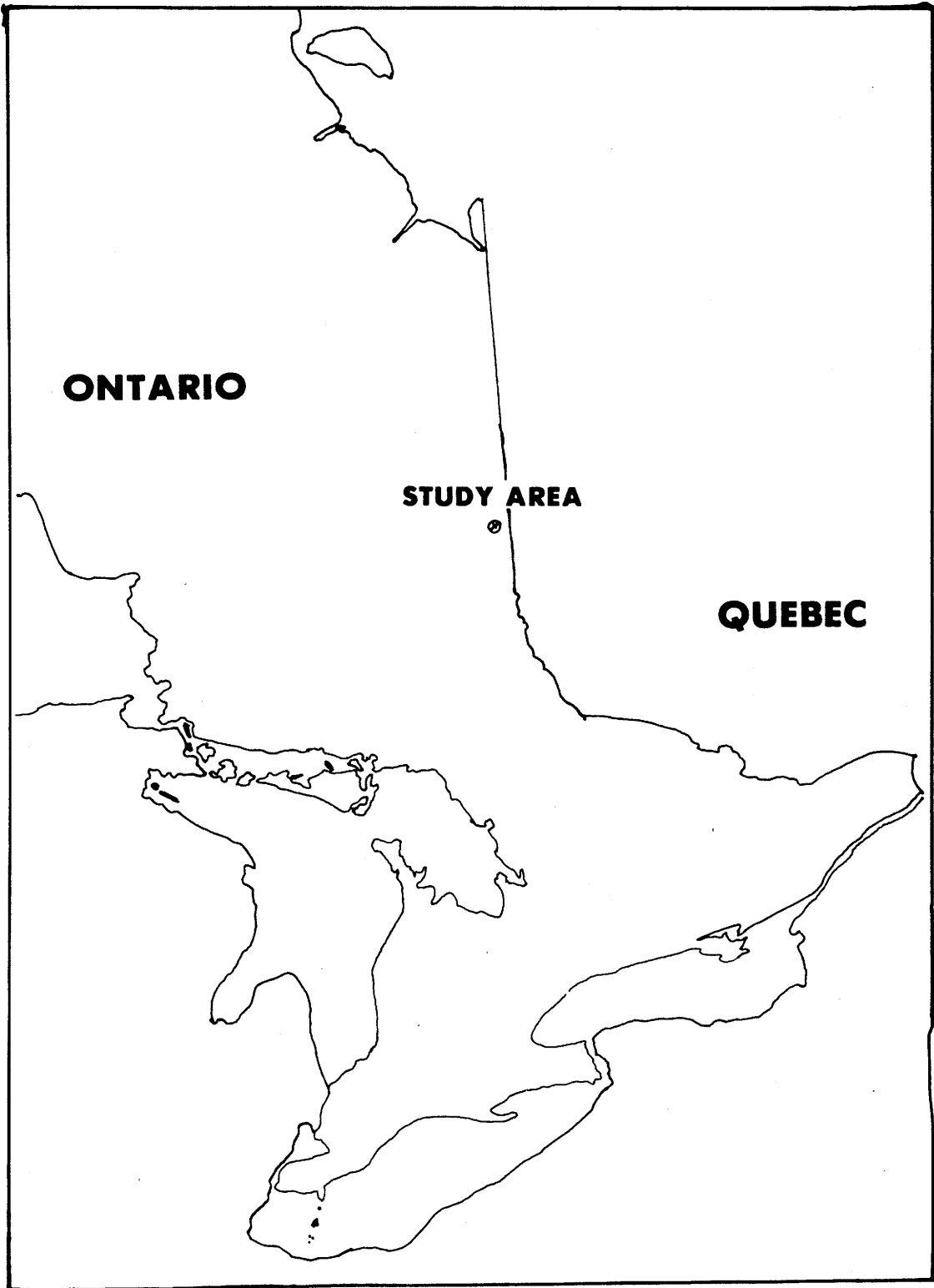


Figure 1

This exposure of the Larder Lake Break is 2.4 kilometres west of the community of Larder Lake (Fig. 2).

The bulk of this study deals with the rocks on the north face of this exposure called the "Misema River Road Cut". The south face was studied by Werniuk (1979).

The geology of the Kirkland-Larder Lake area has been studied numerous times notably by Thompson (1941), Hewitt (1963), Goodwin (1965), Ridler (1970), L.A. Tihor and Crocket (1977), S.L. Tihor (1978), Hyde (1978), Jensen (1979), and Downs (1980).

The Kirkland Lake-Larder Lake area is dominated by a domical volcanic complex several miles in diameter. Mafic volcanics occur at the base of the complex and are overlain by intermediate volcanic flows and breccias. The stratigraphic top of the sequence consists of clastic sediments and felsic pyroclastics, the volcanics showing distinctly alkalic compositional character. This sequence is termed the Timiskaming group volcanics and sediments (Miller, 1911).

Jensen (1980) sees the Timmins-Kirkland Lake region as an 80 to 120 km wide east plunging synclinorium (Fig. 3). Parallel to this trend on the Kirkland Lake-Larder Lake region is a carbonatized structural lineament known as the Larder Lake Break.

Hewitt (1963) correlated the rocks to the south of the LLB (as recognized by Thompson, 1941) with those on the north as being Timiskaming in age. More recent evidence (Jensen, 1979) indicates the rock south of the LLB cannot be correlated as above. The rocks south of the break, in or near the study area are termed the Larder Lake group.

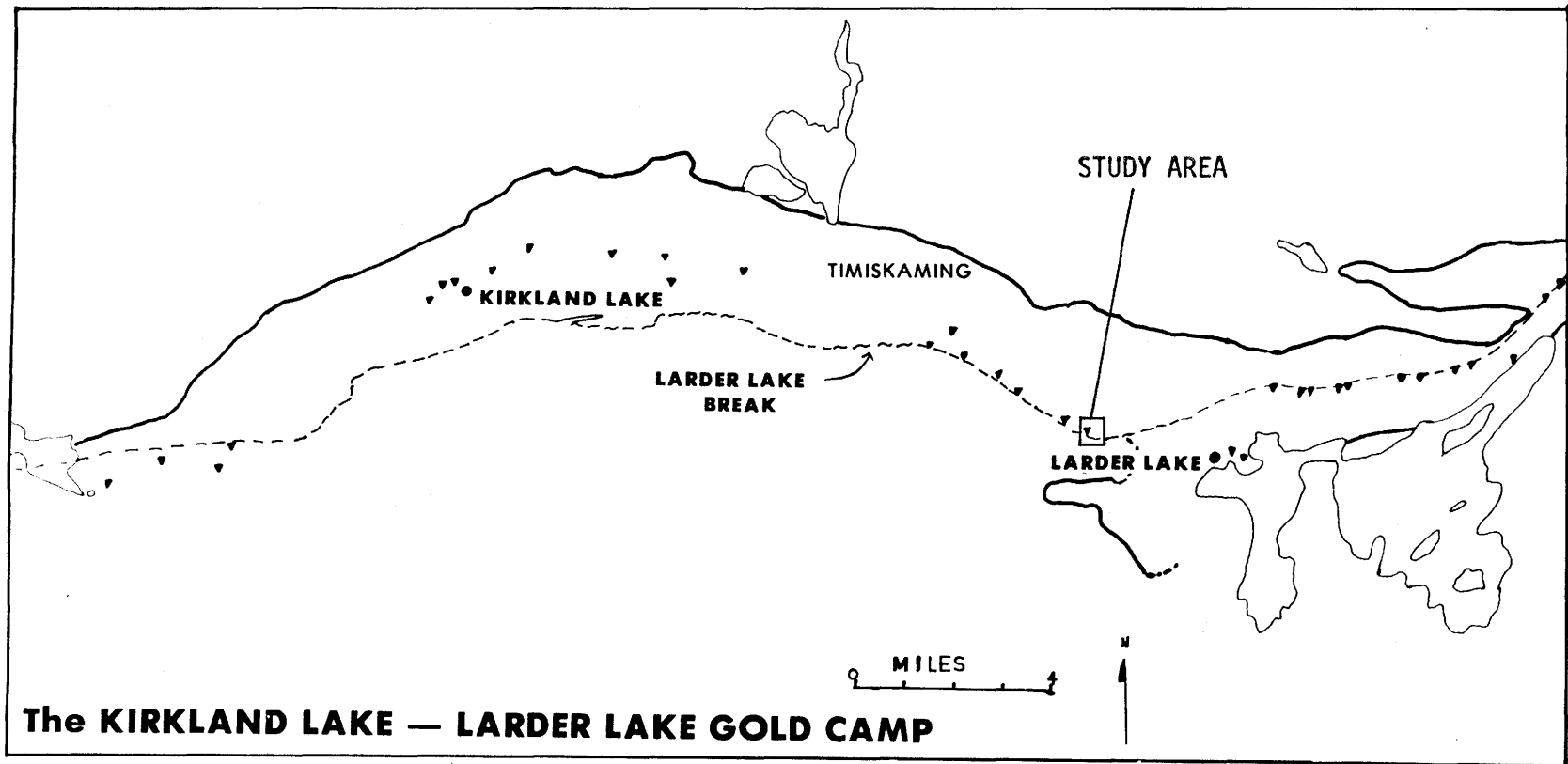
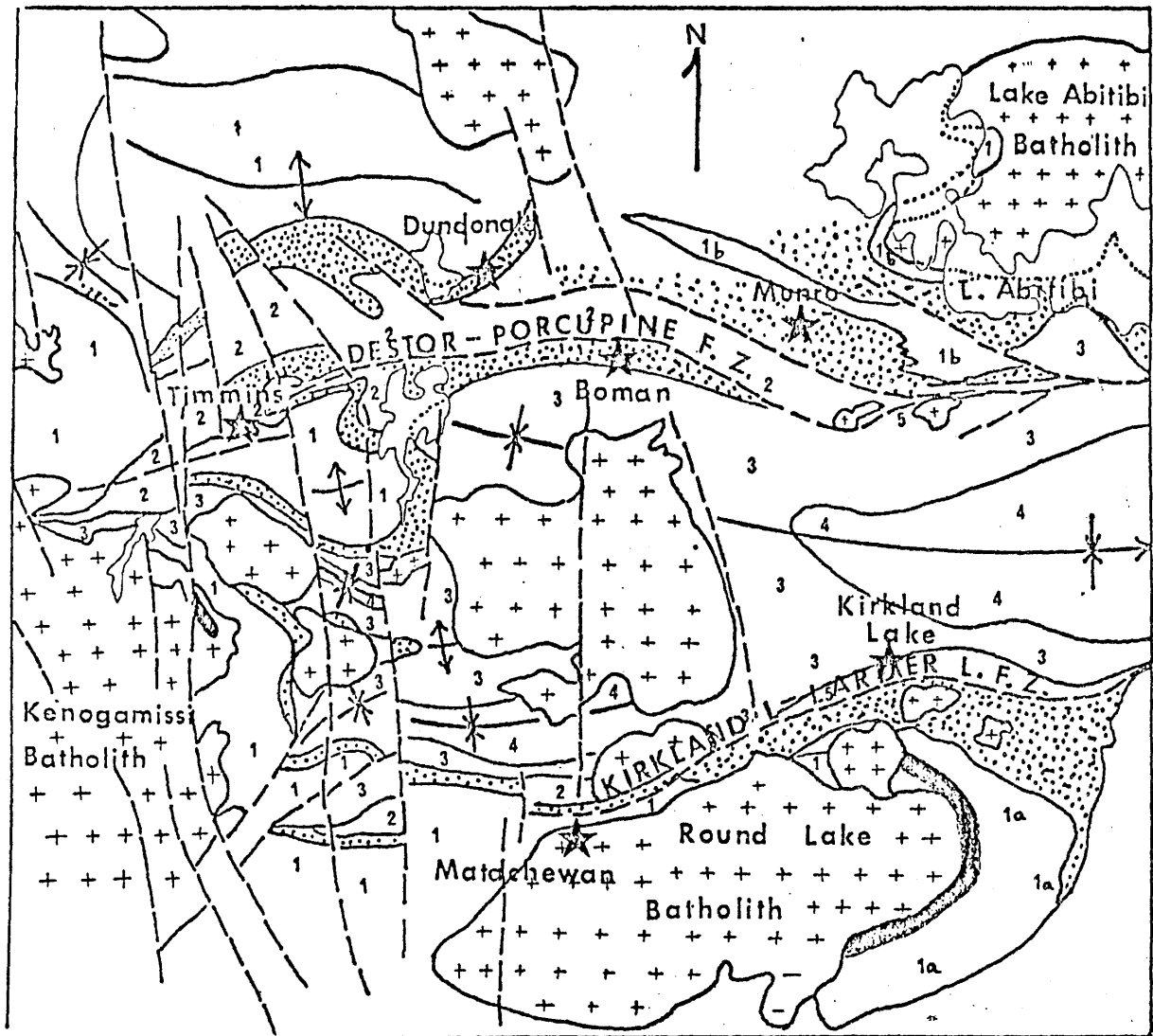


