B.Sc. Thesis

GEOCHRONOMETRY AND CHEMISTRY OF THE CRETACEOUS CARMACKS GROUP, YUKON

by

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ABSTRACT

Volcanic rocks of the Carmacks Group cover scattered areas of the southwestern Yukon. Four stratigraphic sections in the group were measured at various locations surrounding the town of Carmacks. The sections consisted of lava flows, epiclastic breccias, sintered tuff, and immature volcanic sandstone.

Three samples collected from different sections were dated by K-Ar methods. Two whole-rock analyses yielded dates of 73.1 ± 2.5 Ma and 67.9 ± 2.3 Ma. One biotite separate yielded a K-Ar date of 68.0 ± 2.2 Ma. Dates indicate that the Carmacks Group is coeval with the adjacent Mount Nansen Group.

Lava flows and clasts in epiclastic breccias range in chemical compostion from calc-alkaline andesite to alkali basalt, trachybasalt, and tristanite. Chemistry indicates that the Mount Nansen and Carmacks suites form a calc-alkaline to alkaline gradient from volcanic front towards the craton.

69 pages

Supervisor: R.L. Armstrong

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By

Sheila Churchill

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partial fulfillment of the
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TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (cont.)

LIST OF PLATES

LIST OF PLATES (cont.)

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I INTRODUCTION

Description of Problem

The Carmacks Group is recognized throughout the southwestern Yukon, in an area bounded approximately by Whitehorse, the Tintina Fault, Dawson City, and the Shakwak Fault. (Figure 1) These volcanics were first called the Carmacks Basalts by D.D. Cairnes (1910). In 1936 H.S. Bostock renamed the volcanics the Carmacks Group. These rocks are the scattered remnants of a thick volcanic assemblage that probably once covered much of the southwestern Yukon.

No published chemical analysis or isotopic date exist for the Carmacks Group. Previous investigators have thought its age to be Eocene to Miocene (Tempelman-Kluit, 1974, 1976). This thesis will present petrologic and major element chemical data for the Carmacks Group, plus three K-Ar dates and a Rb-Sr isochron that show the Carmacks Group to be Upper Cretaceous.

Present Study

This investigation into the Carmacks Group was undertaken at the suggestion of D.J. Tempelman-Kluit of the Geological Survey of Canada. Field work was completed during the summer of 1979. The study of the Carmacks Group was concentrated in three areas; on Miller's Ridge five kilometers west of the town of Carmacks, in the Glenlyon map sheet nineteen kilometers east of Carmacks, and in the Aishihik Lake map sheet fourteen kilometers south of Carmacks (Figure 2). In each area sections were measured and samples were taken for petrographic studies, chemical analysis, K-Ar dating and pollen dating. Pollen from the immature sandstones of the Carmacks Group is being studied by

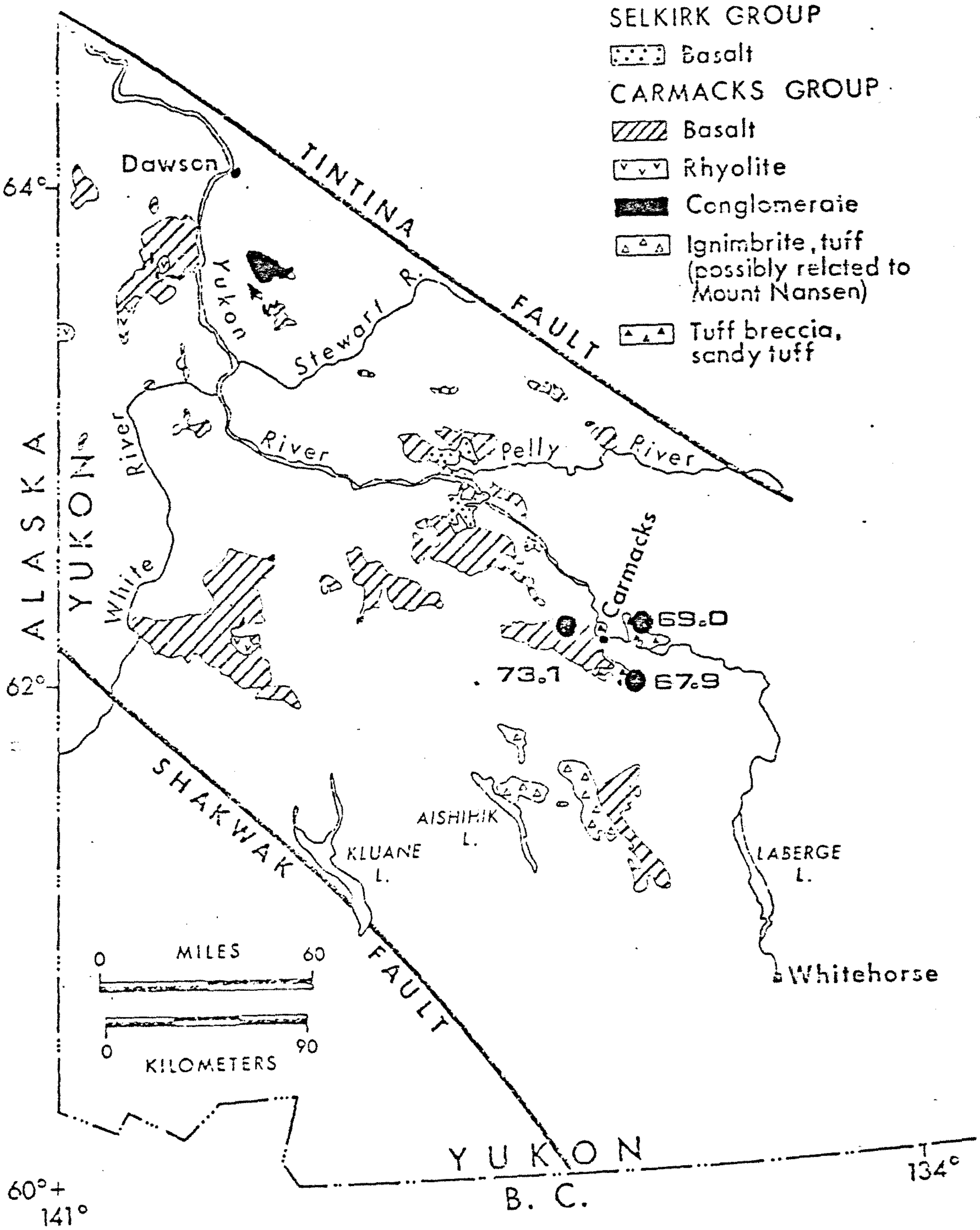


Figure 1 - Distribution of the Carmacks Group and Locations of the Three K-Ar Dated Samples.

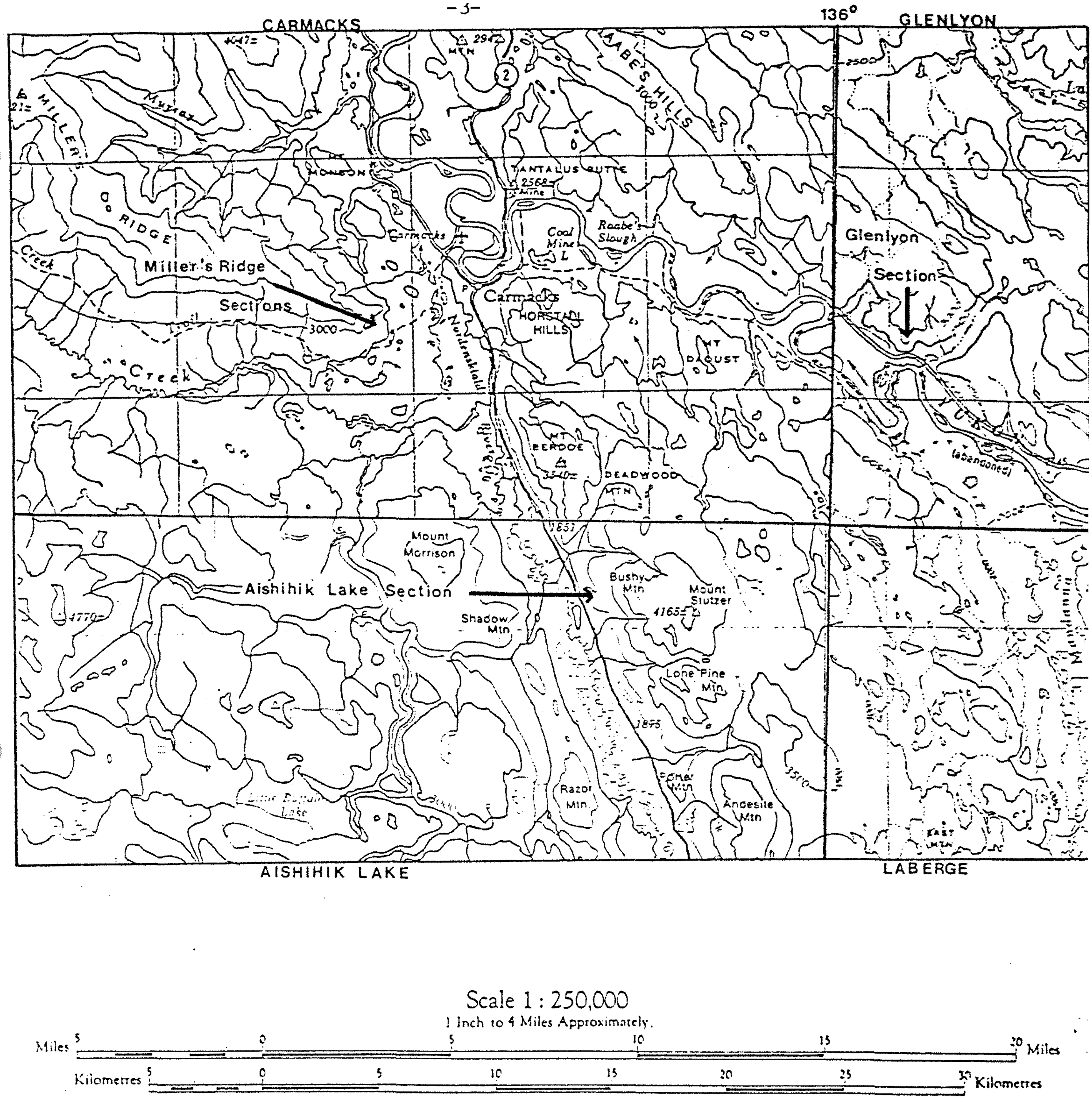


Figure 2 - Topographic map showing locations of the measured sections.

the Geological Survey of Canada.

During the fall and winter of 1979-80 selected rocks from the three areas were studied. One sample from each section was used for K-Ar dating to determine the absolute age of the rocks.

II GEOLOGY

General Geology of Area

The area in which the Carmacks Group is exposed is largely covered by the Carmacks, Glenlyon, Aishihik Lake and Laberge map sheets. These areas were first investigated by D.D. Cairnes at the beginning of the twentieth century. In 1936 H.S. Bostock published a Geological Survey of Canada Memoir on the Carmacks District. Bostock described all the formations in the area, from the metamorphic Yukon Group to the Late Tertiary Selkirk Volcanics. The table of formations which Bostock produced is still used, the only important changes being in the absolute ages of some formations. Bostock considered that the Mount Nansen Group Andesites were Late Jurassic and/or Early Cretaceous and that the Carmacks Group was Eocene or older. K-Ar dates reported here demonstrate that the Carmacks Group is Late Cretaceous, and the same age as the Mount Nansen Group (Grond, 1980).

The following depositional history and tectonic model is summarized from Bostock (1930) and from Tempelman-Kluit (1976,1979 and personal communication).

The Yukon Group is an agglomeration of several distinct groups of metamorphic rocks, with different ages of deposition and different grades and ages of metamorphism. Because of lack of continuity of units and lack of fossils, the depositional ages cannot be established, but they are probably Paleozoic and Early Mesozoic.

The Lewes River and Laberge Groups are Upper Triassic and Lower Jurassic volcanic rocks, limestone reefs, and coarse clastic rocks derived from them. They were deposited in a forearc basin northeast of the Lewes River arc.

The Tantalus Formation was deposited unconformably above the Laberge Group in the Late Jurassic or Early Cretaceous. The formation is terrestrial in origin with a probable source to the east in the Omineca Crystalline Belt.

In the Early to Middle Cretaceous the entire assemblage was metamorphosed, by folding, faulting, and intrusions. Metamorphism was followed by erosion.

In the Late Cretaceous, subduction of Pacific Ocean floor beneath the accreted Intermontane Belt led to plutonism and extrusion of the coeval Mount Nansen and Carmacks Groups.In the Aishihik Lake map area Carmacks volcanics overlie the Mount Nansen Group (Tempelman-Kluit, 1974), but broadly the two groups are coeval. The more acid Mount Nansen Group is found to the southwest of the more basic Carmacks Group. Overlap between the two groups is seen in parts of the Dawson Range (Tempelman-Kluit, 1980).

The Carmacks Group was extruded from a few widely placed centres onto a topographic surface with considerable relief. The relief on the depositional surface was up to 1500 meters. Uplift of the Yukon Plateau accompanied the extrusion (Tempelman-Kluit, 1980).

In the Pleistocene, the Selkirk Lavas were extruded onto the surface of the Yukon Plateau. During the Pleistocene parts of the areas underlain by the Carmacks Group were glaciated.

General Geology of the Carmacks Group

The Carmacks Group has been studied and described in detail by Cairnes (1910), Bostock (1936), and Tempelman-Kluit (1975,76), amoung others. The following is a brief description of the characteristics of the Carmacks Group taken from the above references.

The Carmacks Group forms a thick section of lavas, epiclastic breccias, tuff, and immature volcanic sandstones, unconformably above the Cretaceous Tantalus Formation and older rocks. They are themselves unconformably overlain by the Selkirk Lavas. The dip of the flows ranges from horizontal to 20° and the entire section is cut by northeast trending faults.

The base is marked by a thin conglomerate. Above this conglomerate are thick, massive lavas, that grade upward into interbedded vesicular lavas and epiclastic breccias.

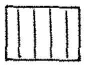
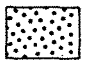
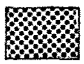
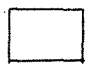
The lavas are generally andesite, but range in composition from rhyolite, trachyte, and dacite to basalt. Individual flows can be anywhere from 0.5m to 50m thick. The lava flows are extremely fresh in appearance. Flows weather brown, reddish brown, red, green or grey. Fresh surfaces are grey, blue-green, brown or black. Massive flows are coarsely jointed and in some places show irregular but distinct columnar jointing. Vesicular flows do not show regular jointing. The lava includes phenocrysts of pyroxene, biotite, plagioclase, and/or olivine in a groundmass of pyroxene, biotite, plagioclase, magnetite and devitrified glass. The plagioclase is generally andesine. Vesicular flows have the same general composition. Vesicles may be filled with carbonate, zeolites, or silica. Some flows are vesicular to the point of being pumiceous or scoriaceous.

Epiclastic breccias of the Carmacks Group are generally well indurated and form large, massive outcrops. These weather brown to red brown and are difficult to distinguish from lavas at a distance. Clasts in the epiclastic flow breccias range in size to

2m and are all volcanic. They are derived from flows of the Carmacks Group. Clasts range in composition from siliceous rhyolite to mafic basalt and from massive to vesicular. The matrix of the epiclastic breccias is fine to coarse grained tuff and volcanic sand. Sporadically between flows are deposits of immature volcanic sandstone.

TABLE 1

SYMBOLS AND ABBREVIATIONS USED IN TEXT, TABLES, AND FIGURES

	lava flow	■ sample 12-2d
	epiclastic breccia	● sample 15-1e
	sintered tuff	○ sample 14
	volcanic sandstone	△ sample 14-1h
	cover	

Ma- million years	Ol'- olivine + 3/4 orthopyroxene
mag- magnification	Ne'- nepheline + 3/5 albite
crs- coarse	Ab- albite
cong- conglomerate	Q'- quartz + 2/5 albite + 1/4 orthopyroxene
SST- sandstone	Opx- orthopyroxene
fg- fine grained	An- anorthite
m- meter	Ab'- albite + 5/3 nepheline
cm- centimeter	Or- orthoclase
mm- millimeter	A- $Na_2O + K_2O$ (weight %)
km- kilometer	F- Fe_2O_3 "
mg- medium grained	M- MgO "
SLST- siltstone	

Normative plagioclase composition = 100 An/(An + Ab')

Normative colour index = olivine + orthopyroxene + clinopyroxene + magnetite + illmenite

III GEOLOGY OF SPECIFIC SECTIONS

Terminology

Nomenclature used in section descriptions was established in the field, by literature investigations, and by thin section studies. In the field basaltic and andesitic flows were distinguished by colour and phenocryst composition. Basalts were black in colour and contained phenocrysts of pyroxene and olivine, while andesites were medium to dark grey and contained phenocrysts of plagioclase and pyroxene. Samples which underwent chemical analysis were given more specific names, after Irvine and Baragar (1971). These samples were found to be more alkaline in nature than could be discerned in the field. Epiclastic breccia was chosen as an appropriate term for the volcanic breccias in the measured sections. The coarse tuff matrix, sorting, compositional variation, and roundness of clasts indicate a moving flow containing brecciated lava, that is mixing and becoming less angular with continued movement, rather than a breccia of explosive origin. The term sintered tuff was given to a specific rock type after thin section analysis. Volcanic sandstone was used in the field to describe lenses of immature, poorly sorted, fine grained clastics, containing angular grains of probable volcanic origin.

Miller's Ridge Area

Miller's Ridge, located 5km west of the town of Carmacks, trends east-west. Its eastern end was carved by Pleistocene ice and forms a cliff approximately 1.5km long. This cliff exposes a 200m section of the Carmack Group (Plate 1). The cliff face shows that the ridge

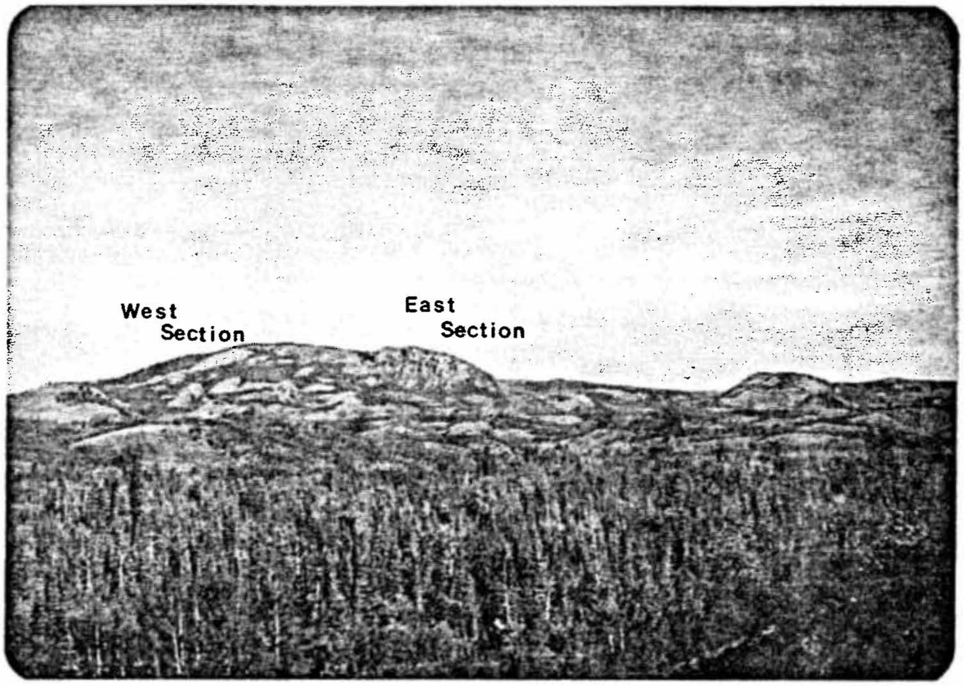


Plate 1 - Section exposed at southern end of Miller's Ridge, giving locations of Miller's Ridge East and West sections.

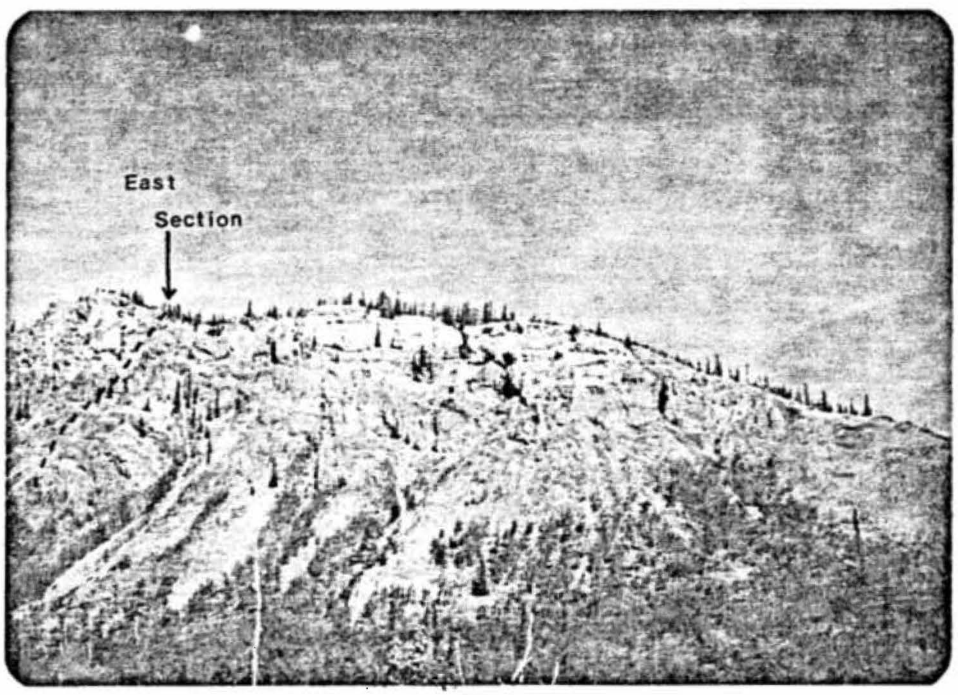


Plate 2 - Close up of location of Miller's Ridge East section.

is faulted. Because of this faulting two different sections are exposed in the cliff. The northeastern and southwestern sections were measured separately.

Miller's Ridge East

Description

The Miller's Ridge East section is summarized in Figure 3 and Appendix I. It consists of 186m of interbedded epiclastic flow breccias, lavas, sintered tuff and immature volcanic sands (Plate 2). Epiclastic breccias predominate. Clasts in the breccias are angular to rounded, and have a size range of 1cm to 1m (Plate 3). Clasts are massive to vesicular andesites and basalts. The epiclastic breccias form massive cliff-like outcrops. Contacts between the breccias, lavas, and volcanic sands are sharp, and contacts between the epiclastic breccias and the sintered tuff are gradational. The lava found in the section is vesicular, brecciated, and mixed with volcanic sand. The sintered tuff forms thick beds that are differentiated by weathering colours (Plate 4). All tuff beds have black pyroxene phenocrysts in variably devitrified glass matrix. Volcanic sandstones outcrop as laterally discontinuous lenses of fine to coarse laminated sandstone. Grains are poorly sorted and angular.

Petrography

In thin section a basalt clast from an epiclastic breccia (sample 11-1) contained phenocrysts of olivine and clinopyroxene in a groundmass of plagioclase (An_{35}). Clinopyroxene shows twinning and zoning. A thin section of the sintered tuff (sample 11-1i) consists of clinopyroxene and plagioclase phenocrysts in a very vesicular, devitrified glass matrix.

