. 179c

PETROLOGY, GEOCHEMISTRY AND STRUCTURE

OF THE LATE INTRUSIVES

OF

THE JAFFRAY-MELICK AREA

NORTH WESTERN ONTARIO

PETROLOGY, GEOCHEMISTRY AND STRUCTURE
OF THE LATE INTRUSIVES
OF
THE JAFFRAY-MELICK AREA,
NORTH WESTERN ONTARIO

By

G. MICHAEL FESTERYGA

Submitted to the Department of Geology
in Partial Fulfilment of the Requirements
for the Degree
Bachelor of Science

McMaster University

May, 1977

BACHELOR OF SCIENCE (1977)
(Geology)

McMASTER UNIVERSITY
Hamilton, Ontario

TITLE: Petrology, Geochemistry and Structure of the Late Intrusives of the Jaffray-Melick Area, North Western Ontario.

AUTHOR: G. Michael Festeryga

SUPERVISOR: Dr. R. H. McNutt

NUMBER OF PAGES: viii, 94

SCOPE AND CONTENTS:

Crosscutting all of the major lithologies of the Jaffray-Melick area are numerous sharply discordant late synkinematic and post kinematic minor intrusions. In terms of field relationships, petrography and geochemistry, these intrusions may be subdivided into four main Groups:

- Group 1 Undeformed suite of micrograni tes, layered pegmatitic-microgranitic mixed intrusives and granite pegmatites.
- Group 2 Deformed suite of microgranites, mixed intrusives and pegmatites very similar to the above Group 1.
- Group 3 Deformed microgranodioritic to microgranitic intrusives temporally associated with the Group 2 suite.
- Group 4 Deformed microgranodioritic intrusions which are chemicaly and morphologicaly distinct from the above 3 Groups.

The form of the intrusives is usually dike like, as they commonly intrude along preformed joint surfaces. Analysis of the orientation of these surfaces for the undeformed Group 1 dikes combined with observations on dike distribution suggests that the emplacement of the dikes

was controlled by structures developed by intrusion of the elliptical Dalles body.

Comparison of the geochemical data on the late intrusives with analyses of one phase of the Dalles intrusion, suggests that the source melt for the Groups 1-3 dikes was a residual phase of the large Dalles body. The chemical differences between these groups, which are not large, could have developed due to polybaric fractionation of the residual phase induced by rapid pressure loss associated with the emplacement of the dikes.

Once expelled from source area, the undersaturated, granitic melt became strongly enriched in volatiles due to a process of along dike accretional crystallization. In this way the pegmatite intimately associated with the microgranites was formed.

Fig. 1 Groups 1 and 2 dikes on outcrop.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the kindness and patience of Mr. C. Gower. Without his helpful advice and friendly prodding, this work may never have been completed.

Thanks should also go to Dr. R. H. McNutt who supervised the project and whose guidence in the realm of Geochemistry was very valuable. The section on structure was reviewed by Dr. P. M. Clifford, who made valuable suggestions which the author gratefully acknowledges.

Lastly, I would like to thank Mr. J. Whorwood for his timely assistance in producing the photographs contained in this volume.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE		PAGE

CHAPTER I

INTRODUCTION

Location and Accessability

The Jaffray-Melick area is located north of Kenora within the southern portion of the English River Subprovince, immediately north of the contact with the Wabigoon Subprovince of the Superior Province of the Canadian Shield. Specifically, it is bounded by latitudes 49° 46' 30", 49° 54' 30" and longitudes 94° 30' 00", 94° 20' 30" and comprises an area of approximately 100 km^2. (Gower (1975)).

Road access to the area is excellent as is shown by Fig. 3. Furthermore, the presence of newly blasted power lines and a natural gas pipeline, as well as major road improvements in progress during the 1975 field season, afforded excellent opportunities to collect very fresh samples for geochemical analysis.

Previous Work and General Geology

Initial recornaissance scale mapping of the area by the Ontario Division of Mines (Breaks et al. (1974)) has shown that the geology is that of a complex intrusive metamorphic terraine of amphibolite grade.

During the 1975 field season one member of the above party (C.F. Gower) returned to the area to conduct a detailed mapping project as part of his Ph.D. degree. The present author being employed at that time by McMaster University as Gower's assistant.

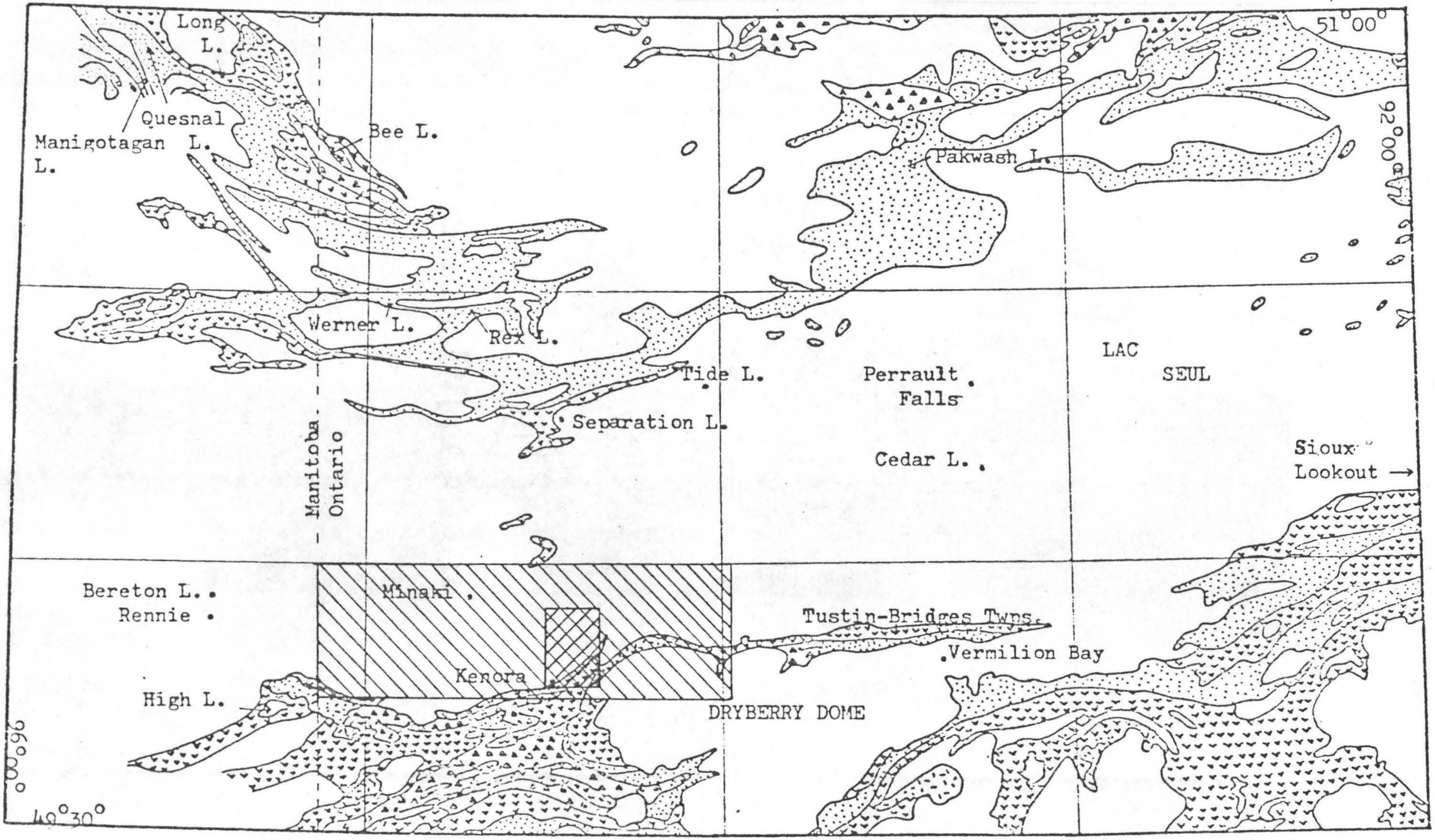


Fig. 2 Regional Geology in the western half of the English River Gneiss Belt. Simplified from Ontario Division of Mines and Manitoba Mines Branch compilation maps.

Mafic, Ultramafic Intrusive Rocks; Mafic Extrusive Rocks; Felsic Volcanic Rocks; Sediments; Granitic Rocks

Kenora District; Jaffray-Melick Area Gower (1975)

Gower (1975)

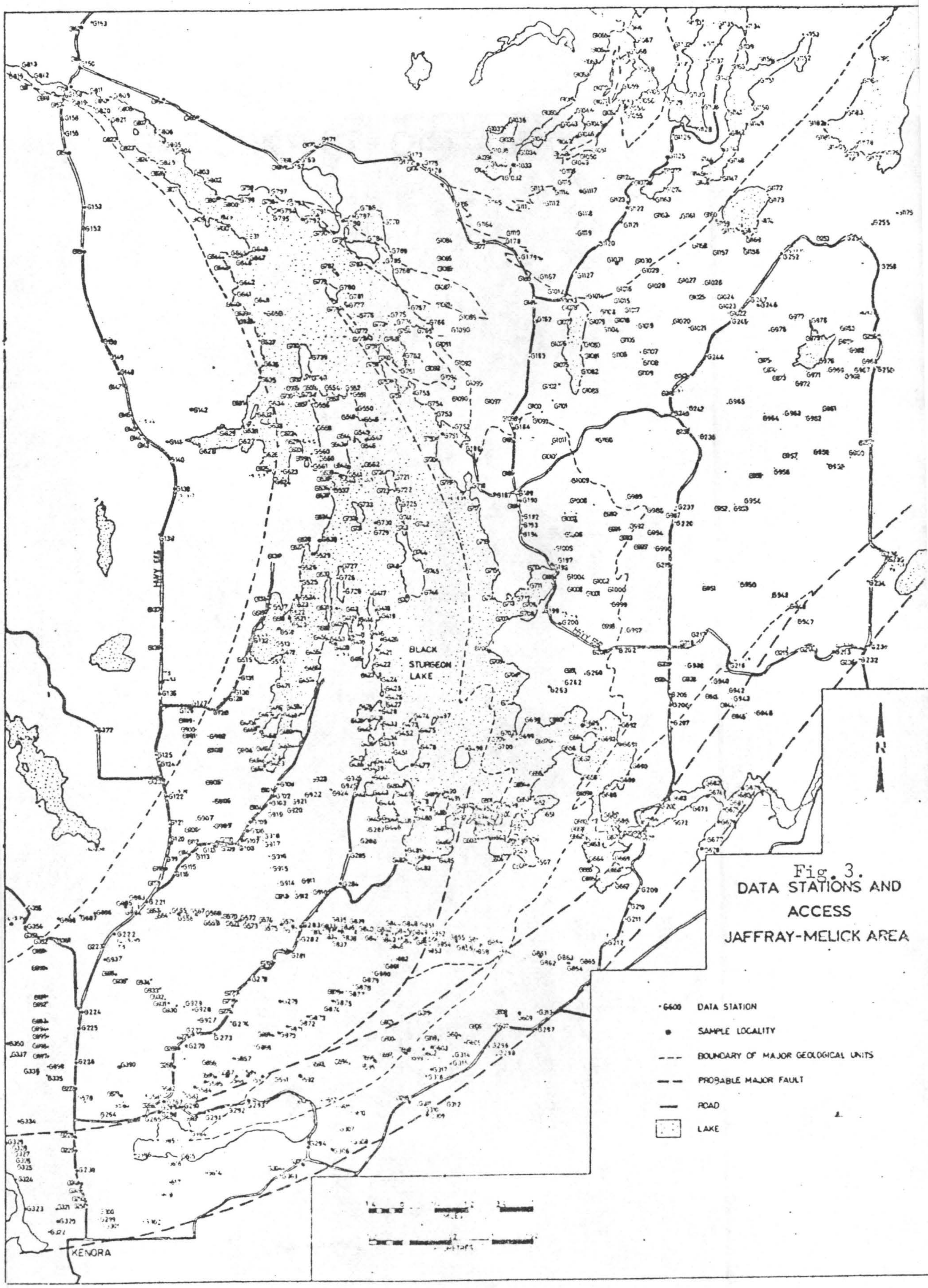
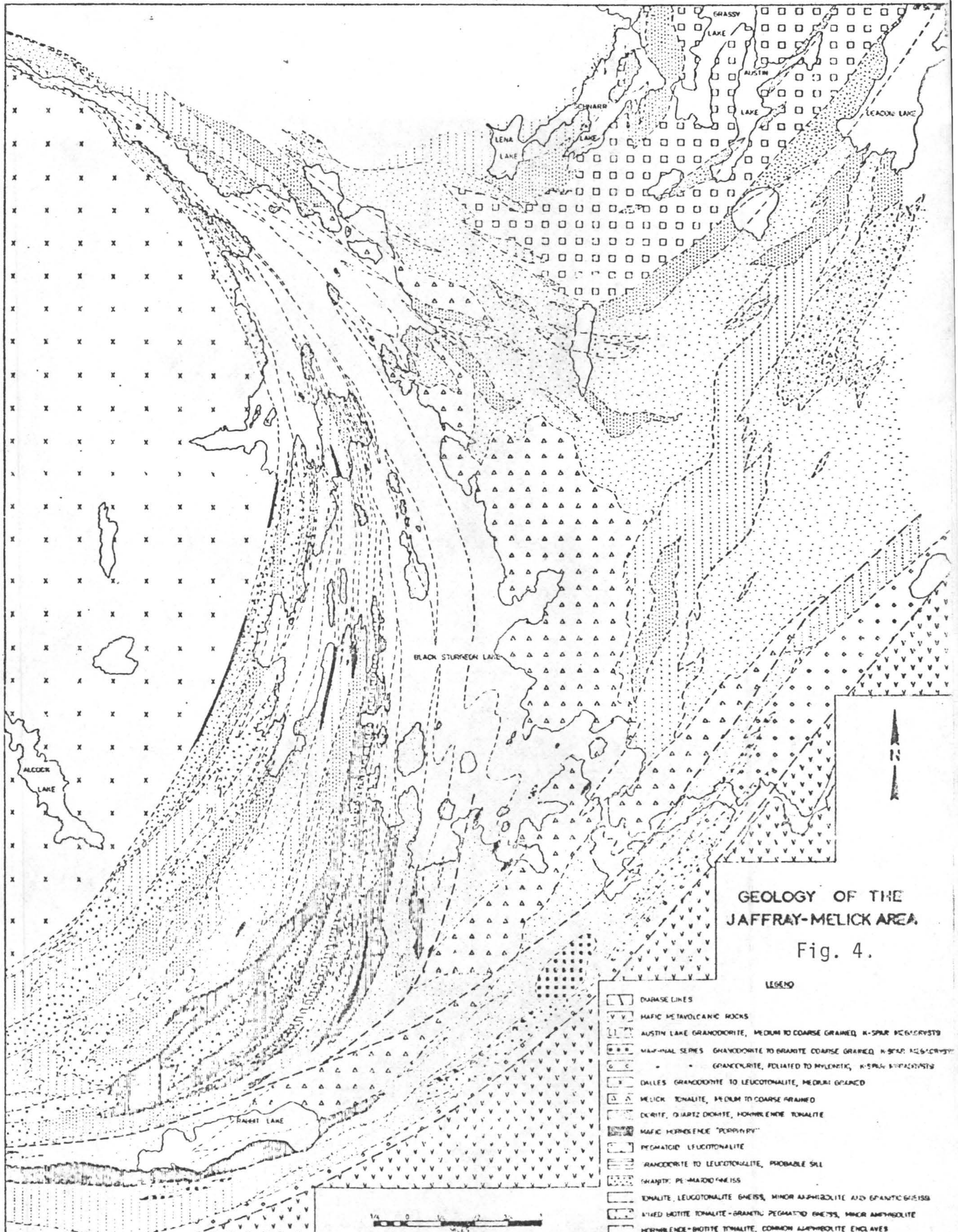


Fig. 3.
DATA STATIONS AND ACCESS
JAFFRAY-MELICK AREA

Gower (1975)



GEOLOGY OF THE JAFFRAY-MELICK AREA

Fig. 4.