Figure 2. The Kirkland Lake-Larder Lake Gold Camp. The small triangles indicate gold showing locations. The Larder Lake Break is represented by the dashed line. (After S.L. Tihor, 1978)



**LEGEND**

**UPPER SUPERGROUP**

- 5. Alkalic Volcanics  
(Timiskaming Group)
- 4. Calcalkalic Volcanics  
(Blake River Group)
- 3. Tholeiitic Volcanics  
(Kinojevis Group)
- ☐ Komatiitic Volcanics  
(Stoughton Roquemaure Group  
and Larder Lake Group)

**LOWER SUPERGROUP**

- 2. Sedimentary Rocks  
(Porcupine Group)
- 1. Calcalkalic and Tholeiitic  
1a (Skead and Catherine Group)  
Volcanics  
1b (Hunter Mine Group)
- ☐ Komatiitic Volcanics  
(Wabewawa Group)

Jensen & Pyke (1980)

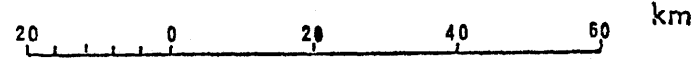
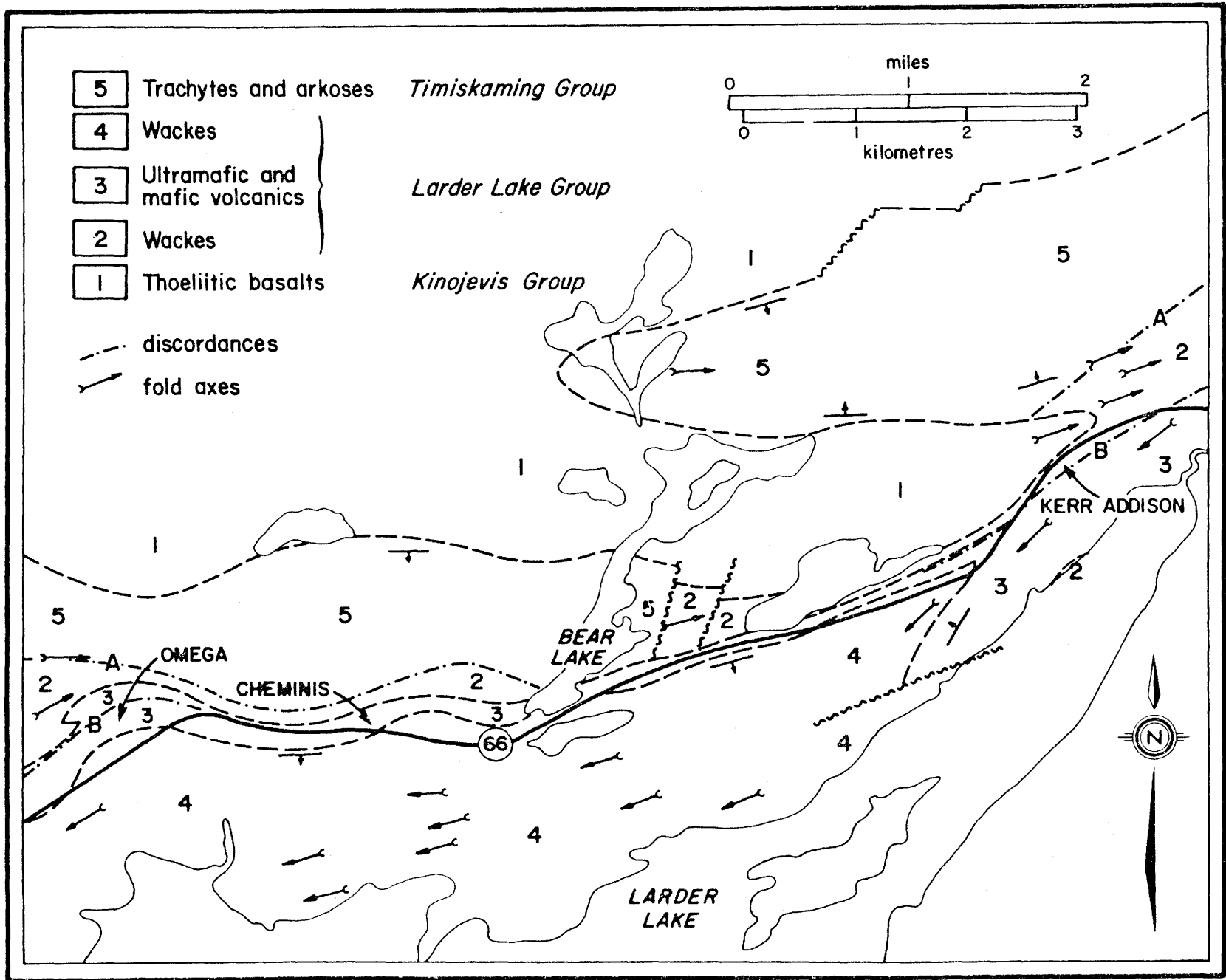


Figure 3. General stratigraphy and structure of the Timmins-Kirkland Lake Area.  
(from Jensen, 1980)





from Downs, 1980

Figure 4. Distribution of major units, discordances, and minor fold axis azimuths

They are overlain unconformably on the north by the Timiskaming group.

Downs (1980) agrees with this division of the Timiskaming, as seen by Hewitt, into the Timiskaming and Larder Lake groups but places the northern boundary of the Larder Lake group at a discordance slightly north of the break (Fig. 4), which is interpreted to be both structural and stratigraphic in nature. Downs notes that south of this discordance, "komatiitic flows per se have not been observed in the area". However, Werniuk (1979) notes very good pyroxenitic spinifex in outcrop as well as geochemical data supporting an ultramafic protolith.

### 1.3 Larder Lake Break

The LLB is a regional lineament originally delineated as a carbonate zone, often intensely foliated and greenish in colour due to the presence of fuchsite (Thomson, 1941). The LLB strikes parallel to the regional structure, and passes through the Misema River road cut (Thomson, 1941). Ridler (1970) however, notes the association of the carbonate rocks of the LLB with carbonate-rich shale, greywacke, tuff, and locally thick beds of chert. He argues that the LLB carbonates are exhalative volcanic sediments and are probably a carbonate facies correlative with the nearby oxide facies of the Boston Iron Formation. He also states that the LLB is not a fault and suggests that the intense foliation sometimes shown by LLB carbonates is an expression of differential structural competency of the

carbonates in comparison with adjacent or nearby lithologies.

There is a basic inability to trace individual units across the break (Hyde, 1978), and the carbonate rocks show chemical and textural indications of an ultramafic protolith (L.A. Tihor and Crocket, 1977). For the purposes of this report, the Larker Lake Break is taken to run approximately along Highway 66 at the Misema River outcrop.

Although its origin is still speculative, the break has been interpreted as being due to strong vertical movements concentrated along the north flank of the uplifted Round Lake Massif (Kaliokoski, 1968). Movement along the fault is thought to be lateral, and of the order 1000 to 1200 m (M.J. Downs, L.S. Lensen, pers. comm.). Field data of Downs (1980) indicates a rotation of 60° in the plane of the LLB.

#### 1.4 Gold Mineralization

Two types of gold deposits occur in the Kirkland Lake-Larder Lake gold camp. Gold occurs as native gold in quartz and quartz carbonate veins, and as an accessory component in pyrite along the LLB itself (Kerr Addison Mines) (Fig. 2). Nearer to Kirkland Lake, the gold occurs in association with syenitic intrusions. These intrusions are often accompanied by carbonate zones. In general, gold mineralization is associated with carbonate alteration throughout the camp.

Downs (1980) envisages the carbonatization, and therefore

the gold deposit formation, to have occurred later than the principle phase of folding. This is evidenced by the carbonatization cutting the break and being more mature in fold hinge zones that are suggested to be a later tectonic event.

## CHAPTER 2

### Sampling and Analytical Methods

#### 2.1 Sample Collection and Preparation

Two series of samples were collected. Series one was collected by J.H. Crocket in August of 1979. These samples are numbered 1 to 7. Series two, numbered 15 to 29, were collected by the author in September of 1979. Samples 9 and 10 were collected by Werniuk (1979) and are from the south side of the Highway.

An effort was made to have the outcrop as systematically sampled (spatially) as possible, taking into account its intensely foliated and partially folded nature. Representative samples of the various rock types were also taken. A representative portion of each sample was crushed (Jaw Crusher), pulverized (disc pulverizer), and powdered (shatter box). This powder was then stored in glass or plastic containers.

#### 2.2 X-Ray Fluorescence

Using a method developed for ultramafic rocks (Norrish and Hutton, 1969) glass beads were prepared for X-Ray fluorescence analysis. Powder pellets were also made. Major elements as well as a suite of trace elements including Rb, Sr, Y, Zr, Nb, Ni, Cr, Co, Pb, Cu, Zn, and

As were analysed.

### 2.3 X-Ray Diffraction

Whole rock XRD analysis was run on sieved samples (-100 mesh). All samples were scanned at a rate of one degree per minute from two theta values of 5 to 60 degrees using Cu K $\alpha$  radiation. The spectra recorded on a chart recorder at two centimetres per minute were compared to calculated peaks (S. Tihor, 1978) (Fig. 5). These results were used to aid in mineralogical identification.

### 2.4 CO<sub>2</sub> and Lithium Analysis

CO<sub>2</sub> analysis was done with a Leco gas analyser. Lithium results were provided by P. Vilks for 10 samples using Atomic Absorption methods.

### 2.5 Gold Analysis

Radiochemical neutron activation methods were used to determine the gold contents of all the samples. Three runs of 10 samples and three standards each were irradiated for 24 megawatt hours in the McMaster Nuclear Reactor. The sample powders were added to zirconium crucibles containing gold carriers, mixed with a Na<sub>2</sub>O-NaOH flux and fused. The fusion cake was dissolved in HCl (converting gold to a chloride AuCl<sub>4</sub><sup>-</sup> complex) and the gold extracted into ethyl acetate. Finally the gold was transferred back to the aqueous phase by evaporation of the acetate. The gold was reduced and precipitated

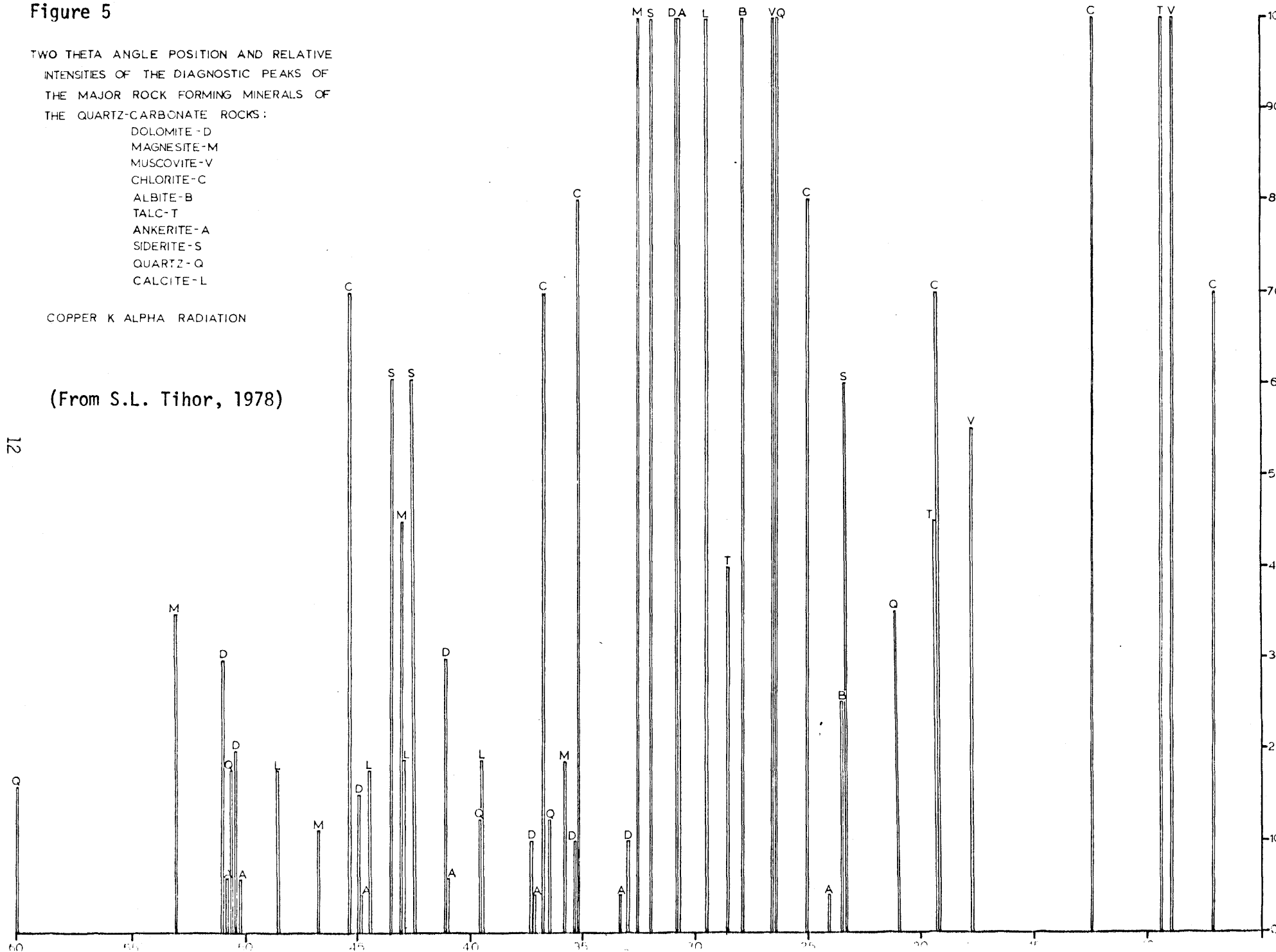
Figure 5

TWO THETA ANGLE POSITION AND RELATIVE INTENSITIES OF THE DIAGNOSTIC PEAKS OF THE MAJOR ROCK FORMING MINERALS OF THE QUARTZ-CARBONATE ROCKS:

- DOLOMITE - D
- MAGNESITE - M
- MUSCOVITE - V
- CHLORITE - C
- ALBITE - B
- TALC - T
- ANKERITE - A
- SIDERITE - S
- QUARTZ - Q
- CALCITE - L

COPPER K ALPHA RADIATION

(From S.L. Tihor, 1978)



as the metal with hydroquinone ( $C_6H_4(OH)_2$ ). The amount of radioactive gold was then measured on a multichannel gamma spectrometer using a Ge (Li) high resolution detector. For a more complete method of description, see Appendix II.