MILLER'S RIDGE EAST SECTION

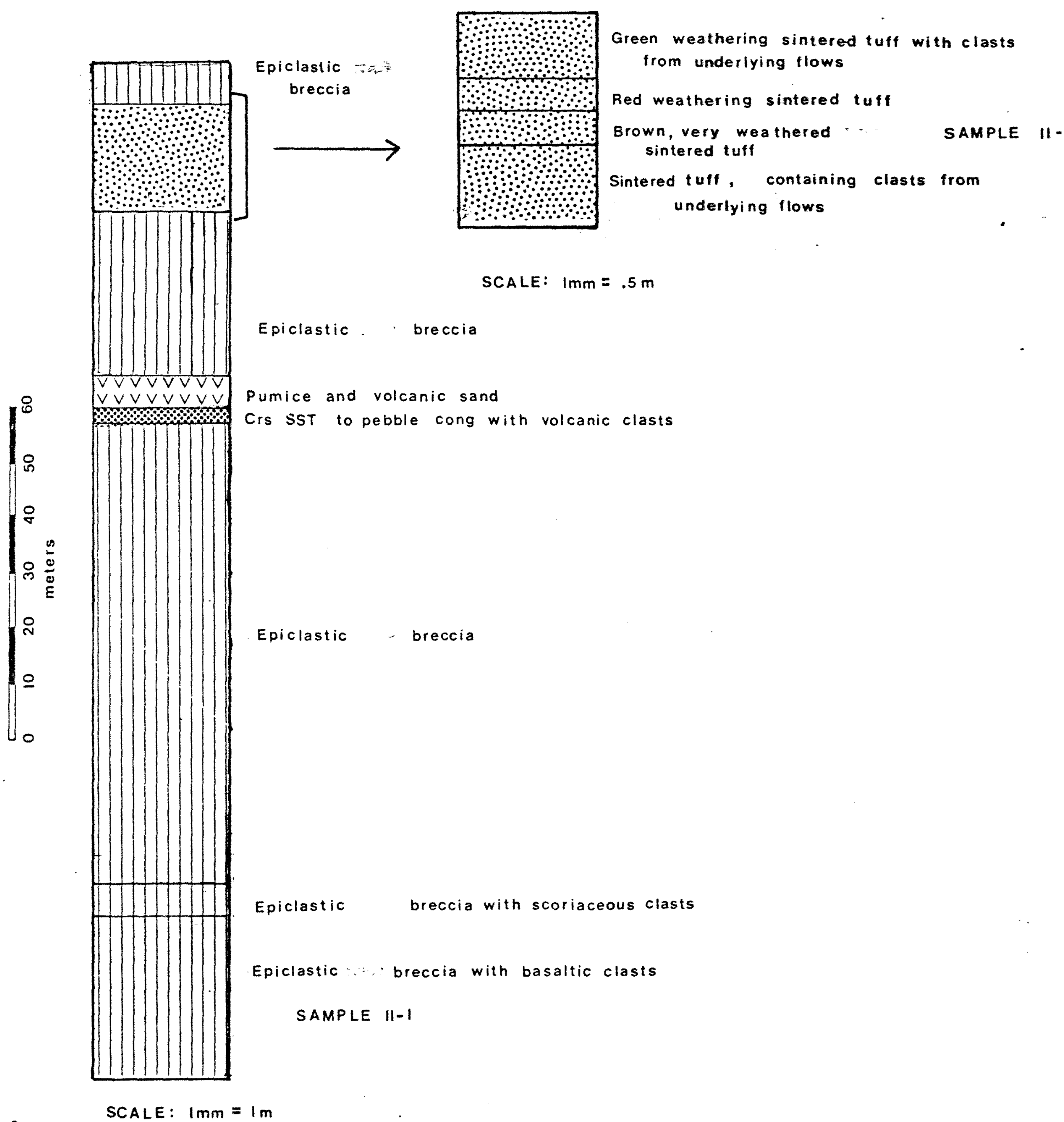


Figure 3 - Miller's Ridge East section

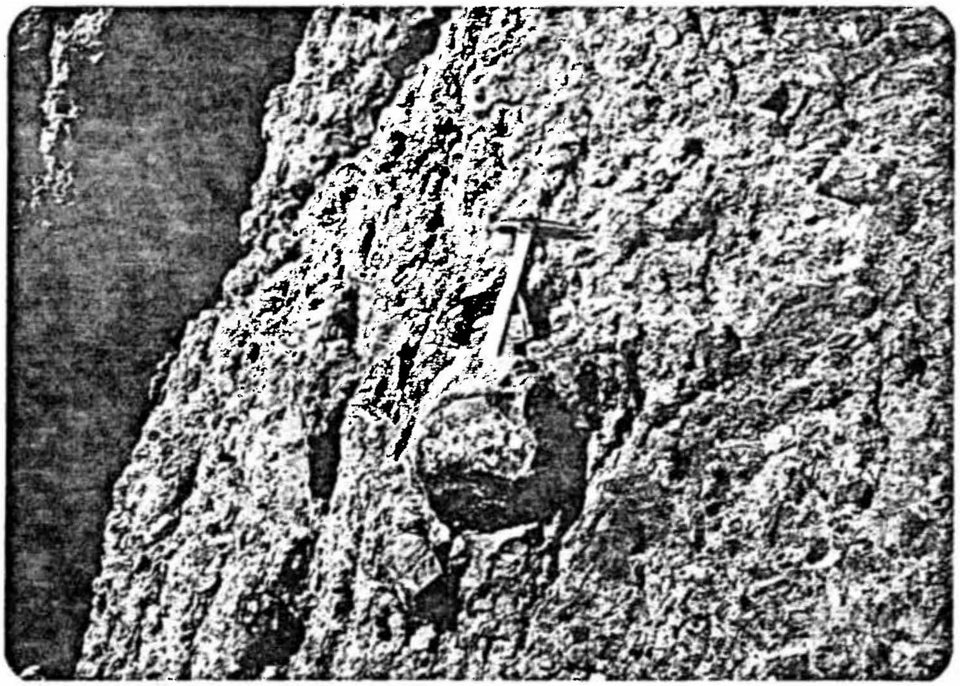


Plate 3 - Epiclastic breccia in Miller's Ridge East section, 48m above base.

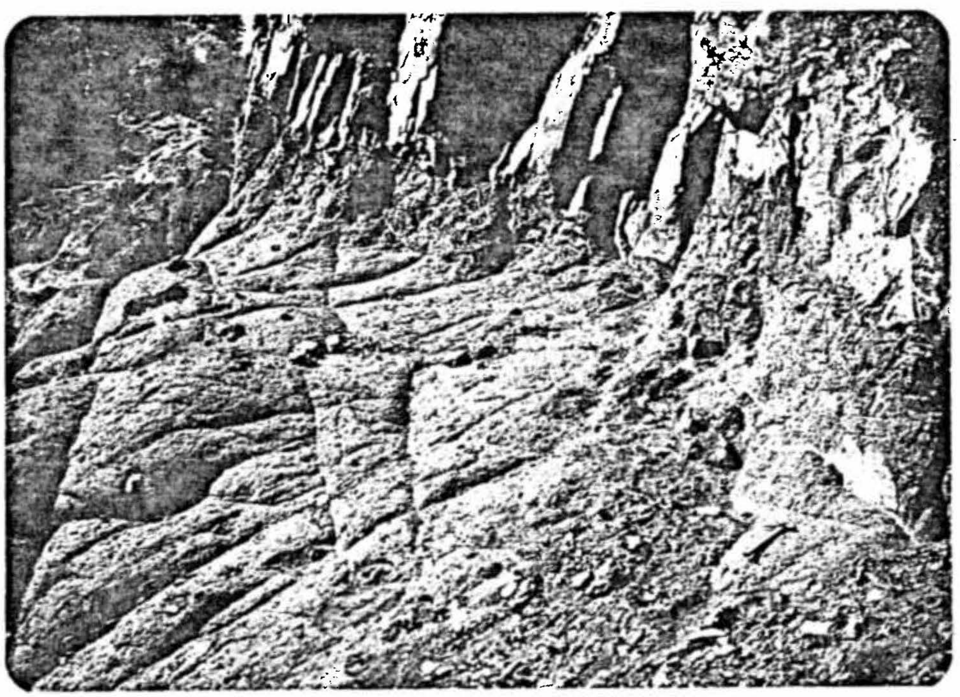


Plate 4 - Contact between two sintered tuff beds in Miller's Ridge East section, 167m above base.

Miller's Ridge West

Description

The Miller's Ridge West section is summarized in Figure 4 and Appendix I. It consists of 79.5m of interbedded epiclastic breccias, lavas, and immature volcanic sandstones. The epiclastic breccias are very similar to those found in the Miller's Ridge East section (Plate 5). They often intertongue with thin lava flows. The lava flows are andesite or basalt and are vesicular to massive. The top of the section is capped by a thick massive basalt (Plate 6), which displays crude columnar jointing.A sample of this lava flow was used for chemical analysis and isotope dating (sample 12-2d).

Petrography

A thin section of an andesitic lava (sample 12-2e) contains phenocrysts of plagioclase (An_{35}) and clinopyroxene. The clinopyroxene is partially altered to actinolite and chlorite and the plagioclase to epidote and zoisite (Plate 7). The presence of these alteration minerals indicates that the rock has undergone lower greenschist facies metamorphism. The basalt used for chemical analysis and isotope dating (sample 12-2d) was also analysed in thin section. The basalt has phenocrysts of twinned clinopyroxene and olivine partially altered to iddingsite (Plate 8), in a groundmass of plagioclase, pyroxene crystals, magnetite, and other opaques.

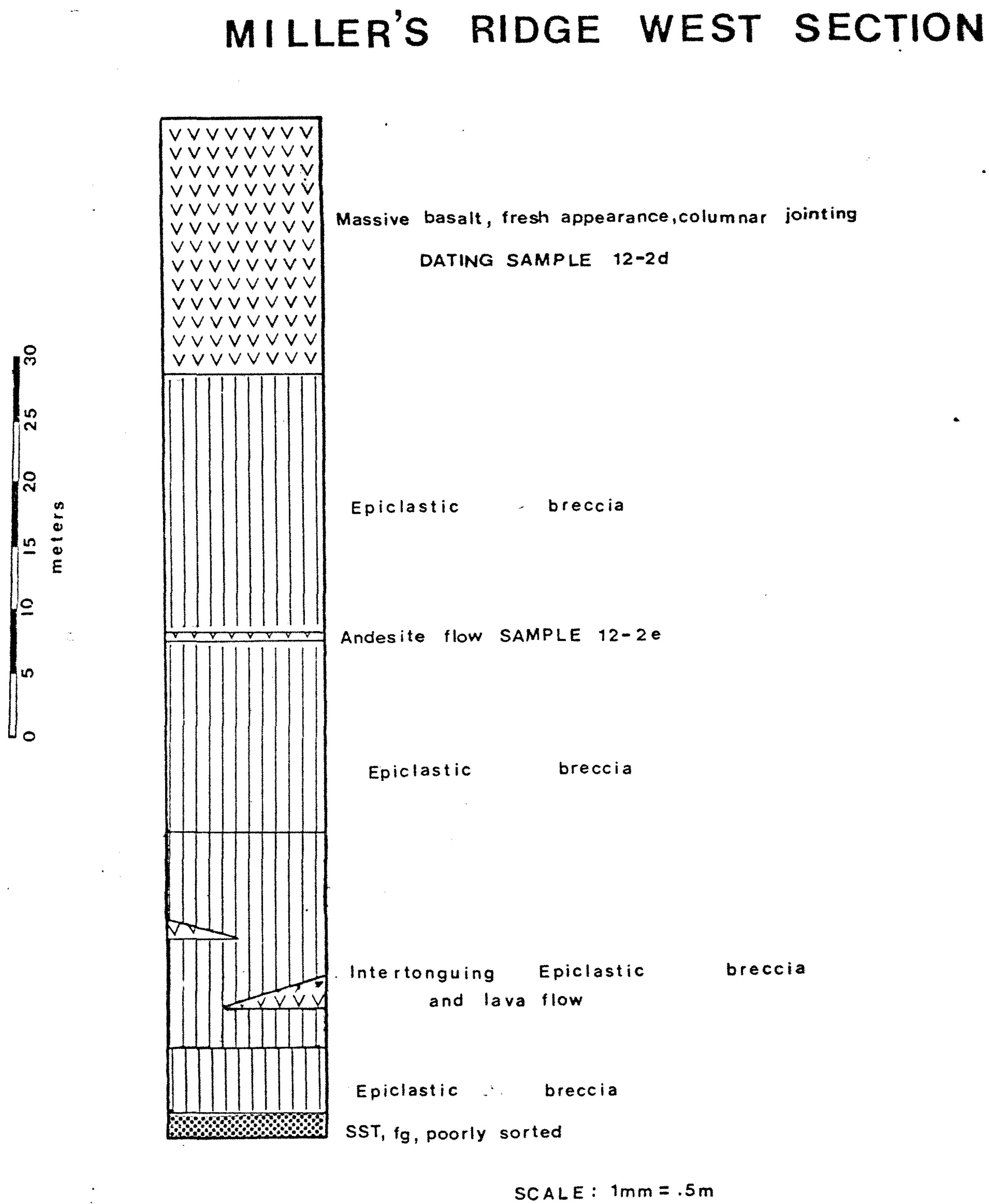


Figure 4 - Miller's Ridge West section

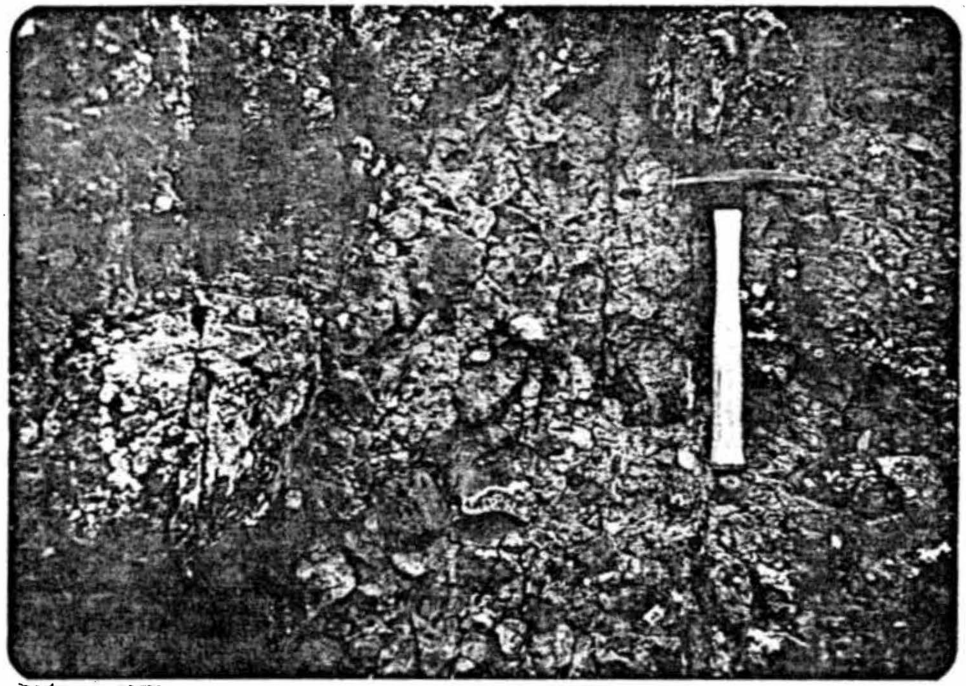


Plate 5 - Epiclastic breccia from Miller's Ridge West section, 25m above base.

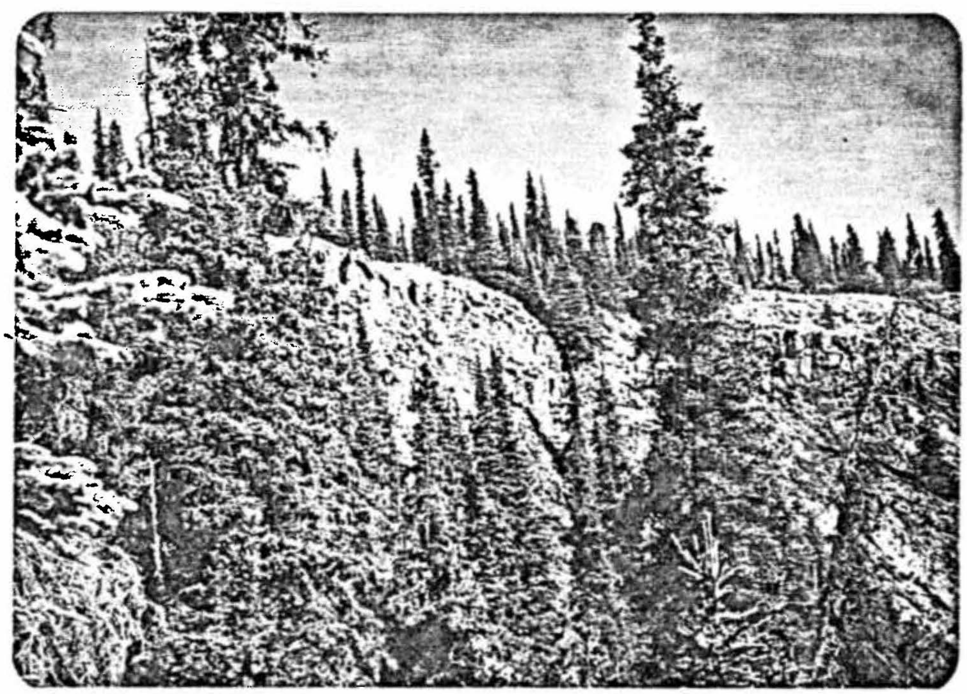


Plate 6- Massive, jointed basalt at top of Miller's Ridge East section. Dating sample 12-2d taken from this basalt.

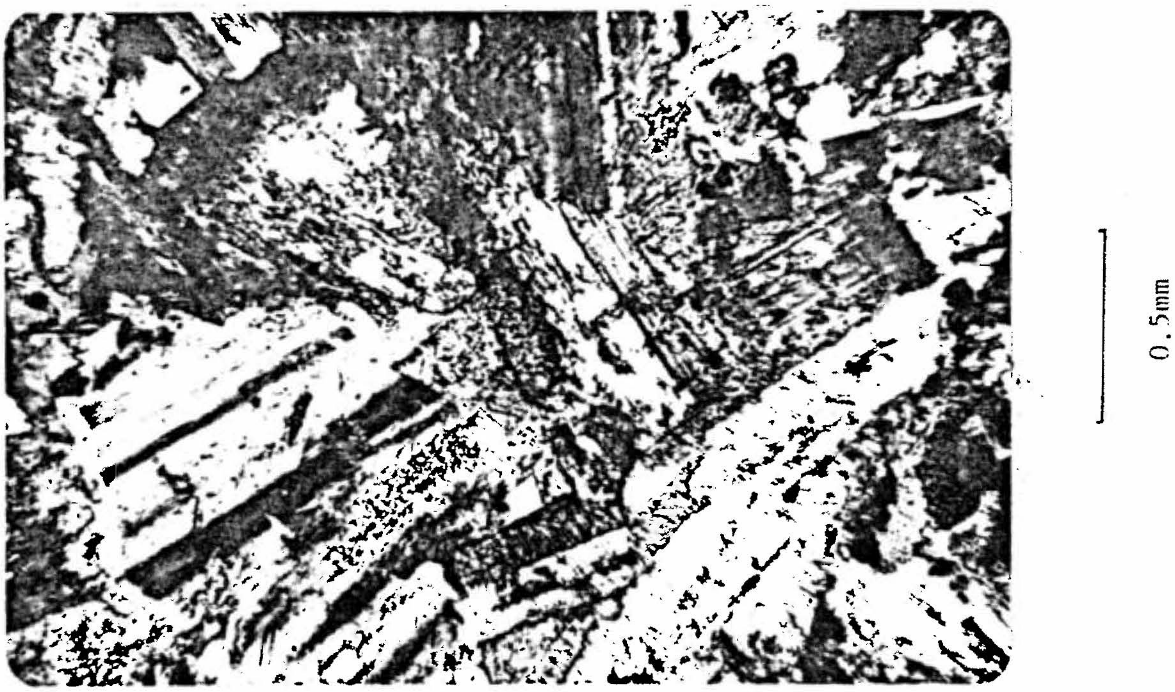


Plate 7 - Thin section of sample 12-2e. Plagioclase altering to epidote.

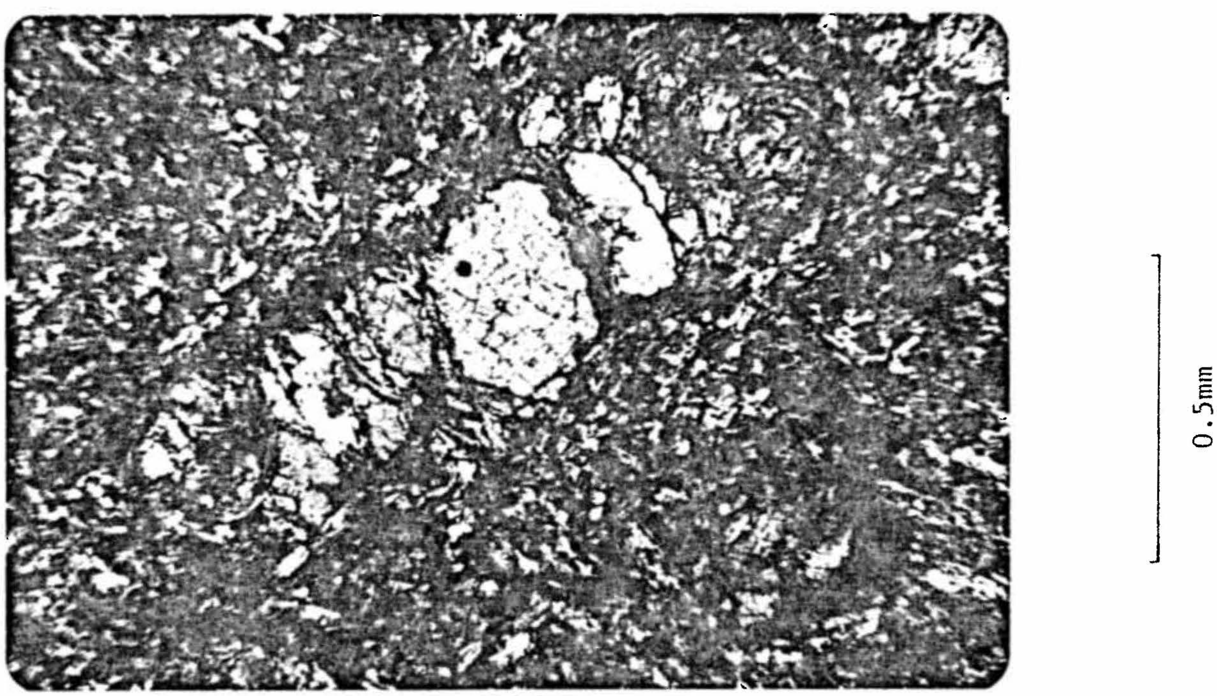


Plate 8 - Thin section of sample 12-2d. Olivine altering to iddingsite.

Aishihik Lake Section

Description

The Aishihik Lake section lies 100m east of the Whitehorse-Dawson highway, 14km south of the town of Carmacks. The bluff which makes up the section does not have good outcrop as at Miller's Ridge (Plate 9). In fact, over half the section is covered. However, the exposed parts of the section are similar in form and mineralogy to the sections at Miller's Ridge.

The Aishihik Lake section is summarized in Figure 5 and Appendix I. It consists of 89m of epiclastic breccias, lava, and covered intervals. Contacts between the different epiclastic breccias and the lava flow are not visible. Clasts in the breccias are up to 2m across (Plate 10), and are rounded to angular basalts and andesites. A sample of one of these large clasts was used for chemical analysis and isotope dating (sample 15-1e). One outcrop shows a series of successive epiclastic breccias which are distinguished by different clast sizes (Plate 11). Between these successive breccias are small lenses of immature, coarse sandstone. The lava flow in the section has covered intervals below and above it. It consists of a highly altered andesite.