As determined by Gower (1975), the geology may be subdivided into four main lithologic units: 1) gneisses, 2) Melick tonolite, 3) Dalles granodiorite-tonolite and 4) Austin granite.

The isoclinally folded and refolded banded gneisses were subdivided by Gower (1975) into mappable units by estimating the outcrop proportion of three end member components; 1) amphibolite, 2) granitic pegmatoid material, and 3) biotite tonalite. These units themselves have been deformed and are intimately associated with the somewhat conformable body of homogeneous, medium grained foliated biotite tonolite which dominates the east side of Black Sturgeon Lake. (Melick tonalite).

The largest igneous body in the area is a nose of the large Dalles intrusive, which intruded and severely flattened the already complexly deformed gneisses into a north-easterly dipping rim synform.

The Dalles itself is a remarkably homogeneous body, being composed of greyish pink, equigranular biotite granodiorite-tonolite. The margins of this intrusive are gneissic, but the boundary is not gradational as it is always mantled by a thin layer of amphibolite.

Apart from minor quartz dioritic bodies, the last major intrusive phase in the area is the Austin granite, which is a medium to coarse grained seriate to porphyritic biotite granite. This body intrudes the gneisses of the North east with sharp contacts and large angular roof pendants.

The contact between the gneisses and the greenschist metavolcanics of the Wabigoon belt is intruded, by a thin .5 km wide band of cataclastic granodiorite of unknown relationship to the other intrusives of the area. In addition the southern portion of the area has been crosscut by the Rabbit Fault along which, there has been apparent dextral displacement of several kilometers.

Statement of the Problem

Crosscutting all the major lithologies of the Jaffray-Melick area are numerous, sharply discordant intrusives of primarily granitic or granitic-pegmatitic composition. Although generally volumetrically minor, these intrusives, none the less, represent a discrete phase of igneous activity. Hence, a description of the geological history of the area would be incomplete without their inclusion.

Therefore the purpose of the present work will be to describe the late postkinematic discordant minor intrusives of the Jaffray-Melick area and to relate their petrogenesis (in terms of petrography, geochemistry and structure) to the development of the geology of the area as a whole.

CHAPTER II

FIELD OBSERVATIONS AND DESCRIPTIVE PETROGRAPHY

In terms of field interrelationships and petrographic evidence, the late post kinematic intrusives of the Jaffray-Melick area may be subdivided into four separate groups.

Group 1 is volumetrically the most significate and also the youngest. Quantitative estimates of this proportion are difficult, but appears to be 75-80%.

Group 2 contributes some 18 to 22% of the late granitic material. Temporarily related to Group 2, but compositionally distinct is Group 3 which is insignificant volumetrically. Both these groups are cross cut by Group 1.

The oldest intrusives dealt with in this study are those of Group 4 which are crosscut by all of the above intrusive groups. This group may contribute 2-3% of the total late intrusive material.

GROUP 1

Form

The form and size of the intrusions of the late (Group 1) suite are highly variable, ranging from fine rectiplanar, en echelon veins less than 1 cm in width to a large (2500 m^2) irregular granitic body at G188.

Intrusives less than .5 m in width are numerically the most abundant (95%) and are always dike like in form. The very thinest

Fig. 5 FINE EN ECHELON VIENS

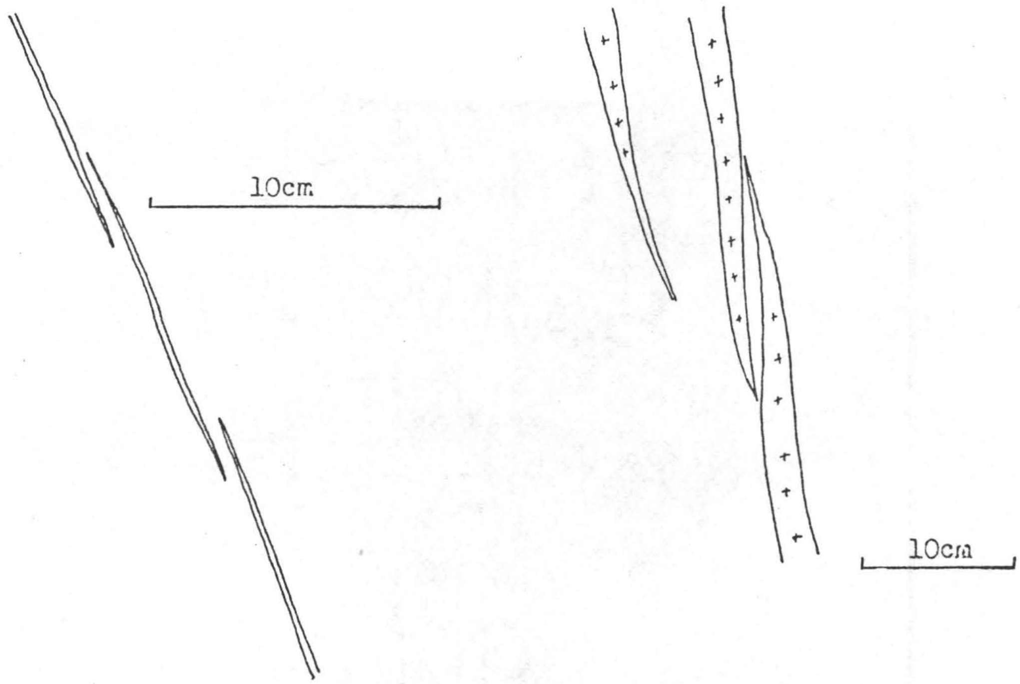
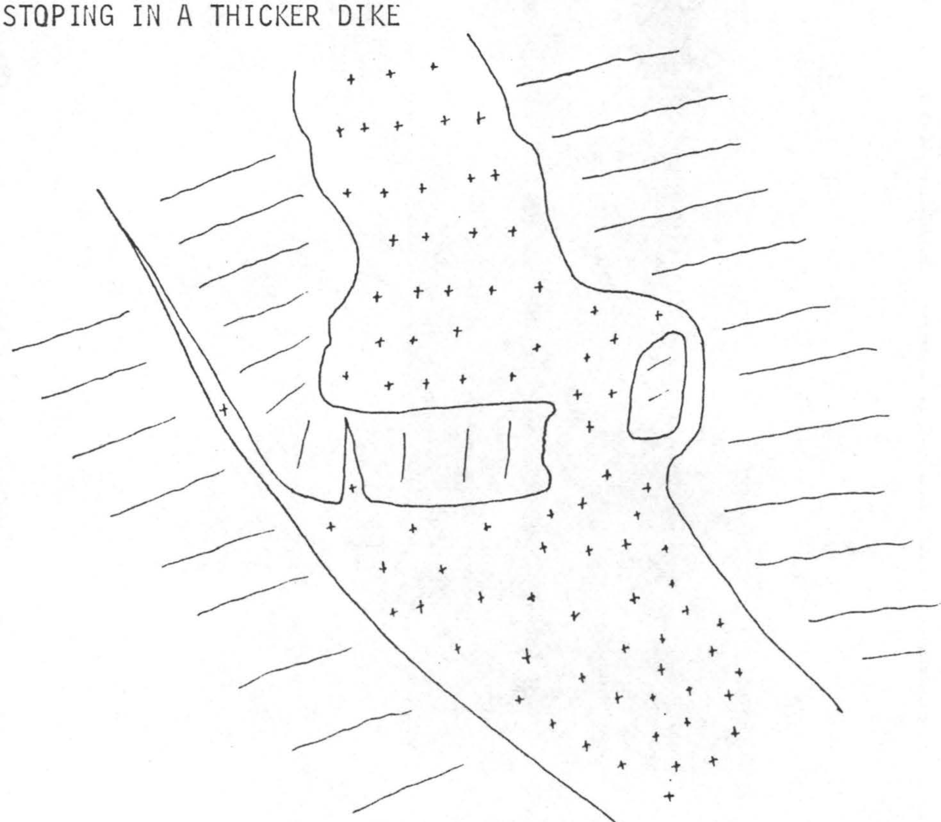


Fig. 6 STOPING IN A THICKER DIKE



(less than 5 cm) are generally rectiplanar, smooth sided and of nearly constant width. Tensional en echelon separations are common and the veins clearly crosscut the country rock.

As the veins become thicker (less than 50 cm) they occasionally depart from these smooth surfaces. Though rectiplanar in trend, these intrusives have rough, uneven, angularly irregular boundaries that frequently match, indicating tensional origin. In addition stopping and rotated angular inclusions were noted (see Fig's. opposite).

The location of the intrusives greater than .5 m in width is indicated in Fig. 7. In form they are very similar to those dikes already described, however in the case of the larger bodies at G188 187 and 103 limited outcrop and a lack of time prevented definition of the boundaries. Where seen however, they were straight and smooth with pronounced angular shifts (G187). At G696 the outcrop consisted of interconnected 1 to 5 metre wide dikes of variable orientation, which appeared to envelop rectangular blocks of the country rock.

Unfortunately, it was not practical to follow individual larger dikes between outcrops. Limited attempts to do so were unssuccessful due to a tendency for abrupt angular shifts in strike.

Where individual dikes intersect on the outcrop, the contacts are sharp and clearly crosscutting. Indeed, there is frequently translation greater than that which would be expected from simple dilation.

Composition and Internal Morphology

The bulk of the intrusives of this suite may be considered morphologically and compositionally in terms of two end members.