## CHAPTER 3

### Observations and Results

#### 3.1 Field Observations

The north face of the Misema River road cut has been mapped in detail, and tentatively divided into three main sections along its 225' length (Fig. 6) (Plate 1). The top of the outcrop was examined and characteristics were noted. However, due to vegetation cover, and confusion arising from extremely well developed foliation (Plate 2), detailed mapping of the surface was not completed.

The outcrop is generally well foliated, fuchsite bearing, and moderately to heavily carbonatized. There are variations in alteration intensity and bulk composition across the outcrop, although these differences are not always apparent in hand specimen or outcrop.

All point locations refer to distances from the western edge of the outcrop face. Feature locations are listed as their intersection with the base of the outcrop face, or the intersection of a vertical line with the base.

Section I (0 - 70' (Fig. 6)) is fairly massive and is heavily intruded by small (average width about 10 cm) syenite dykes. Quartz veining is prominent.



Plate 1. The Misema River Road cut, north face. Divided into sections I, II and III. (24 mm lens)



Plate 2. The Misema River Road cut, north face. Sun is reflecting off of foliation planes in section II.

# MISEMA RIVER ROAD CUT NORTH FACE

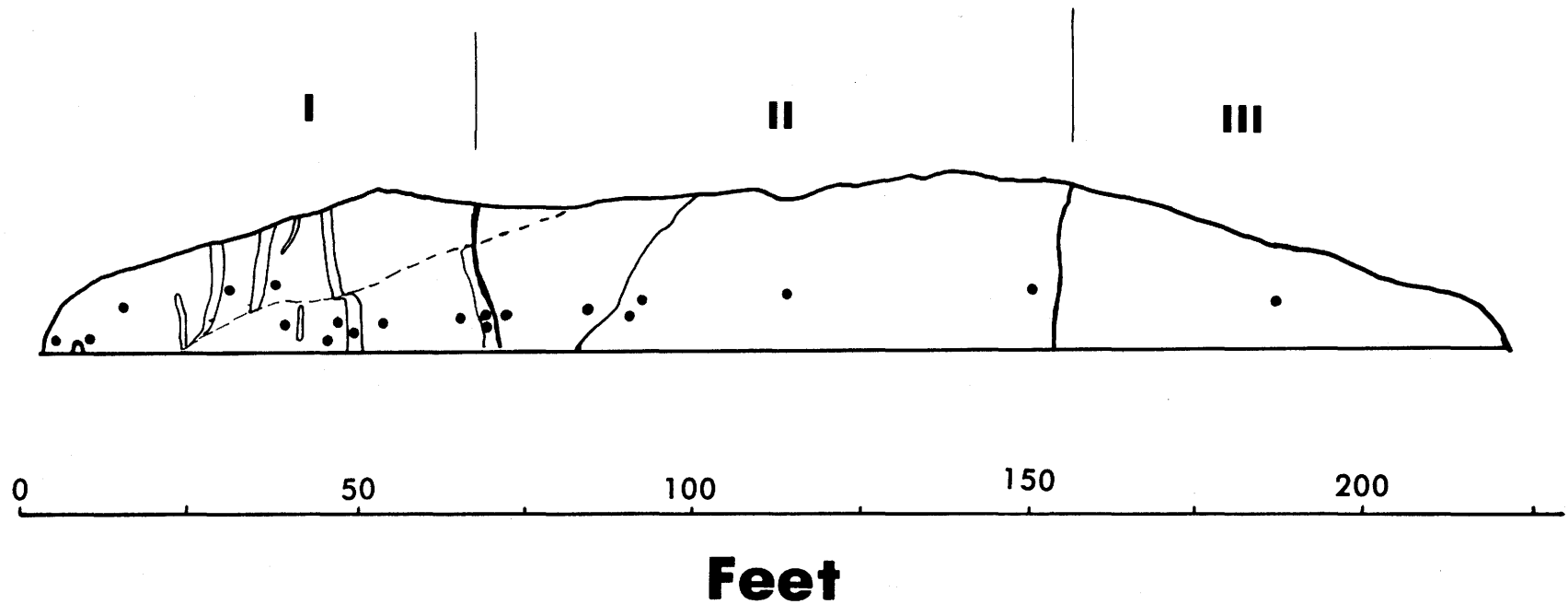


Figure 7. Misema River Road Cut, north face as divided into the three main sections. Dots indicate sample locations.

---

Distance from west end of outcrop (feet)	Rock Description
0 - 6	Dark green chloritic fuchsite bearing qtz. carb., little qtz. veining. Fuchsite content appears to increase towards a syenite dyke.
6 - 9	Syenitic dyke. Contact at 6', is heavily pyritized.
9 - 20	Fuchsite-qtz.-carb., qtz.-carb. veining increases eastwards, chlorite content decreases.
20	Small syenitic dyke, heavily pyritized.
20 - 23	Fuchsite bearing qtz.-carb.
23 - 27	Dark green chloritic fuchsite bearing qtz.-carb. fuchsite content increases towards a syenitic dyke.
27-- 29	Syenitic dyke material, ladder qtz.-carb. veining.
29 - 44	Dark green chl. Fuchsite bearing qtz. carb. Chlorite content decreases eastwards as fuchsite contents increases. Qtz.-carb. veining increases eastwards. Next to 44' carbonate is very prominent and the country rock is pyritized, the maximum pyrite grain width is .5 cm.
44	Syenitic dyke material.
50 - 67	Heavily carbonatized qtz. fuchsite. Very prominent veining.
67 - 70	Syenitic dyke.

---

Section II occurs 70 to 155' east along the face from the west end of the outcrop. The foliation is extremely well developed and in points is nearly parallel to the outcrop face. The weathered

upper surface of section II alternated between rougher, more easily weathered "units" (1 to 2 feet) and more massive "units" of the same thickness. These textures were not evident on the cut face.

There are no sharp contacts within section II itself. Any changes on the rock are gradational. Syenitic dyke material is absent.

At approximately 140', section II is cut by an apparently highly siliceous vein (6 inches in diameter).

---

Distance from western edge of outcrop (feet)	Rock Description
70 - 81	Well foliated chlorite schist. Minor pyritization
81 - 94	Chlorite content decreases, fuchsite content increased relative to chlorite, well foliated.
94 - 101	Very fine grained fuchsite-qtz.-carb. schist, pyritized, leucoxene present.
101 - 155	Fuchsite content slowly decreases, apparent carbonate content increases, minor pyrite and relatively abundant leucoxene is observed.

---

Tracing changes in rock type, the foliation appears to roughly parallel the "bedding".

Section III (155 to 225') resembles section I through its more massive nature. No syenitic dykes are present. The exact western boundary of section III is somewhat questionable. It is drawn at 155' due to a sudden increase in fuchsite content but could well be at the

base(?) of a coarse grained chlorite schist at 170'.

Distance from western edge of outcrop (feet)	Rock Description
155 - 170	Fuchsite Qtz.-carb. moderately veined, slightly more reddish weathering surface. Qtz.-carb. content decreases eastwards.
170 - 225	Relatively coarser grained chlorite schist, fuchsite content increases rapidly eastwards.

A fault occurs at 25' and leaves the outcrop face at the upper surface at 80'. This fault shows little movement in the plane of the face.

Just west of the section I - section II contact (60' and mid way up the face), breccia consisting of country rock fragments in dyke material occurs. The fragments are foliated and the foliation is not parallel to that of the country rock, nor is there a preferred foliation direction in the fragments (Plate 3). However, there does appear to be a preferred orientation of the long axes of the fragments. The fragments appear to be of the surrounding country rock and are fuchsite quartz carbonates with a small amount of chlorite.

Spinifex texture is found locally on the western end of the Misema River road cut south face (Plate 4), and approximately 75 feet north of the north outcrop face even with 200' (Werniuk, Field Notes, 1979). Spinifex texture is also seen frequently in the bush to the south of Highway 66 between the Misema River and the south outcrop face.



Plate 3. Breccia at edge of syenitic dyke. Note differing foliation of fragments. A ten cent piece is used for scale.



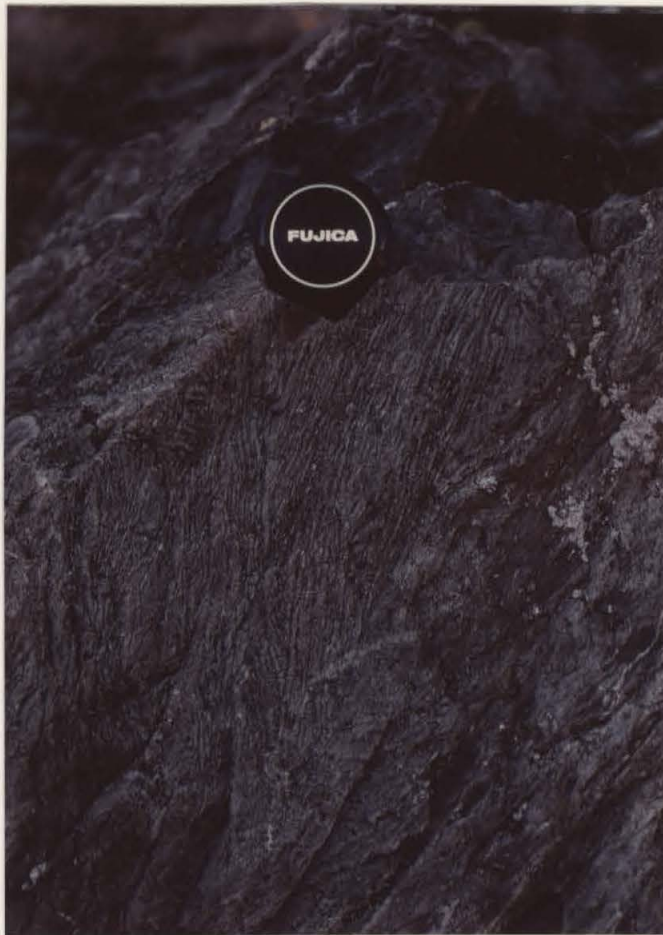


Plate 4. Spinifex texture on Misema River Road cut, south face.  
Indicative of a pyroxenitic komatiite.

## 3.2 Mineralogy and Petrography

### 3.2.1 Whole Rock X-Ray Diffraction and X-Ray Fluorescence Analysis

Sections I and III show different textures, mineralogy, and bulk composition as compared to section II. These differences were established through thin section examination, whole rock x-ray diffraction, and x-ray fluorescence analysis.

Modal percentages of minerals present in each thin section are shown in Table 1, and a break down of the carbonate mineralogy is shown in Table 2. Specific carbonate minerals were not distinguishable in thin section.

The major and trace element analyses have been averaged for each of the major sample groupings and presented in Table 3. The data take into account loss on ignition (L.O.I.), and have been normalized to 100% oxides. The results for section III were not averaged due to the large variation in chemical composition present in the samples.