Petrography

A thin section was taken of the epiclastic breccia clast used for chemical analysis and isotope dating (sample 15-1e). The clast is andesite with clinopyroxene and plagioclase phenocrysts, in a groundmass of plagioclase, chlorite, devitrified glass and opaques. The chlorite may be the result of olivine alteration. The plagioclase phenocrysts are zoned (Plate 12), but an accurate

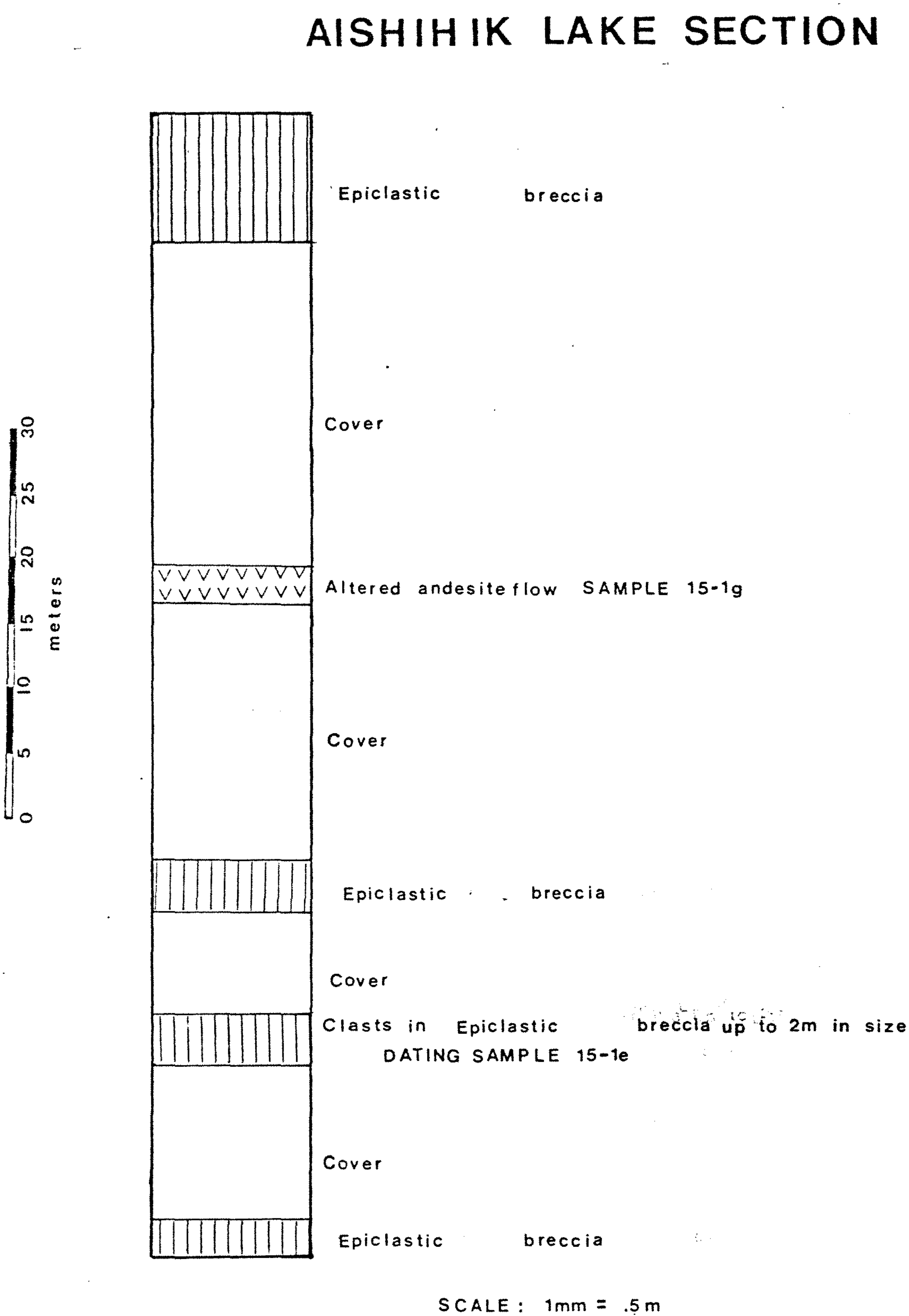


Figure 5 - Aishihik Lake section

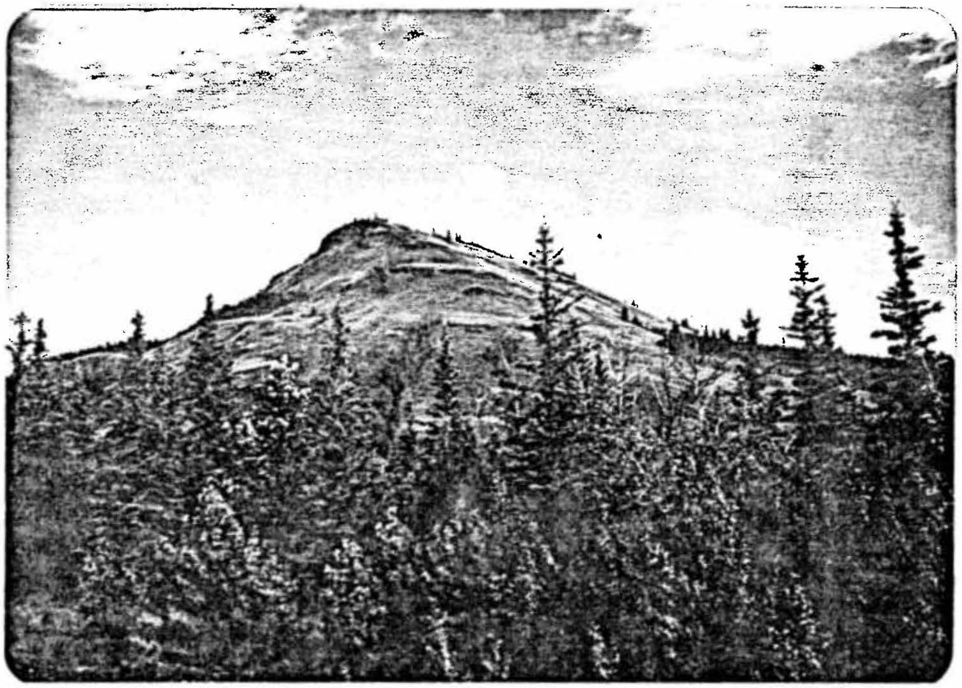


Plate 9 - Slope on which the Aishihik Lake section **was** measured.

Plate 10 - Clast in epi-
clastic
breccia from which
dating sample 15-1e
was taken. 15m
from base of section.

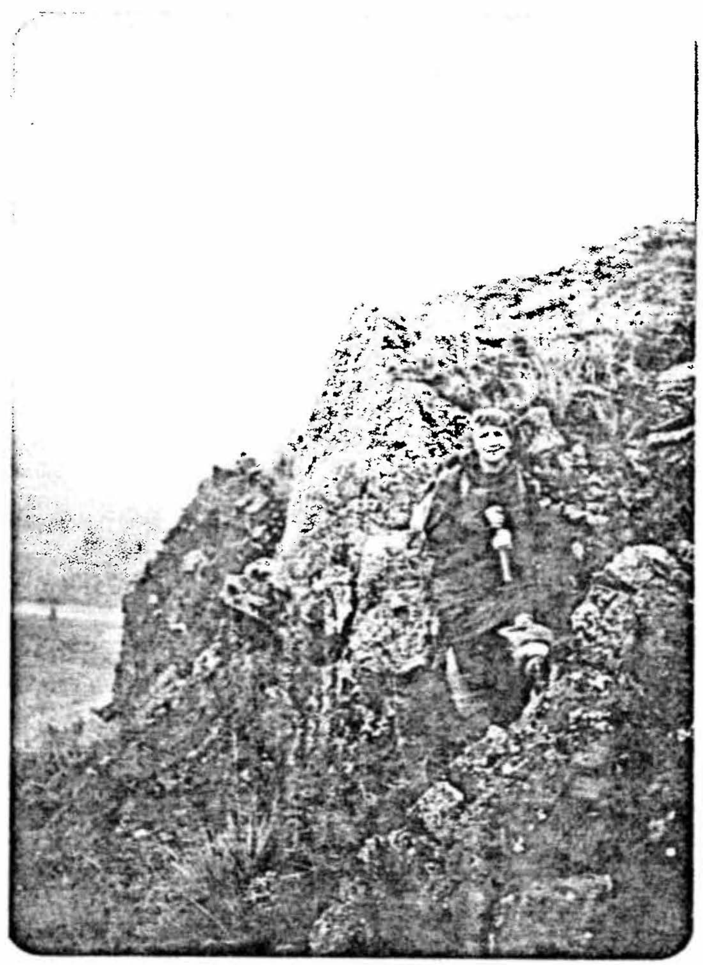


Plate 11 - Epiclastic breccia in Aishihik Lake section. Size grading of clasts indicates successive flow breccias. 79m from base of section.

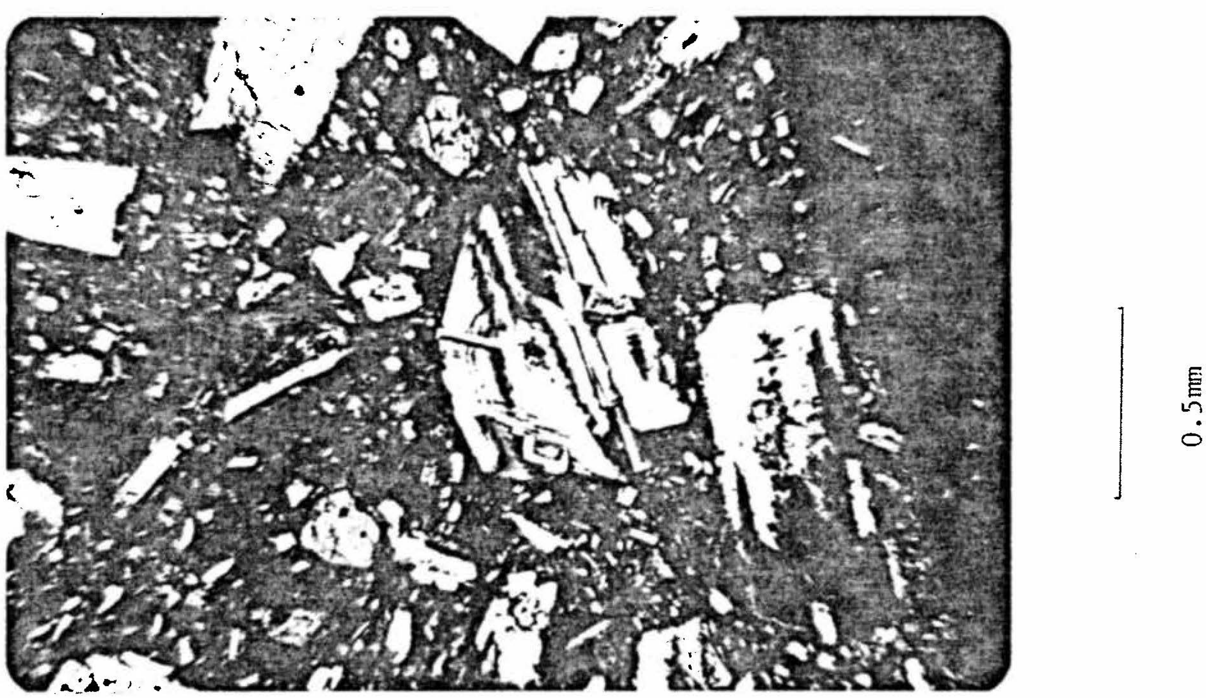


Plate 12 - Thin section of dating sample 15-1e showing plagioclase zoning.

plagioclase determination was not possible. A thin section taken of the altered andesite (sample 15-1g) consists of phenocrysts of altered plagioclase and clinopyroxene in a fine grained groundmass of plagioclase and opaques with groundmass voids filled by celadonite and silca (Plate 13).

Glenlyon Section

Discription

The Glenlyon section starts on the north bank of the Yukon River, 19km east of Carmacks. The section crosses the Carmacks-Faro highway and continues north to the top of the bluff. This section is also partially covered. None of the epiclastic breccias so common in the Miller's Ridge and Aishihik Lake sections were observed.

The Glenlyon section is summarized in Figure 6 and Appendix I. It consists of 122m of lava flows, immature volcanic sandstone, and covered intervals. The sandstone is fine grained and interbedded with siltstone (Plate 14). It is found on the shore of the Yukon River at the base of the section. The lava flows are massive, and contacts between the flows are sharp where exposed. The flows appear to be andesitic but chemical analysis on samples from two of the flows indicate that they are a trachybasalt and a tristanite. The trachybasalt flow is exposed on the road cut of the Carmacks-Faro highway and shows crude columnar jointing (Plate 15).

Petrography

A thin section of the sandstone (sample 14-1b) shows it to have a few rounded quartz grains as well as angular plagioclase and volcanic rock fragments. The quartz may be from some distal source but the rest of the rock is definitely proximal to its source. A thin section

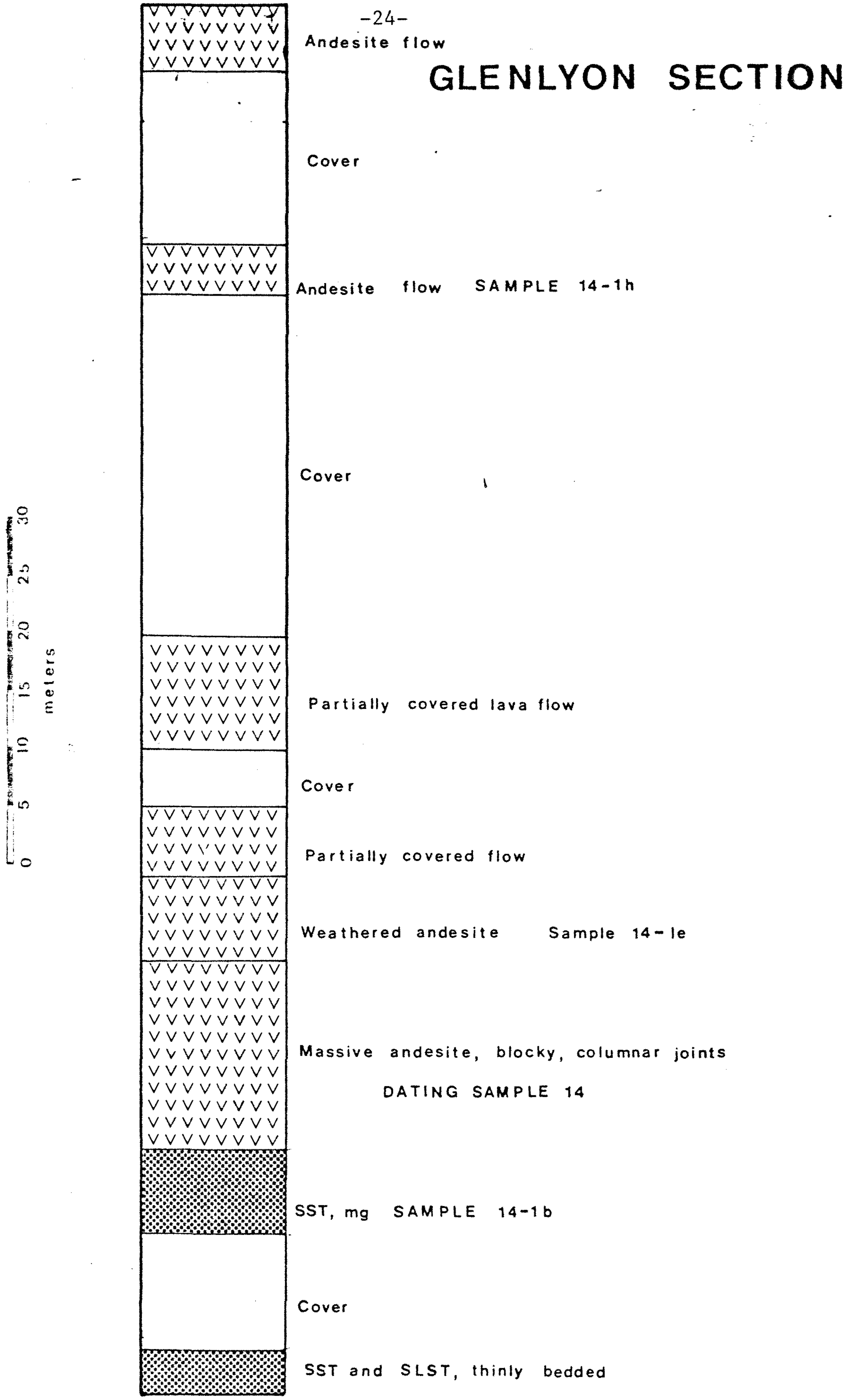


Figure 6 - Glenlyon Section SCALE: 1mm = .5m

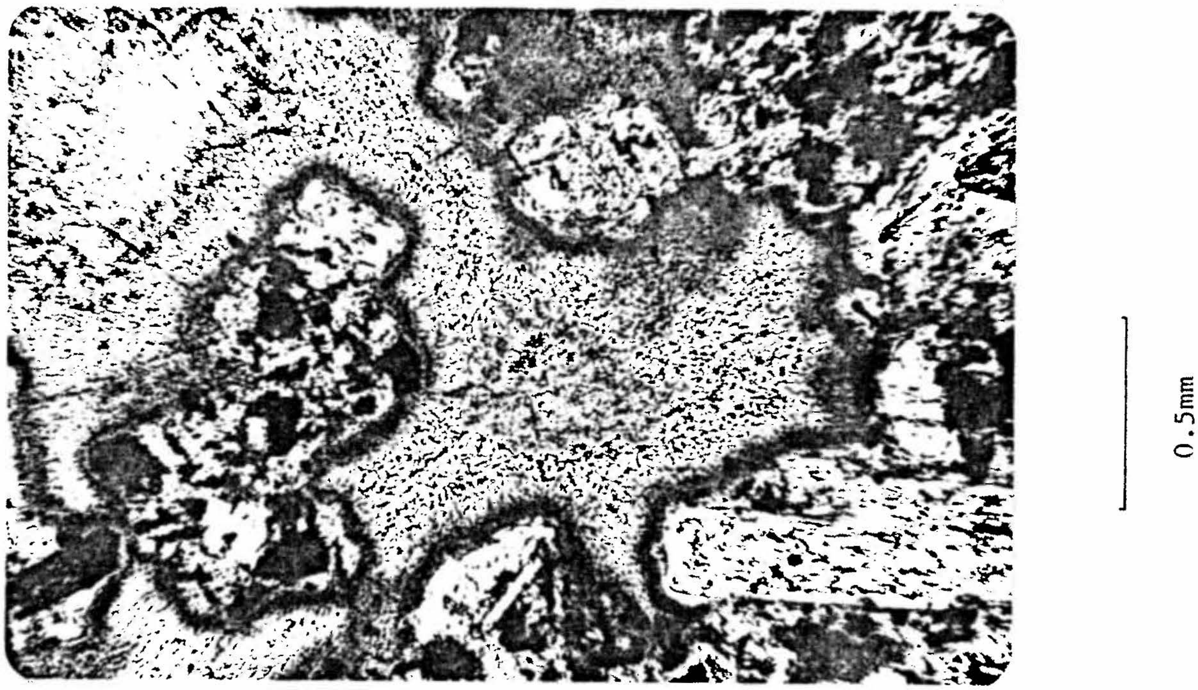


Plate 13 - Thin section of sample 15-1g. Celadonite and SiO_2 in vesicles. (uncrossed nicols)

Plate 14 - Siltstone from Glenlyon section, 2m from base of section.

of the trachybasalt (sample 14) contains phenocrysts of plagioclase (An_{35}), clinopyroxene, and olivine (almost completely altered to iddingsite). The groundmass is of plagioclase,poikilitic biotite,apatite and opaques. A thin section of an andesitic flow (sample 14-1e) contains phenocrysts of plagioclase (An_{32}), clinopyroxene,and olivine (mostly altered to iddingsite) in a groundmass of plagioclase,orthoclase, poikilitic biotite, and opaques. A thin section of the tristanite flow (sample14-1h) contains phenocrysts of twinned clinopyroxene, plagioclase (An_{28}) rimmed by orthoclase (Plate 16) and olivine (almost completely altered to iddingsite and chlorite). The groundmass consists of plagioclase, pyroxene crystals, orthoclase, poikilitic biotite,and opaques.

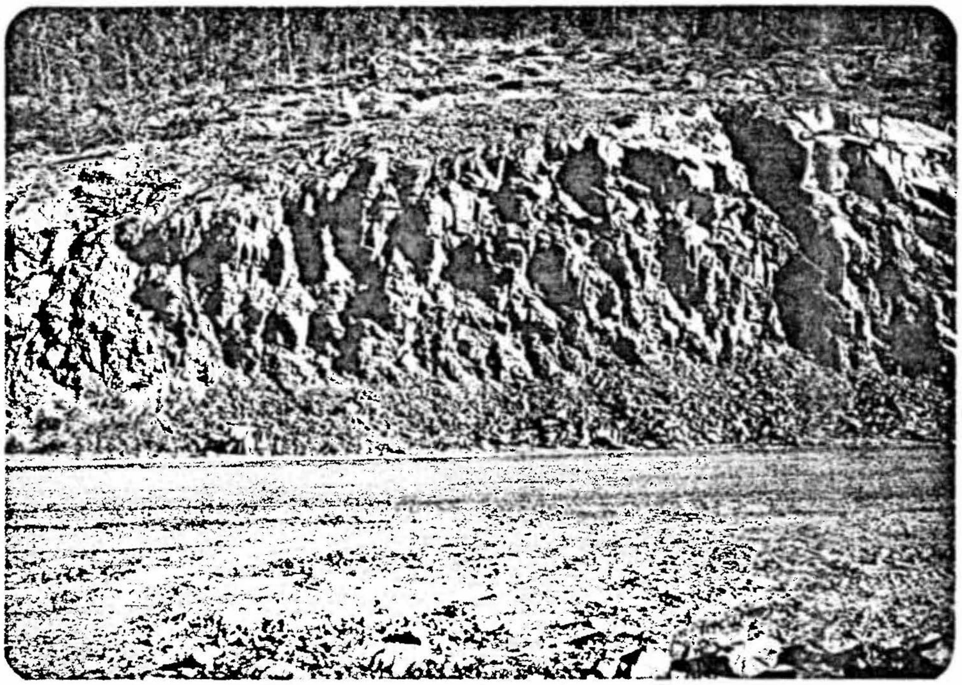


Plate 15 - Road cut exposing trachybasalt flow in Glenlyon section. Dating sample 14 taken from this flow, 27m from base of section.

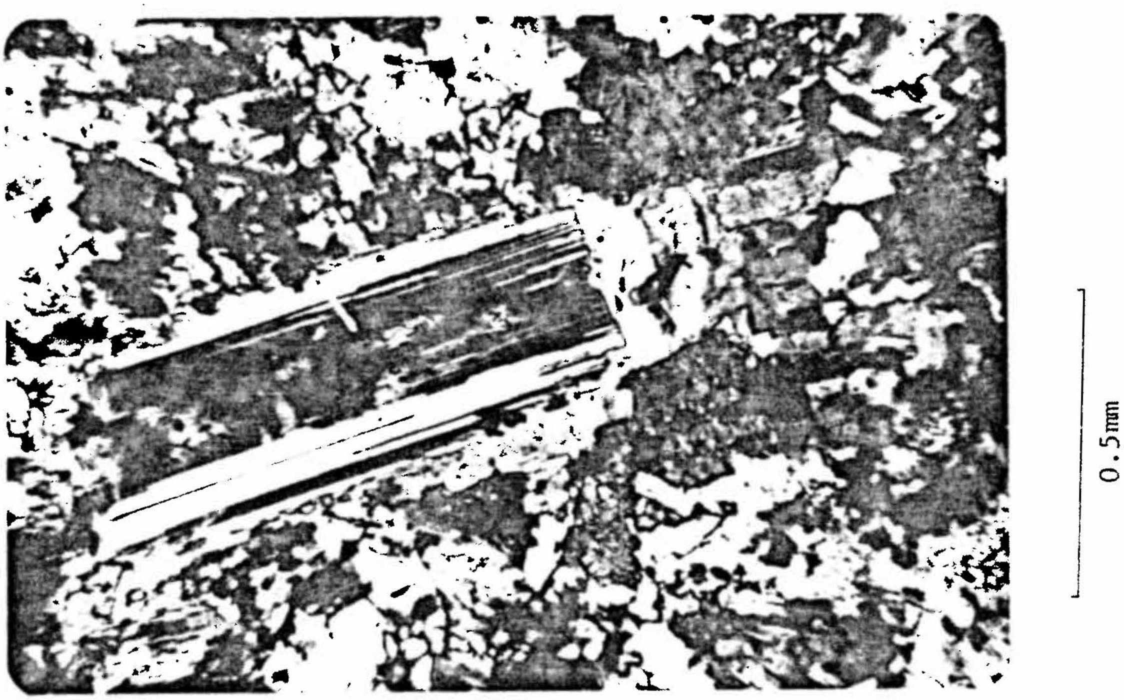


Plate 16 - Thin section of sample 14-1h. Orthoclase rimming plagioclase.