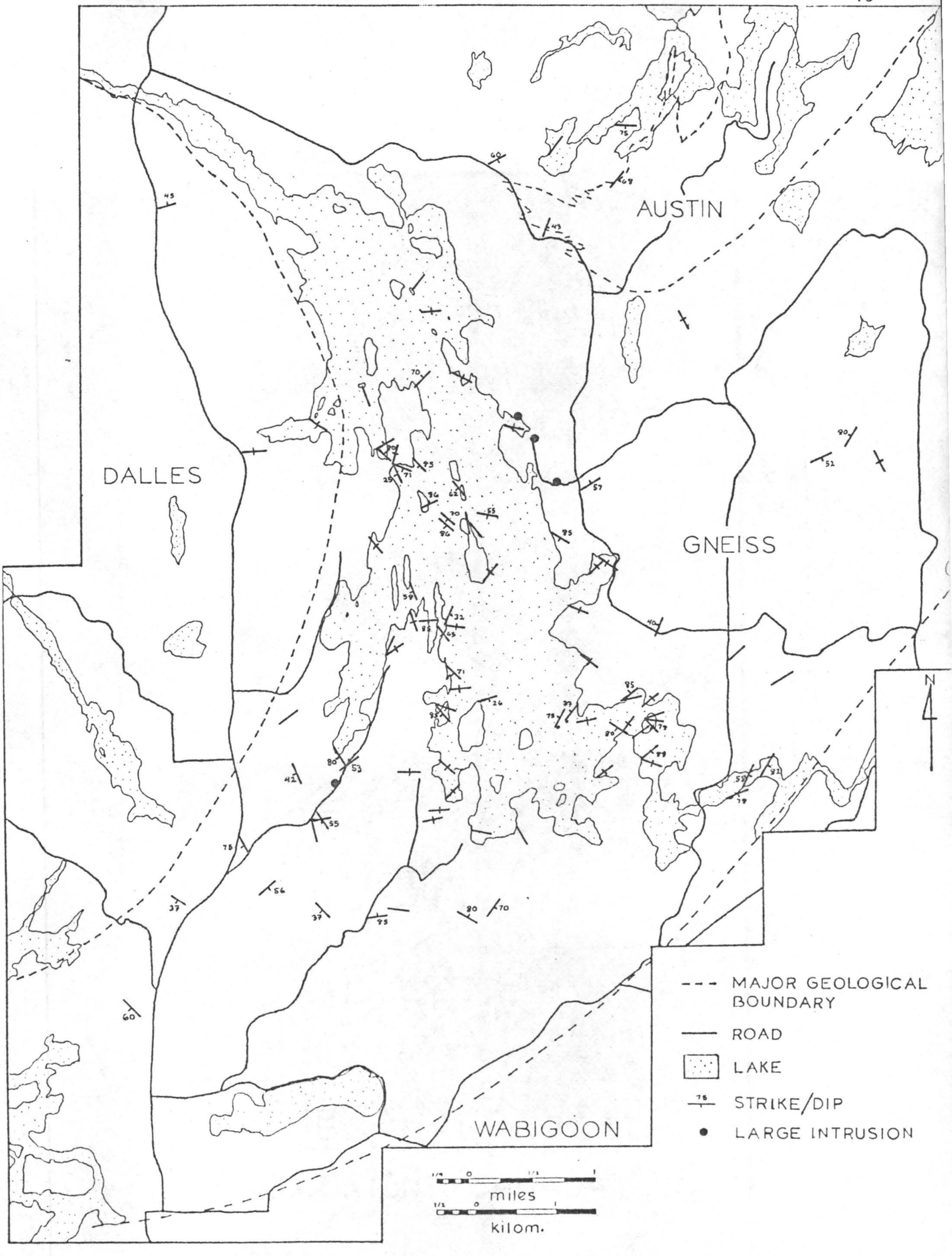
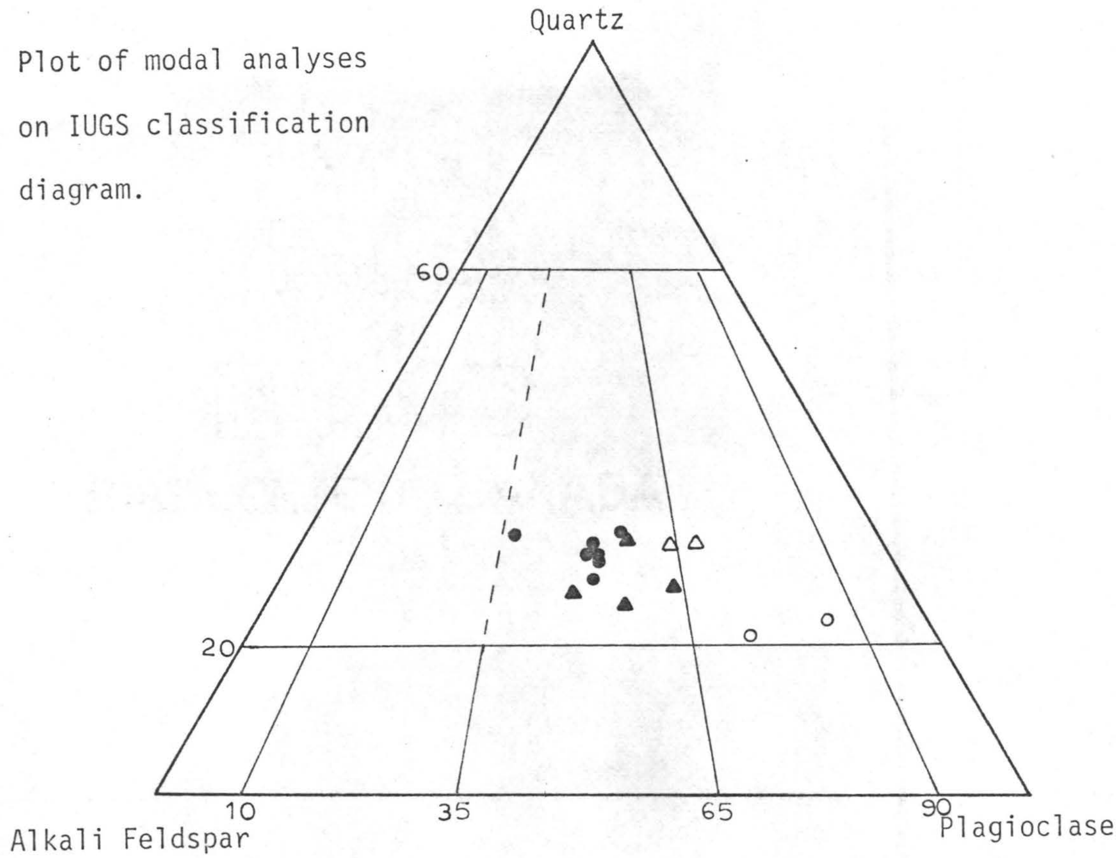


Fig. 7 Location and strike of Group 1 intrusives greater than 1m in width.

Fig. 8. Plot of modal analyses on IUGS classification diagram.



<u>Symbols</u>

Group 1	micrograrites	●
Group 2	micrograrites	▲
Group 3	microgranodiovite	△
Group 4	microgranodiovite	○

TABLE 1 NORMALIZED MODAL ABUNDANCES

		Qtz.	Plag.	Kspar.	Bio.	Epi.	Mus.	Chl.	Opaq.	Ap.	Cal.	Zircon	Beryl
●	F101A	32.3	33.0	26.2	2.5	1.5	3.2	0.3	1.0	-	-	-	-
○	F139	17.8	49.7	18.6	11.6	0.3	1.7	tr	0.3	tr	tr	tr	
○	F148	20.3	58.7	10.0	8.0	0.5	2.0	tr	0.5	tr	tr	tr	-
▲	F158	23.5	39.5	30.2	2.3	0.3	3.5	tr	0.6	tr	tr	-	-
▲	F160	24.8	33.3	36.5	2.2	tr	3.2	tr	tr	tr	tr	-	-
△	F190A	31.1	43.1	19.0	3.3	1.3	2.2	tr	tr	tr	-	-	-
●	F201B	26.7	34.8	34.5	0.5	0.5	1.5	tr	tr	-	tr	-	tr
●	F203	30.7	31.1	30.6	1.5	2.0	3.4	t	tr	-	tr	-	-
●	F263A	29.5	34.7	33.0	1.2	tr	1.3	tr	tr	-	tr	-	-
●	F359	34.0	32.5	29.5	1.9	0.5	1.5	tr	1.0	tr	-	-	-
▲	F424A	23.7	40.3	23.3	6.0	1.2	5.0	tr	0.5	tr	tr	-	-
●	F435	31.3	22.3	39.6	2.0	1.5	3.0	tr	0.3	-	tr	-	-
●	F490	30.1	30.7	33.0	0.5	1.0	3.0	tr	0.3	-	-	-	-
△	F544A	31.8	33.3	27.3	3.8	0.5	3.3	tr	tr	tr	tr	-	-
△	F581	29.1	37.5	22.2	11.2	tr	tr	-	tr	tr	-	-	-
●	F924	28.5	33.5	30.5	4.0	1.5	2.0	tr	tr	-	tr	-	-

Microgranites

These are dikes composed of fine to medium grained, reddish to buff white inequigranular biotite microgranite. Some dikes are slightly porphyritic with the development of scattered subhedral alkali feldspar phenocrysts (1 cm). However, all the dikes are homogeneous.

These intrusives commonly, though not always, have thin (1-2 cm) coarser margins of up to 1 cm grain size subhedral alkali feldspar, plagioclase and quartz. In addition, the dikes occasionally show a foliated fabric with alignment of biotites, or as in the case of a dike at G263, linear alignment of feldspars. This alignment, particularly of the biotites is frequently discordant to both the dike margins and the gneissocity.

Modal analyses determined for eight representative samples shows that these microgranites are quite similar compositionally (see Fig. 8), averaging 30% quartz, 32% plagioclase, 33% alkali feldspar, with minor biotite, muscovite and epidote.

The plagioclase occurs primarily as subhedral to anhedral poikilitic to myrmakitic grains with rare development of patch antiperthite. These grains show varying degrees of alteration, with the development of anhedral to subhedral "myrmakitic" epidote and muscovite, as well as anhedral calcite and microgranular hematite (Fig. 9).

The grain boundaries, particularly where in contact with interstitial alkali feldspar, are irregular, interlobate with occasional development of an unaltered albite rim. These larger grains are gradational to smaller blebs of altered plagioclase which occur as discrete

Fig. 9(a). Plagioclase altering to epidote, muscovite, hematite and calcite (F490). 125 x nichols crossed.

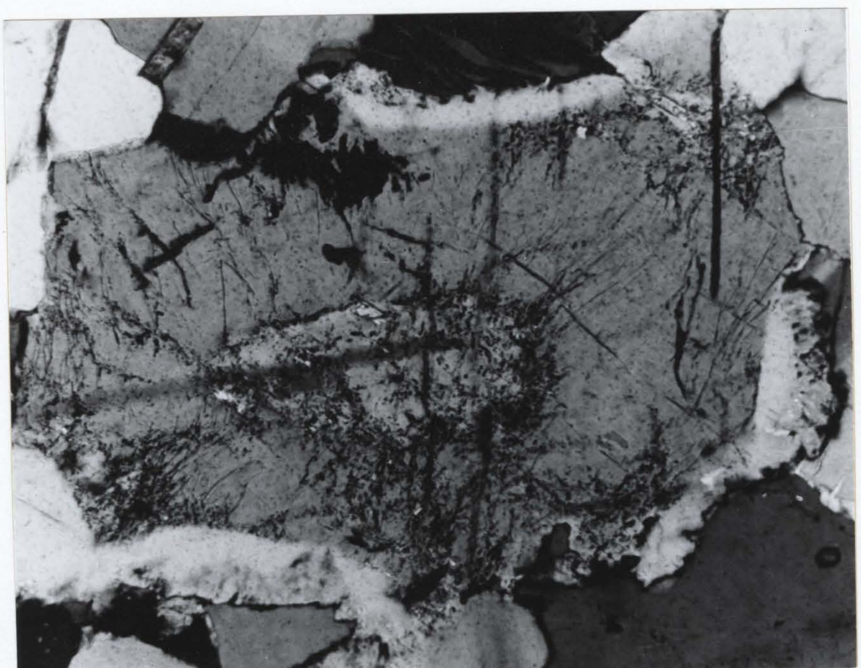


Fig. 9(b). Albitization of a plagioclase with only minor core alteration (F359). 125 x nichols crossed.

Fig. 10. Plagioclase strip dividing two alkali feldspars (F490). 125 x nichols crossed.

Fig. 11. Tattered plagioclase enveloped in well twinned microcline (F263A). 125 x nichols crossed.

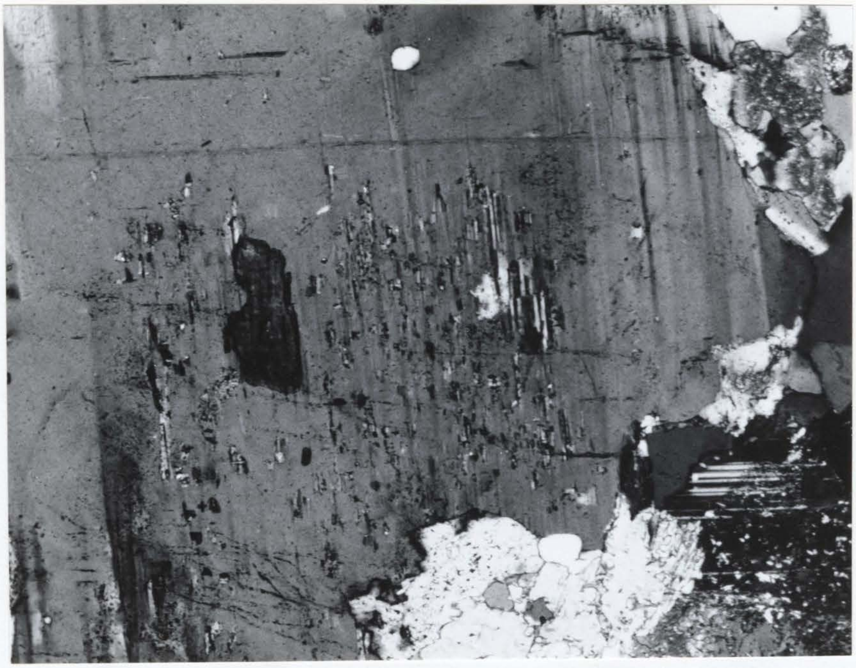


Fig. 12. Patch perthite (F490).

125 x nichols crossed.

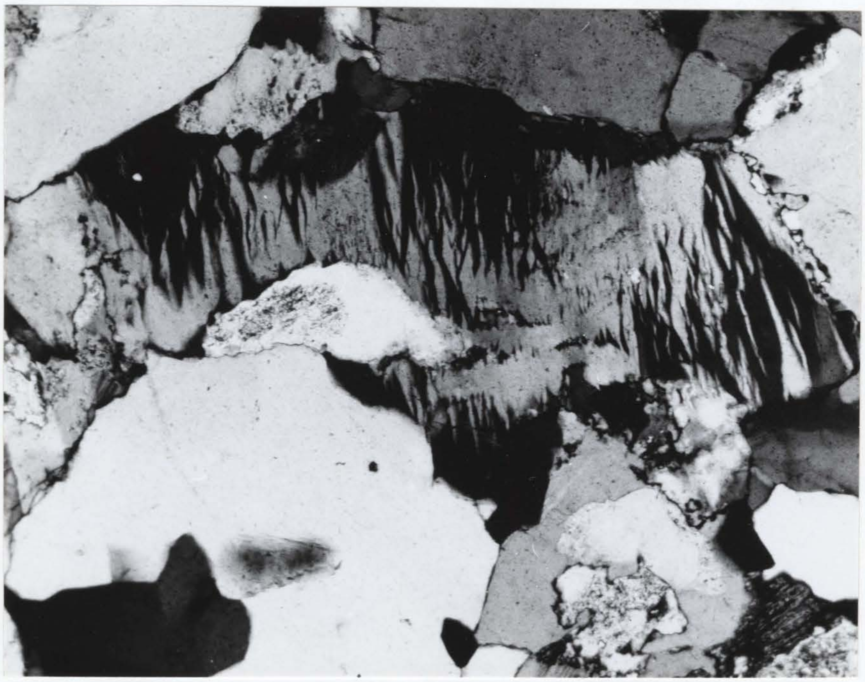


Fig. 13. Flame perthite (F924).

125 x nichols crossed.

Fig. 14. Allanite cored epidote replacing biotite.

125 x nichols crossed.

embayed inclusions within the alkali feldspars and as discontinuous strips rimming them (Fig. 10).

The alkali feldspars occur as anhedral to subhedral, somewhat tabular, inequigranular, frequently poikilitic grains which are clearly interstitial to the plagioclase (Fig. 11). In rare instances patch antiperthite with altered plagioclase is developed. However, more common is flame perthite in which the plagioclase is unaltered and may be seen to "feed" microgranular interstitial ribbons of an altered plagioclase (Fig. 12) (Fig. 13). The boundaries of the alkali feldspars with the interstial quartz ranges from smooth to slightly lobate.