As one moves eastward from the section I-section II boundary, a gradual change in composition occurs:

SiO<sub>2</sub> increases (43.79 - 50.00%)  
 Al<sub>2</sub>O<sub>3</sub> increases (9.64 - 14.08%)  
 Fe<sub>2</sub>O<sub>3</sub> decreases (11.00 - 5.06%)  
 MgO decreases (12.08 - 6.59%)  
 CaO roughly constant ( $\bar{X}$  = 5.34%)  
 TiO<sub>2</sub> roughly constant ( $\bar{X}$  = 0.57%)  
 Cr decreases (3080 ppm - 652 ppm)  
 Ni decreases (     ppm -     ppm)

Figure 7 shows marked differences in the chrome:nickel ratio for the various sample groupings.

TABLE 1

Approximate Modal Percentages (Excluding Opaques) as Estimated by Thin Section Examination

Sample No.	Section (location feet)	Rock Type (field classification)	Albite	Carbonate	Chlorite	Muscovite	Quartz	Sericite
6	I (40)	dgct		40	9	6	45	
16	I (2 1/2)	dgct		43	13	4	40	
18	I (13)	fqc	2	56	7	6	29	
19	I (26)	fqc		55	5	10	30	
21	I (42)	dgcf		45	9	6	40	
22	I (50)	hcqf		60	5	10	25	
23	I (61)	hcqf	15	15	2	4	60	4
1	I (65)	sd	41	20		1?	28	10
7	I (45)	sd	50	13		10	20	8
15	I (32)	sd	40	8		12	30	10
24	I (65)	sd	60	12		2	18	8
17	I (8)	m	30	20		8	35	6
20	I (32 1/2)	m	30	25		10	30	5
2	II (75)	cs		35	25	?	40	
26	II (84)	cs		40	30	?	30	
4	II (89)	wfqc		55	15	10	20	
27	II (88)	wfqc		53		14	30	3
28	II (115)	wfqc	2	40		10	46	2
29	II (147)	wqc	10	30		14	43	4
5	II (162)	sv	15	10		5	62	8
3	III (182)	fqc		65	3	12	20	

TABLE 1  
(continued)

sd - syenitic dyke  
m - mixed syenite and country rock  
cs - chlorite schist  
wfqc - well foliated fuchsite quartz carbonate  
wqc - well foliated quartz carbonate  
sv - siliceous vein  
dgcfc - dark green chloritic fuchsite bearing quartz  
carbonate  
hcqf - heavily carbonatized quartz fuchsite  
fqc - fuchsite quartz carbonate

TABLE 2  
Mineralogy (X-Ray Diffraction)

	Section	Albite	Calcite	Magnesite	Dolomite	Siderite	Ankerite
6	I (dgcf)			X	X	?	
16	I (dgcf)	X		X	X		?
18	I (fqc)			X	X		
19	I (fqc)			?	X		?
21	I (dgcf)	?		X	X	X	
22	I (hcqf)	?		X	X	X	?
23	I (hcqf)	X		X	X	?	
1	I (sd)	X	?	X	X		
7	I (sd)	X		X	X	X	
15	I (sd)	X	X	X	X		
24	I (sd)	X	X	X	X		
17	I (m)	X		X	X		?
20	I (m)	X	?	X	X		?
2	II (cs)	X		X	X		
26	II (cs)	X	X	?	X	?	
4	II (wfqc)	?		X	X		
27	II (wfqc)	?	X	X	X		
28	II (wfqc)	X	X	X	X		
29	II (wqc)	X	?	X	X		
5	II (sv)	X		X	X	?	
3	III (fqc)			X	?		

X - mineral present

? - small amount or questionable identification

TABLE 3  
Average Bulk Composition (XRF) of Sample Groupings

	Sections I and III			Section II	
	Country Rock (st. dev.)	Dykes	Dyke Contact	Siliceous Dyke	Chlorite Schists
SiO <sub>2</sub>	38.87 (4.37)	52.05	37.61	64.97	44.41
Al <sub>2</sub> O <sub>3</sub>	6.08 (1.75)	14.58	10.18	11.98	10.20
Fe <sub>2</sub> O <sub>3</sub>	7.24 (1.46)	5.58	9.36	3.16	10.40
MgO	17.32 (3.92)	5.29	11.05	3.86	11.30
CaO	5.27 (3.02)	3.76	6.40	2.76	5.84
Na <sub>2</sub> O	0.09 (0.25)	6.86	2.90	5.43	2.43
K <sub>2</sub> O	0.82 (0.50)	1.73	1.98	0.83	0.13
TiO <sub>2</sub>	0.26 (0.06)	0.54	0.85	0.32	0.57
MnO	0.11 (0.02)	0.10	0.20	0.05	0.15
P <sub>2</sub> O <sub>5</sub>	0.04 (0.02)	0.44	0.68	0.04	0.06
L.O.I.	23.90 (3.23)	9.07	18.79	6.60	14.52
Ni (ppm)	1384 (441)	100	249	123	399
Cr (ppm)	4248 (528)	153.5	1223	53	2991
Sr (ppm)	261 (186)	553	515	192	91
Zr (ppm)	27.5 (9.3)	248.5	142	73	40
Cu (ppm)	9.25 (3.45)	117.8	25.5	11	119
n	8	4	2	1	2

TABLE 3  
(Continued)

Sample Groupings

Sections I and III country rock: 6, 16, 18, 19, 21, 22, 23, 3

dykes: 1, 7, 15, 24

dyke contact: 17, 20

siliceous dyke: 5

chlorite schists: 2, 26

It should be noted that the presence of any vein in a sample can significantly effect the analytical results. Samples 19 and 23 are effected the most in this aspect.

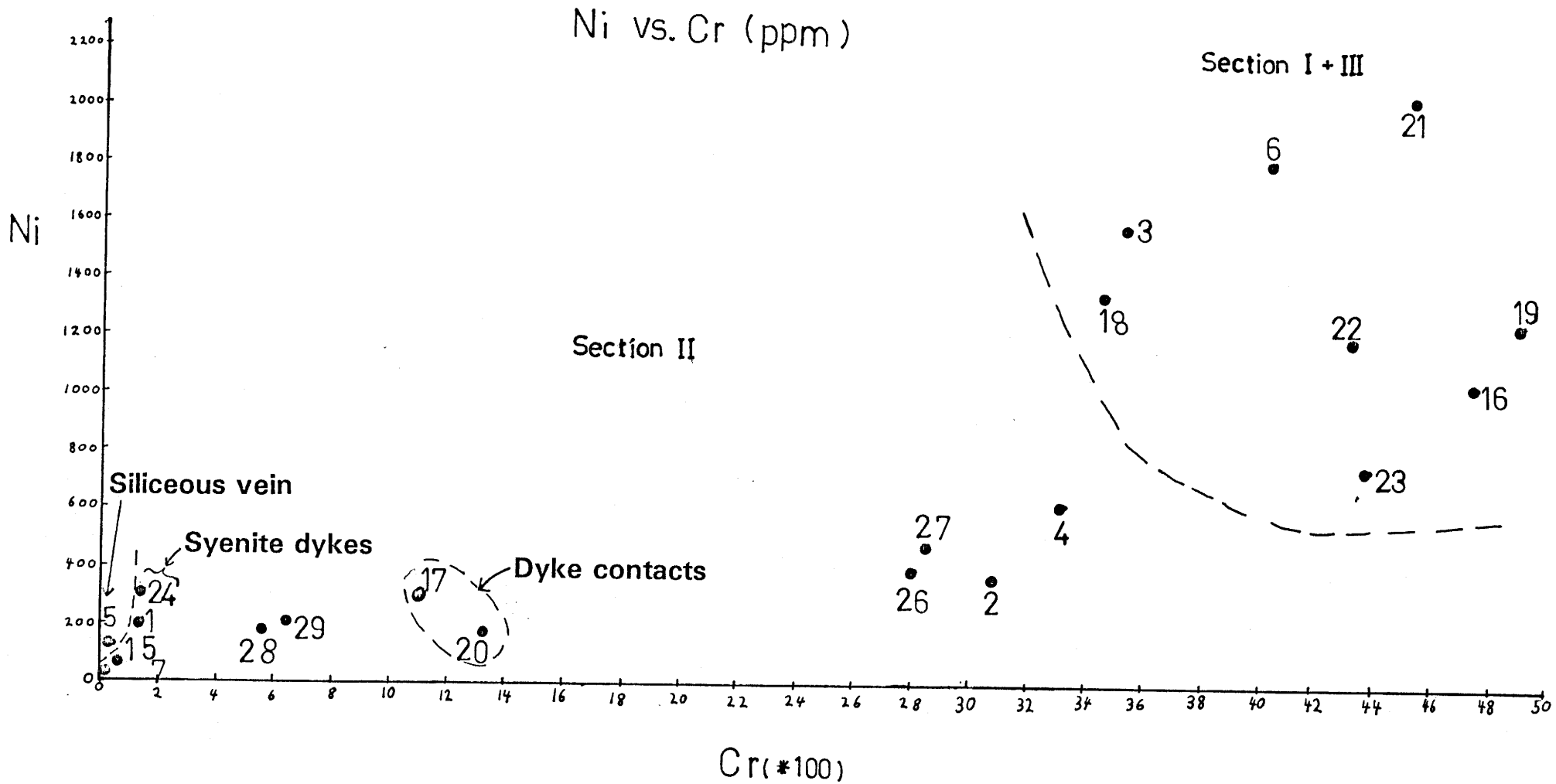


Figure 7. Nickel versus Chrome



### 3.2.2 Textural Description

#### 3.2.2.1 Sections I and III

Similar textures are observed in thin section examination of section I and section III samples (Plates 5 - 7). The samples are medium to fine grained and show a preferred orientation of the micaceous minerals. Quartz is polycrystalline, exhibits very undulose extinction, and is often found in veins.

#### 3.2.2.2 Carbonate Minerals

Carbonate minerals are found in four modes:

- 1) fine, apparently deformed grain aggregates, often oriented parallel to the foliation (Plate 15)
- 2) medium grained, anhedral to subhedral carbonates, often showing excellent twinning (Plate 7)
- 3) as in "2" but associated with quartz in veins (Plate 15)
- 4) cross cutting carbonate veins (Plate 5)

The individual carbonate minerals cannot be distinguished one from another, therefore are likely intermixed. This holds true throughout the outcrop.

#### 3.2.2.3 Syenite Dykes

Syenite dykes intrude section I (Plate 9 - 11), and are composed primarily of albite and quartz. Normally fine grained, a mortar texture is present suggesting intrusion by a partially crystallized magma. Coarse grained albite is present in small veinlets in the dykes. These albite-rich veins also cross into the surrounding

country rock. The albite often is moderately to heavily sericitized especially the larger albite grains (Plate 8). Polycrystalline quartz veins cut through the dyke material and the country rock (Plate 9).

Carbonate minerals are often twinned and show no preferred orientation with respect to the foliation of the country rock. The syenitic dykes show no apparent foliation.

A thin chill margin is observed at the dyke-country rock contact (Plate 12). It is finer grained and more heavily carbonatized.

#### 3.2.4 Section II

Although section II samples vary compositionally, a common characteristic is their intensely foliated (1 - 2 mm spacings), fine grained nature (Plate 13 - 17). The textural variety of carbonate occurrence described for section I occurs in section II.

Crenulation is seen in the samples and is indicative of multiple periods of deformation. Evidence of at least two previous deformation can be seen in the chlorite schist (disturbances in the foliation direction).

### 3.3 Opaque Mineralogy

Sections were cut such that areas with maximum opaque mineral content or interest could be polished. Modal percentages for the individual reflecting minerals would not be accurate for each sample and modal estimates were not attempted. Pyrite was by far the most abundant of any reflecting mineral. The ratio of pyrite to the total

of other reflecting minerals was about 20:1. Chromite:magnetite:chalcopyrite 2:2:1. These ratios cover the entire outcrop. Other observations on the opaque suite are summarized as follows:

pyrite: present in all samples

chalcopyrite: minor reflecting mineral in syenites

leucoxene: ubiquitous in section II, high concentration at  
dyke-country rock contact

chromite: chlorite schist

magnetite: chlorite schist

Pyrite is subhedral to euhedral in the outcrop except in section II where some is cataclastically deformed (Plate 17). Pyrite content increases near and in dykes but the grain size is not significantly increased (Plates 11 and 18). Chalcopyrite is only found in dykes in association with pyrite. High leucoxene content ( $TiO_2 = 0.54\%$ ) occurs in the syenitic dykes (Plate 19) and a very high leucoxene concentration is present at the dyke-country rock contact ( $TiO_2 = 0.85\%$ ). Fine grained aggregates of leucoxene occur throughout section II but there are no apparent mineralogical or textural associations as with section I. The long axes of the section II leucoxene appear to be preferentially oriented parallel to the foliation.

Chromite and magnetite occur only in the chlorite schist of section II. The grains are fairly euhedral (Plate 14) and the chromite is mantled by magnetite.



Plate 5. Carbonate vein cross cutting quartz-carbonate vein. (63 X)  
Sample 19, location 26'.