IV CHEMISTRY OF THE CARMACKS GROUP

General Statement

Chemical analysis of the Carmacks Group volcanic rocks was undertaken on four samples, the three dating samples plus one sample from the Glenlyon section. These samples were each crushed and ground, then made into pellets for Na_2O determinations, and into fused discs for major element determination. Determinations were obtained using x-ray fluoresence, following a method outlined by G. Nixon. A computer program obtained from G. Nixon was used for norm calculations. Chemical classification was made using the method outlined by Irvine and Baragar (1971). Chemical data is summarized in Appendix III. Normative compositions are shown in Table 2.

Sample 12-2d

This sample, taken from the Miller's Ridge West section, was also used for whole rock K-Ar dating. On the total alkalies (Na_2O + K_2O) versus SiO_2 diagram it is classified as alkaline. On the Ol'-Ne'-Q' ternary diagram it is classified as subalkaline but it is very near the subalkaline - alkaline boundary. Therefore this rock can be generally classed as alkaline. On the An-Ab'-Or ternary diagram this rock plots in the potassic field of alkaline basalts. Using the normative plagioclase - normative colour index plot for potassic alkaline basalts, the sample falls into the alkali basalt field. Thus sample 12-2d can be classified as an alkali basalt.

Sample 15-1e

This sample was taken from the Aishihik Lake section and was also used for whole rock K-Ar dating. The rock is classified as subalkaline on both the total alkalies versus SiO_2 and the Ol'-Ne'-Q' ternary diagram. In both cases it is close to the subalkaline – alkaline boundary. On both the normative plagioclase versus Al_2O_3 and the AFM ternary diagram the sample plots as calc-alkaline. On the An-Ab'-Or ternary diagram for subalkaline rocks the sample plots as an average rock. On the normative plagioclase - normative colour index plot for subalkaline rocks, the rock plots as an andesite. Therefore, sample 15-1e can be classified as a calc-alkaline, average andesite.

Sample 14

This sample, taken from the Glenlyon section, also provided a biotite separate for K-Ar dating. On the total alkalies versus SiO_2 the rock is classified as alkaline. On the Ol'-Ne'-Q' ternary diagram the rock is classified as subalkaline, but again it is very near the subalkaline – alkaline boundary. Therefore, this rock can be generally classified as alkaline. On the An-Ab'-Or ternary diagram for alkaline rocks the rock is classified in the potassic series. Using the normative plagioclase - normative colour index plot for the potassic series of alkaline rocks the sample falls into the trachybasalt field. Thus, sample 14 can be classified as a trachybasalt.

Sample 14-1h

This sample was also taken from the Glenlyon section, but not used for dating. The rock can be classified as alkaline on both the total alkalies versus SiO_2 and on the Ol'-Ne'-Q' ternary diagram. On the An-Ab'-Or ternary diagram the rock is classified as one of the potassic series. Using the normative plagioclase - normative colour index plot for the potassic series the rock falls into the tristanite field. Thus, sample 14-1h can be classified as a tristanite. This is the most differentiated rock of the suite analysed.

Samples 14 and 14-1h are very high in potassium, therefore they can be alternatively classified into the shoshonite series rather than the potassic alkali basalt series. The shoshonite series was first outlined by Joplin (1965) as being composed of high alkali basalts with Na_2O/K_2O ratios from 1 to .5 or less. These rocks contain relatively abundant potassium feldspar in addition to plagioclase as groundmass phases.

TABLE 2

TABLE OF NORMATIVE COMPOSITIONS

	12-2d	15-1e	14	14-1h
Orthoclase	18.80	8.75	31.16	29.68
Albite	26.19	38.72	33.35	39.63
Anorthite	15.50	23.88	12.05	7.52
Nepheline	0.00	0.00	0.00	1.85
Diopside	15.20	9.99	6.23	9.61
Hypersthene	1.01	13.14	10.93	0.0
Forsterite	13.86	0.00	0.90	5.07
Fayalite	4.59	0.00	0.41	1.73
Quartz	0.00	1.26	0.00	0.00
Magnetite	2.53	2.41	2.50	2.47
Ilmenite	1.31	1.14	1.26	1.23
Apatite	1.00	0.70	1.24	1.21

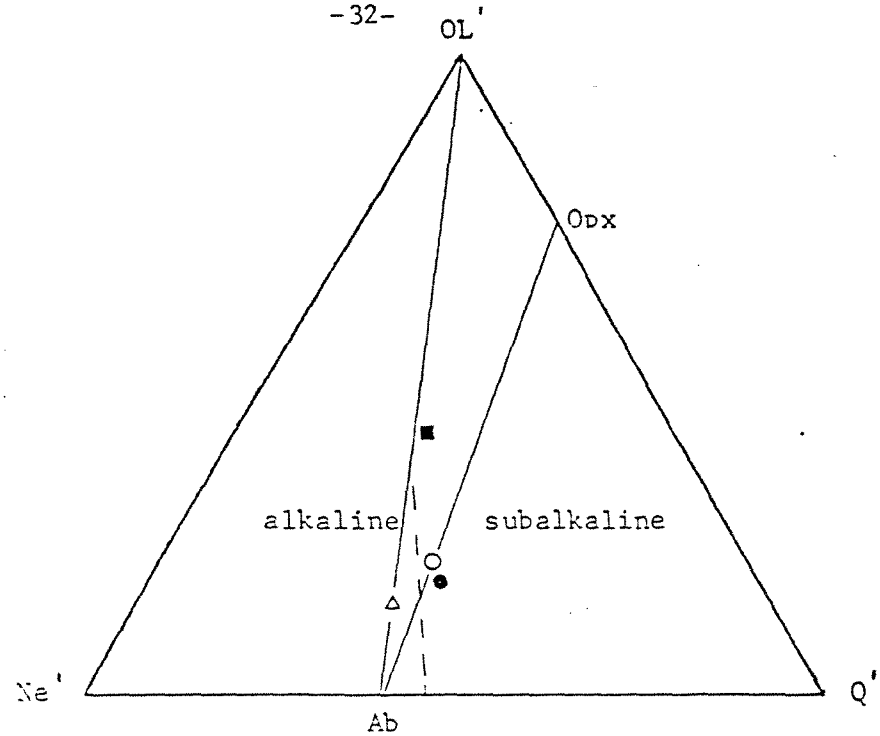


Figure 7 - Ol'-Ne'-Q' projection showing rock analyses on alkaline and subalkaline fields.

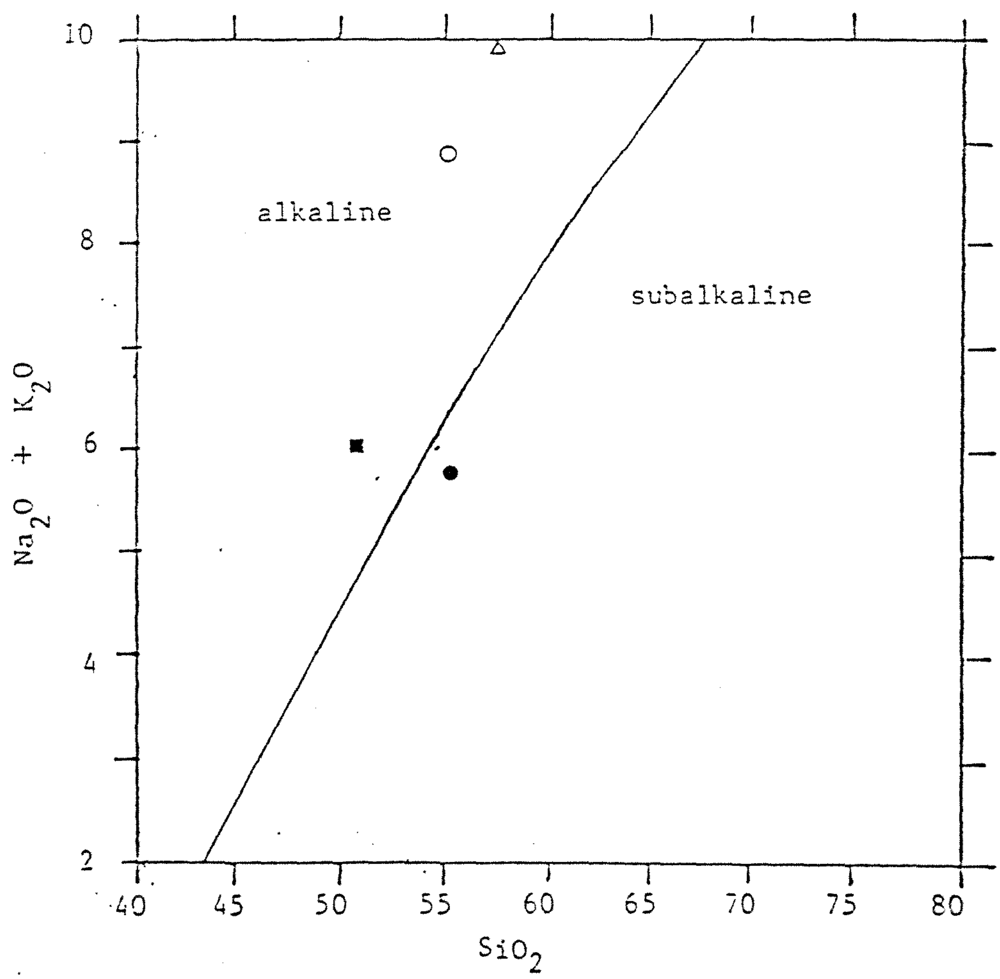


Figure 8 - Total alkalies vesus SiO_2 plot showing rock analyses on alkaline and subalkaline fields.

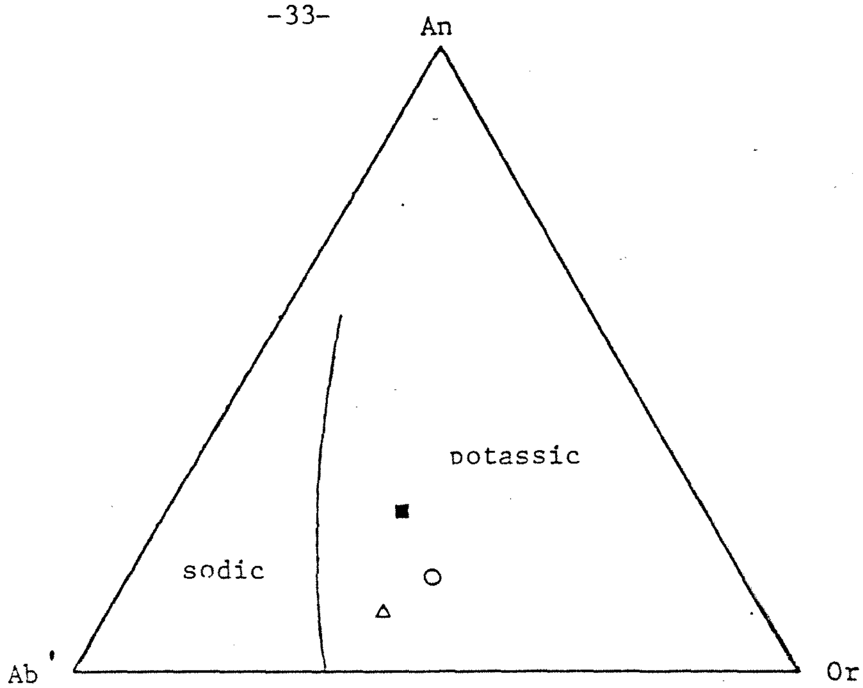


Figure 9 - An-Ab'-Or projection of sodic and potassic alkali rocks.

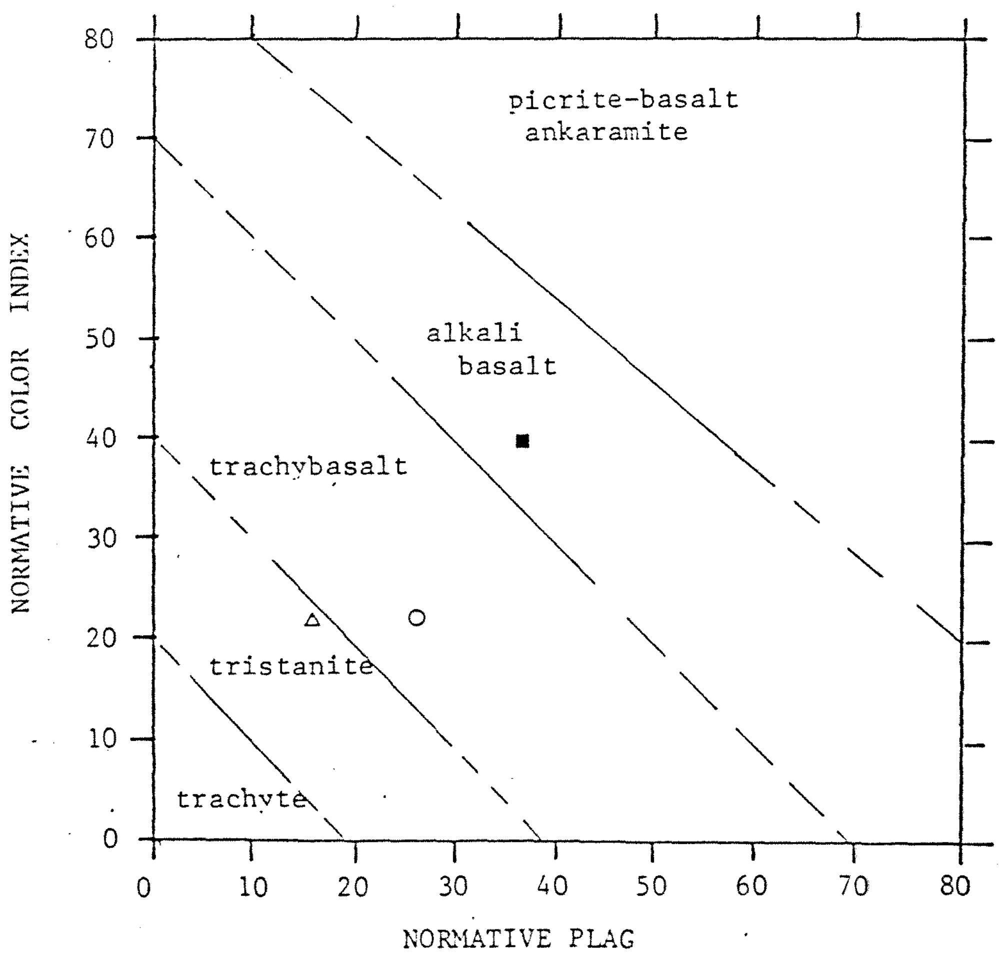


Figure 10 - Normative plagioclase - normative colour index plot for potassic alkaline rocks.

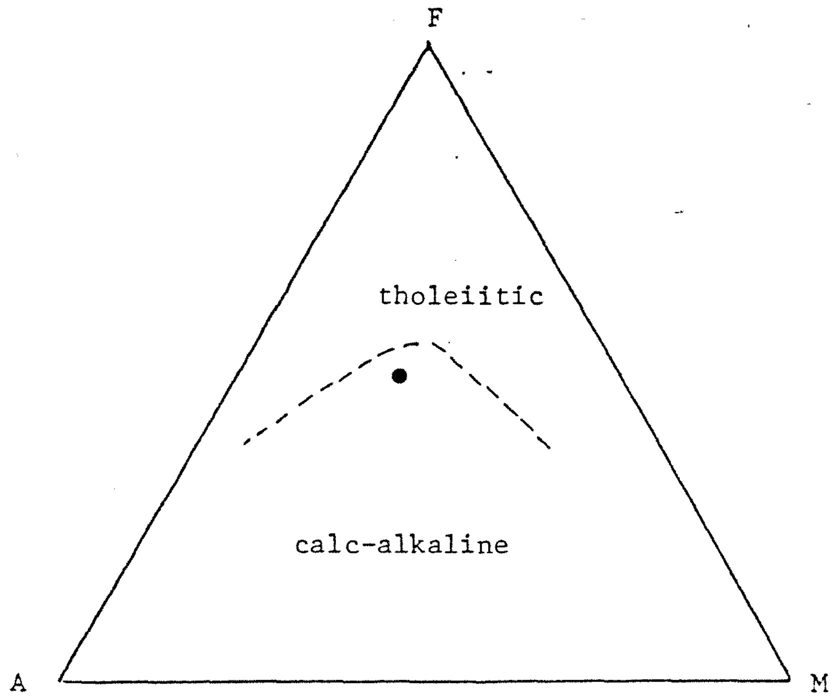


Figure 11 - AFM plot of subalkaline rocks.

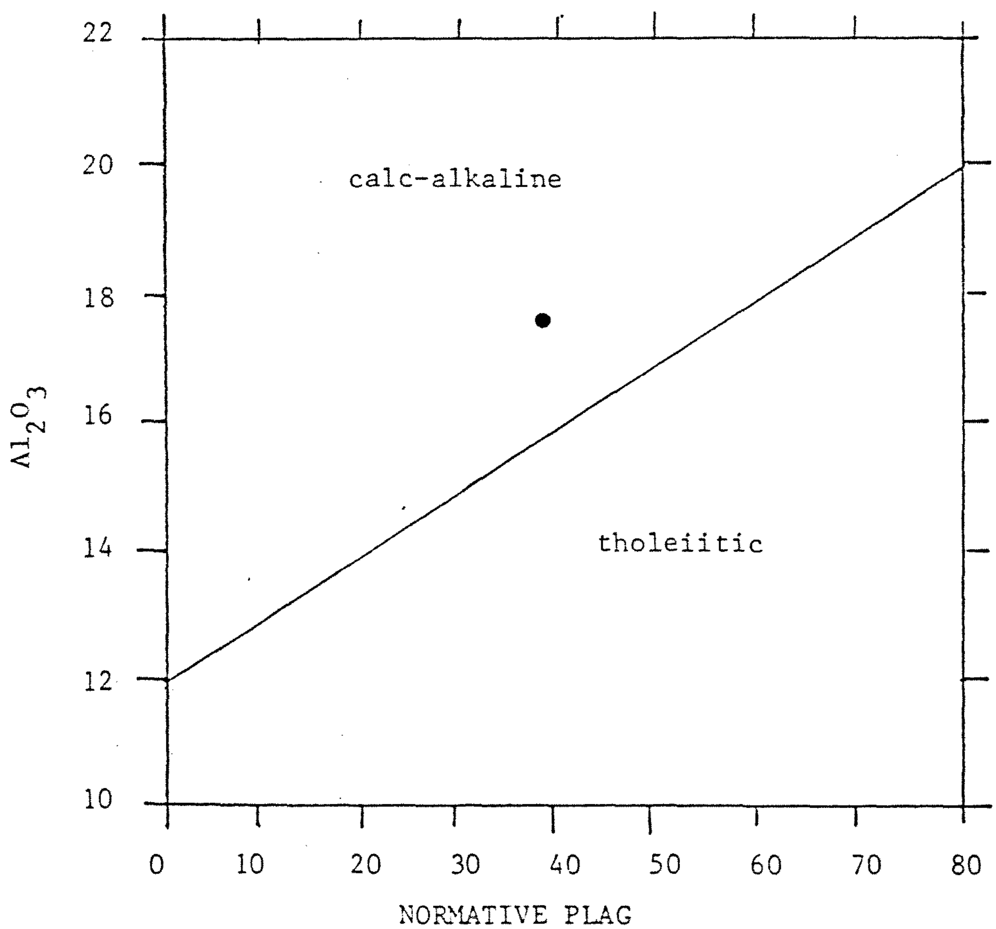


Figure 12 - Normative plagioclase versus weight percent Al_2O_3 for subalkaline rocks.

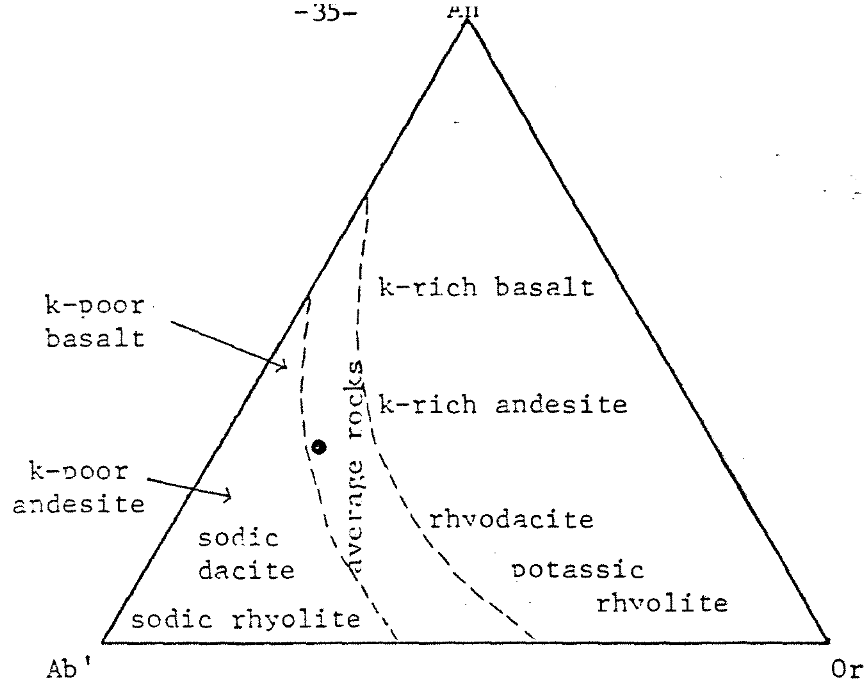


Figure 13 - Subdivison of the subalkaline rocks using the An-Ab'-Or projection.

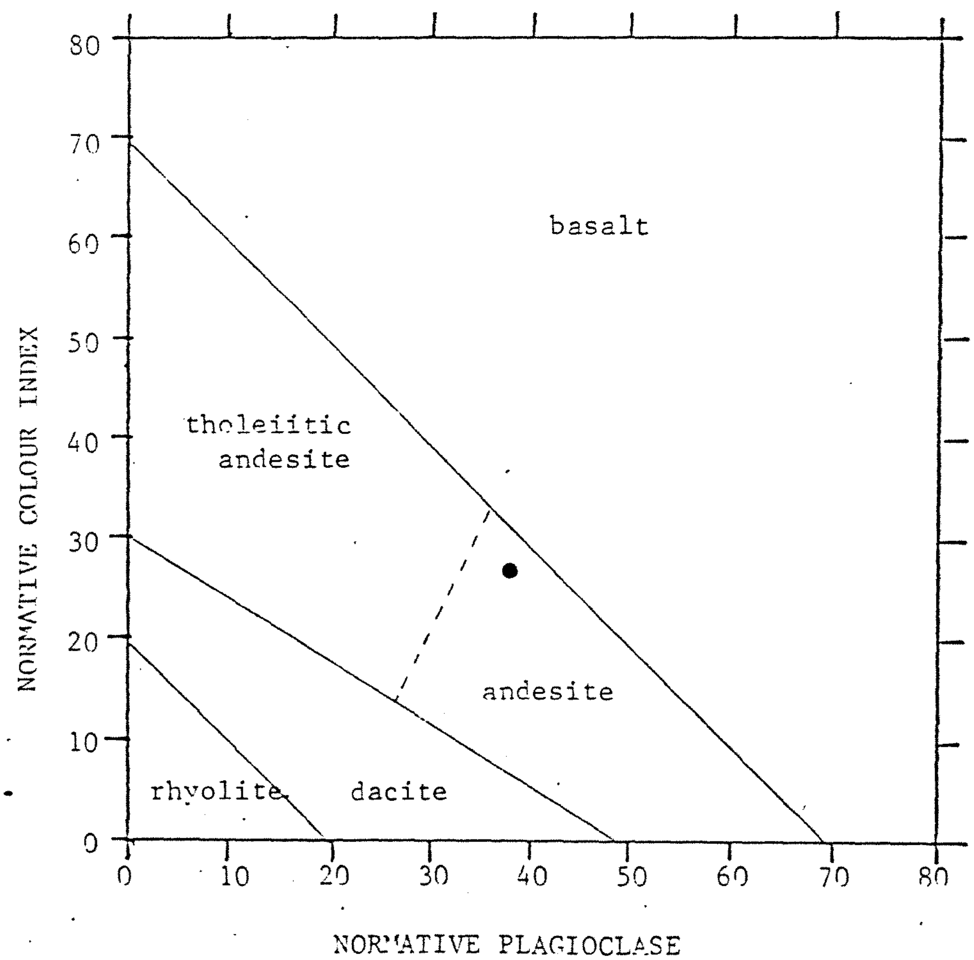


Figure 14 - Subdivision of the subalkaline rocks using normative colour index versus normative plagioclase plot.