The quartz occurs as anhedral, irregular, equidimensional grains that range from strongly undulose to polygonized.

Biotite occurs as subhedral to anhedral tabular laths, with minor chlorite alteration, that appear to crosscut the feldspars. Chlorite also occurs as minor anhedral interstial blebs.

Crosscutting the biotite in turn is muscovite and epidote. These minerals are generally enhedral against the biotite and "myrmekitic" against the feldspar. Frequently, the epidotes are cored by rod like microgranular allanite.

Sphene and apatite occur as minute scattered subhedral inclusions along with a spheroidal reddish brown, microgranular, near isotropic mineral.

Opaques are common, but variable in occurrence. In certain sections (F201B & F490) the opaques consist of dark red near translucent pseudomorphs after magnetite. Fractures in these sections are stained red and there is little doubt as to the origin of the red coloration of these rocks. In other sections the opaques occur partially replaced by calcite or are rimmed by sphene (F101A).

Pegmatites

In contrast, many dikes are composed of coarser grained granite pegmatite. Unfortunately, the larger grain size of these dikes and veins (15 cm max) makes thin section work unrepresentative. Hence, these dikes are described from hand specimen. Consequently, quantitative modes are lacking and the reader is referred to the normative analyses of two pegmatites of which geochemical analyses were obtained, F177 and F830 as approximations of the bulk mineralogy.

Like the microgranites, these dikes range in colour from buff white to reddish, however pink predominates. As well the pegmatites show no evidence of chilled margins. Rather, the boundaries are usually mantled by euhedral to subhedral tabular alkali crysts that are oriented with their long axes perpendicular to the boundary surface. Quartz is interstitial in appearance, frequently with a pronounced bluish tinge. Plagioclase is minor, occurring as smaller subhedral to anhedral grains. Towards the core of the dike the plagioclase diminishes and the size of the alkali crysts increases, reaching 15 cm in isolated cases (G150). As well as increasing crystal size, the proportion of interstial quartz usually increases, resulting in cores composed of bluish monocrystalline quartz with isolated euhedral inclusions of alkali feldspar. It should be noted,however, that most dikes do not show this development of a quartz core, suggesting considerable compositional variation between dikes, particularly with respect to SiO_2 content.

The only significant texture noted was good graphic intergrowth of alkali feldspar and quartz. However, it is isolated in its development and the feldspars commonly contain only round inclusions of quartz.

On the whole, mafic minerals are minor in these dikes. Biotite occurs as long thin sheaf like crystals that frequently have an orientation subperpendicular to the margin. As well, the sheafs occur in more irregular form following fractures that appear to crosscut the feldspars and quartz, giving a crude foliated appearance. Irregular interstial clots of biotite are also seen.

Muscovite is clearly secondary in development as it occurs only as thin bands developed along fractures cutting the alkali feldspar.

As may be expected the accessory phases are exotic and quite varied. The most spectatular being garnets which are subhedral to euhedral in form and range in size from less than 1 mm to 10 cm. The larger garnets (G150 etc.) usually show development of a radial net intergrowth with quartz which is described as simplectic by Deer et al. (1966).

Tourmaline was observed at two localities and reached a maximum grain size of 1 cm in a 4 cm vein. The crystals are subhedral in form with no preferred orientation in the plane of the intrusion. However, in both cases the crystals were thin and inhabited the exact center of the vein. In addition, these veins had less free quartz than average.

Of the opaque minerals, magnetite was most common, usually occurring as small subhedral grains scattered throughout the intrusion. Irregular interstial clots of sulphides were common, though of small size and

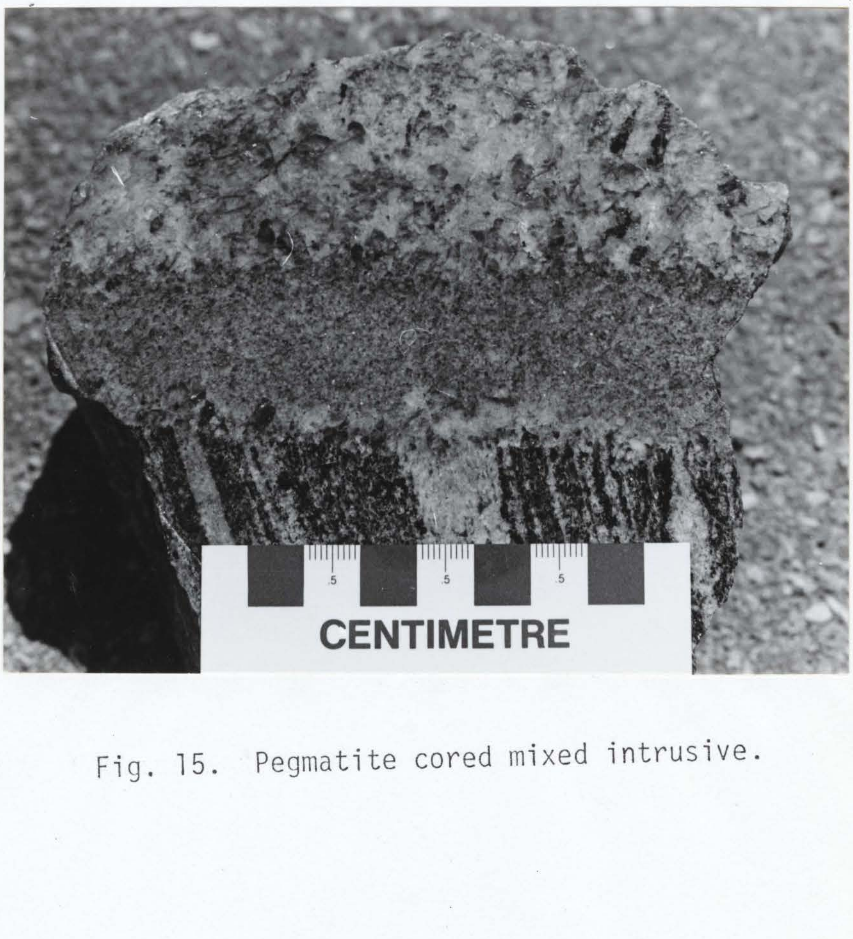


Fig. 15. Pegmatite cored mixed intrusive.

Fig. 16(a). Microgranite cored mixed intrusive.

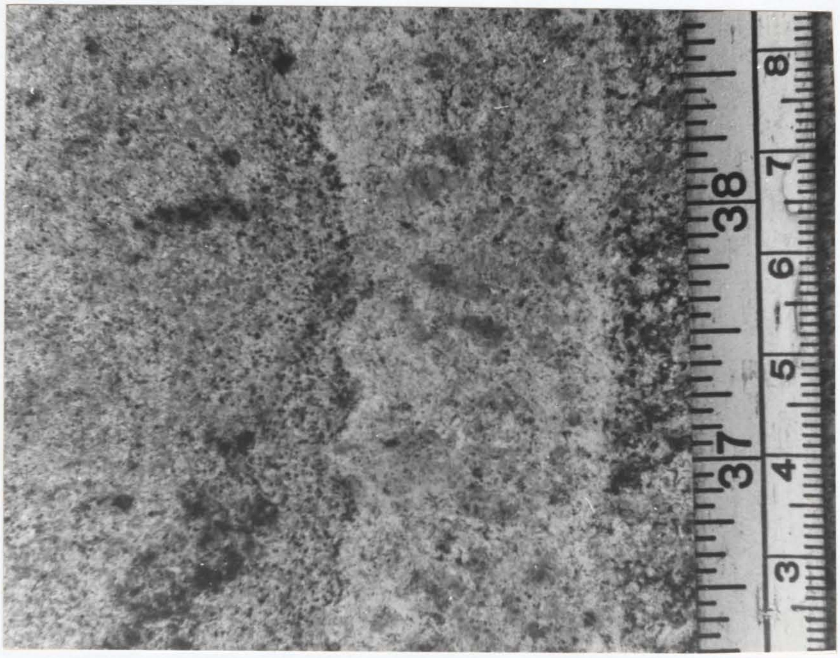


Fig. 16(b). Detail of above dike showing accumulation of opaques along one side of the core.

abundance. Finally, two showings of molybdenum were found at G883 and G569. The greatest development was at G569 were several plugs of up to 1 cm^3 were noted.

Mixed Intrusvies

The remainder of the intrusives of this group may be considered best as mixtures of varying proportions of the two previously mentioned end members. Such mixtures are usually heterogeneous, with frequently development of a pronounced layering parallel to the margins of the intrusion which generally takes one of two forms.

In one form the intrusive has thin rims (1-2 cm) of coarse grained (5-1 cm) subhedral alkali feldspar, plagioclase and quartz which pass abruptly into the fine to medium grained microgranite described above. This microgranite in turn mantles a core of coarse alkali feldspar and quartz. The core may be of variable development, ranging from a strong band to discontinuous lensoidal pods (Fig. 15).

In the second type, coarse subhedral alkali feldspar grows perpendicularly to the margin providing a thick (5-10 cm) mantle for a core of fine to medium grained microgranite. The core material is usually free of phenocrysts, however it may show flow banded textures defined by microgranular magnetite and garnet. In one dike at G281 there was a suggestion of settling of these equidimensional, denser grains to produce patches accumulating in hollows between alkali phenocrysts of the coarse mantle (Fig. 16).

An entirely different type of mixed intrusive is the Type 3, so-called because typically it is comprised of three separate components.

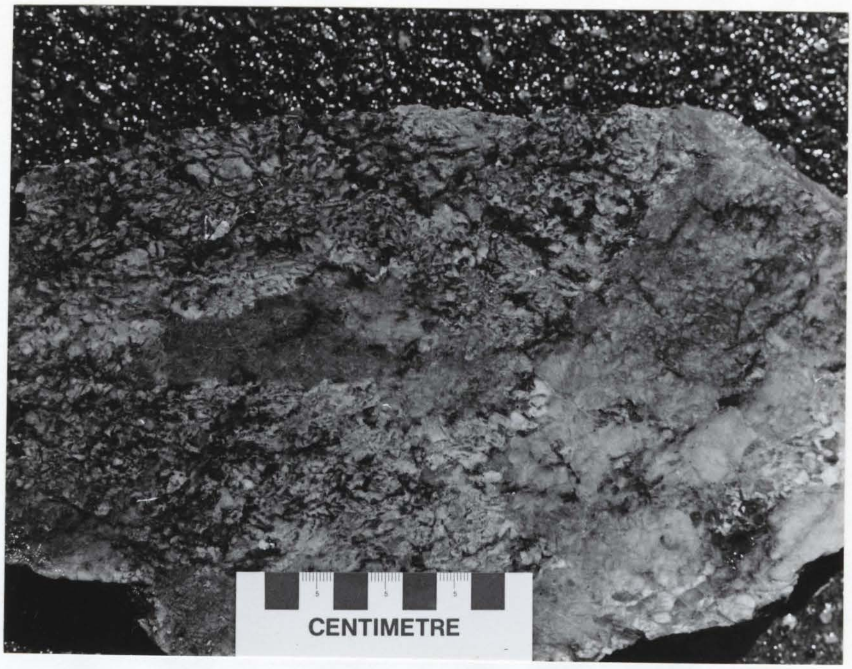


Fig. 17 (a) Slabbed sample of type 3 mixed intrusive

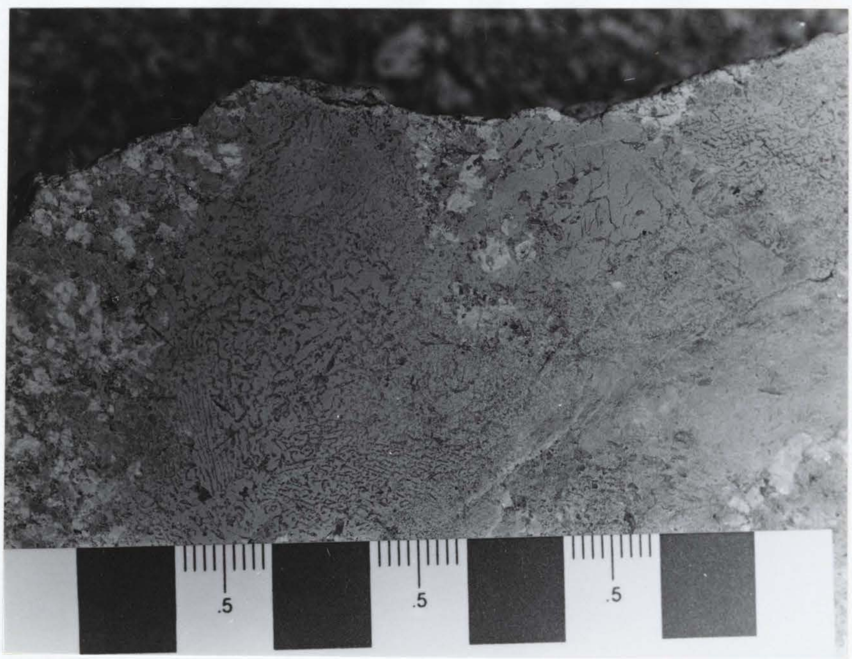


Fig. 17 (b) Detail of fine myrmakite of a stained slab (sodium cobaltinitrate) of type 3 mixed intrusive.

1) Large (5-13 cm) subhedral to anhedral megacrysts of finely intergrown myrmekitic alkali feldspar and quartz.

2) These crysts are set in a finer grained (.1-.7 cm) matrix of subhedral to anhedral plagioclase and alkali feldspar with ribbony interstial quartz. In certain dikes the matrix plagioclase tends to take on a massive graphic appearance and good graphic alkali feldspars are also seen.

3) This assemblage mantles a coarse core of monocrystalline blue quartz with interstitial euhedral to subhedral alkali phenocrysts.

Biotite is minor in these dikes and generally restricted to the matrix, occurring as thin blades that range up to 3-4 cm in length. These blades are interstial in development and may be seen following fractures (Fig. 17).

Modal analyses of such a rock are again impractical and the reader is referred to the normative analyses of G187 as an approximation of the proportionate minerology.

<u>Relationship to Size</u>

Several qualitative generalizations may be made regarding the relationships of size and composition. Firstly, pegmatites tend to be less than 20 cm in width and are usually less than 10, whereas mixed intrusives are commonly greater than 10 cm in thickness and the Type 3 intrusive is most commonly developed in dikes of between 30 cm and 1 m. Microgranite occurs in dikes of all thicknesses and is the primary component of the larger irregular intrusive bodies such as those at G103 and G188. In these bodies coarser material is minor to absent, occurring as scattered irregular clots.