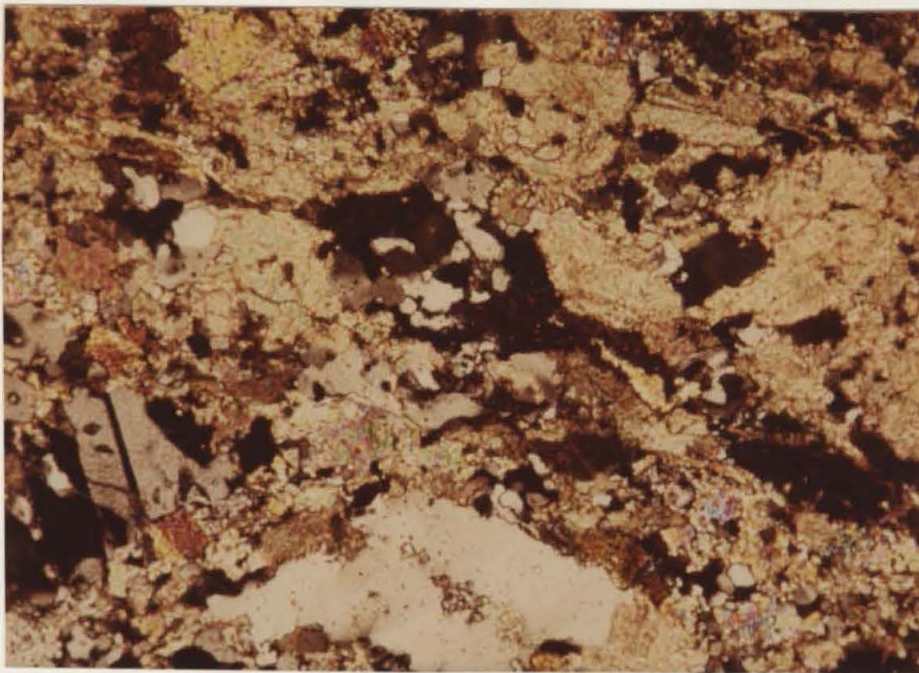


Plate 6. Fuchsitic quartz carbonate. Carbonate (yellow), quartz (white), albite (grey) (twinned), fuchsite (green, blue, red) (63 X). Sample 18, location 13'.

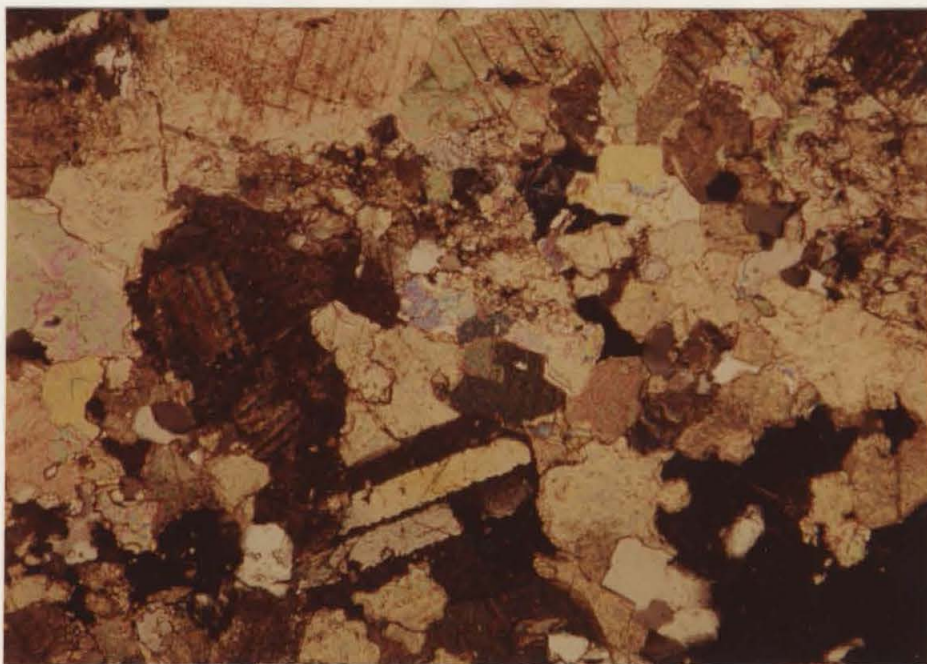


Plate 7. Fuchsitic quartz carbonate showing well twinned carbonate (yellow-greenish), quartz (white), and fuchsite (birds eye appearance, green-purple) (63 X). Sample 3, location 182'.





Plate 8. Larger albite grain at extinction. Note amount of sericitization as well as twinned nature of albite (63 X).  
Sample 23, location 61'.

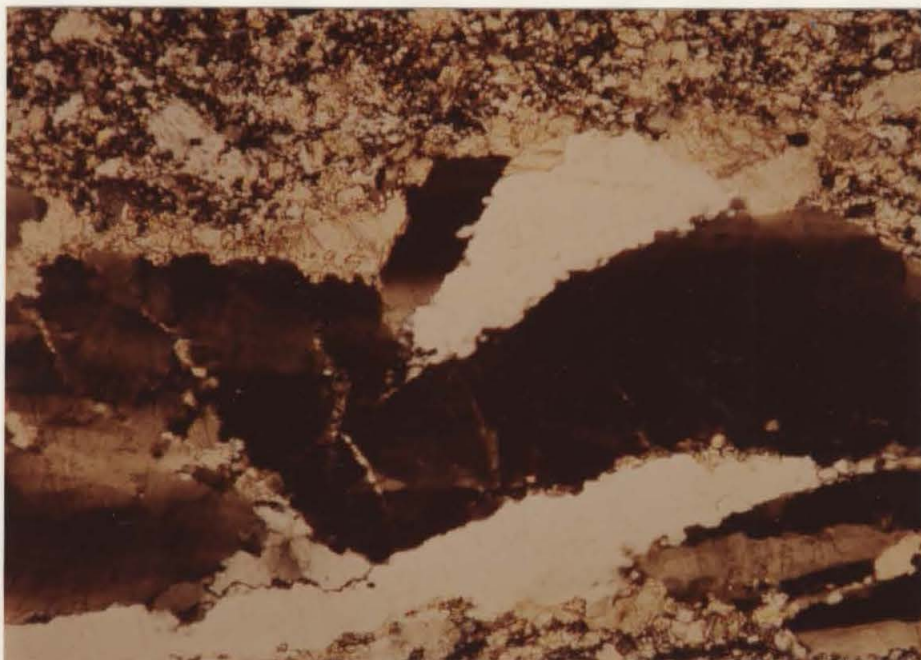


Plate 9. Polycrystalline quartz showing undulous extinction. Note carbonate vormation in vein (63 X). Sample 1, location 65'.





Plate 10. Syenitic dyke.. Note different grain sizes of albite as well as presence of carbonate and micaceous minerals (67 X).  
Sample 24, location 65'.



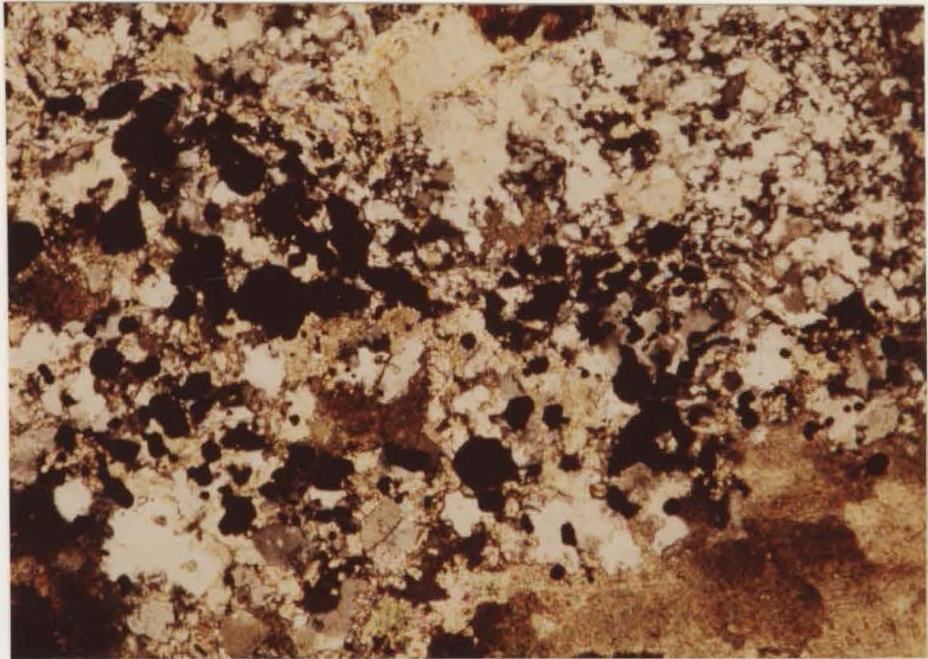


Plate 11. Syenitic dyke near country rock contact. Note extent of carbonate and pyrite development (63 X). Sample 7, location 45'.

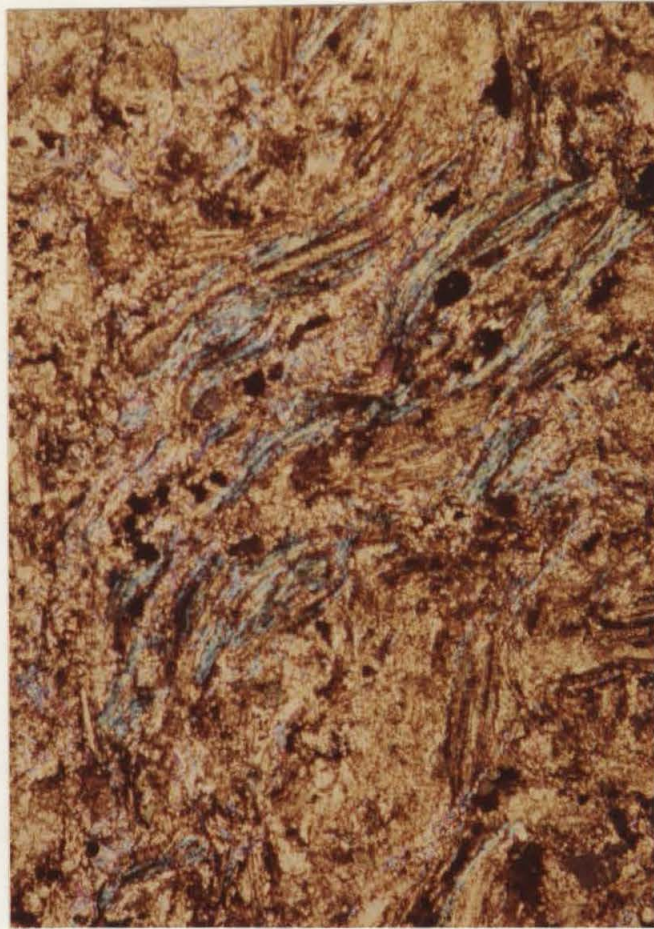


Plate 12. Chill margin at dyke-country rock contact. Note extreme carbonatization and increased fuchsite content. The indistinct opaques are leucoxene, the distinct are pyrite (63 X). Sample 20, location 32 1/2'.



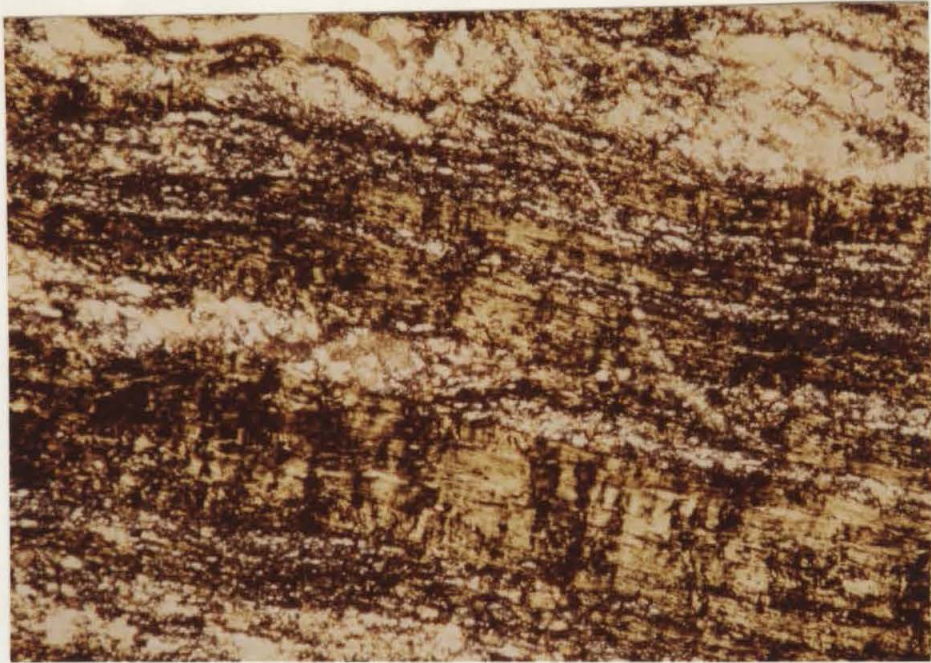


Plate 13. Chlorite schist showing intensely foliated nature (63 X).