V GEOCHRONOLOGY

K-Ar Dating

Three samples of Carmacks Group volcanic rocks were dated using K-Ar methods, which are summarized in Appendix IV. The samples were chosen from three different areas in order to confirm that all three sections were from the Carmacks Group and to establish a range in ages for the extrusion of the Carmacks Group. The samples taken were all of relatively fresh and unaltered rock.

Sample 12-2d, an alkali basalt collected from the Miller's Ridge West section, gave a date of 73.1 ± 2.5 Ma. Sample 15-1e, a calc-alkaline andesite collected from the Aishihik Lake section, gave a date of 67.9 ± 2.3 Ma. Biotite, separated from sample 14, a trachybasalt from the Glenlyon section, was found to be 68.0 ± 2.2 Ma.

These dates establish an approximate range of ages, from 68 to 73 Ma for extrusion of the Carmacks Group. In other words, the Carmacks Group is Upper Cretaceous - Campanian in age.

K-Ar dating of the Mt. Nansen Group by H. Grond (1980) has resulted in two dates, 72.4 Ma and 69.1 Ma. These dates establish that the Mt Nansen and Carmacks Groups are coeval.

Rb-Sr Dating

The samples chosen for K-Ar dating were also analysed for Rb and Sr trace elements. Results obtained are summarized in Appendix IV. The initial ratio calculated by the York Least Squares Regression (York, 1969) was 0.70489 ± .00015. The isochron obtained gave an age of 76.8 ± 19.6 Ma (Figure 15).

The Carmacks Group Rb-Sr data was compared with two samples from the Mount Nansen Group (Grond, 1980) and one sample from the Hutshi Formation of Graham Inlet, British Columbia. The intial ratio, again calculated by the York Least Squares Regression, was 0.70484 ± .00007. The isochron obtained gave an age of 72.4 ± 2.1 Ma.

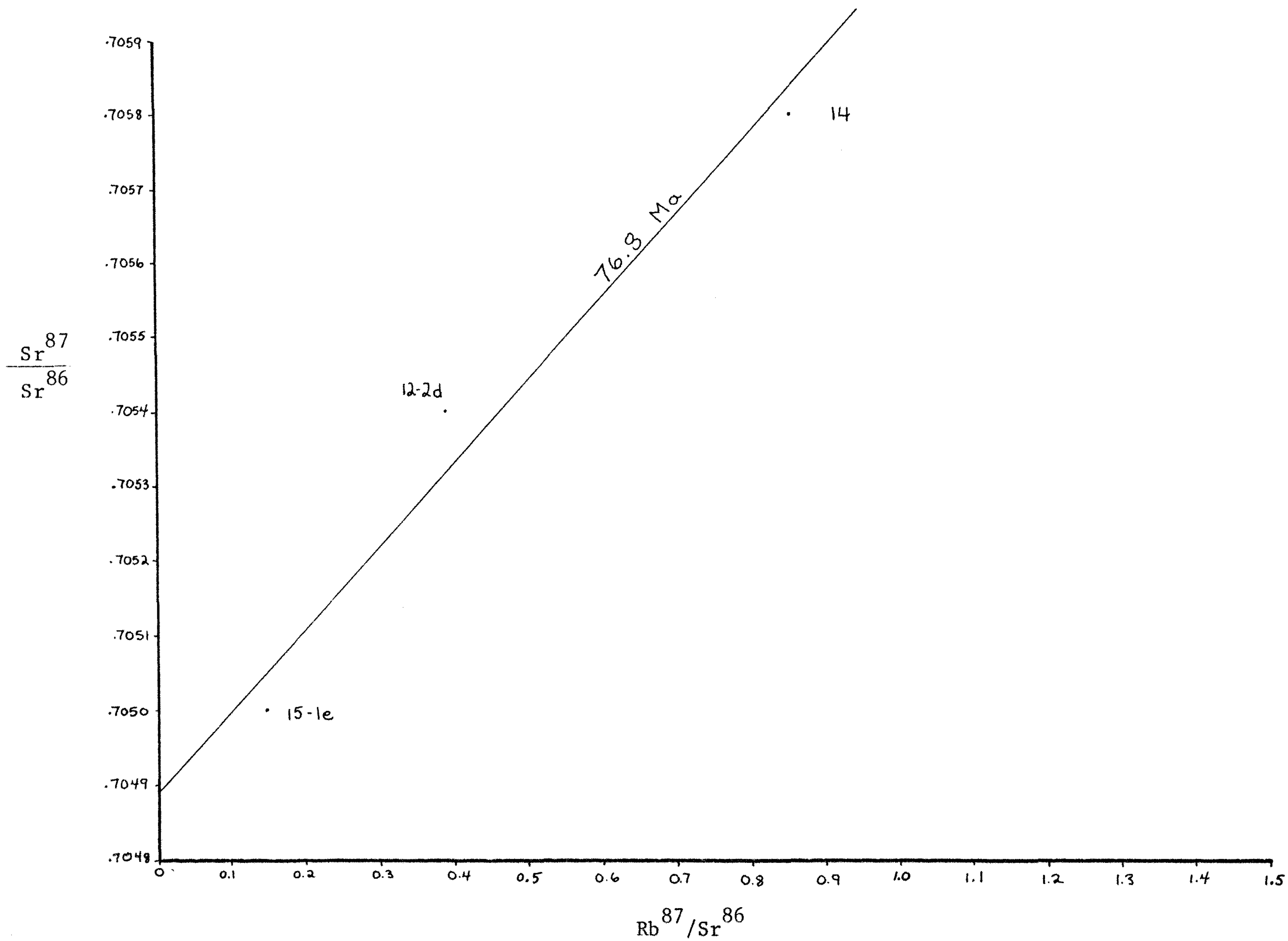


Figure 15 - Rb-Sr isochron for the Carmacks Group

VI DISCUSSION OF CHEMISTRY

Investigations into the chemistry of the Carmacks Group makes it possible to illustrate chemical trends which these rocks follow. First, looking just at the Carmacks Group, the lavas differentiate in that the oldest lavas are alkali basalts, a younger lava is a trachybasalt, and a still younger lava is a tristanite (samples 12-2d, 14, and 14-1h respectively). The alkali basalt and trachybasalt have no normative nepheline or quartz, while the tristanite has normative nepheline. This chemical trend follows the fractionation trend in alkali rocks, first elaborated by Kennedy in 1933. The trend is that silica undersaturation increases in successively younger flows from the same parental basalts. An explanation of how the Kennedy trend originates is given by Yoder and Tilley (1962).

On a more regional scale, the Carmacks Group appear to be part of a chemical gradient first outlined by Kuno (1966). Kuno observed that the chemical composition of volcanics in an island arc and/or continent changes from tholeiitic to calc-alkaline to alkalic, from active volcanic arc towards the stable craton. The Carmacks Group form a linear belt of volcanics trending approximately northwest - southeast (see Figure 1). Directly to the southwest, the Mount Nansen Group forms a parallel linear belt of volcanics, but these volcanics are calc-alkaline in composition (Grond, 1980). Thus, the two suites of volcanics show the gradient outlined by Kuno - calc-alkaline near trench to alkaline cratonward.

There are two theories to explain this gradient. Kuno (1966) postulates that magmas formed at higher pressures will be more alkalic, and also that the further inward on a continent, the deeper is the level of melting of the magma. Thus it makes sense that the further inward on a continent, the more alkalic the volcanism. This trend may be caused by different magma reservoirs at different depths or by one common reservoir supplying all the magma, which differentiates at deeper depths as you move inward on the continental side. Miyashiro (1975) postulates: The continentward increase in K_2O across the arc is not due to the successive occurence of tholeiitic, calc-alkaline, and alkaline rocks but is mainly due to the continentward increase of K_2O in tholeiitic as well as in calc-alkaline series rocks across the arc.

The one calc-alkaline rock found in the Carmacks Group was a sample of an epiclastic breccia in the southwestward edge of the Carmacks Group. This epiclastic breccia could have its origin further west, which would account for its calc-alkaline composition. The calc-alkaline composition could also be just normal variation within the Carmacks Group.

VII CONCLUSIONS

The studied sections of the Carmacks Group were found to be composed of lava flows, epiclastic breccias, sintered tuffs, and volcanic sandstones. Chemical analysis revealed that the lava flows were alkaline and high in potassium. K-Ar dating established an Upper Cretaceous age for the Carmacks Group, which was previously thought to be Eocene to Miocene. Rb-Sr isotope dating also gave an Upper Cretaceous age.

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APPENDIX I

SUMMARY OF MEASURED SECTIONS

MILLER'S RIDGE EAST SECTION

Height in Section (m)	Thickness (m)	Description
0	30	Epiclastic breccia. Clasts range in size from 1cm to 30cm. Clasts are of basaltic compostion. Matrix is coarse tuff.
30	6	Epiclastic breccia. Clasts are light coloured and highly vesicular.
36	84	Epiclastic breccia. Clast composition is andesite to basalt, mainly massive rather than vesicular. Clasts are 1cm to 2m in size.
120	3	Laminated volcanic sandstone grades up into pebble conglomerate and then to coarse, unlaminated volcanic sanstone.
123	6	Extremely vesicular lava brecciated and mixed with volcanic sandstone.
129	30	Epiclastic breccia. Clast composition is andesite to basalt.
159	7.5	Very weathered, brown sintered tuff with pyroxene phenocrysts. Clasts from underlying epiclastic breccias at base.
166.5	3	Brown weathering sintered tuff with pyroxene phenocrysts.
169.5	3	Red weathering sintered tuff with pyroxene phenocrysts. Some volcanic clasts 10cm-30cm in size.
172.5	6	Green weathering sintered tuff with pyroxene phenocrysts. Contains numerous volcanic clasts 1cm to 30 cm in size
178.5	7.5	Epiclastic breccia. Clasts are andesitic to basaltic in composition.
186		

MILLER'S RIDGE WEST SECTION

Height in Section (m)	Thickness (m)	Description
0	2	Volcanic sandstone, fine to medium grained, finely laminated. Poorly sorted.
2	5	Epiclastic breccia intertonguing with vesicular, brecciated, lava flows.
24	15	Epiclastic breccia with basaltic and andesitic clasts.
39	.5	Blocky andesitic lava flow. Massive at bottom, becoming extremely vesicular at top. Phenocrysts of feldspar and pyroxene.
39.5	20	Epiclastic breccia with andesitic and basaltic clasts. Base of breccia contains vesicular clasts from underlying lava flow.
59.5	20	Massive, blocky basaltic lava flow, with pyroxene phenocrysts. Crude columnar jointing. Dating sample 12-2d obtained from this unit.
79.5		

AISHIHIK LAKE SECTION

Height in Section (m)	Thickness (m)	Description
0	3	Epiclastic breccia. Clasts are andesitic and basaltic in composition. Size range from 1cm to 50cm.
3	12	Covered interval
15	4	Epiclastic breccia. Clast size range from 1cm to 2m. Dating sample 15-1e obtained from this unit.
19	8	Covered interval
27	4	Epiclastic breccia. Clasts are andesitic and basaltic in composition. Size range 1cm to 50cm.
31	20	Covered interval
51	3	Altered andesitic lava flow. Green weathering, brecciated in places.
54	25	Covered interval
79	10	Successive epiclastic breccias in large outcrop. Clasts show size grading from coarse to fine, then coarse again. Clast sizes range from 1cm to 1m.
89		

GLENLYON SECTION

Height in Section (m)	Thickness (m)	Description
0	4	Thinly bedded fine grained sandstone and siltstone, poorly sorted.
4	10	Covered interval
14	7.5	Interbedded coarse and fine grained volcanic sandstone. Poorly sorted.
21.5	16.5	Massive, blocky andesite lava flow in sharp contact with underlying sandstone. Flow has phenocrysts of pyroxene, feldspar, and biotite. Crude columnar jointing.
38	7.5	Medium grey andesite lava flow , blocky weathering, pyroxene phenocrysts.
45.5	6	Partially covered andesitic flow.
51.5	5	Covered interval
56.5	10	Partially covered andesitic flow. Very weathered, does not crop out well.
66.5	30	Covered interval
96.5	4.5	Partially covered andesite lava flow.
101	15	Covered interval
116	6	Partially covered andesitic lava flow.
122		

NEW K-Ar DATES AND GEOCHEMISTRY

FOR

MOUNT NANSEN VOLCANICS, YUKON

By

Helen C. Grond

U. B. C.
GEOLOGY LIBRARY

A thesis submitted in
partial fulfillment of the
requirements for the
Degree of Bachelor of Science

in

The Faculty of Science
Department of Geological Sciences
The University of British Columbia

April, 1980

ABSTRACT

Volcanic rocks of the Mount Nansen Group occur southwest of the Whitehorse Trough where they unconformably overlie the Yukon Crystalline Terrane and related rocks that extend into Northern British Columbia. A large volume of these volcanics is preserved in the Miners Range in south central Yukon which contains the area mapped. The volcanic rocks studied are porphyritic, locally vesicular andesite flows. The phenocrysts in order of decreasing abundance are andesine, augite and hornblende. Extensive albitization and sericitization is present in most of the rocks. The andesite flows are associated with autoclastic flow breccias and a sandstone layer and are intruded by dykes and sills. The dykes and sills are mainly alkali rhyolites but two feldspar-porphyry dykes are present as well. The lava flows and one dyke are calc-alkaline andesite. The other dyke is a calc-alkaline alkali rhyolite.

One whole-rock and one plagioclase separate were dated by K-Ar as 72.4 ± 2.5 Ma and 69.1 ± 2.6 Ma old, respectively. K-Ar dates indicate that the Mount Nansen Group is coeval with volcanic rocks of the Carmacks Group which occur further northeast. The calc-alkaline character of the Mount Nansen Group and the alkaline character of the Carmacks Group demonstrate the presence of a chemical gradient (increasing K, continentward) across the Late Cretaceous volcanic arc in the Yukon.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ACKNOWLEDGEMENTS

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I INTRODUCTION

The "Mount Nansen Group" was the name given by Bostock (1936) to volcanic rocks, previously known as the Older Volcanic Group in the south central Carmacks map-area. Bostock considered the Mount Nansen Group to be Late Jurassic or Cretaceous. Other groups of volcanic rocks which have been correlated to the Mount Nansen Group include: the Skukum Group in Whitehorse map-area (Wheeler, 1961), the Sloko Group in Tulsequah map area (Souther, 1971), Bennett Lake Complex in Northern British Columbia (part of the Sloko Group) (Lambert, 1974), Mush Lake Group (Kindle, 1952) in the Sifton Range, Casino Volcanics in the Snag map-area, the Carmacks Group, the Hutshi Group in the Miners Range and the Little Ridge Volcanics west of the Miners Range (Bostock and Lees, 1938). These correlations are based on similar lithology, stratigraphy and structural relations (Tempelman-Kluit, 1974).

The volcanic rocks in the Miners Range were originally included in the Hutshi Group by Bostock and Lees and were believed to be no older than Late Cretaceous. These rocks show many similarities to the Mount Nansen Group and have been correlated with them by Bostock and Lees (1938) and Tempelman-Kluit (1974). Tempelman-Kluit (1974) found the Mount Nansen closely associated with the Nisling Range Alaskite and therefore considered them contemporaneous. K-ar and Rb-Sr dates of 67 to 52 Ma (Latest Cretaceous to Eocene) have been obtained for the

Alaskite and this is now considered to be the age of the Mount Nansen Group (Tempelman-Kluit, 1977). The only K-Ar date for the Mount Nansen Group itself was on a sample from the Snag map-area - a whole-rock date of 58.4 Ma (Tempelman-Kluit and Wanless, 1975).

The purpose of this study was to determine the age of the Mount Nansen Volcanics of the Miners Range. Chemical studies were done to classify the volcanic rocks and compare their composition and tectonic setting.

Location and Field Work

The Mount Nansen Volcanics described in this report are in the Miners Range, longitude 61° 10', latitude 135° 38', approximately 40 km. north-northwest of Whitehorse, Yukon. Figure 1. shows the geologic setting and location of the study site as well as spatial distribution of K-Ar dates of Mount Nansen Volcanics and related subvolcanics, Nisling Range Alaskite and Ruby Range Granodiorite.

The Geology of the Laberge map-area was originally described by Cockfield, Lees and Bostock of the Geological Survey of Canada in 1936. Revision of the Laberge map sheet is currently in progress by D.J. Tempelman-Kluit of the Geological Survey of Canada. The field work for this thesis was carried out during the summer of 1979 as part of his project.

A field camp was set up for two weeks to map an area of approximately fifteen square kilometres in detail. Air photographs at a scale of approximately 1:40,000 were used. Samples of all rock units were collected for petrography, chemical analysis and K-Ar dating.

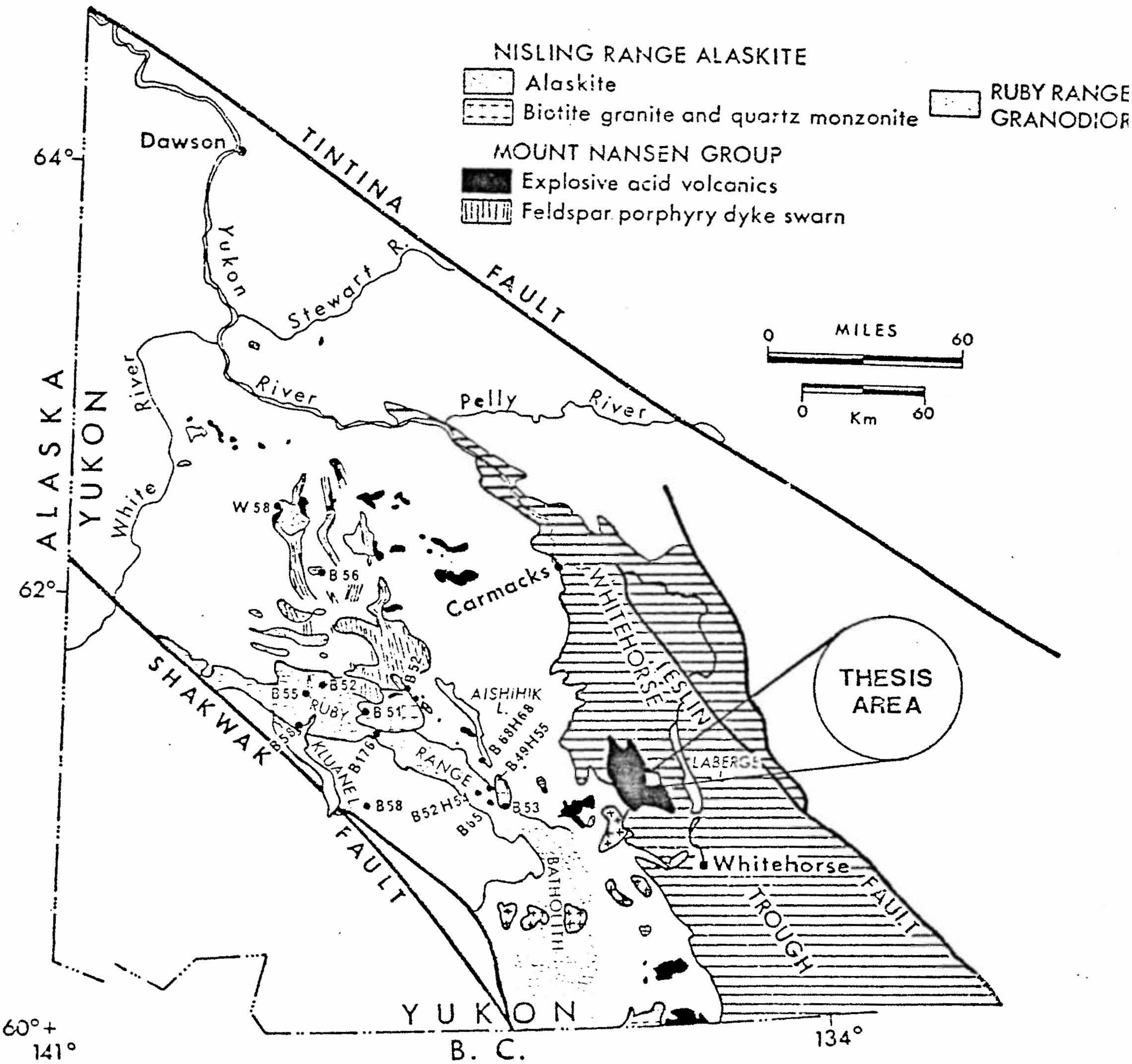


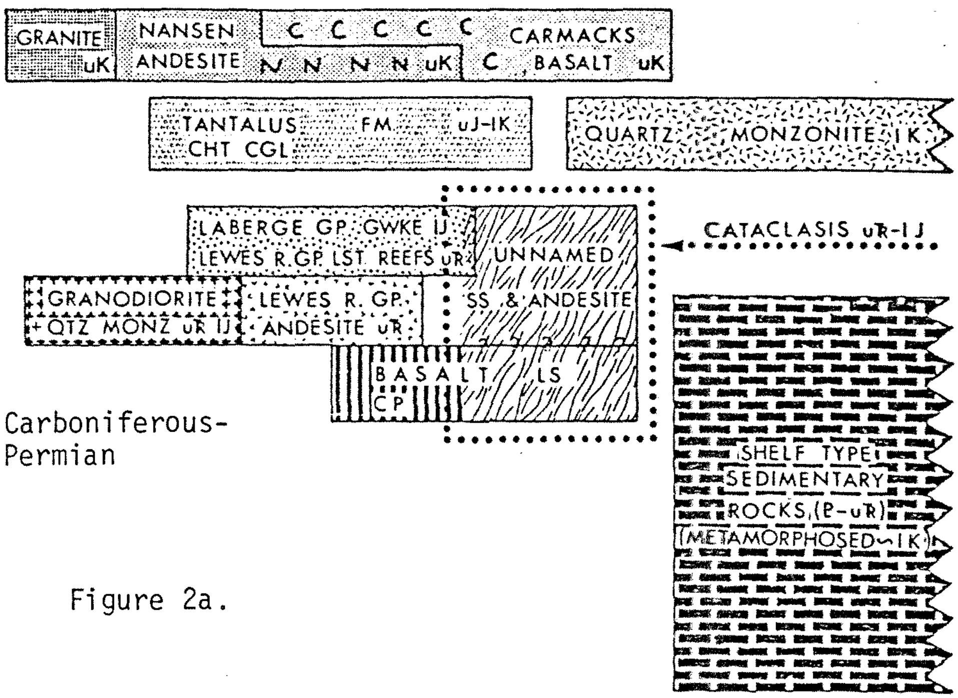
Figure 1. Geologic setting and location of study site as well as spatial distribution of K-Ar dates of Mount Nansen Volcanics and related subvolcanics, Nisling Range Alaskite and Ruby Range Granodiorite.

II REGIONAL SETTING

Laberge map-area comprises 4,500 square miles bounded by latitudes 61 and 62 degrees North and longitudes 134 and 136 degrees West. Most of the Laberge map-area lies within the Intermontane Belt. The eastern quarter of the map sheet is part of the Omineca Belt. Figure 2a. shows the ages and stratigraphic relations between the main rock units of the Laberge map area. The distribution of the main rock units as well as the main tectonic divisions are shown in Figure 2b.

The Intermontane Belt is subdivided into three elements including Yukon Cataclastic Complex, Whitehorse Trough and Yukon Crystalline Terrane (Tempelman-Kluit, 1980). The Yukon Cataclastic Complex includes the Teslin Suture Zone and consits of intensely deformed Upper Paleozoic basalt and Mesozoic sedimentary rocks. The contact between the Teslin Suture Zone of the Intermontane Belt and the Omineca Belt is a southwest dipping thrust fault (Tempelman-Kluit, 1980). Whitehorse Trough comprises Upper Triassic volcanics and overlying carbonate reefs of the Lewes River Group. Also in the Trough are Lower Jurassic greywacke, shale and conglomerate of the Laberge Group. Yukon Crystalline Terrane consists of Early Paleozoic schist, quartzite, marble and amphibolite.

An unconformity separates the Upper Jurassic to Lower Cretaceous chert-pebble conglomerate of the Tantalus Formation from underlying older rocks. Quartz monzonite batholiths of Mid to Upper Cretaceous age intrude Omineca and Intermontane Belt strata in the eastern section



CP - Carboniferous-
Permian

Figure 2a.