Deformation

Although the dikes of Group 1 are largely rectiplanar in form, there is considerable evidence, both on the outcrop scale and thin section to suggest that they have been caught up in a pervasive weak regional deformation.

The most obvious evidence is provided by Fig. 18 which illustrates the location, strike and sense of movement of late minor faults which clearly crosscut the dikes. These faults commonly occupy the plane of the gneissocity and where developed are coated with thin (.5-2 cm) quartz, epidote or biotete bands. They crosscut the dikes sharply and the displacement is not greater than 1 m. Where the faults intersect the dikes at a shallow angle, polygonized quartz and granulated feldspars may be developed. However, these textures are observable only in pegmatites.

Further evidence of deformation on the outcrop scale is provided where the dikes crosscut biotite "amphibolite" bands. Frequently dikes that are rectiplanar in the gneiss are warped or sheared within the biotite rich amphibolite.

The presence of undulose, partially to completely polygonized quartz in all thin sections of microgranites from this group, suggests that all of the samples have been subjected to some deformation. However, the degree of deformation does not appear to have been uniform. It ranges from F101A-F263 in which some of the quartz grains are non-polygonized to F359-F490 which show complete polygonization of quartz, microfaulting and bending of feldspars, to F924 in which the feldspars have been rifted and kinked to the point of near granulation,

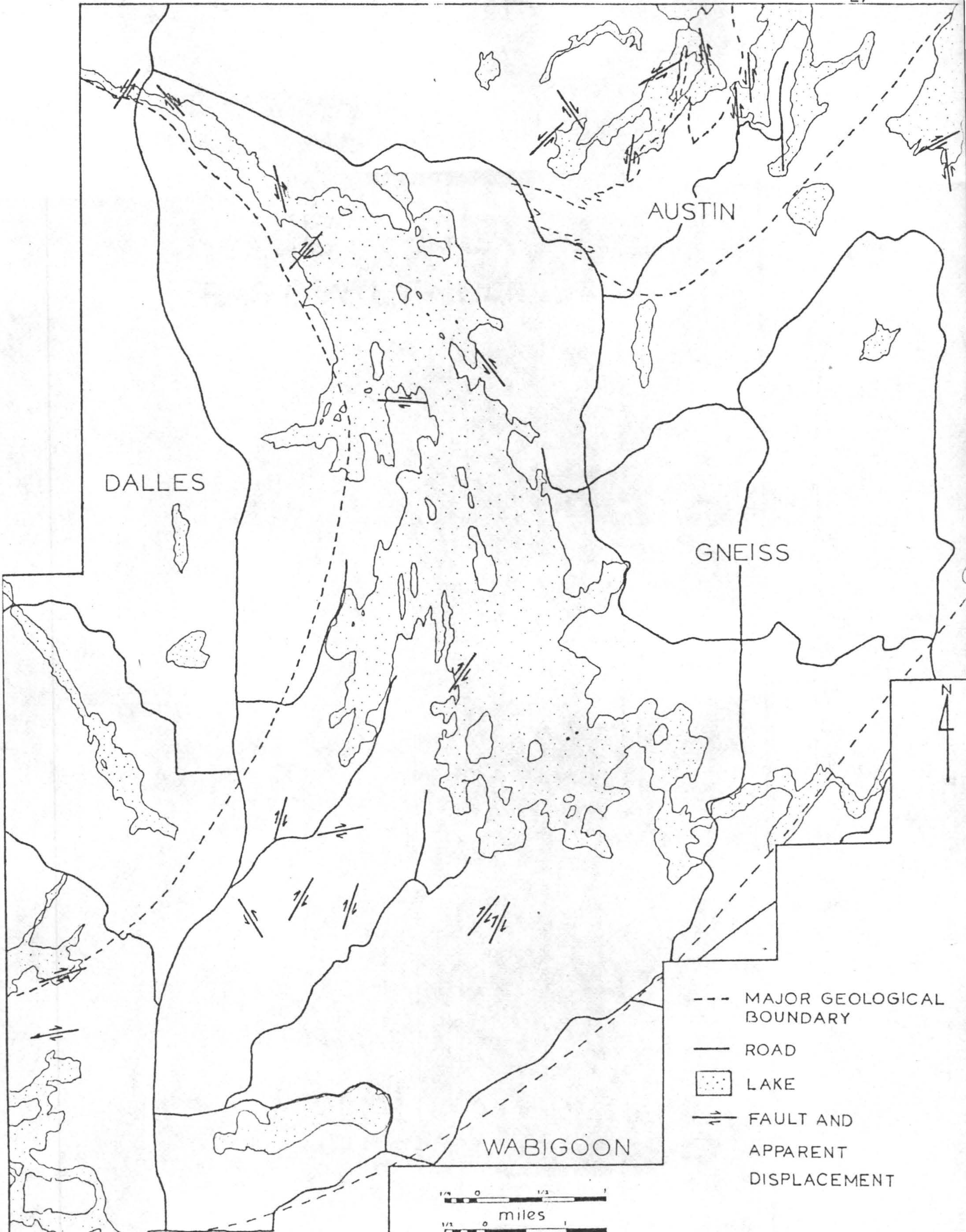


Fig. 18 Location, strike and sense of movement of late minor faults.

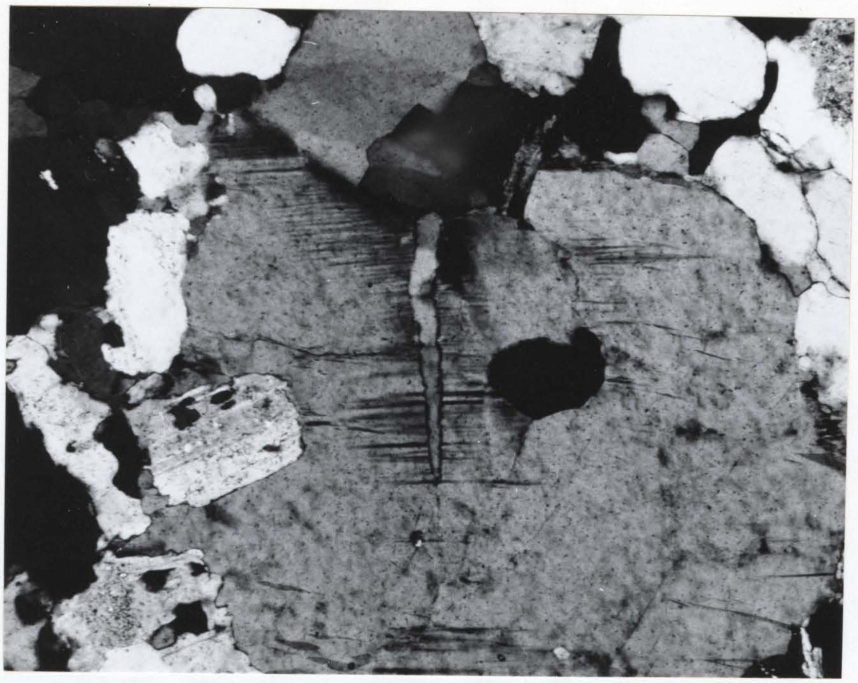


Fig. 19. Rifted alkali feldspar (F924).

125 x nichols crossed.

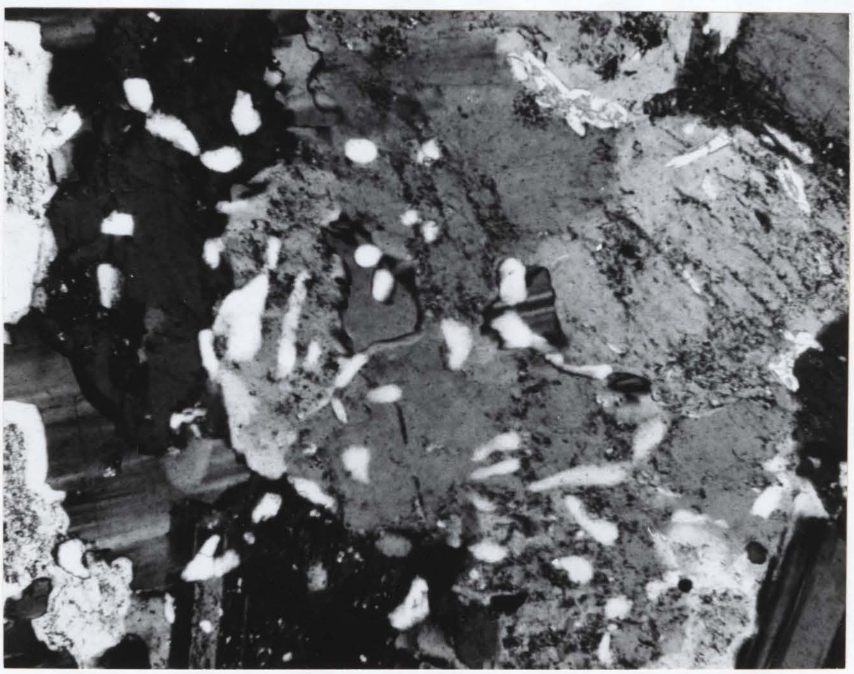


Fig. 20. Myrmakitic plagioclase (F490).

125 x nichols crossed.

Fig. 19.

In addition to structure certain textural characteristics appear to vary with deformation.

The biotite of the less deformed sections does not show a marked foliation and occurs as tuabular laths. In F359 and F490 the biotite tends to occur in two forms: a chloritized tattered form and an unaltered form that shows a slight orientation. Finally, in F924 the biotite as well as muscovite show a pronounced foliation, frequently occurring along fracture planes and may themselves be bent.

The nature of the grain boundaries also seems to vary with degree of deformation, becoming much more intricately interlobate as evidence of deformation increases. This would suggest that the interlobate nature of the boundaries is not a primary igneous feature, but rather, represents boundary mobility induced by differential strain energy densities (Spry (1969)).

Similarly, the occurrence of flame perthite increases from F101A to F490. In addition the flames tend to occur in an en echelon form similar to tension gashes and frequently eminate form contact points on grain boundaries. The plagioclase of these flames is unaltered relative to that of the patch perthite, suggesting exsolution of the flames after exsolution and alteration of the patches.

Plagioclase myrmakite in the altered grains also shows a parallel increase in development, with increased apparent deformation (Fig. 20).

GROUP 2

Form

In form, the dikes of Group 2 are essentially identical to those of Group 1. The only exception being that dikes greater than .5 m in width are only rarely seen, the bulk of the intrusives being less than 20 cm. As well, the large irregular microgranitic bodies developed in Group 1 are not seen.

Composition and Internal Morphology

As in Group 1, the intrusives of Group 2 may be grouped into three subtypes.

Microgranites

Many dikes are composed of fine to medium grained greyish-red inequigranular biotite microgranite. Unlike the microgranites of Group 1 these dikes do not develop thin coarse margins. Rather, thin selvages of biotite are frequently formed.

Modal analysis determined for four representative samples may be seen above (Table 1). Quartz, alkali feldspar and plagioclase average 26%, 29% and 35% respectively. In contrast to the microgranites of Group 1 biotite is more significant, varying from 2.2 to 5%.

The plagioclases occur as anhedral poikilitic grains with round inclusions of quartz and alkali feldspar. Myrmekitic margins are also common and patch anti-perthite occurs sporadically. Although altered, with the development of inclusions of microgranular hematite, anhedral calcite, subhedral epidote-muscovite, the degree of alteration is generally less than in Group 1.

The alkali feldspars are poikilitic as well and at least in F160 appear to be interstiial to the plagioclase, forming anhedral irregular grains. In the other sections however, the boundaries between

Fig. 21. Irregular nature of grain boundaries (F544A).

125 x nichols crossed.

individual grains becomes so intricately interlobate and recrystallized that interpretation of original textures is impossible (Fig. 21). Indeed feldspars are frequently intruded by quartz which is continuous with the irregular interstitial masses, suggesting considerable mobility. As in the alkali feldspars of Group 1 patch and flame perthite are developed.

Crosscutting the quartz and feldspar are subparallel, subhedral tabular laths of green biotite. These laths define powerful foliation which is usually discordant to the dike margins. Muscovite occurs as smaller euhedral laths which mantle biotite.

In all the sections minor amounts of biotite also occur as tattered chloritized laths which are discordant to the primary foliation

Anhedral inclusions of sphene are common throughout the section along with subhedral apatite.

Opaques occur as scattered subhedral inclusions (less than 1 mm) primarily of magnetite. In F158 magnetite develops as skeletal crystals which either overprint a felted mass of brownish acicular material or are veined with calcite (Fig. 22). Biotite is not developed adjacent to these grains, creating a biotite deficient halo. A dike at G474 shows this texture particularly well with the development of scattered 1-2 mm magnetic megacrysts enveloped by 1 cm diameter haloes. The best development of this fabric is at G162 where a thick (1 m) intrusive contains lensoidal subparallel biotite deficient blebs which are cored by large discontinuous (1-4 mm) interstitial clots of magnetite. The grain size of these lenses is slightly higher than the enclosing intrusive, but is

Fig. 22 Magnetite porphyroblast viened with calcite.

125 x nichols crossed.

perfectly gradational. Gower (1975) has also recorded this texture in the Dalles granodiorite and its gneiss envelope.

Epidote varies in development, being most common in F158. In this section it occurs as anhedral to subhedral inclusions, primarily in quartz and feldspar. These epidotes frequently nucleate around one end of a rod like allanite crystal. However, they only rarely envelop the whole grain.

Pegmatites

The pegmatites of Group 2 generally contain more plagioclase than those of Group 1. As a result, on the outcrop, they appear whitish rather than reddish in colouration.

Morphologically, however, they ar quite similar with the same development of tabular subhedral laths of plagioclase and minor alkali feldspar growing perpendicularly to the dike margin. No chill zone is seen and quartz is largely interstitial. The margins grade imperceptibly into a .5 to 2 cm matrix of anhedral to subhedral alkali feldspar and plagioclase with interstitial ribbony quartz which envelops 2-5 cm subhedral to euhedral megacrysts of alkali feldspar. These megacrysts are usually poikilitic with quartz and are occasionally graphic. In contrast to Group 1 pegmatites, monocrystalline quartz cores are only rarely developed.