Sample 26, location 84'.

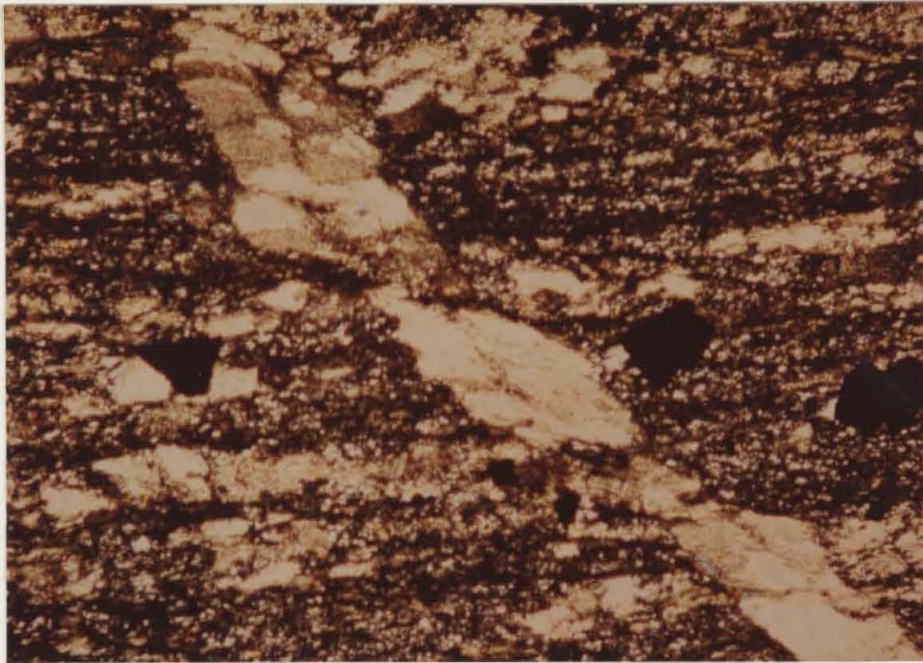


Plate 14. Chlorite schist (chlorite at extinction) showing deformed carbonate vein. Opaques are chromite mantled by magnetite.



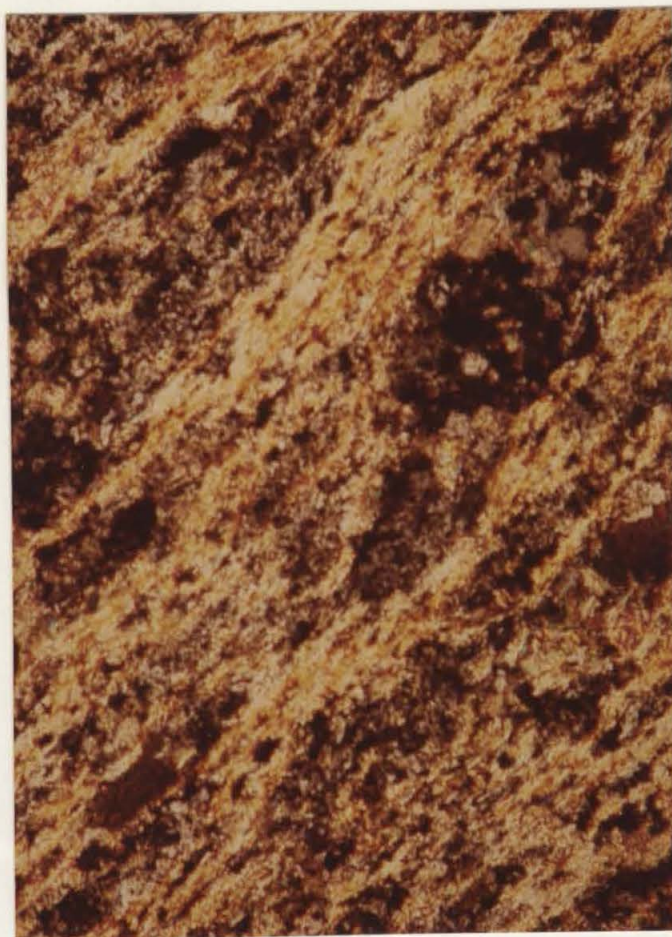


Plate 15. Well foliated quartz-carbonate showing muscovite (Cr-poor, dark yellow), carbonate (light yellow), and quartz (extinct, crystallographically preferred orientation evident) (63 X).  
Sample 29, location 147'



Plate 16. Well foliated fuchsite quartz-carbonate showing cataclastic pyrite grain in quartz-carbonate augen. Note fuchsite (green) (63 X). Sample 4, location 89'.





Plate 17. Well foliated quartz-carbonate showing carbonate vein.  
Note the different carbonate textures present and compare  
with Plate 15 (63 X). Sample 29, location 147'.

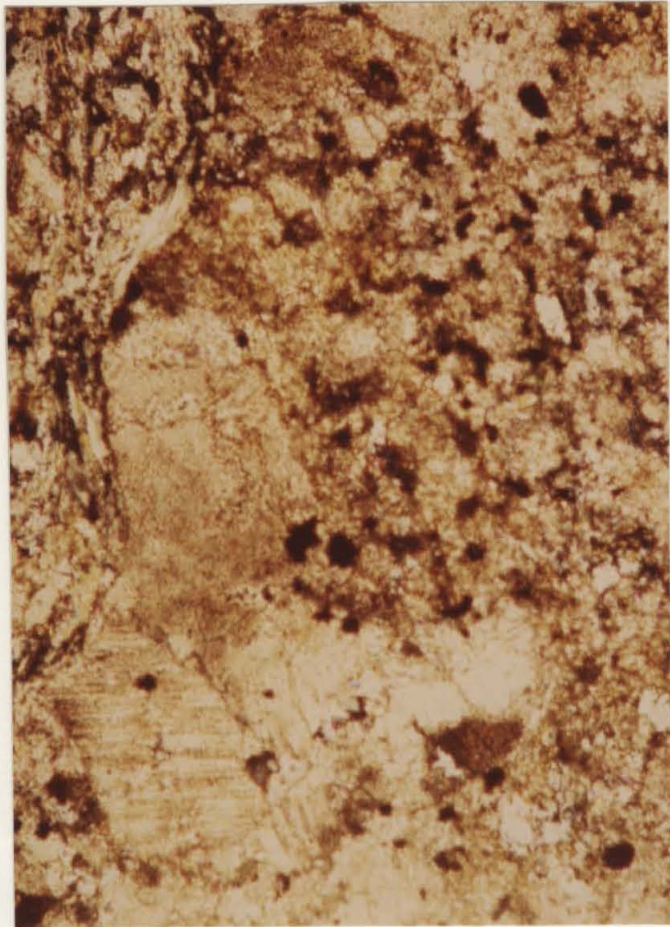


Plate 18. High pyrite content of sample 16, dark green chloritic fuchsite bearing quartz-carbonate (63 X). Location 2 1/2'.



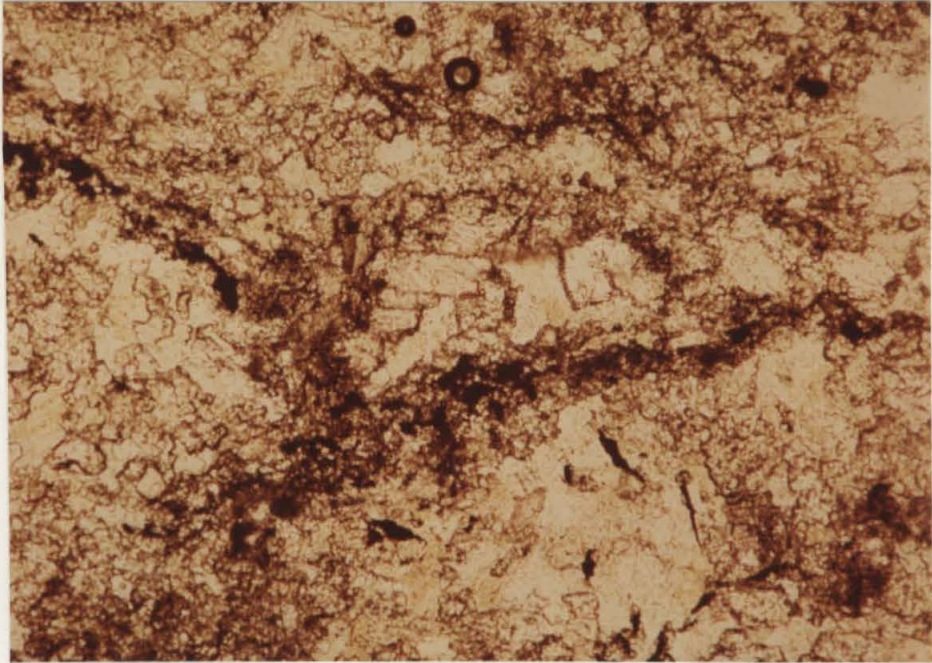


Plate 19. Leucoxene as it occurs on a syenitic dyke near the country rock contact (63 X). Sample 17, location 8'.

### 3.4 CO<sub>2</sub> and Lithium Analysis

The CO<sub>2</sub> and Li data are presented in Tables 4 and 5 respectively. Syenitic dykes recorded the lowest CO<sub>2</sub> values. Sections I and III country rock recorded the highest, whereas section II varied considerably.

Analyses of lithium contents by atomic absorption methods were carried out on ten samples by Peter Vilks. The distribution of lithium was found to be of a bimodal nature. Six samples range from 19 to 30 ppm and four samples from 1 to 5 ppm. The lithium-rich samples are either high carbonate rocks of Sections I and II or chlorite schists of Section II where as the low lithium samples are mainly syenite and siliceous dykes.

### 3.5 Gold

Gold was found to be heterogeneous in the individual samples, but sample groupings do show marked differences (Fig. 8). A peak value of 64.2 ppb Au was found at a dyke-country rock contact (sample 17). Excluding dyke sample 24, dykes average 13.7 ppb Au, and the dykes are clearly the most auriferous rocks in the suite. The fuchsite-bearing rocks of sections I and III averages 1.2 ppb Au (excluding sample 16 which showed 14.44 ppb). Section II Au content increased from the chlorite schist (75') to the sample 27 (88') area and then decreased to sample 29 (147'). Gold content seemed to rise with intensity of pyritization. For complete experimental results, see Appendix I.

TABLE 4  
CO<sub>2</sub> Content (% by wt.)

Sample	CO <sub>2</sub> (%)	Sample Grouping	Avg. CO <sub>2</sub> (%)
6	25.55		
16	19.89		
18	22.73		
19	20.28	sections I and III country rock	22.29%
21	26.61		
22	22.43		
23	18.15		
3	22.65		
-----			
1	11.45		
7	4.75	syenitic dykes	9.23%
15	9.53		
24	11.17		
-----			
2	10.44	chlorite schist	11.81%
26	13.17		
-----			
4	20.22		
27	23.18	section II, excluding chlor- ite schist	17.84%
28	15.24		
29	12.70		
-----			
5	7.08	siliceous dyke	7.08%
-----			
17	19.84	dyke-country rock contact	19.76%
20	19.68		