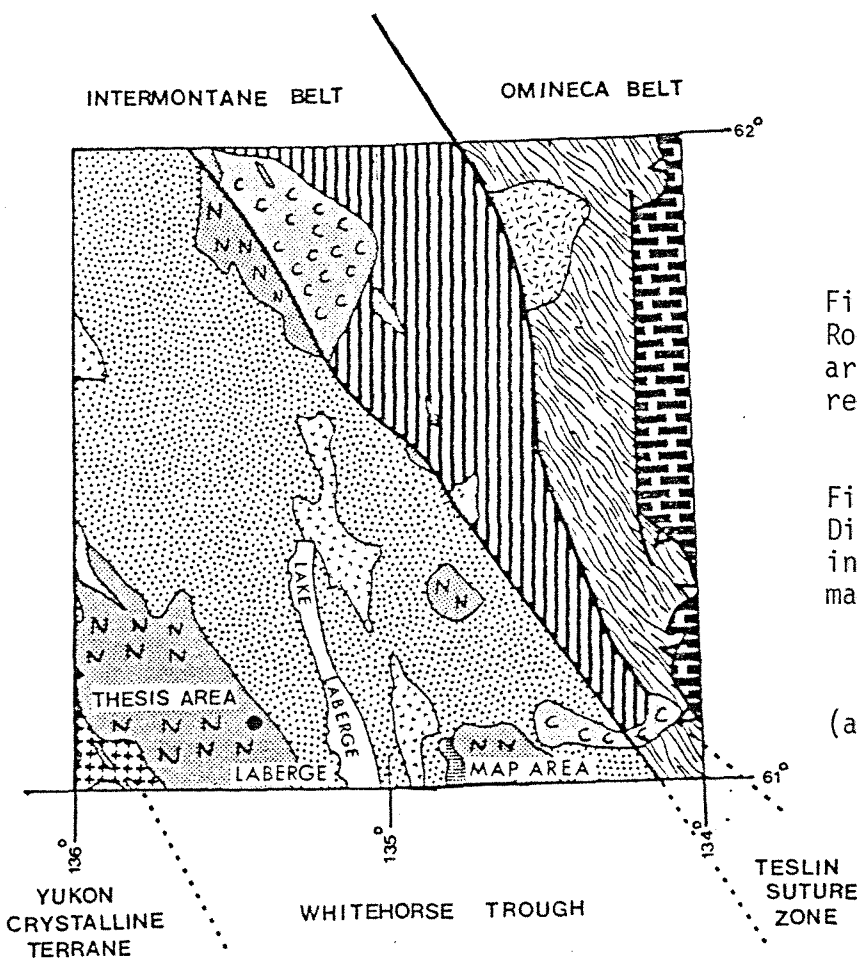


Figure 2b.

Figure 2a.
Rock units of Laberge map-area, age and stratigraphic relations to one another.

Figure 2b.
Distribution of rock units in Laberge map-area and the major tectonic divisions.

(after Tempelman-kluit, 1980)

of the Laberge map-area, and the Whitehorse map-area to the south Morrison et. al, 1979). Volcanic rocks of the Mount Nansen and Carmacks Groups unconformably overlie Cretaceous and older rocks of the Western half of the map sheet and are the youngest rocks present. Associated with the Mount Nansen Group are feldspar porphyry dykes and plugs of the Nisling Range Alaskite which occur in a belt that trends northwest diagonally across Laberge map-area. Tertiary and younger volcanics occur in adjacent map-sheets but are not present in the Laberge map-area. Glacial till and recent sediments overlie much of the area.

III MOUNT NANSEN VOLCANICS

Volcanic rocks of the Mount Nansen Group occur throughout the Yukon Crystalline Terrane east of the White River and south of Dawson, extending into Northern British Columbia (Figure 1.) (Tempelman-Kluit, 1976). The Nisling Range Alaskite, a leucogranite, occurs west of the exposures of Mount Nansen Volcanics. Associated with the Alaskite is an extensive swarm of feldspar porphyry dykes which are its subvolcanic relatives. These feldspar porphyry dykes are closely related to the Mount Nansen Group and locally cut as well as show gradational contacts with it.

Bostock (1936) identified lava flows, breccias and tuffs within the Mount Nansen Group and described them as typically dark grey or greenish grey in colour with a composition ranging from andesitic to basaltic. The rocks are typically porphyritic in texture; the common phenocrysts are hornblende, pyroxene and plagioclase. The lavas are vesicular in places, the vesicles normally filled with carbonate and zeolites. A marked feature of the Mount Nansen Volcanics is their resistance to erosion. They underlie high hills with long steep slopes.

Volcanic rocks of the Skukum Group, Mount Nansen Group equivalents in the Whitehorse map-area, consist of brightly coloured andesites, felsitic and basaltic breccias, tuffs and lavas (Wheeler, 1961). The flows in the Mount Skukum type area have been described as "dark grey and purple porphyritic basalt with plagioclase phenocrysts, pale-green andesite, dark green porphyritic basalt and buff to pale brown rhyolite" (Wheeler, 1961).

Souther (1971) described the Sloko Group, Mount Nansen Group equivalents in the Tulsequah map-area, as mainly pyroclastic rocks, consisting of dark purple, green grey and reddish brown andesites and trachytes alternating with lesser amounts of dacite and rhyolite.

IV LOCAL GEOLOGY, THESIS AREA

The mapped area consists of layered volcanic flows, breccias and an immature sandstone, all of which have been intruded by abundant dykes and sills. Figure 3. shows a map of the thesis area with distribution of rock types. The general structure of the area if a homocline with an average strike and dip of 315 /20 SW. There is some evidence for a SE striking fault through the main valley, including a slight discontinuity of projected lithologies across the valley, and various differences in rock types occuring on either side of the valley. Plate 1. gives a general view of the area and shows the appearance of the layering (looking south).

A total thickness of approximately 2000 metres of the Mount Nansen Group was exposed, 1200 metres of which was measured and described (Figure 4.). The volcanics of the study area can be divided into and upper and a lower assemblage. The upper is distinguished from the lower assemblage by the abundance of carbonate-filled vesicles and a lower abundance of hornblende phenocrysts. Upper assemblage lavas typically have about 2% hornblende, compared to 12% in the lower assemblage. The lower assemblage is host to a much higher density of alkali-rhyolite dykes and sills.

Alkali-rhyolite cuts all the flow units and therefore is the youngest bedrock unit. In the upper assemblage, the rhyolite occurs as dykes and forms lenticular bodies among the flows. In the lower assemblage, the rhyolite occurs as both dykes and sills but both strike

Plate 1. A general view of the study area showing the structure of the volcanic layering (looking south).

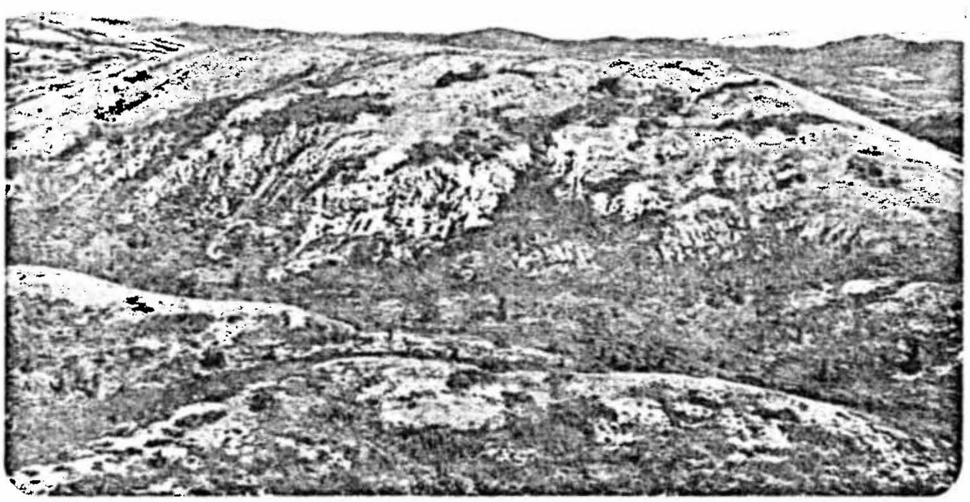


Plate 2. Rhyolite sheets (buff-coloured rock) cutting through the lavas (dark grey rock) and dipping NE. (looking NE)

parallel to the strike of the stratified volcanic rocks. In most cases the rhyolite sheets are conformable with the lava flows but in several areas they dip approximately 60 degrees northeast. Plate 2. shows the rhyolite sheets cutting through the lavas and dipping northeast.

Eight main rock types have been distinguished in the study area. These include three lavas, two types of intrusive rock, two volcanic breccias and one sedimentary unit. The lavas were distinguished on the basis of phenocryst and vesicle abundance. The breccias were grouped according to clast and matrix type. The two intrusive rocks were chemically as well as physically very different. The alkali rhyolite was buff- coloured on a fresh surface and weathered a characteristic rusty orange. The feldspar porphyry dyke was bright green and glomeroporphyritic. Figure 4. shows the distribution of the various rock types throughout a composite section through the volcanics and also gives stratigraphic positions for thin-sections, chemically analysed samples and dating samples. The following descriptions for the various rock types are given in order of first appearance in the section.

Hornblende-Feldspar Porphyry

The lava occurs extensively throughout the lower assemblage. It has abundant altered plagioclase phenocrysts approximately 2 mm. to 8 mm. across. The dark green to black rocks are highly fractured.

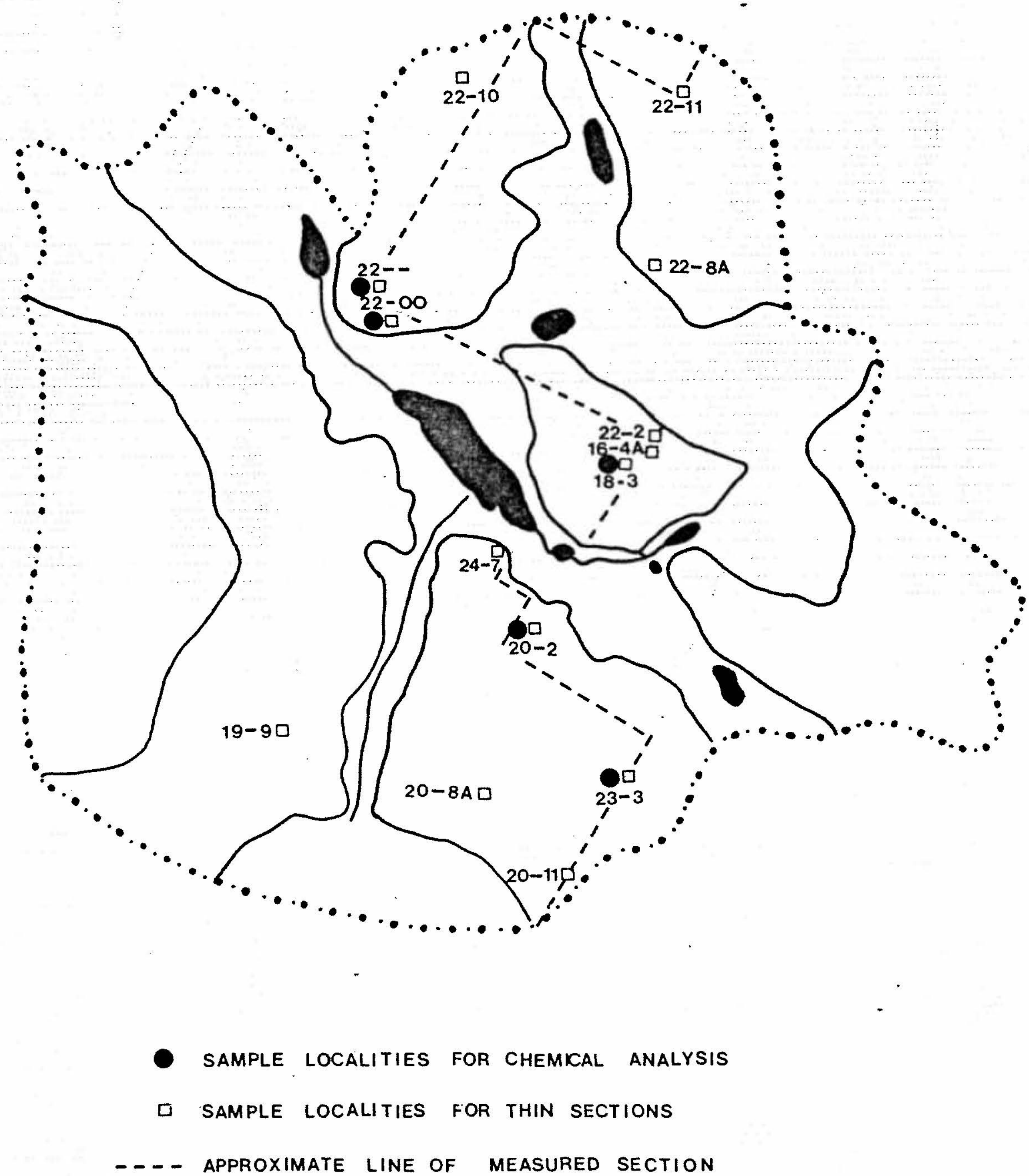

22-10
22-11
22-8A
22--
22-OO
22-2
16-4A
18-3
24-7
20-2
19-9
20-8A
23-3
20-11
SAMPLE LOCALITIES FOR CHEMICAL ANALYSIS
SAMPLE LOCALITIES FOR THIN SECTIONS
APPROXIMATE LINE OF MEASURED SECTION

FIGURE 3a.

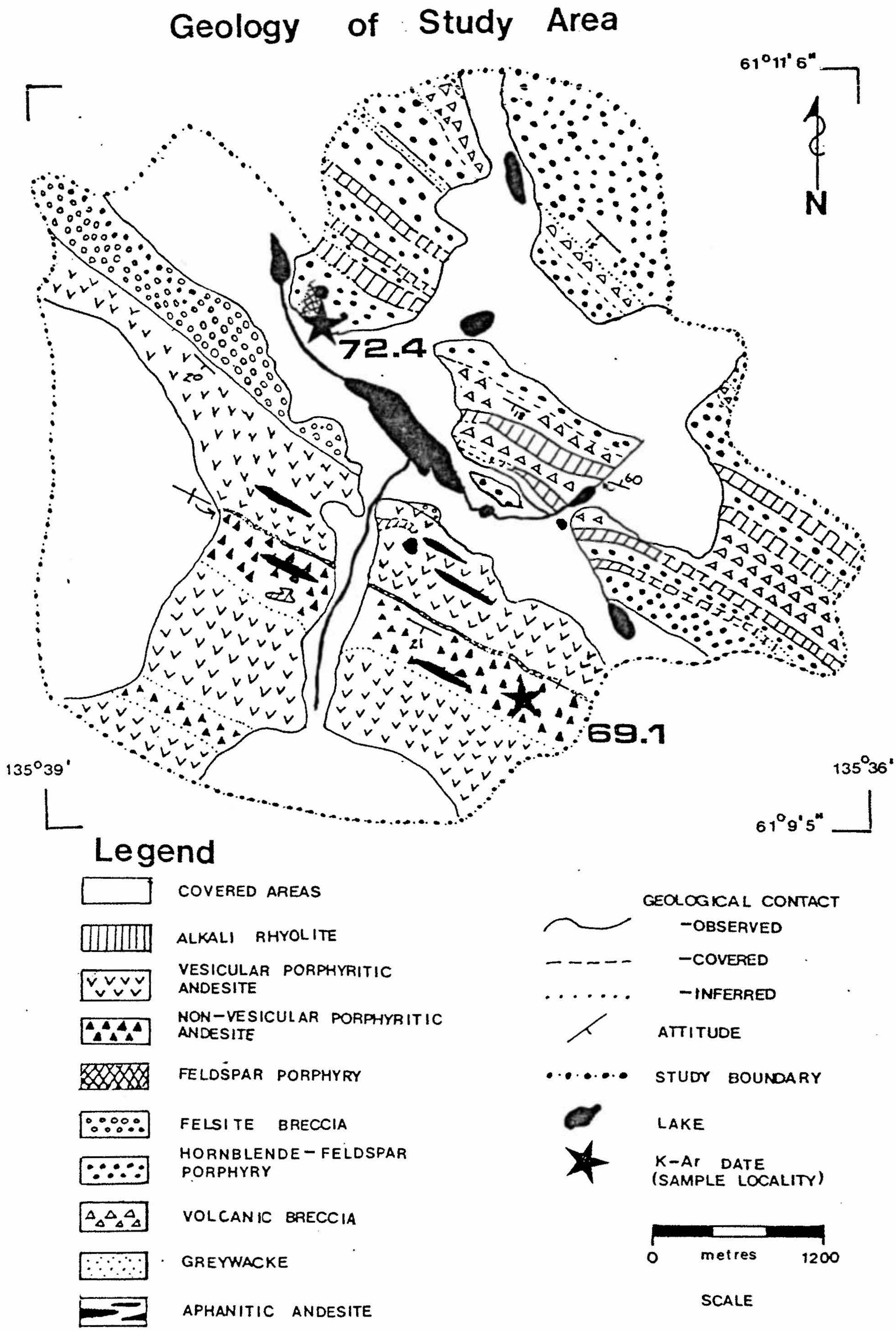

Geology of Study Area
61°11'6"
N
72.4
69.1
135°39'
135°36'
61°9'5"
Legend
COVERED AREAS
ALKALI RHYOLITE
VESICULAR PORPHYRITIC ANDESITE
NON-VESICULAR PORPHYRITIC ANDESITE
FELDSPAR PORPHYRY
FELSITE BRECCIA
HORNBLENDE-FELDSPAR PORPHYRY
VOLCANIC BRECCIA
GREYWACKE
APHANITIC ANDESITE
GEOLOGICAL CONTACT
-OBSERVED
-COVERED
-INFERRED
ATTITUDE
STUDY BOUNDARY
LAKE
K-Ar DATE (SAMPLE LOCALITY)
0
metres
1200
SCALE

Figure 3b.

COLUMNAR SECTION THROUGH MOUNT NANSEN VOLCANICS

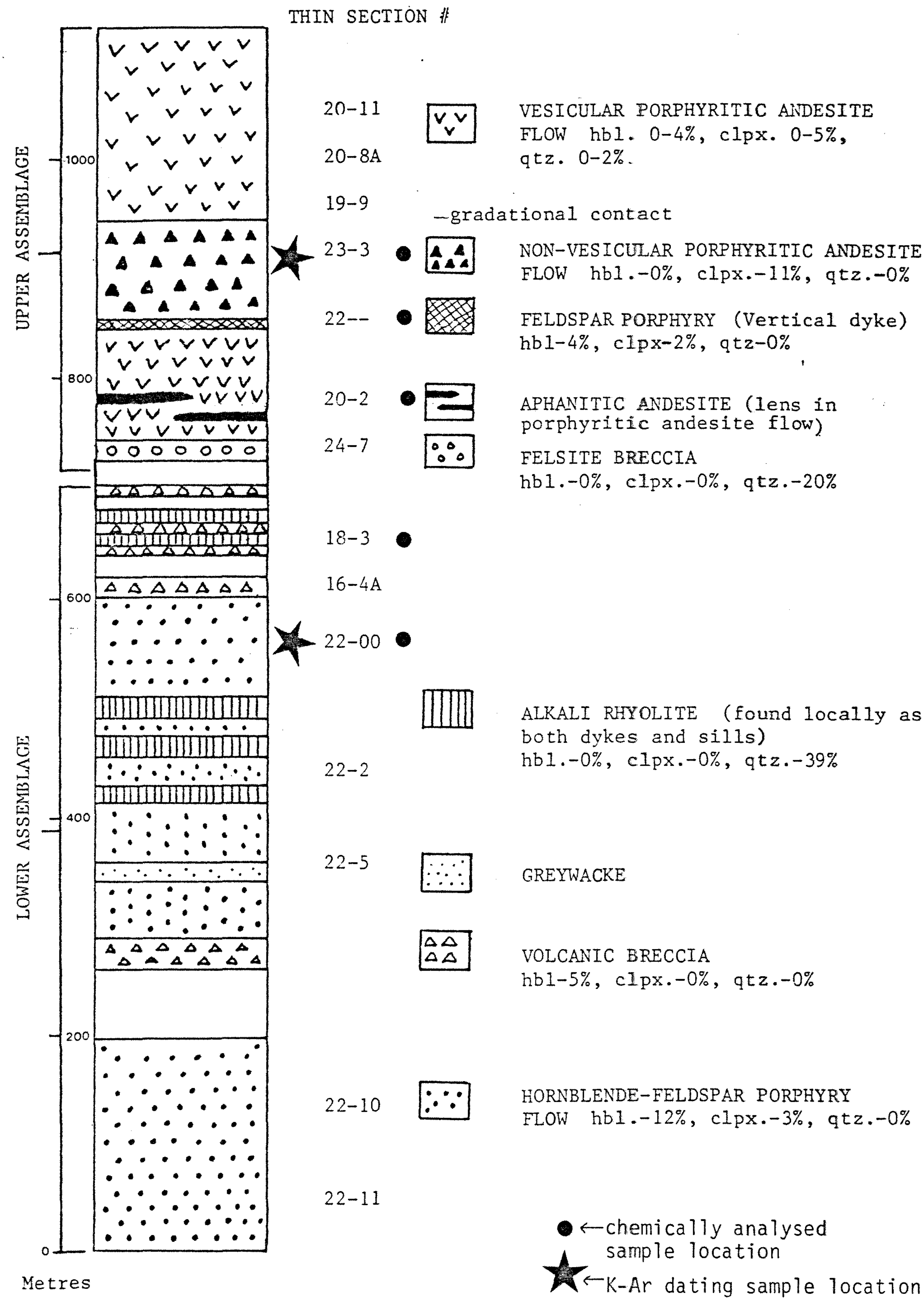


Figure 4.

In thin section a trachytic and pilotaxitic feldspathic groundmass contains feldspar, augite and hornblende. As in all the rock types, magnetite ia abundant in the matrix. Andesine, abundant hornblende and scarce augite phenocrysts are present. The andesine phenocrysts tend to be highly sericitized and albitized. Plate 3. shows the well developed twinning and iron oxide rims of the euhedral hornblende phenocrysts. Extremely fresh augite phenocrysts tend to be glomeroporphyroblastic.

Volcanic Breccia

Volcanic breccia is almost totally composed of angular volcanic clasts. The rocks tend to be dark green to black with paler green patches representing different chemical composition of clasts. In some areas, individual clasts are barely discernable from one another due to the absence of contrasting matrix. In others, such as that shown in Plate 4., the large angular clasts of variable composition, stand out well in contrast to the finer-grained matrix. The clasts are porphyritic with abundant, highly altered plagioclase phenocrysts. A few hornblende phenocrysts are also present. The feldspathic groundmass of the various clasts ranges in texture from hyalophilitic to intersertal to intergranular. Plate 5. shows the intersertal texture of the groundmass of a volcanic clast.