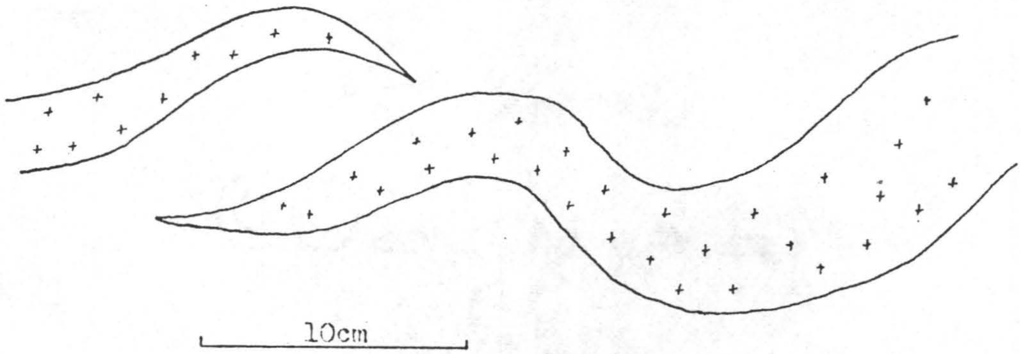
Biotite is minor in these dikes occurring only as fine interstitial laths of small size (1-2 mm).

Mixed Intrusives

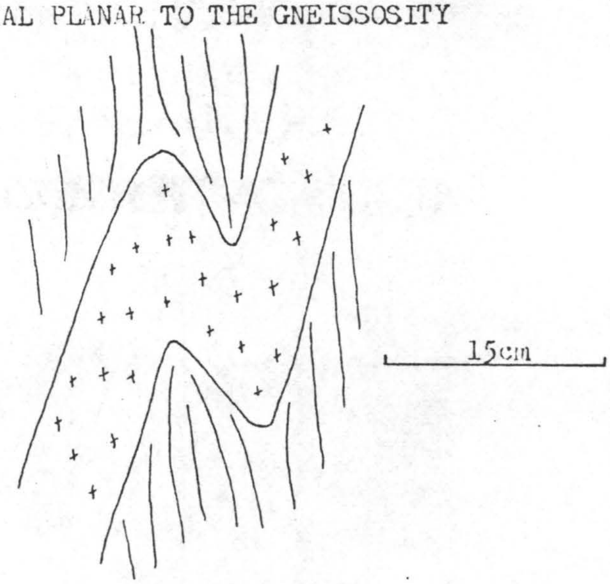
As a whole, this type of intrusive is only developed on a minor

Fig. 23

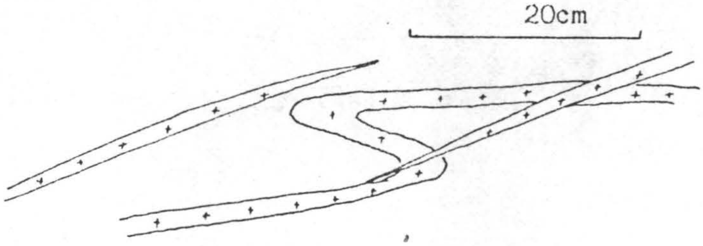
FOLDED EN ECHELON SEPARATION (GROUP 2)



SHARP FOLD AXIAL PLANAR TO THE GNEISSOSITY



GROUP 1 DIKE CROSSCUTTING FOLDED GROUP 2 DIKE



scale. Those examples recorded were similar to the microgranite cored, layered intrusives of Group 1.

Deformation

As may be gathered from the preceeding descriptions the morphological and minerological differences between dikes of Groups 1 and 2 are relatively slight. Fortunately, there is a marked difference in their deformational styles.

While the dikes of the first group are predominantly deformed by brittle faulting and shearing, the dikes of the second group are deformed by plastic folding and compression.

The folding is highly variable in form ranging from broad warps 4 to 5 m in wavelength and .5 m in amplitude to broad isoclial folds with linear shortening up to 50%. Some dikes, particularly those in homogeneous bodies like the Dalles, buckle in a plastic irregular fashion with round open fold hinges. The lack of obvious hinge thickening in these folds suggests little or no viscosity contrast between the dike and the country rock.

This behaviour contrasts with dikes in laminated country rocks which frequently are S or Z folded with the development of spaced short wavelength folds that are separated by intervals of rectiplanar dike. Dikes of this nature pose a practical problem in that on a small outcrop one may only see the inter kink portion and think the dike undeformed (Fig. 23).

A similar problem is posed by dikes which have simply suffered compression and extension. The microgranites in particular probably

Fig. 24. Effects of compression on a Group 2 pegmatite dike.

had a viscosity not significantly different from the country rock. As a result, compression would produce no boudinage, and cursory inspection of the dike would yield no evidence of deformation beyond a biotite foliation. In contrast pegmatites tend to show compression well, as the large rigid phenocrysts resist and frequently portrude into the margin of the intrusive (see Fig. 24). As well the coarse grain size of the pegmatite allows us to see that the matrix grains, particularly quartz have been stretched into a crude foliation parallel the margins.

In thin sections, the microgranites show clear evidence of pervasive deformation. The quartz is strongly undulose to completely polygonized and in F544 and F424 occurs as stretched blebs. The feldspars have been clearly granulated and in F160 several have been rifted and intruded by matrix quartz. As well, grain boundaries, particularly between feldspars, are highly intricate interlobate surfaces suggesting considerable strain induced boundary mobility. Other textures, such as radial myrmekite and flame perthite also suggest considerable recrystallization.

GROUP 3

Form

In form the intrusives are identical to those of Group 2.

Composition and Internal Morphology

The intrusives of this gorup are entirely finer grained in nature and on the outcrop appear as foliated fine to medium grained, grey inequigranular biotite granodiorite.

Modal analyses on two samples F190A and F581 may be seen in Table 1. The agreement between the two samples is good, giving an average composition of 30% quartz, 40% plagioclase, 21% alkali feldspar and 3.5% biotite. This feldspar composition effectively straddles the IUGS granite-granodiorite boundary, however for the sake of separation from the previously described rocks, they will be called granodiorites.

The foliation is defined by euhedral to subhedral green biotite laths which appear to define two surfaces intersecting at a steep angle. Muscovite mimics these trends and along with the biotite, may also occur as undulating belts of subparallel laths which define major shear zones.

Sphene, epidote and apatite occur as subhedral to euhedral inclusions in the biotite. The sphene often occurs as strips of individual crystals aligned parallel to the biotite basal cleavage. As well, some of the larger grains have opaque cores. The epidotes, a gain frequently are cored by a greenish brown near isotropic material thought to be allanite. However, a similar material which is microgranular nature occurs as irregular ragged accumulations that are crosscut by magnetite-calcite grains as well as biotite, muscovite and epidote. One such mass has a well developed relict cleavage which would tend to suggest that it is an alteration pseudomorph after biotite.

As mentioned above, composite magnetite-calcite grains and magnetites veined with calcite are common.

The quartzo-feldspathic matrix which is crosscut by the biotite foliation is highly inequigranular in nature with 1-2 mm anhedral poikilitic grains of alkali feldspar and plagioclase set in an increasingly finer grained mosaic of anhedral irregular quartz, alkali feldspar and plagioclase. These smaller grains are also poikilitic with grain boundaries that range from interlobate to seriate to completely recrystallized. Myrmekite and flame perthite are well developed in the plagioclase and alkali feldspars respectively. The degree of the alteration of the plagioclase is qualitatively speaking, less than in Group 2. However, "myrmekitic" epidote as well as microgranular hematite and anhedral calcite are seen.

Deformation

The deformational style of Group 3 intrusives is very similar in terms of both macroscopic and microscopic behaviour, to that of Group 2.

GROUP 4

Form

A description of the intrusives is really inseparable from one of macroscopic deformation. Where seen these intrusives were always dikelike with thicknesses invariably less than .5 m. However they were frequently discontinuous pinching out after several meters and invariably showed a tendency to pinch and swell.

The margins of the intrusive are usually smooth and no evidence of tensional injection was noted.

Composition and Internal Morphology

The intrusives are grey in colour, holocrystalline, fine to medium grained with a pronounced biotite foliation.

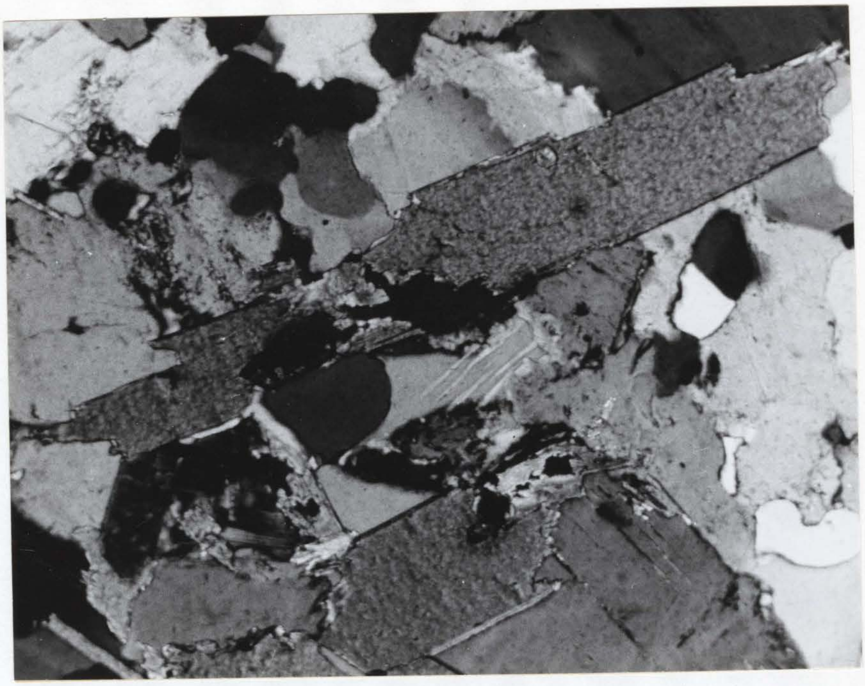


Fig. 25. Euhedral green biotite (F148).

125 x nichols crossed.

Fig. 26. Cored epidote replacing biotite.

125 x nichols crossed.

Modal analyses (Table 1) for two samples F148 and F139 suggest that the compositional range for this group is considerable, but still clearly that of quartz poor granodiorites.

The biotites, which define the foliation, are green in colour, euhedral to subhedral in form and clearly crosscut the quartzo-feldspathic matrix (Fig. 25). These laths show no evidence of alteration, with the exception of radioactive halows around zircon inclusions. In addition to the zircon, sphene and epidote occur as euhedral inclusions. The epidotes again are frequently cored in this by a green accicular material (Fig. 26). Sphene occurs throughout the section.

Muscovite is minor in development, but appears to crosscut the biotite. Euhedral apatite and magnetite are also common, the magnetites frequently being mantled by a thin veneer of sphene.

The plagioclase grains in the matrix are well twinned with very little alteration. These grains are generally inequigranular and somewhat poikilitic with the development of minor patch antiperthite.

The alkali feldspars are equally irregular in form, well twinned again and unaltered. Minor flame perthite is developed.

The boundaries between these two mineral types and indeed between similar minerals are highly irregular complexly interlobate to seriate surfaces. Also, the plagioclase grains are frequently mantled by myrmekitic margins which may protrude into an adjacent alkali feldspar.

As usual the quartz is interstitial in appearance, but individual grains have a conspicuous elongation parallel to the foliation.

Calcite is a common accessory mineral, occurring as anhedral granular patches.

Fig. 27. Dissagredation of a plagioclase lath (F139). Note how the fractures have been healed recrystallization of feldspar and quartz. 63 x nichols crossed.

Deformation

Consistant with macroscopic evidence of deformation of a highly plastic nature, the microfabric is of irregular anhedral grains with confused intricate boundaries that envelop larger grains that are clearly being rifted. The rifts commonly being healed with interstitial quartz. As in Group 2 many grains are crosscut by microgranular zones, and the impression particularly of F139 is one of a complexly sutured granulated mass. In a qualitative sense, the deformation of this group appears to have been of a less brittle nature than that of Group 2 (Fig. 27).

DISTRIBUTION

In the field, the author estimated the % areal contribution of late intrusives to a $3m^2$ outcrop. As Group 1 makes up the bulk of those intrusives, the contoured distribution obtained (Fig. 28) accurately reflects that group only. However, it is interesting that the distribution is not homogeneous and that the bulk of the intrusive material occurs in a broad east-west trending band.

This suggests that the late intrusives of this area are not ubiquitous and their emplacement has been influenced by specific structural controls.