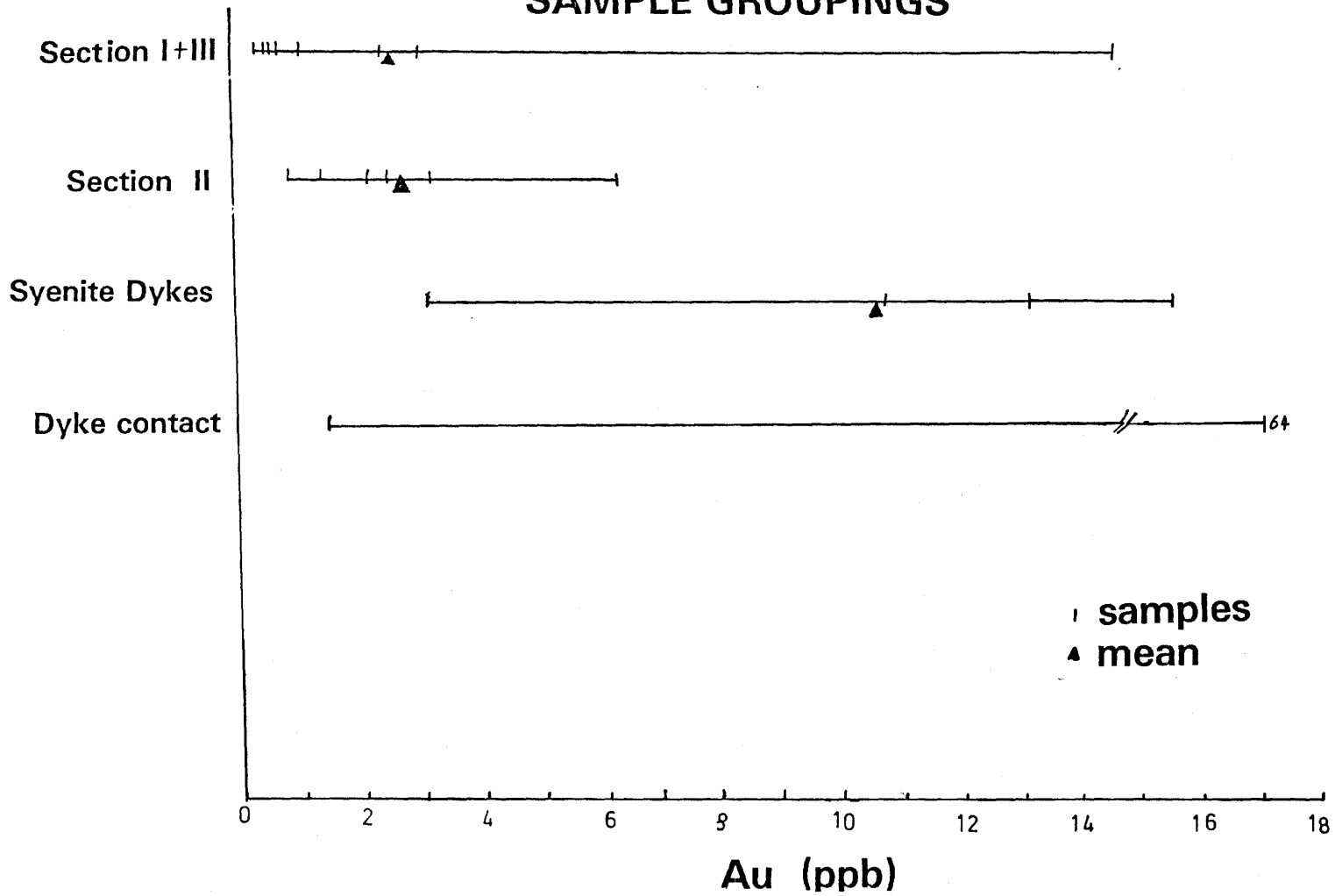
TABLE 5  
Lithium Content of Ten Samples

---

Sample	Li Content (ppm)
2	$24 \pm 0.5$
3	$26 \pm 0.5$
5	$1 \pm 0.2$
15	$5 \pm 0.2$
16	$19 \pm 0.5$
18	$30 \pm 0.5$
22	$24 \pm 0.5$
24	$1 \pm 0.2$
26	$26 \pm 0.2$
28	$3 \pm 0.2$

---

Figure 8. **DISTRIBUTION OF GOLD IN THE DIFFERENT SAMPLE GROUPINGS**



## CHAPTER 4

### Discussion and Interpretation

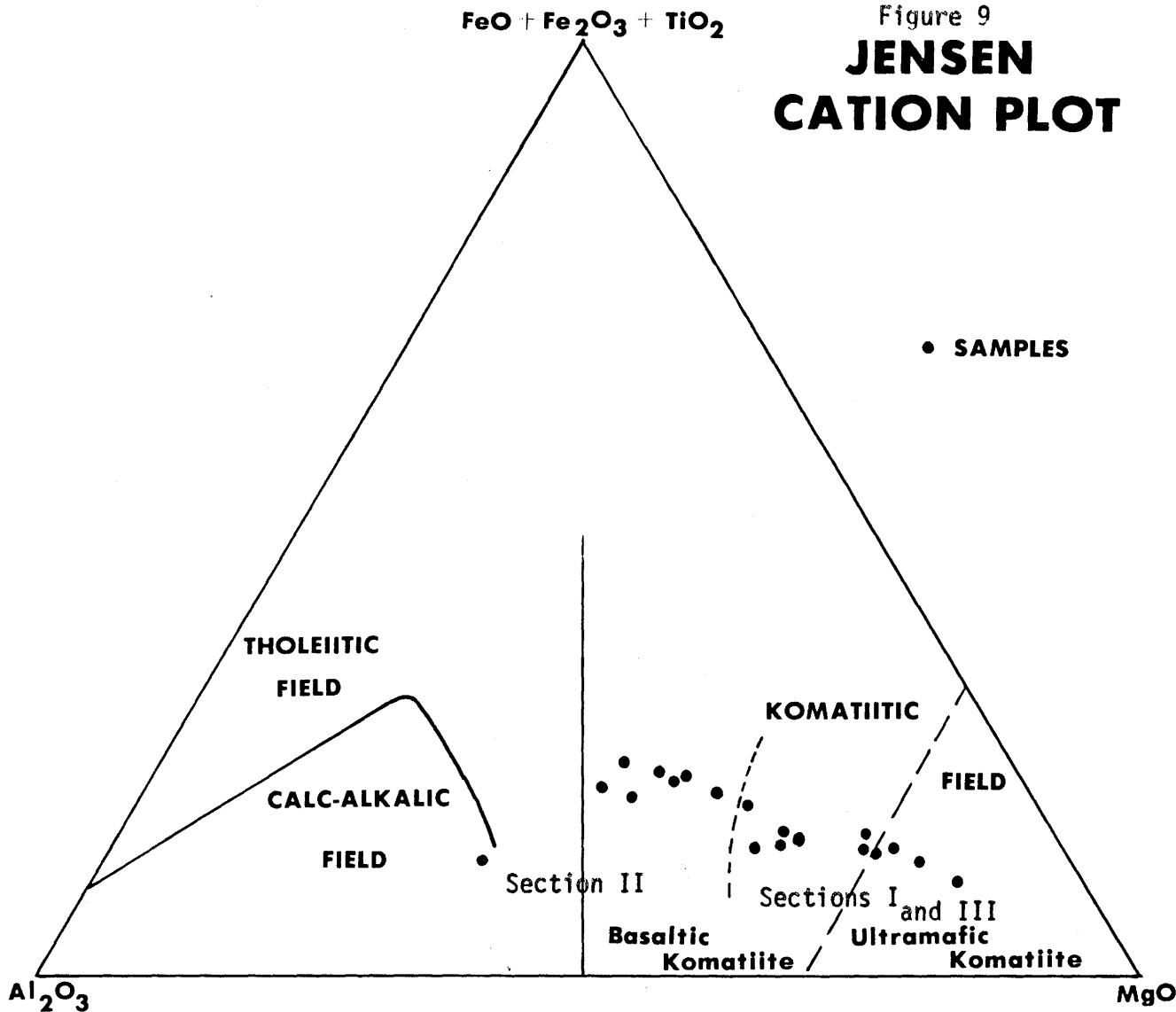
#### 4.1 Inferred Primary Lithologies

A Jensen cation plot (Jensen, 1976) may be used to indicate possible protoliths (Tihor, 1977). After plotting the samples (Figure 9), a distinct separation of sections I and III from section II is apparent.

All section I and III samples fall in the "Komatiitic Field", and most are in or very close to the ultramafic komatiite region. Some of the more altered samples plot well within the basaltic komatiite region possibly due to the extent of alteration or veining present. Section II samples plot in the middle and left side of the basaltic komatiite region, and one sample (29) plots in the calc-alkalic field. All dyke and siliceous vein samples plot in calc-alkalic field. The contact samples plot in the basaltic komatiite region (halfway between the calc-alkalic field and the ultramafic komatiite region) as would be expected from their bimodal compositions.

Section I rocks are massive, even though they are close to a major fault. Their chemical composition is consistent with ultramafic komatiites. No sedimentary textures are found in section I rocks, but spinifex texture occurs locally in the more massive rocks. Therefore section I is interpreted as a komatiitic flow. It should be noted that

Figure 9  
**JENSEN  
CATION PLOT**



no volcanic textures were found in the section I country rock probably because of the extent of deformation of the outcrop.

Section II chemistry shows some ultramafic signatures (MgO, Cr, and Ni contents are high) but it has a "contaminated" nature. It is exceedingly fine grained and the foliation is intense. The upper surface of the outcrop shows alternating rubbly and slightly more massive weathering surface. Section II is interpreted as a polymodal sediment. One would expect a sediment to become foliated more easily than a flow during deformation.

The chlorite schist likely represents a metamorphosed sediment containing a relatively unaltered komatiitic component. High chrome content is distinctive of an ultramafic source. The occurrence of chromite in the sediment is indicative of a highly proximal source.

The sedimentary rock becomes fuchsite-bearing at 85 feet. This may represent progressive alteration of the komatiitic source. The fuchsite is a primary detrital constituent of section II, specifically samples 4 and 27. It is unlikely fuchsite is of a secondary or epigenetic nature for the following reasons:

- 1) Small grain size -- very small grains are not thermodynamically stable, larger grains would have formed secondarily;
- 2) There is no visible source of potassium metasomatism -- there are no syenitic dykes or siliceous veins in samples 4 and 27 area;
- 3) A lack of fluid access structures;
- 4) Totally pervasive fuchsite occurrence -- suggests lack of focussed source.



Also the Cr content of samples 2, 26 (chlorite schists), 4 and 27 (well foliated fuchsite bearing quartz carbonate) are all high but the Cr in 2 and 26 is found as chromite, whereas 4 and 27 have muscovite as the Cr sink.

Samples 28 and 29 show a higher calc-alkalic component of an unknown source content. Therefore section II must be thought of as "polymodal".

Section III resembles section I chemically and texturally. Chemically, the distinctive high Cr, Ni and MgO contents of ultramafic rock characterize section III samples, and texturally section III is fairly massive. However, since parts of III are intensely foliated, the presence of some thin interflow sediments cannot be ruled out.

From variations in Cr content and mode of occurrence in section II with respect to the ultramafic komatiite flows of section I, the stratigraphic top of the sequence is deemed to be towards the east along the outcrop face (nearly south with respect to the local apparent strike).

#### 4.2 Model of Origin

The following is a possible model of origin for the rocks of the Misema River outcrop (1 is the first event and 8 the last):

- 1) Extrusion of komatiitic flows, some crystallizing with the development of spinifex texture

- 2) Alteration and initial carbonatization of flows. The high lithium contents (Beus, 1964) suggest Archean sea water is assumed to

carry a Li content similar to modern sea water. Seawater would most likely supply the  $\text{CO}_2$ . Initial alteration of the flows must take place at this time to explain why the overlying chlorite schist is not heavily altered.

3) Continued carbonatization of flows and deposition of sediments followed by extrusion and deposition of section III flows and sediments(?). Carbonatization had to occur in both the flows and sediments prior to deformation in order to account for carbonates showing deformational textures indicative of all stress field orientations.

4) Deformation. Crenulation is present and indicative of at least three stress field orientations. The intense foliation is imparted to the rocks. It is felt that near the end of this deformation, major faulting occurred in the area creating the Larder Lake break and the Misema River fault.

5) Intrusion of the syenitic dykes. The syenitic dykes are possibly related to the intrusion of the McElroy and associated syenite and gabbro plutons immediately to the south of the outcrop location. They must have been intruded after deformation (Stage 4) due to the presence of breccia fragments which have foliation orientations not parallel to that of the country rock or each other. Also, carbonates associated with the dykes are not deformed.

6) Secondary carbonatization. An episode of secondary carbonatization is suggested by cross cutting carbonate veins and non-deformed carbonate occurrences, and from changes in alteration

intensity approaching a syenitic dyke as well as high concentrations of elements at the dyke-country rock contact. The secondary carbonatization event is attributed to a hydrothermal system set up by the intrusion of the syenitic dykes.

7) Minor faulting. A minor fault cuts some of section I and a little bit of section II. Very little motion ( $\approx 3'$ ) is thought to have occurred.

8) Weathering and erosion to today's form.

#### 4.3 Carbonates

A long unanswered question is whether the LLB is heavily foliated because it is carbonatized, or whether it is carbonatized because it is heavily foliated? It is possible that a combination of both factors is involved. Initial carbonatization or sea water alteration could produce a plane of weakness and be more easily faulted. This fault, now the LLB, would then aid fluid circulation during secondary carbonatization.

Calcite is found only in those rocks thought to be sediments, whereas siderite and ankerite occur only in the flows. This is possibly due to the mechanism of weathering of the source region. The weathering of siderite breaks the Fe-CO<sub>3</sub> bonds. The CO<sub>3</sub><sup>2-</sup> would be carried in solution. With increased Ca content of the sediment, due to the calc-alkalic component, it is feasible that calcite could form.

#### 4.4 Gold Mineralization

Excluding the syenite dykes, the gold contents of section I rock are low, averaging slightly over 1 ppb, except for sample 16 (2 1/2') which shows 14 ppb. Sample 16 is closest to the Misema River fault which is on the river adjacent to the sample location. This fault may have channeled circulation of fluid leading to Au concentration.

Section II gold contents are slightly higher than the flow rocks, though still low at 1 to 6 ppb.