Greywacke

This immature sandstone is composed primarily of volcanic clasts

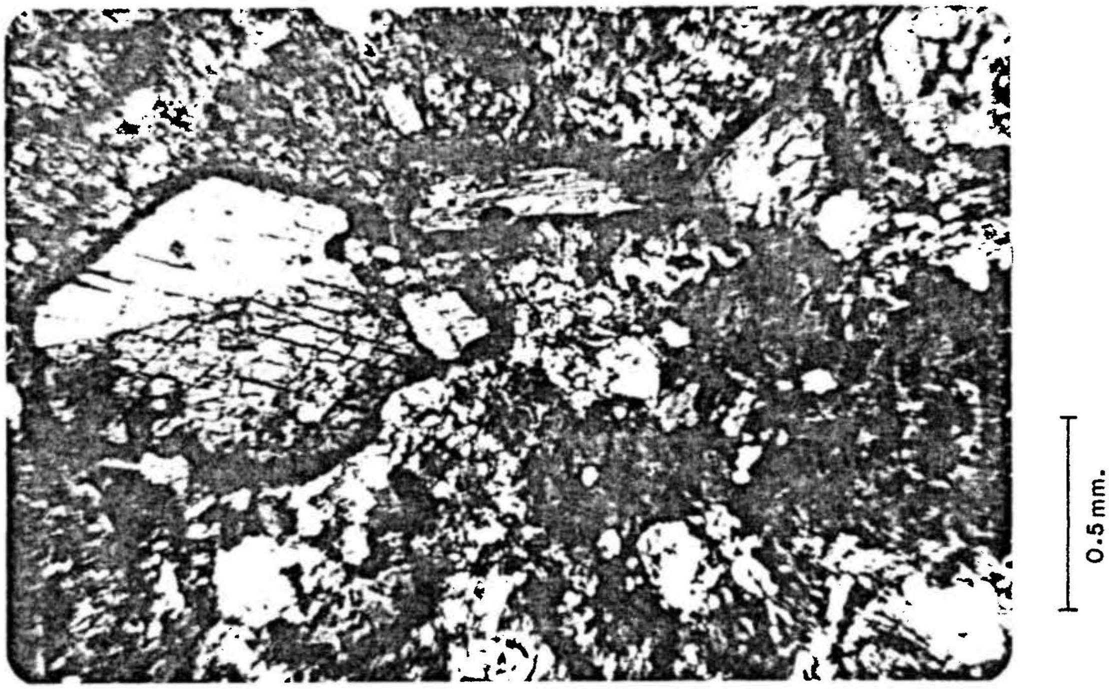


Plate 3. Well developed twinning and iron oxide rims in euhedral hornblende phenocrysts. TOG-79-22-00

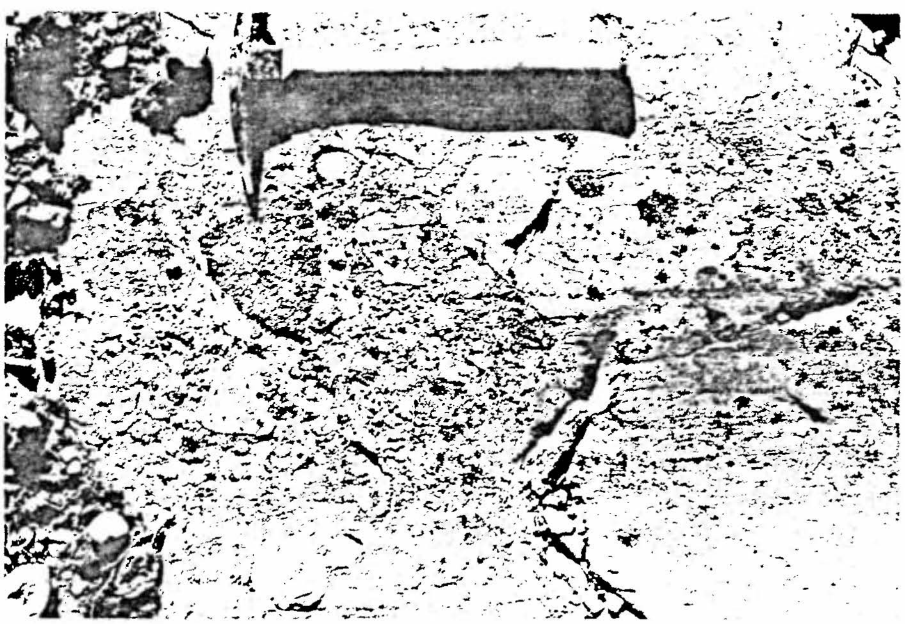


Plate 4. Volcanic breccia with variable sized angular fragments of different composition.

and angular grains. It is pale green to blue in colour and tends to weather to a unique bright rusty ted. Calcite cement is common throughout the rock. The angular quartz grains are free of inclusions and do not exhibit any strain features. There is no immediate source for the quartz within the volcanics themselves. A possible source is the Mesozoic granites which occur south in the Whitehorse map-area. The volcanic clasts are quite angular and certainly were not transported over a great distance before being deposited. They are porphyritic in texture and compostionally are very similar to the volcanics is the area. Plate 6. shows a thin-section of the greywacke with its extremely clean quartz grains and porphyritic volcanic clasts.

Alkali Rhyolite

This highly fractured felsic rock is buff-coloured with orange-red weathered surfaces. It is porphyritic in texture with albitized phenocrysts. The groundmass is mainly fine grained quartz and feldspar. Secondary chlorite, sericite and iron clay minerals are common in both the phenocrysts and matrix. Compositionally, this rock is very similar to the Nisling Range Alaskite to which it is probably related.

Felsite Breccia

This breccia consists of buff-coloured, felsite fragment matrix containing volcanic fragments ranging in size from a few millimetres to several metres in diameter. The volcanic fragments are purple in colour and contain abundant vesicles and feldspar phenocrysts.

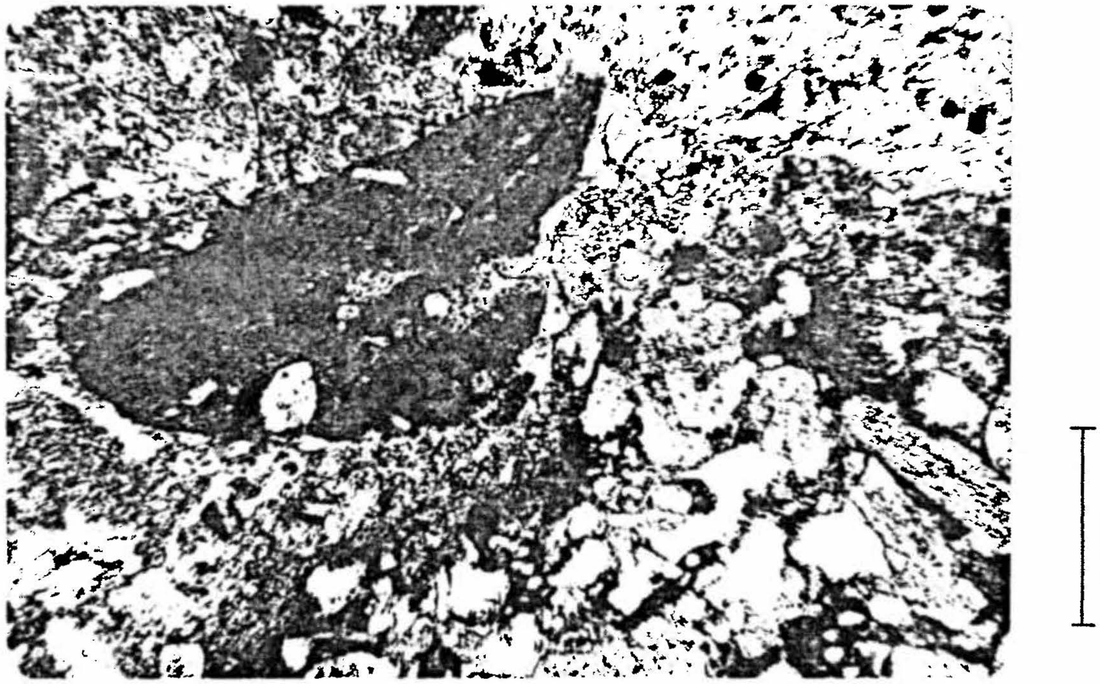


Plate 5. Intersertal texture of the groundmass in volcanic clast in volcanic breccia. TOG-79-16-4A

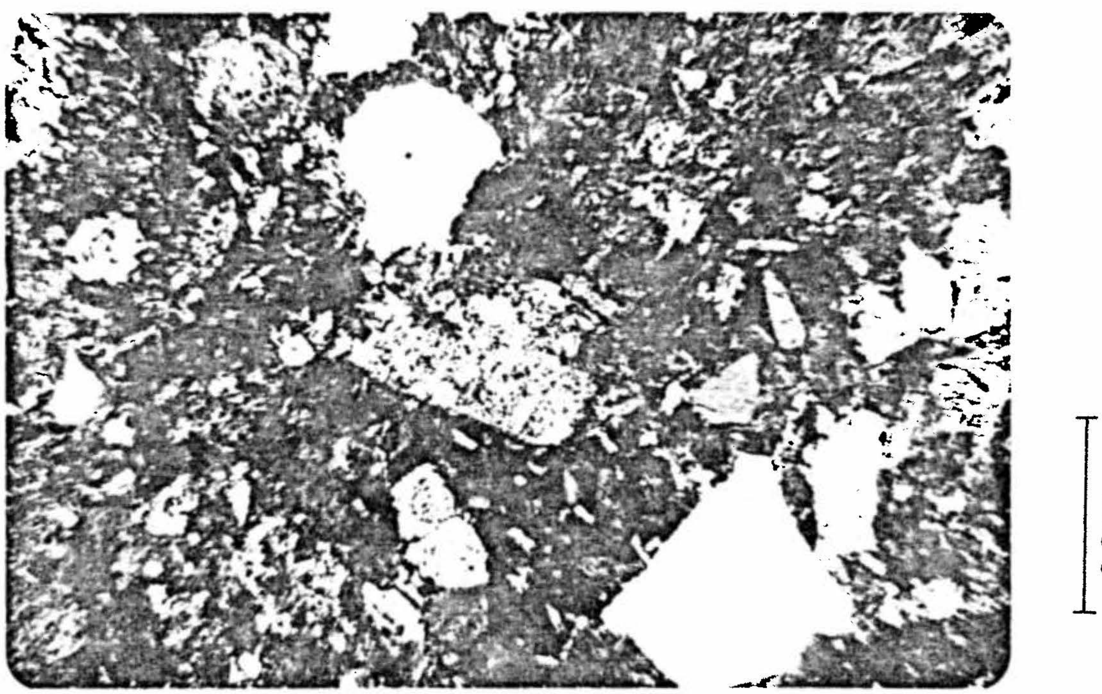


Plate 6. Greywacke with extremely clean quartz and porphyritic volcanic clasts. TOG-79-22-5

The felsite fragments in the matrix bear a strong resemblance to the alkali rhyolite dykes and sills which invade the area.

Aphanitic Andesite

This is a fine grained andesite which can be found as lenticular bodies in both the vesicular and non-vesicular porphyritic andesites. Dark green to black in colour, the rock is less fractured than most of the other rock types. Thin section analysis revealed the presence of minor large feldspar and hornblende phenocrysts which had been almost totally replaced by calcite and chlorite. The majority of the rock was composed of feldspar microlites with trachytic texture. Intense sausseritization is present throughout much of the rock.

Vesicular Porphyritic Andesite

This lava is characterized by abundant calcite and minor chalcedony filled vesicles. The vesicles range in size from 1-3 mm. The structure of the vesicles usually consists of an outer rind of fine-grained quartz, followed by another of magnetite or in some cases specular hematite. Internal to this are radiating chlorite crystals which surround a calcite-filled centre. Plate 7. shows a thin section of a vesicle with the above structure. In some specimens, the vesicles are stretched and parallel in orientation.

The rock ranges in colour from purple to green with no clear spatial colour distinctions. The abundant feldspar phenocrysts are

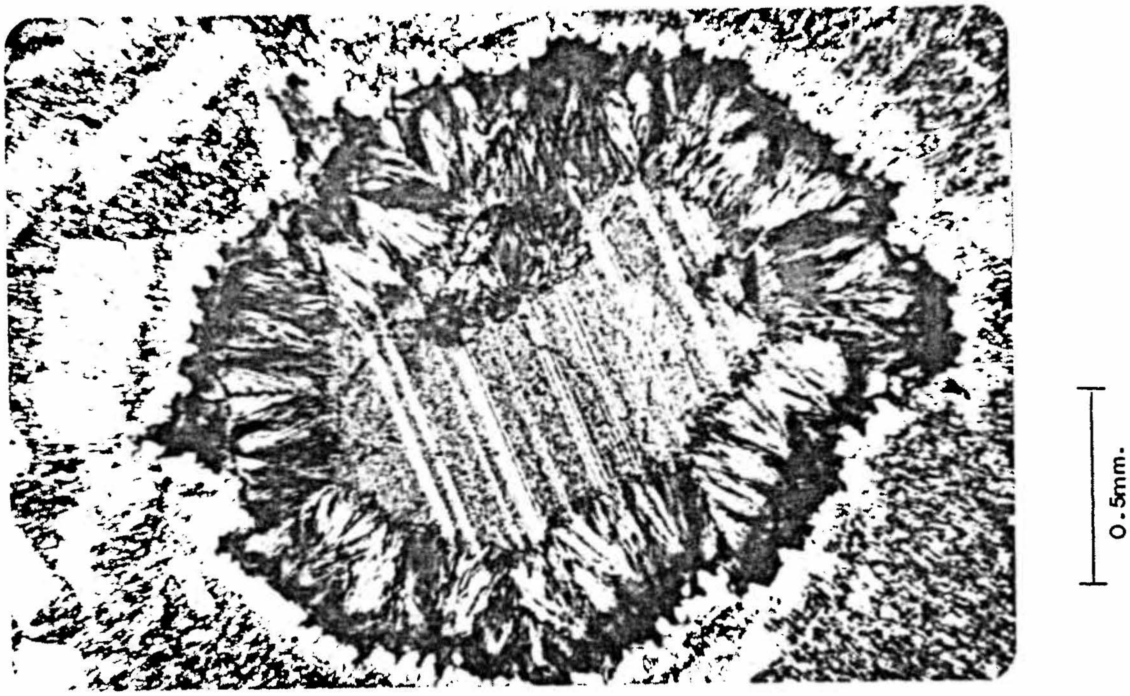


Plate 7. Internal structure of a vesicle with outer quartz rim followed by magnetite, radiating chlorite and infilled with calcite. TOG-79-20-8A

Plate 8. Feldspar porphyry with andesine glomeroporphyroblasts. TOG-79-22--

highly albitized and have been extensively replaced by calcite. The groundmass has relict intergranular texture composed mainly of feldspar microlites with secondary chlorite and sericite.

Feldspar Porphyry

This light green porphyritic rock occurs as dykes in both the upper and lower assemblages. In the upper assemblage it is present in the form of a vertical dyke with strike parallel to volcanic rock strike. The andesine phenocrysts are approximately .5-1 cm. long and are occur as glomeroporphyroblasts as shown in Plate 8. The augite phenocrysts are also glomeroporphyritic but unlike the albitized andesine phenocrysts, they are unaltered. The groundmass mainly consists of feldspar microlites with intergranular augite and hornblende. The groundmass has been highly chloritized and albitized.

Non-Vesicular Porphyritic Andesite

This rock which has a gradational contact with the vesicular porphyritic Andesite is typically dark grey to black in colour with abundant fresh plagioclase phenocrysts. Fresh augite glomero-porphyroblasts are also common as are hypersthene phenocrysts with chloritized rims. The hyalophilitic matrix consists of plagioclase microlites with interstitial hypersthene and augite. Secondary chlorite, calcite and iron clay minerals are present but in minor amounts.

V. GEOCHRONOLGY

K-Ar dating

One whole rock and one plagioclase sample were dated. Sample locations are shown in Figure 3a. and data, technical comments and constants for the analyses are given in Appendix A.

The plagioclase mineral separate was obtained by using heavy liquids and the Frantz-isodynamic separator. The relatively unaltered plagioclase and whole rock were obtained from samples TOG 79-23-3, and TOG 79-22-00 respectively. The dates were 69.1 $\pm$ 2.6 Ma for the plagioclase separate and 72.4 $\pm$ 2.5 Ma for the whole rock. These two dates are concordant and considerably older than the previously reported Mount Nansen whole rock date of 58.4 Ma (Tempelman-Kluit and Wanless, 1975)

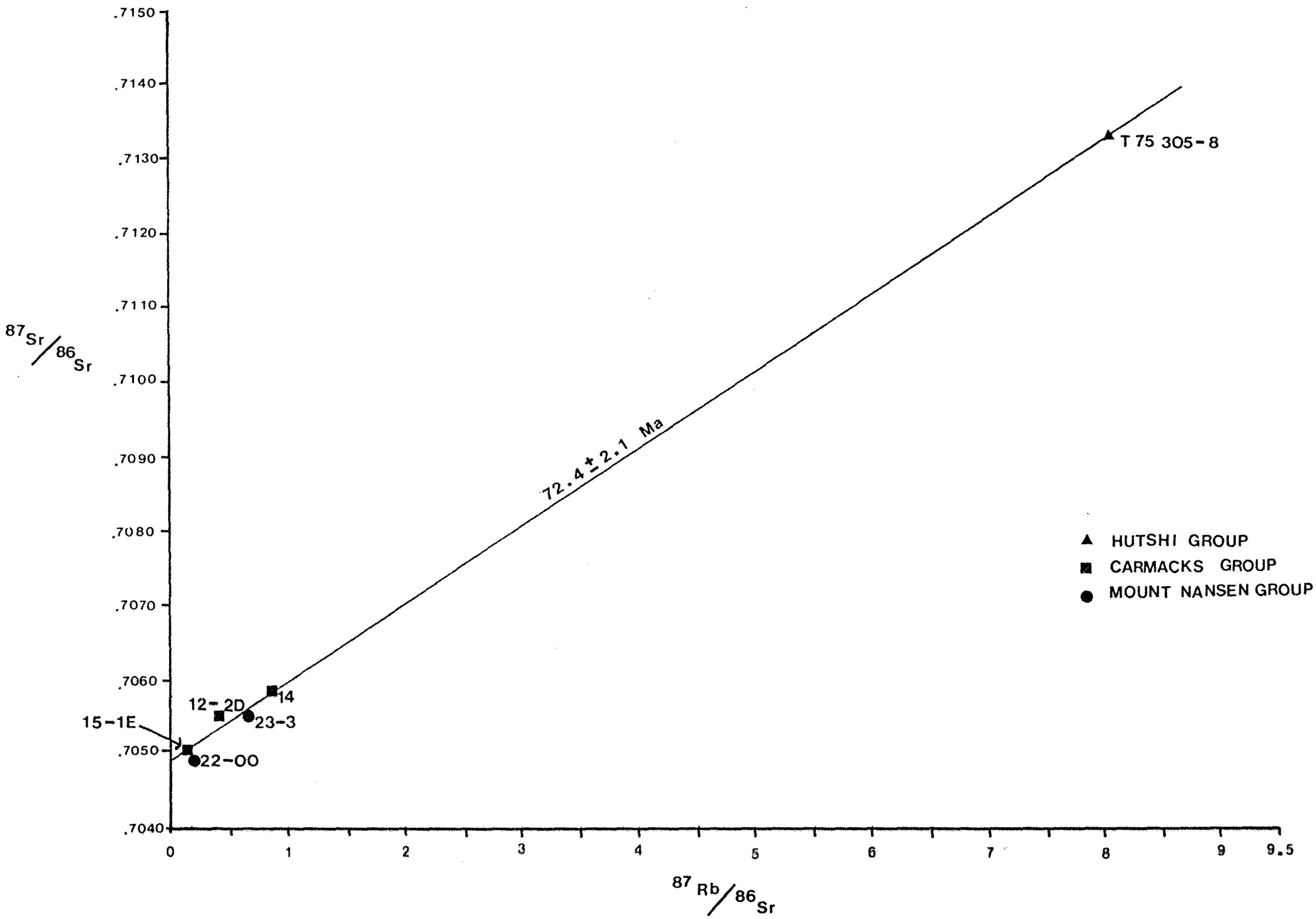
Isotopic dates for igneous rocks of similar age to those in this study include: K-Ar dates for Nisling Range Granodiorite Suite, 67.3 $\pm$ 1.1. Ruby Range Granodiorite Suite, 65.0 $\pm$ 5, 67.6 $\pm$ 2.7, 68.3 $\pm$3.4. Casino Complex, 71.2 $\pm$ 2.6, 69.5 $\pm$ 2.2 (Tempelman-Kluit and Wanless, 1975), Biotite-Quartz Monzanite, Whitehorse map-area, 75.3 $\pm$ 2.8, 64.3 $\pm$ 2.2 (Morrison et. al, 1979), Carmacks Volcanics, 67.9 $\pm$ 2.3, 73.1 $\pm$ 2.5, 68.0 $\pm$ 2.2 (Churchill, 1980) and a Rb-Sr date for Hutshi Volcanics, 72.0 $\pm$ 2(Armstrong, unpublished).

Sr Isotopic Composition

The trace elements, Rb and Sr and Sr isotopic composition were determined on the same samples that were chosen for K-Ar dating. The two Mount Nansen Group Rb/Sr ratios and Sr isotopic composition were compared with three samples from the Carmacks Group (Churchill, 1980) and one sample from the Hutshi Group of Graham Inlet, B.C. The chemical and isotopic data used in the Rb/Sr dating as well as calculated initial ratios are given in Appendix A.

The initial ratio, calculated by the York Least Squares Regression (York, 1969) was .70484 $\pm$ .00007. The isochron obtained gave an age of 72.4 $\pm$ 2.1 Ma (Figure 5.). The Sr initial ratios calculated for the Mount Nansen Volcanics are slightly lower than those of the Carmacks Group which occur further north-east. This south-westerly decrease in Sr initial ratios has been demonstrated in the Yukon (Le Couteur and Tempelman-Kluit, 1976). The values obtained for Sr initial ratios by Le Couteur and Tempelman-Kluit are consistantly higher than those found in this study, although the trend remains clear. This difference is largely due to the fact that igneous rocks were used by Le Couteur and Tempelman-Kluit (1976) while the rocks in this study were volcanic.

Figure 5. Isochron obtained by plotting $^{87}Sr/^{86}Sr$ (initial ratio) versus $^{87}Rb/^{86}Sr$.


.7150
.7140
.7130
.7120
.7110
.7100
.7090
.7080
.7070
.7060
.7050
.7040
87Sr/86Sr
0
1
2
3
4
5
6
7
8
9
9.5
87Rb/86Sr
72.4±2.1 Ma
T 75 305-8
14
12-2D
23-3
15-1E
22-OO
HUTSHI GROUP
CARMACKS GROUP
MOUNT NANSEN GROUP

VI. CHEMISTRY OF MOUNT NANSEN VOLCANICS

Five samples of volcanic rocks including the two dating samples, which were also analysed for Rb and Sr, were analysed for major elements. Two samples, TOG 79-18-3 and TOG 79-22 -- were from dykes and three samples, TOG 79-23-3, TOG 79-22-00 and TOG 79-20-2 were from flows. Sample locations are given in Figure 3.

Standard XRF techniques were used in the determination of the major oxides, Rb and Sr. Fused discs, made following the method of G. Nixon (personal communication) were used to measure SiO_2, TiO_2, Al_2O_3, total iron as Fe_2O_3, MnO, NgO, CaO, K_2O and P_2O_5. All samples were run in duplicate. Na_2O, Rb and Sr were done on pressed pellets of the powdered samples. Loss on ignition was measured on separate aliquots of rock powder. The analyses and molecular normative minerals are given in Appendix B and Table 1 , respectively.

Chemical Classification

Classification of the Volcanics was made using the method of Irvine and Baragar (1971). The initial decision in classifying volcanics is to distinguish between alkaline and subalkaline rocks. This is done using the Ol'-Ne'-Q' triangle (Figure 6.) and the total alkalies versus SiO_2 diagram (Figure 7.)