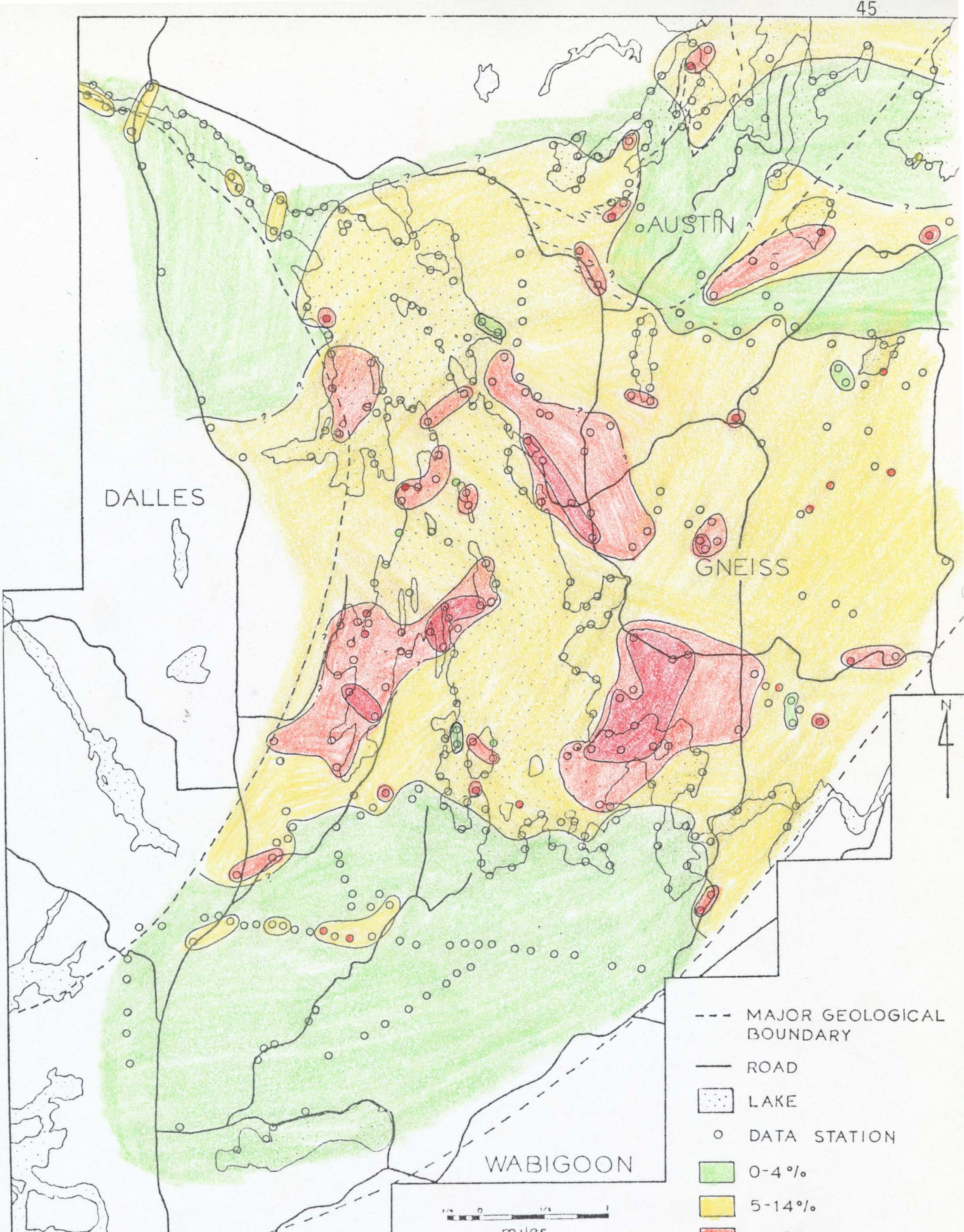


Fig. 28. Per cent areal contribution to outcrop

CHAPTER III

ANALYSIS

ANALYTICAL GEOCHEMISTRY

Nineteen selected samples were analysed for major elements and selected trace elements by X-ray fluoresence spectrometry. The breakdown of sample subdivision was as follows:

Group 1	microgranites	(8)
	mixed intrusives	(1)
	pegmatite	(2)
Group 2	microgranite	(4)
Group 3	microgranodiorites	(2)
Group 4	microgranodiorites	(2)

The bias of the samples towards Group 1 microgranites reflects a previous conviction, since proven false, that the Group contained an internal subdivision.

After all weathered surfaces were removed, the samples were reduced to -200 mesh by successive crushing in a Braun Chipmunk, Bico Crusher, and Spex Industries tungsten carbide shatter box. Great care was taken to avoid contamination and to ensure homogeneity of sample. In the case of the coarser grained samples, 15-20 pounds of rock were reduced to grit size and thoroughly homogenized before final grinding.

For major element analyses (Si, Al, Fe, Mg, Ca, Na, K, Ti, Mn, P) 2.0000 grams of powder was mixed with 4.0000 grams of $Li_2B_4O_2$ and fused in a carbon crucible at 1150°C for twenty minutes. The glass bead thus formed was allowed to cool and then crushed to -200 mesh powder in a tungsten carbide shatter box. This powder was then made up as a boric acid backed powder pellet following the procedure of Marchand (1973). The pellets were then analysed on a Phillips Model 1450 AHP automatic sequential spectrometer.

For trace analyses (Rb, Sr, Y, Nb, Zr) a whole rock powder pellet was made as per Marchand (1973). These pellets were analysed on the same machine as above.

Tabular representation of the data obtained as well as a discussion of the analytical error may be found in Appendix 1.

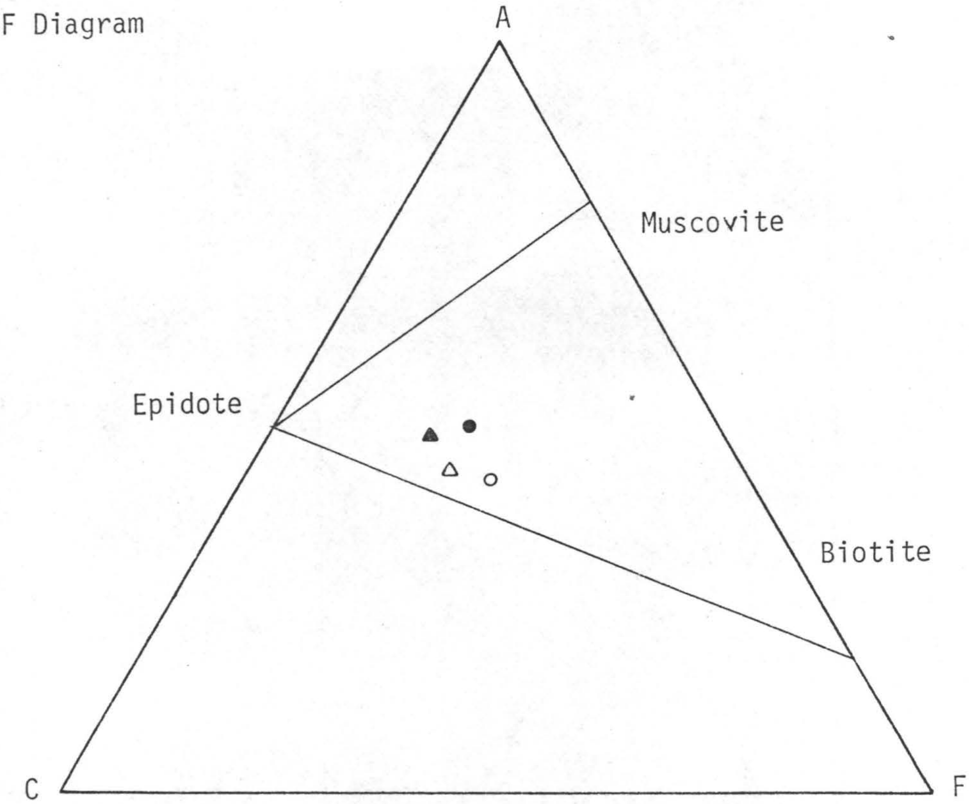
Appendix 1 also contains tabulated Mesonorm values calculated for the above data after the method of Barth (1959). Actual calculations were made utilizing a computer program written by N. Stephenson and subsequently modified by C. Gower.

CONDITIONS OF EMPLACEMENT

The characteristic retrograde metamorphic assemblage in all the groups is that of biotite-muscorite-epidote-calcite. According to Turner (1968) this assemblage is characteristic of middle greenschist metamorphism of quartzo-feldspathic rocks. The conditions implied therefore are pressures of greater than 1 Kb and temperatures of 400-500°C.

Furthermore, the presence of porphyroblastic magnetites with biotite deficient haloes, suggests that the temperature of metamorphism was not much less than 450°C, which is the reported minimum temperature

Fig. 29. ACF Diagram



Symbols

Average Group 1 microgranite	●
Average Group 2 microgranite	▲
Average Group 3 microgranodiorite	△
Average Group 4 microgranodiorite	○

for the breakdown of biotite to magnetite (Wones and Eugster (1965)).

Evidence for relatively high temperatures for the country rocks during emplacement is supported by the universal absence of chilled margins.

Assuming an Archean geothermal gradient of approximately 30°C/Km (Fyfe (1970)), the above temperature estimates suggest pressures of approximately 4 Kb, corresponding to 8-12 Km depths within the crust. However, it should be noted that as steeper gradient of 35-40°C/Km due to heat dissipation from the Dalles intrusion could result in a lower pressure estimate.

Further estimates of the pressure conditions may be derived from the two feldspar nature of the dikes.

Tuttle and Bowen (1958) found that a tenary eutectic formed at pH_2O = 5 Kb in the system Q-Ab-Or-H_2O (water excess) above which there was a complete solid solution. However, later work by Maaloe and Wyllie (1971) as well as Winkler (1976) has suggested that crystallization of two feldspars in the system Q-Ab-Or-An-H_2O (water excess) may take place at pressures as low as 2 Kb for melts of An = 8%. As the An range of the dikes of Groups 1-3 ranges from 5-8 (microgranites-granodiorites) crystallization of two feldspars imposes pressure constraints of between 2-5 Kb. This estimate is consistent with that derived above.

Further, the near universal presence in Groups 1-3 dikes of patch and flare perthite suggests that these dikes crystallized under conditions just below the hypersolvus-subsolvus transition. Hence, pressure conditions may have been at the lower end of the stated range, i.e., 3 Kb.

Therefore it would appear that the dikes were intruded into country rock of 450-500°C temperature under confining pressures of 3-4 Kb.

STRUCTURE

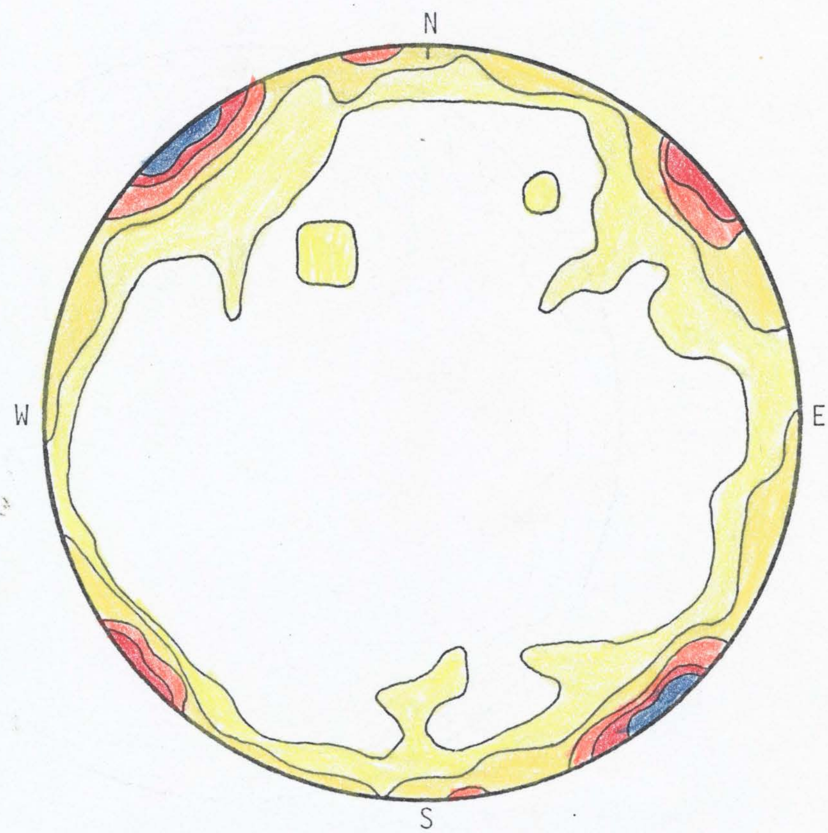
As noted previously, the characteristic form of the vast majority (80%+) of the late intrusives is that of smooth, systematic, en echelon surfaces which sharply crosscut the country rock and are interconnected by crossfractures or hackle surfaces. This description closely matches that of Price (1969) for simple shear joints, suggesting that the dikes simply represent expansion of preformed shear joint surfaces.

Further, the intricate crosscutting relationships of the dikes (particularly Group 1) on many outcrops, suggests that joint formation was an ongoing process concurrent with igneous intrusion. Hence, stereographic analyses of dike/joint surfaces may yield some insight into the stress systems governing the environment of emplacement.

Fig. 30 shows the contoured (Schmidt method, Stauffer (1966)) plot for all the strike/dip pairs recorded for the relatively underformed Group 1 dikes. As may be seen the 1,300 points (poles to planes) yields three trends, all subvertical: 140° (5%), 050° (4%) and 175° (3%). These pole trends correspond to planar trends of 050°, 140° and 085° respectively. However, it should be noted that these are average values for trends that are rather broad (± 10°).