Generally, the gold contents are not significantly different from those of unaltered komatiitic rock (MacRae and Crocket, 1979). Therefore, the gold is unlikely to originate from the komatiitic component of the outcrop. The calc-alkalic component of the sediments is also discounted due to the low gold contents of samples 28 and 29.

All syenite dyke samples except number 24 contain more than 10 ppb gold. These samples are only slightly carbonatized and therefore the gold is thought to be primary to the syenite dykes.

Upon intrusion of the dykes a hydrothermal system was probably created. Fluids circulating through the dyke material would become increasingly briney and could 'pick up' elements such as Au, Zn, P, and Ti, and form complexes. The stability of these complexes is highly dependent upon the Eh-pH conditions. As convection brings the Au bearing fluid out of the dyke, stability is lost due to interaction with ground water (or waters out of equilibrium with the brine), and minerals would be deposited at or near the dyke margins.

This would explain the high content of many elements at these locations.

No phosphorous-rich mineral was found at the dyke margins and therefore the phosphorous likely entered the carbonate structure creating a type of Francolite (Deer, Howie and Zussman, 1977).

Pyke (1975) indicates a strong spatial relationship between Au deposits and ultramafic volcanics in the Timmins area, and that they are a possible gold source. The spatial relationship is recognized but the idea of the gold originating from the komatiites is not supported. Komatiitic flows, by their chemical nature, appear strongly reactive in carbonatizing environments, and thereby provide suitable points of concentration for Au from an 'outside' (i.e., epigenetic) source.

## CHAPTER 5

### Conclusions

The north face of the Misema River road cut, although problematical, can be divided into sections or domains which are of volcanic or sedimentary origin. It is argued (Chapter 4) that the stratigraphic top is to the east (along the outcrop face), so that the basal rocks in the outcrop are the komatiitic flows of section I. These are overlain by chlorite schists (section II) which carry a relatively pure komatiitic component. The sediment was derived in part from an increasingly altered komatiitic flow source regions, and is polymodal with the komatiitic component decreasing relative to a calc-alkalic component. Section II is overlain by komatiitic flows and possibly thin interflow sediments. The area was then subjected to deformation which induced foliation. The Larder Lake Break could have formed at this time. The rock was then intruded by syenitic dykes, possibly contemporaneous with intrusion of the McElroy and associated syenite and gabbro plutons immediately to the south.

At least two periods of carbonate alteration took place; one accompanying the extrusion of komatiites and the other associated with the intrusion of the syenitic cykes.

The gold content of the komatiites and associated interflow

sediments is generally low ( 1 - 4 ppb). The syenite dykes average 10.6 ppb Au. A number of elements are concentrated at or near the dyke-country rock contact. A peak gold content of 64.2 ppb is recorded at a contact. The high gold contents clearly originated from the syenite dykes. The dykes also provide a heat source for the second period of carbonatization.

## APPENDIX I

### Experimental Results



CO<sub>2</sub> Content and Normalized Composition, Including Loss on Ignition

Sample No.	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	TiO <sub>2</sub>	MnO	P <sub>2</sub> O <sub>5</sub>	L.O.I.	CO <sub>2</sub>	
6	38.14	3.38	5.93	20.84	4.59	0.00	0.11	0.13	0.07	0.01	26.79	25.55	
16	38.64	8.82	9.66	15.27	5.52	0.70	1.36	0.34	0.11	0.02	19.54	19.89	
18	36.34	7.97	8.07	17.27	3.31	0.00	1.53	0.31	0.11	0.04	25.05	22.73	
19	40.23	6.73	5.30	11.65	11.87	0.00	1.19	0.25	0.14	0.05	22.59	20.28	section
21	33.97	4.59	7.07	21.18	3.90	0.00	0.42	0.27	0.14	0.07	28.39	26.61	I and
22	36.77	5.99	8.04	19.80	3.57	0.00	0.60	0.30	0.11	0.04	24.78	22.43	III
23	48.17	5.86	5.90	12.04	6.97	0.00	0.89	0.22	0.09	0.05	19.30	18.15	
3	38.23	5.33	7.92	20.51	2.42	0.00	0.48	0.25	0.09	0.02	24.75	22.65	
1	51.60	12.71	5.12	6.49	4.75	6.99	1.03	0.52	0.08	0.53	10.17	11.45	
7	55.28	18.57	5.42	2.82	1.81	6.43	2.97	0.56	0.12	0.37	5.65	4.75	syenite
15	50.45	13.89	6.02	5.30	4.62	6.50	1.89	0.57	0.11	0.36	10.29	9.79	dyke
24	50.85	13.13	5.76	6.53	3.87	7.52	1.04	0.52	0.10	0.51	10.18	11.30	
17	38.08	9.66	10.09	11.33	6.19	2.33	2.09	0.88	0.20	0.63	18.51	19.84	dyke
20	37.14	10.70	8.66	10.77	6.61	3.46	1.86	0.81	0.20	0.72	19.07	19.68	contact
2	45.04	10.76	11.00	10.52	6.03	3.09	0.13	0.60	0.14	0.05	12.65	10.44	
26	43.79	9.64	9.80	12.08	5.65	1.78	0.13	0.54	0.16	0.06	16.38	13.17	
4	39.72	8.95	9.85	11.70	5.34	0.00	2.85	0.53	0.14	0.05	20.88	20.22	section
27	35.44	8.95	9.68	13.18	5.24	0.00	2.97	0.53	0.15	0.05	23.82	23.18	II
28	50.47	9.22	7.43	8.04	5.36	0.69	2.27	0.65	0.12	0.06	15.70	15.24	
29	50.00	14.08	5.06	6.59	4.39	3.52	2.21	0.58	0.07	0.03	13.46	12.70	
5	64.97	11.98	3.16	3.86	2.76	5.43	0.83	0.32	0.05	0.04	6.60	7.08	siliceous vein

## Trace Element Analysis (ppm)

Sample No.	Ni	Cr	Co	Pb	Cu	Zn	As	Rb	Sr	Y	Zr	Nb
6	1813.9	4040	93	8	11	46	35	2	176	7	11	0
16	1051.7	4756	78	14	7	98	12	26	448	11	33	0
18	1348.8	3470	102	15	16	55	1	43	121	9	21	0
19	1264.1	4911	48	14	8	77	3	37	520	13	27	0
21	2030.9	4535	93	11	7	68	24	11	146	13	41	0
22	1201.3	4355	90	15	6	55	14	20	133	13	25	0
23	764.2	4395	33	18	7	60	45	15	479	13	39	0
3	1582.2	3544	113	12	12	46	0	14	67	7	18	0
1	148.4	202	17	12	192	36	7	14	427	25	246	2
7	26.4	33	17	17	42	50	8	66	640	39	239	23
15	73.4	61	18	18	131	46	3	28	749	41	260	28
24	151.4	318	23	14	106	44	12	17	396	28	249	12
17	316.9	1120	52	13	8	168	6	42	396	30	112	15
20	181.9	1326	48	17	43	118	11	47	634	28	172	11
2	389.0	3080	70	9	143	72	1	3	91	18	42	0
26	409.2	2811	66	13	94	72	8	2	91	16	37	1
4	635.2	3329	70	9	63	68	0	69	102	17	36	0
27	498.6	2857	76	12	60	61	0	81	119	19	36	0
28	187.6	567	45	17	23	59	13	57	188	21	65	0
29	214.4	652	31	15	8	38	8	64	187	14	62	0
5	122.5	53	11	1	11	31	1	21	192	9	73	0

## Cation Molar Proportions -- as plotted on Jensen Cation Plot

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Sample Number	Al	Mg	Fe + Ti
6	10.06	78.51	11.43
16	25.63	56.20	18.16
18	22.74	62.33	14.93
19	26.96	59.07	13.98
21	12.74	74.43	12.83
22	16.53	69.10	14.37
23	23.52	61.11	15.36
3	14.63	71.29	14.08
1	52.41	33.86	13.73
7	72.29	13.90	13.81
15	56.62	27.37	16.02
24	52.22	32.87	14.91
2	34.49	42.67	22.84
26	30.77	48.86	20.36
4	29.70	49.09	21.21
27	28.02	52.57	19.72
28	38.03	42.02	19.95
29	54.76	32.45	12.79
5	63.33	25.83	10.84
17	31.56	46.87	21.56
20	35.65	45.45	18.90

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## APPENDIX II

### Radiochemical Neutron Activation Procedure

### Radiochemical Neutron Activation Analysis Procedure

A total of three experiments were carried out in December of 1979 using the McMaster University Nuclear Reactor and Laboratory facilities. Each run of the experiment irradiated 10 unknowns and three standards.

#### Preparation of Standards and Unknowns

Standards. Standards were prepared by evaporating a known weight of gold chloride solution into silica powder. A standard solution was prepared from high purity Au metal dissolved in aqua regia and converted to a HCl solution. This was then diluted to a solution of known concentration (run #1, #3, and part of run #2 = 9.8624 mg Au/ml; the remainder of run #2 = 10.9088 mg Au/ml).

An aliquot was weighed into a silica ampule. Crushed silica glass was added to give approximately the same volume of material as in the sample capsule. The solution was evaporated to dryness at approximately 70°C and sealed.

Samples. Known quantities of sample powder were weighed into silica ampules and sealed. All ampules were cleaned previous to irradiation.

Irradiation. The three runs were irradiated in the McMaster Nuclear reactor for 24 megawatt hours (nominal flux = 2 megawatts/hr).

The samples were cooled approximately two days.

Treatment of Standards. Procedure must be followed for each standard ampoule. Steps 1 to 4 are required to dilute possible active gold contamination on ampoule surface with non-active gold.

- 1) Add two drops of Au carrier in a small (25 ml) beaker.
- 2) Add 10 ml aqua regia, and place unopened ampoule in the aqua regia.
- 3) Warm for about five minutes at low temperature.
- 4) Remove standard ampoule and clean.
- 5) Break (carefully) the standard ampoule using "lead fingers" (small lead tubes) into a 100 ml beaker containing 2ml gold carrier ( $\approx 20$  mg Au).
- 6) Add 10 ml aqua regia, cover with watch glass, and warm for five minutes. Flush liquid from ampoule with aid of a capillary pipette.
- 7) Clean remains of the broken ampoule using a capillary pipette (throw out after use).
- 8) Evaporate until approximately 2 ml of the solution remains. Do not let it dry or material precipitate, or else return to step 7.
- 9) Add 2 ml of conc. HCl, cover with a watch glass and evaporate to incipient dryness.
- 10) Repeat step 9.
- 11) Repeat step 10.

- 12) Repeat step 9.
- 13) Add 25 ml of 2 molar HCl.
- 14) Filter into 50 ml centrifuge tube, wash filter paper and beaker with 2 molar HCl.
- 15) Precipitate Au metal through reduction by adding hydroquinone ( $C_6H_4(OH)_2$ ).

#### Preparation of the Fusion Cake for Unknowns

- 1) Add 2 gm of 10:1 of  $Na_2O_2$  - NaOH flux to a 30 ml zirconium crucible. Dry under heat lamp (over crucible).
- 2) Add irradiated powder, mix, and fuse in a Meeker burner flame (2 minutes low heat, 3 minutes full blast).
- 3) Cool 10 minutes.

#### Dissolution of the Fusion Cake

- 1) Place the zirconium crucible in a 250 ml beaker and cover with a watch glass.
- 2) Add 15 ml  $H_2O$  (2-3 ml at a time) (via eye dropper) \*\* Caution: fusion cake may react violently.
- 3) Add 15 ml conc. HCl (2-3 ml at a time) \*\* Caution: fusion cake may react violently.
- 4) 30 ml of 6 m HCl are now present in the crucible. Carefully tip crucible, emptying contents inside the beaker. Wash crucible and watch glass with 20 ml, 6 M HCl, bringing the volume of solution in the beaker to 50 ml.

5) Put on hot plate (with watch glass covering) for approximately 20 minutes or until the solution is quite yellow. Digest for one hour.

#### Solvent Extraction using Ethyle Acetate

- 1) Filter the solution into a separation funnel.
- 2) Add an equal volume of ethyl acetate (50 ml).
- 3) Shake approximately 2 minutes to separate gold into the ethyl acetate phase.
- 4) Drain off HCl phase, transfer ethyl acetate to Au phase beaker.
- 5) Add 50 ml 2M HCl, put on hot plate at low heat and evaporate the ethyl acetate phase transferring the Au to the HCl.
- 6) Transfer the solution to a centrifuge tube and add hydroquinone such that all gold is precipitated as the metal.
- 7) Centrifuge and pour off liquid, add distilled water, centrifuge, remove Au using a capillary pipette, dry, and weight the Au metal.

#### Counting Conditions

All samples were counted with a Ge (Li) detector with a resolution of 2 keV (at 663 keV), and a peak to background ratio of approximately 12:1. The detector was coupled to a Nuclear Data gamma spectrometer set at 1000 channels. The 412 keV photopeak of Au was counted for Au assay. The majority of samples were counted to a minimum of 1000 counts.



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