In the case of the Mount Nansen volcanics in the study area, all the rocks analysed fit closely together in the subalkaline area of

TABLE 1

Table of Normative Compositions

Sample no.	22-00	23-3	20-2	22 --	18-3
symbol	●	■	▲	○	□
orthoclase	10.59	16.30	10.70	15.42	17.44
albite	31.65	34.56	37.48	39.22	49.90
anorthite	23.81	17.97	20.62	20.82	0.0
nepheline	0.0	0.0	0.0	0.0	0.0
diopside	7.7	4.61	7.98	1.09	0.0
hypersthene	13.0	11.60	11.09	9.99	1.06
forsterite	0.0	0.0	0.0	0.0	0.0
fayalite	0.0	0.0	0.0	0.0	0·0
quartz	9.55	10.89	7.69	8.87	24.24
magnetite	2.23	2.37	2.45	2.52	0.0
ilmenite	.88	1.07	1.18	1.27	.19
apatite	.59	.64	.80	.79	.16

Symbols used in Figures 7 to 11

symbol	sample
●	22-00
■	23-3
▲	20-2
○	22 --
□	18-3

Normative plag. = 100 An/(An+Ab')

Normative colour index = C.I.=

Ol + Opx + Cpx + Mt + Il

Ol' - Ol + 3/4 Opx

Ne' - Ne + 3/5 Ab

Q' - Q + 2/5 Ab + 1/4 Opx

An - anorthite, $CaAlSi_2O_8$

Ab - albite, $NaAlSi_3O_8$

Or - orthoclase, $KAlSi_3O_8$

Q - quartz, SiO_2

Ne - nepheline, Na $AlSiO_4$

Opx - hypersthene, $MgSiO_3$ + Fe_2Sio_4

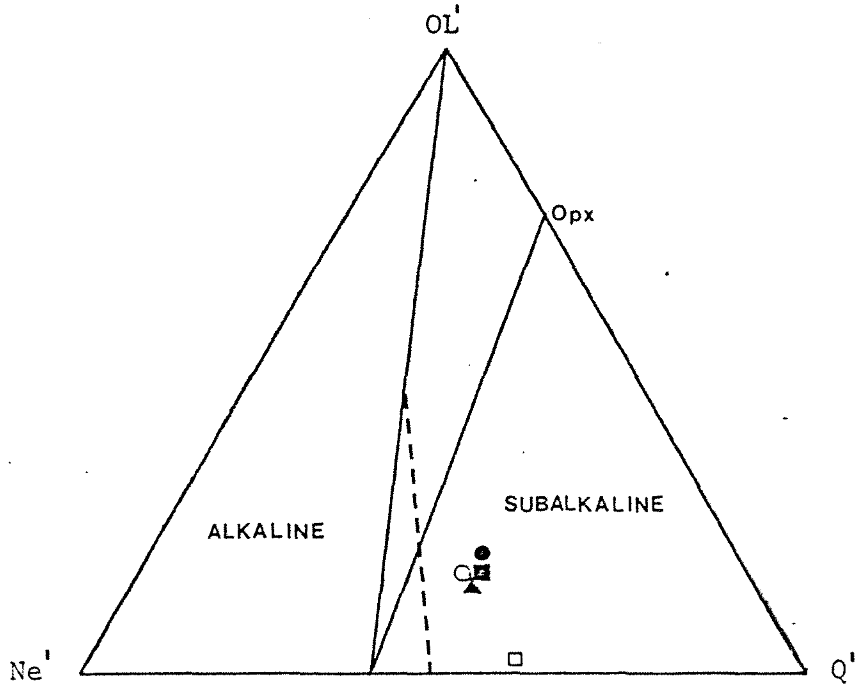


Figure 6. Ol'-Ne'-Q' projections of alkaline and subalkaline rocks. Symbols defined in Table 1.

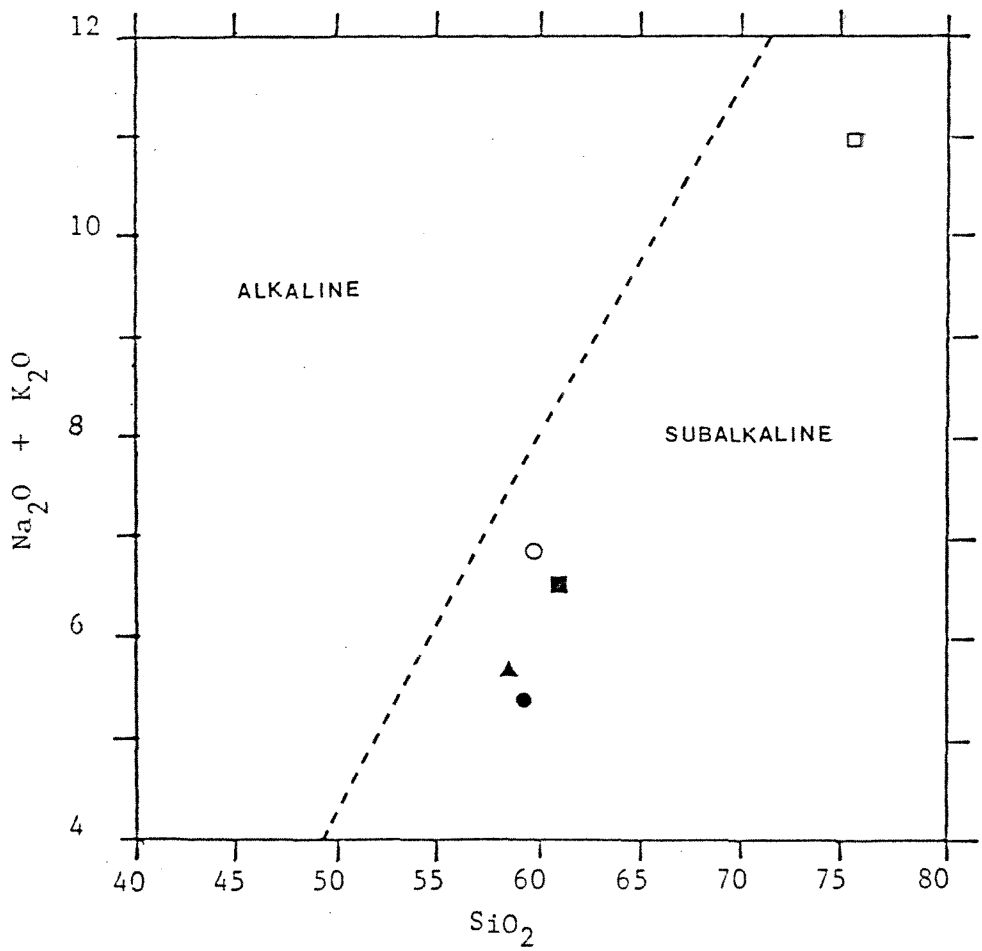


Figure 7. Total alkalis versus silica plot for alkaline and subalkaline rocks. Symbols defined in Table 1.

the Ol'-Ne'-Q' triangle and the total alkalis versus SiO_2 diagram. These subalkaline rocks can be further subdivided into the theoleiitic and calc-alkaline series by means of the A-F-M triangle (Figure 8.) and the Al_2O_3 against normative plagioclase diagram (Figure 9.)

All of the Mount Nansen volcanics were in the calc-alkaline series. The alkali-rhyolite (TOG 79-18-3) is classified as a rhyolite as it is greater than 70% SiO_2 (Irvine and Barragar, 1971). This rock has approximately 10% more SiO_2 than the flow rocks which all have about 60% SiO_2. Chemically and physically the rhyolite is very similar to the Nisling Range Alaskite of the Snag map-area to which it has been correlated (Tempelman-Kluit, 1976). It is likely that the rhyolite is part of the extensive dyke swarm associated with the Alaskite. The other four volcanic rocks analysed were classified as average andesites. This classification is done using the An-Ab'-Or projection (Figure 10.) and the Normative colour index versus the normative plagioclase diagram (Figure 11).

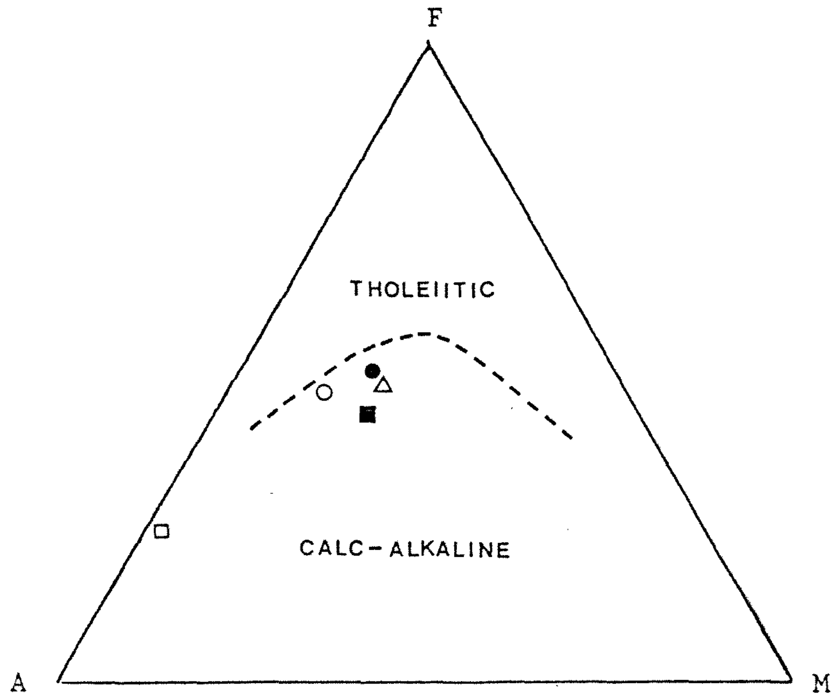


Figure 8. AFM plot dividing average ocean floor tholeiites from calc-alkine rocks. Symbols defined in Table 1.

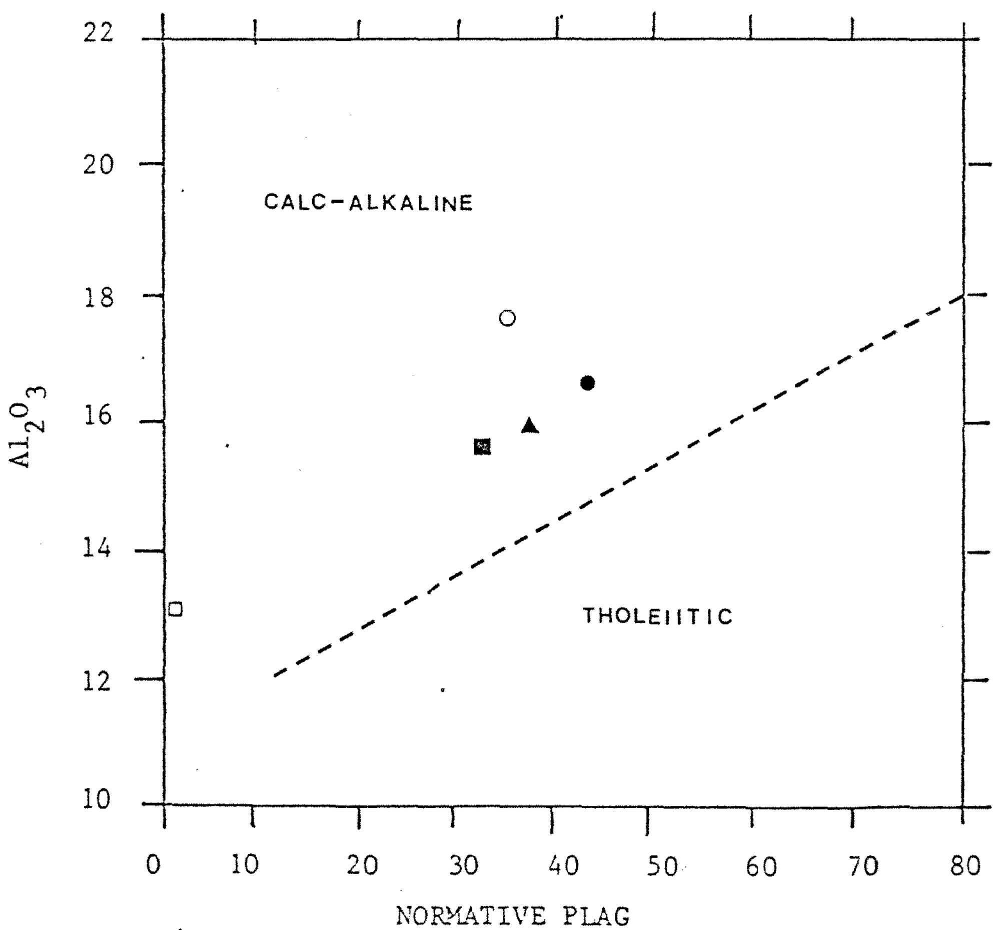


Figure 9 . Plot of wt% Al_2O_3 versus normative plagioclase for subalkaline rocks. Symbols defined in Table 1.

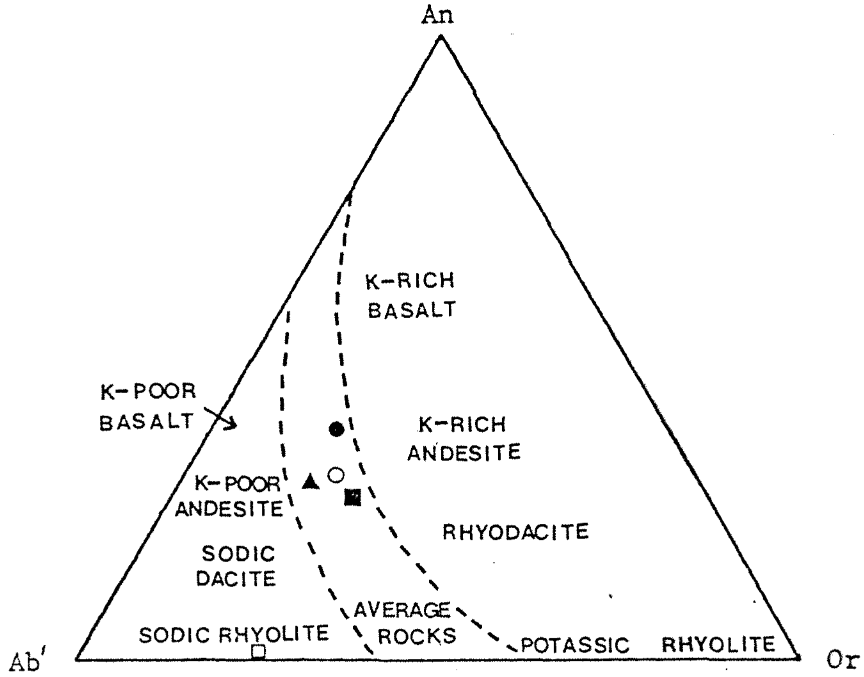


Figure 10. Subdivision of the subalkaline rocks using the An-Ab'-Or projection. Symbols defined in Table 1.

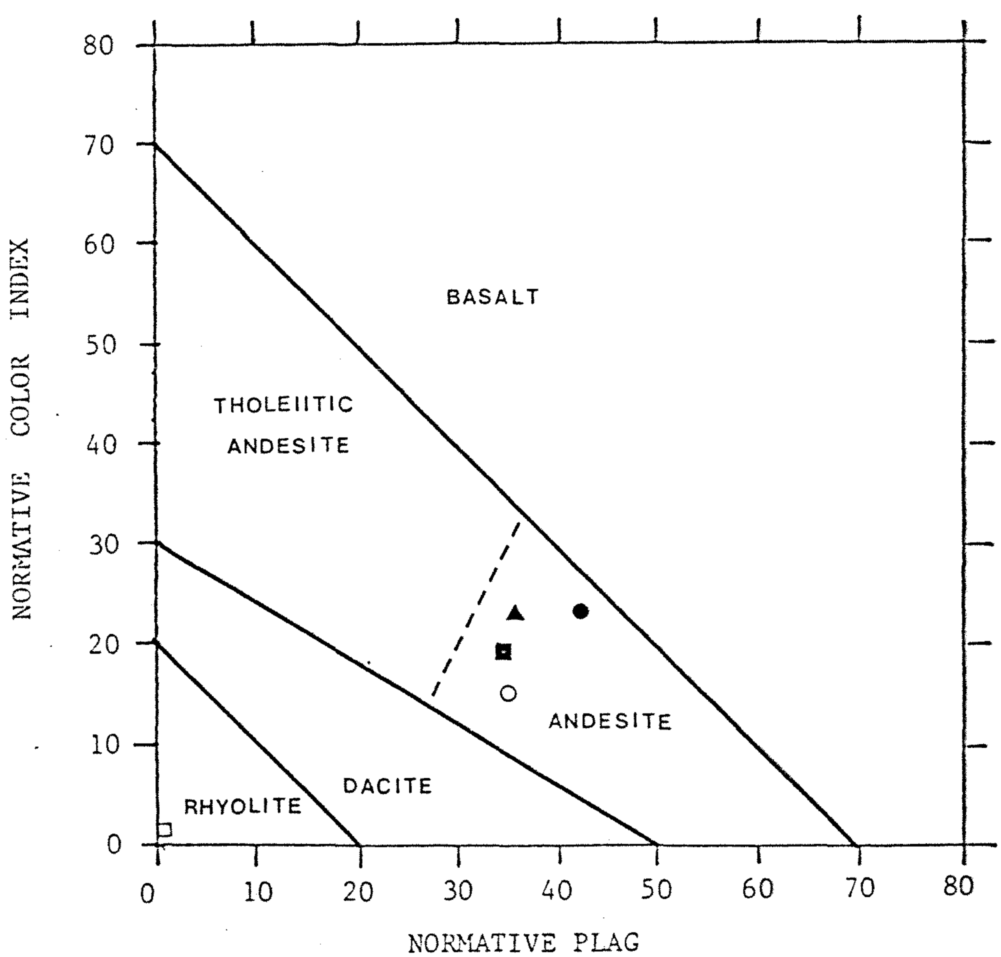


Figure 11. Subdivision of the subalkaline rocks using the normative color index versus normative plagioclase plot. Symbols defined in Table 1.

VII DISCUSSION

The compositional variation of volcanic rocks across Island Arcs has been discussed by several authors including: Kuno (1966), Sugimura (1967), Dickinson (1967, 1968), Coombs and Wilkinson (1969) and Miyashiro (1974, 1975, 1978). Two main types of lateral variation exist including (1) a continuous inland variation from tholeiite to high-alumina basalt to alkali olivine basalt. (2) the same inland variation, minus the tholeiite (Kuno, 1966). The first type of compositional variation exists in Quarternary volcanics in Japan and Kamchatka while the second can be found in the Aleutian Islands, Southwestern Japan, Western United States and Indonesia (Kuno, 1966)

There are several explanations for this phenomena and it appears that different explanations work for different areas. According to Kuno (1966) the two main reasons are: a) Different magmas are produced at different depths; tholeiite at depths around 100 km., high alumina basalts at depths around 200 km. and alkali olivine basalts at depths greater than 250 km. b) A primary olivine tholeiitic magma is produced at a uniform level (100-150 km.) but fractionation of magma occurs at successively greater depths, moving towards the continent. This results in an SiO_2-oversaturated tholeiite on the ocean side, becoming progressively more alkaline towards the continent.

In the central Yukon, a similar type of compositional variation can be found in the Upper Cretaceous volcanics. The Mount Nansen volcanics of the study area are calc-alkaline in composition while the Carmacks Volcanics which occur further northwest on the continent side of the arc are alkaline basalts (Churchill, 1980). The Carmacks volcanics which have been dated as Upper Cretaceous (Churchill, 1980) are coeval with the Mount Nansen Group. These Cretaceous volcanics certainly display the compositional variation across an arc which has been so well demonstrated in Quaternary rocks.

VIII CONCLUSIONS

The K-Ar dates of 69.1 Ma and 72.4 Ma indicate that the Mount Nansen Group of Volcanics in the Miners Range are considerably older than the previous date of 58.4 Ma obtained from a sample collected in the Snag map-area. These, along with the dates of related volcanic and subvolcanic rocks indicate that an age of 65 Ma to 75 Ma is more representative of this volcanic stage than the 50 Ma to 60 Ma that was previously given (Tempelman-Kluit and Wanless, 1975).

The andesite volcanics of the study area consist mainly of porphyritic flows with locally vesiculated layers. Autoclastic breccias as well as an immature greywacke occur between flows. An alkalic rhyolite, probably related to the Nisling Range Alaskite, intrudes the volcanics as a system of dykes and sills.

The calc-alkaline nature of the Mount Nansen Volcanics along with the alkaline basalts of the Carmacks Group represents a good example of compositional variation across a volcanic arc.

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i. Km. 16.3. Drainage work site

2. Km. 5.7. Borrow Pit

3. Km. 22.9. Borrow pit

4. Km. 21.4. Drainage work target

5. Km. 30. Rowlinson Creek, 70-ft.
Bailey bridge D.S.

6. Km. 30. West Bank

7. Km. 30. Rowlinson Creek Bridge - missing transom clamp

8. Km. 30. Rowlinson Creek Bailey bridge

Note: Stressed transom forward of crib.

9. Km. 32.8. Drainage works target

10. Km. 25.1. Drainage work target

11. Km. 36.3. Drainage work site

12. Km. 44.8. Drainage work site

13. Km. 44.8. Drainage work site

14. Km. 46.7. Drainage work site

15. Km. 42.9. Borrow pit

16. Km. 44.8. Drainage work site (major target)

17. Km. 53.1. West aspect from east bank of ford at Victoria Creek

18. Km. 53.1. Looking upstream from east bank of Victoria Creek

19. Km. 53.1. Looking east to west immediately north of ford centreline. Note previous approach development on far bank (west) in left background. Victoria Creek

20. Km. 53.1. South southwest aspect from east bank looking downstream. Ford crossing photo centre. Victoria Creek

APPENDIX `C´

Geometric Road Design Standards

GEOMETRIC ROAD DESIGN GUIDELINES

These are the recommended minimum guidelines for design of Yukon highways. Designs should not be restricted to the minimum if a better standard can be achieved at little or no extra cost. In areas where severe economic penalty would be paid to achieve the minimum then a design of lesser standard may be incorporated.

CLASS		RAU 90	RCU 80	RLU 60		
SADT		400<	<400	<400		
DESIGN SPEED km/h		90	80	60		
Right of Way (m)		60	60	60		
Width	Surface (m)	~~9~~ 11	9	8		
	Grade (m)	~~#~~ as req'd	10	8		
Minimum Radius (m)		700	500	230		
	With Spiral (m)	300	230	120		
SAG. K		40	30	10		
CREST K		85	55	20		
Gradient	Max. %	6	8	11		
	Ditch. %	0.5	0.5	0.5		
Lane width		3.5	3.5	3.5		
Shoulder width		2.0	1.0	0.5		
Ditch width		3.5-1.0	3.5-1.0	3.5-0		
Side Slope	Up to 3m	4:1	3:1 (2m)	3:1 (2m)	7:1	Approaches
	Over 3m	2:1	2:1 (2m)	2:1 (2m)	2:1	
Back Slope		2:1	2:1	2:1	¼:1	Rock
Ditch Slope		20:1	20:1	20:1		
Crown %	Grade	4	4	4	4	1) shoulder
	BST	4	4	4	5	2) on curves
	Asphalt	3	-	-	4	shoulder same as super elev.
TRUCK CLIMBING LANE*						
Speed Reduction		20	30	-		
Accel Taper (m)		190	170	-		
Approach Taper (m)		90	90	-		
Min Length (m)		250	200	-		

*using R.T.A.C. B.2:4a & B.2:4b

Note: Based on RTAC - with some reduction of standard.

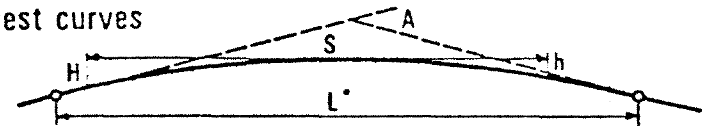
TABLE A

vertical curvature for minimum stopping sight distance

B.2.7

L – length of vertical curve in metres
A – algebraic difference in grades percent
S – minimum stopping sight distance in metres
H – height of drivers eye 1.05m
h – height of object
K – $\frac{L}{A}$

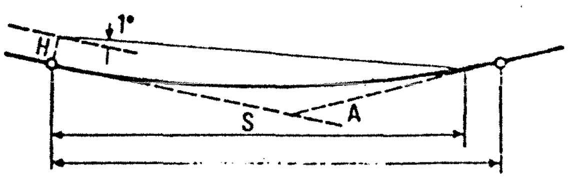
crest curves



design speed (km/h)	stopping sight distance (m)		crest, K (m)	
	minimum (a)	desirable (b)	minimum (c)	desirable (d)
40	45	45	4	5
50	65	65	7	10
60	85	90	15	20
70	110	120	22	35
80	140	150	35	55
90	170	180	55	85
100	200	210	70	110
110	220	240	85	140
120	240	260	105	170
130	260	280	120	200
140	270	300	130	220

* L in metres should be not less than design speed in kilometres per hour
(a) based on fixed perception reaction time of 2.5 s
(b) based on variable perception reaction time of 2.5 s at 40 km/h to 3.5 s at 140 km/h
(c) based on fixed perception reaction time and tail light height of 380 mm
(d) based on variable perception reaction time and object height of 150 mm

sag curves



L – length of vertical curve in metres
A – algebraic difference in grades percent
S – minimum stopping sight distance in metres
H – height of head lamps 0.6 m
1° – angle of light beam upward from plane of vehicle
K – $\frac{L}{A}$

design speed (km/h)	stopping sight distance (m)	sag, K (m) minimum	
		headlight control	comfort control
40	45	7	4
50	65	11	6
60	85	20	10
70	110	25	15
80	140	30	20
90	170	40	20
100	200	50	25
110	220	55	25
120	240	60	30
130	260	65	
140	270	70	

* L in metres should be not less than design speed in kilometres per hour
centripetal acceleration 0.3 m/s²