To determine whether this diffuseness is due to lithologic variation, plots of data from adjacent domains of markedly different

Fig. 30

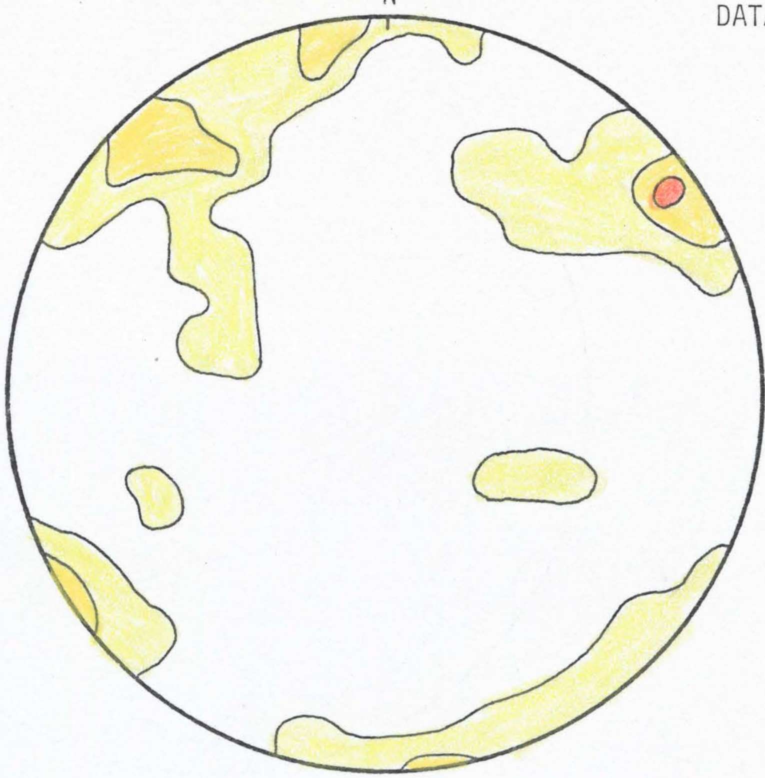


PLOT OF ALL GROUP 1 DATA

1300 POINTS

CONTOUR INTERVAL 1%

Fig. 31

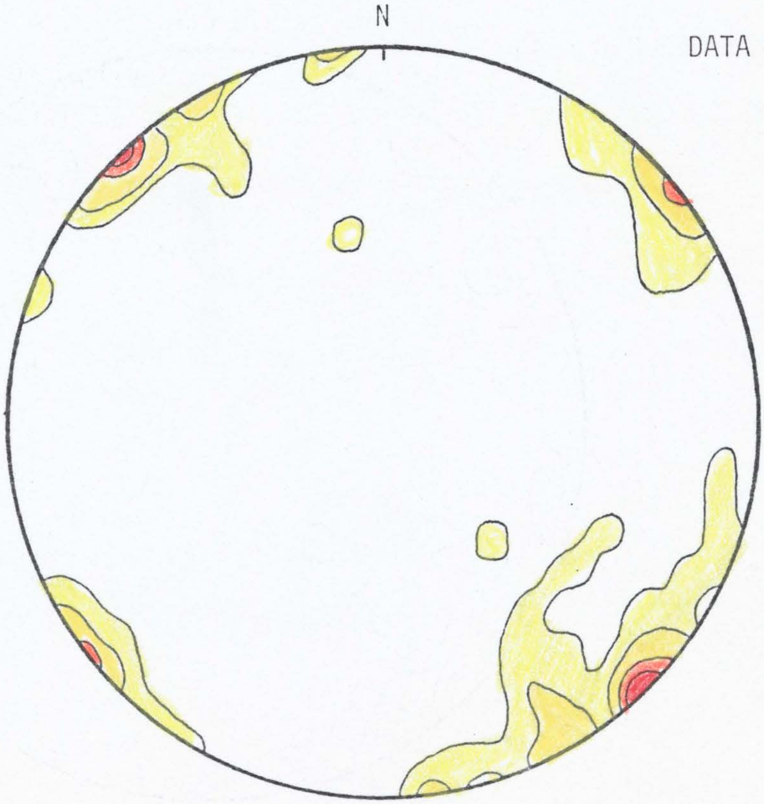


DATA FROM GNEISSES ADJACENT TO MELICK TONOLITE

300 POINTS

CONTOUR INTERVAL 2%

Fig. 32



DATA FROM MELICK TONOLITE

100 POINTS

Gower (1975)

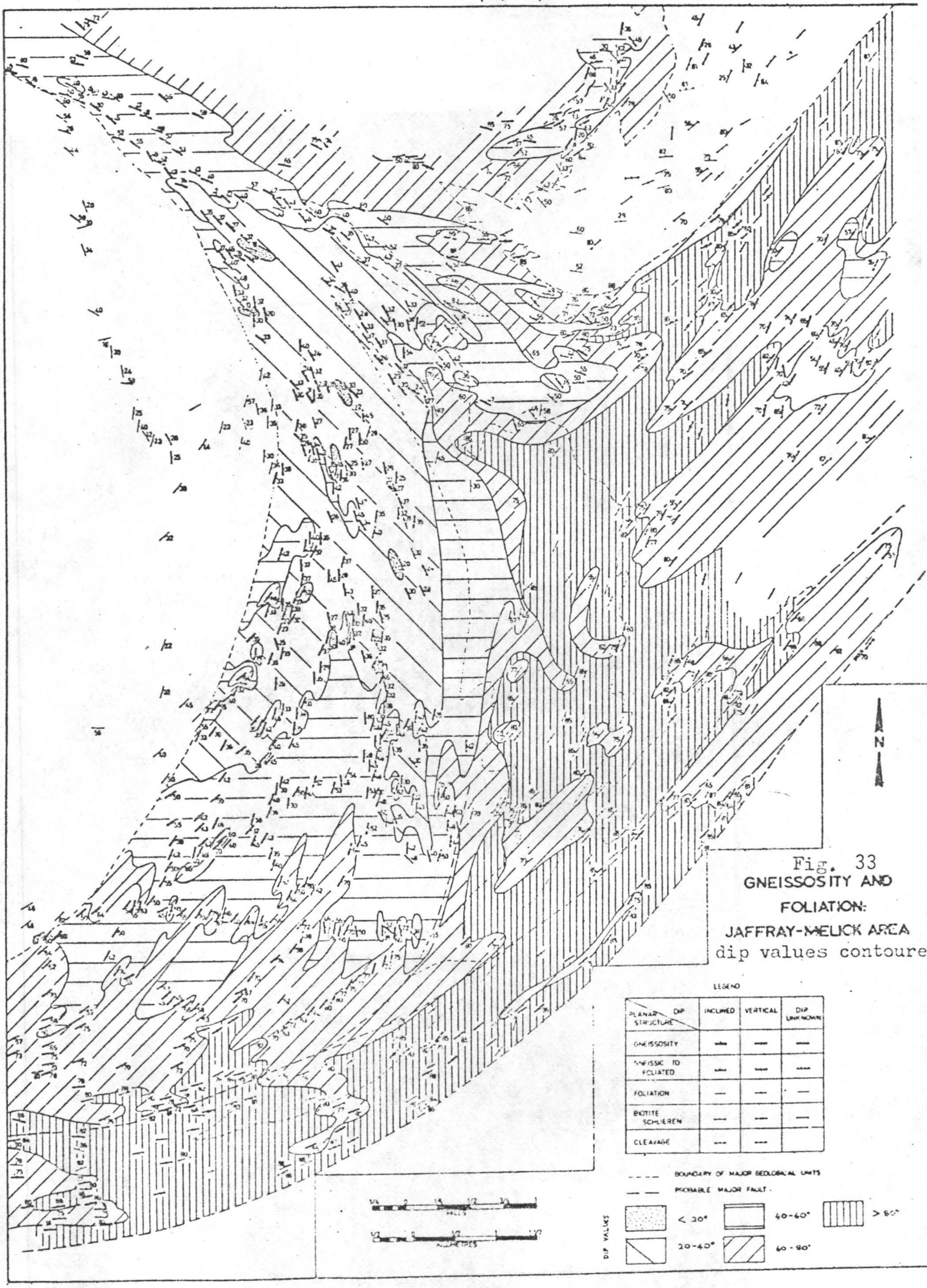


Fig. 33
GNEISSOSITY AND FOLIATION:
JAFFRAY-MELICK AREA
dip values contoure

lithologies (Fig's. 31, 32) were made. As may be seen the surface trends in the gneisses are more diffuse than for the Melick Tonolite probably reflecting country rock heterogeneities. However, the basic trends remain unchanged.

Examination of the regional lineaments shows that there are two basic trends at approximately 150° and 060°. Since the microgranites and pegmatites of Group 1 crosscut all the major lithologies of the area, it would seem reasonable to suggest that these intrusions are unrelated late injections which have penetrated along regionally developed fracture trends. However, the inhomogeneous distribution of the intrusives noted in Fig. 28 argues against this idea. Particularly as the basic fracture trends appear to be independent of lithology.

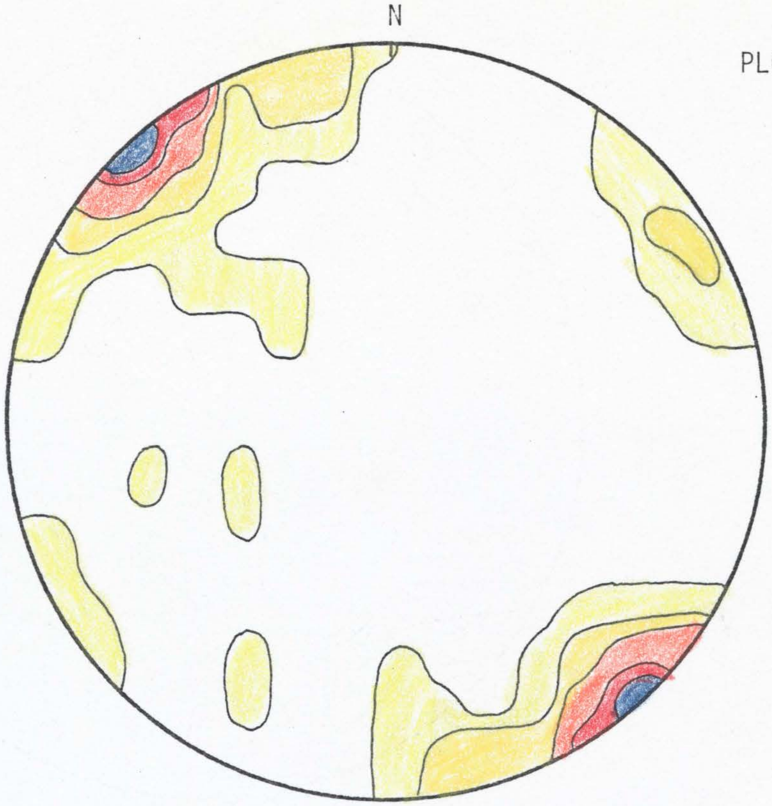
Closer examination of the geology of the Jaffray-Melick area, yields some interesting results. Firstly, the Dallis intrusion is probably not a vertically sided plug. Analyses of the dips of gneiss adjacent to the margins of the body suggests that it is half ellipsoidal in form with shallow dips to the ENE and WSW. To the north and south the body has steeply dipping boundaries (Gower, 1975). Furthermore, the region of shallowest dip in the east coincides with the area of highest late intrusive concentration on the west side of Black Sturgeon Lake. As a result, the east-west trending band of high late intrusive concentration is roughly underlined by the ENE trending east limb of the Dalles ellipse. A rough estimate of the azumuth of a line joining areas of lowest dip on opposite sides of the body is 065° with a complementary short axes azimuth of 155° (Gower, pers. comm.).

Fig. 34

PLOT OF OLDEST GROUP 1

DIKE ON OUTCROP

200 POINTS



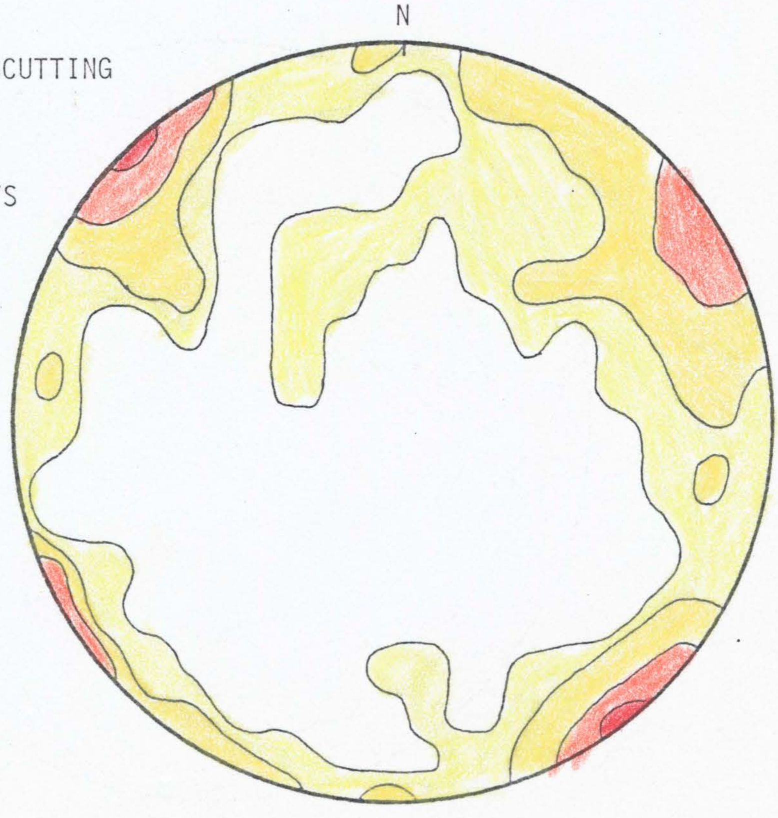
CONTOUR INTERVAL 2%

Fig. 35

PLOT OF CROSSCUTTING

DIKES

200 POINTS



In this context the significance of the joint surfaces becomes much clearer. Doming of the solidified outer skin of the Dalles and the overlying species caused by progressive emplacement of the largely plastic mass of the Dalles, would cause an extensional environment in the above mentioned elements.

This environment would not be unlike that of an antiform above the neutral boundary surface where σ_1 is subvertical and much greater than σ_2 and σ_3. According to Price (1969) such conditions would result in the formation of subvertical axial as well as associated conjugate shear joint sets.

This model corresponds very well to the observed trends. The splay of dike surfaces between 040° and 090° could then represent the conjugate and axial joint sets to the plunge culmination developed by the Dalles. While the 140° trend could represent complementary cross fractures.

The exact relationship of the former to the latter may be determined by order of appearance plots. These plots (Fig. 34, 35) suggest that the 140° dikes were the last to form. Hence it may be that this set was developed slightly later than the axial set due to progressive doming of the body twoards the west.

This model is also consistent with the clearly tensional nature of some of the dike surfaces.

Therefore it would seem reasonable to suggest that the Group 1 dikes have intruded along tensional and shear joints, and fractures created by progressive emplacement of the eliptical Dalles body in the brittle upper region of the crust.

Up to this point I have been considering the Group 1 dikes only. However, certain aspects of the earlier dike Groups, particularly 2 and 3 suggest that this model is applicable in their case as well.

The gradation in deformational styles of the Groups 2 and 3 dikes suggest that these features are in fact synkinematic and have been intruded during an ongoing phase of deformation. In addition, though plastically deformed, the primary form of these intrusives is identical with that of the Group 1 intrusives. Given these two considerations, I suggest that the Groups 2-4 dikes represent intrusion of material into fractures formed in an identical manner to the Group 1 dikes. However, these intrusives occurred at an earlier stage in the progressive emplacement of the Dalles. As a result continued doming combined with a constant heat flux from the large, possibly partially molten body, could have resulted in a brittle to ductile transition. This transition producing the plastic folded deformation characteristic of these groups.

As this would be a continuing process of surface formation, injection and deformation, the observed gradation in degree of deformation could easily be developed.

PETROGENESIS

Water and the Origin of Pegmatite

Before considering the petrogenesis of the dike groups as a whole, let us first examine the relationship between the pegmatites and their respective microgranitic partners.

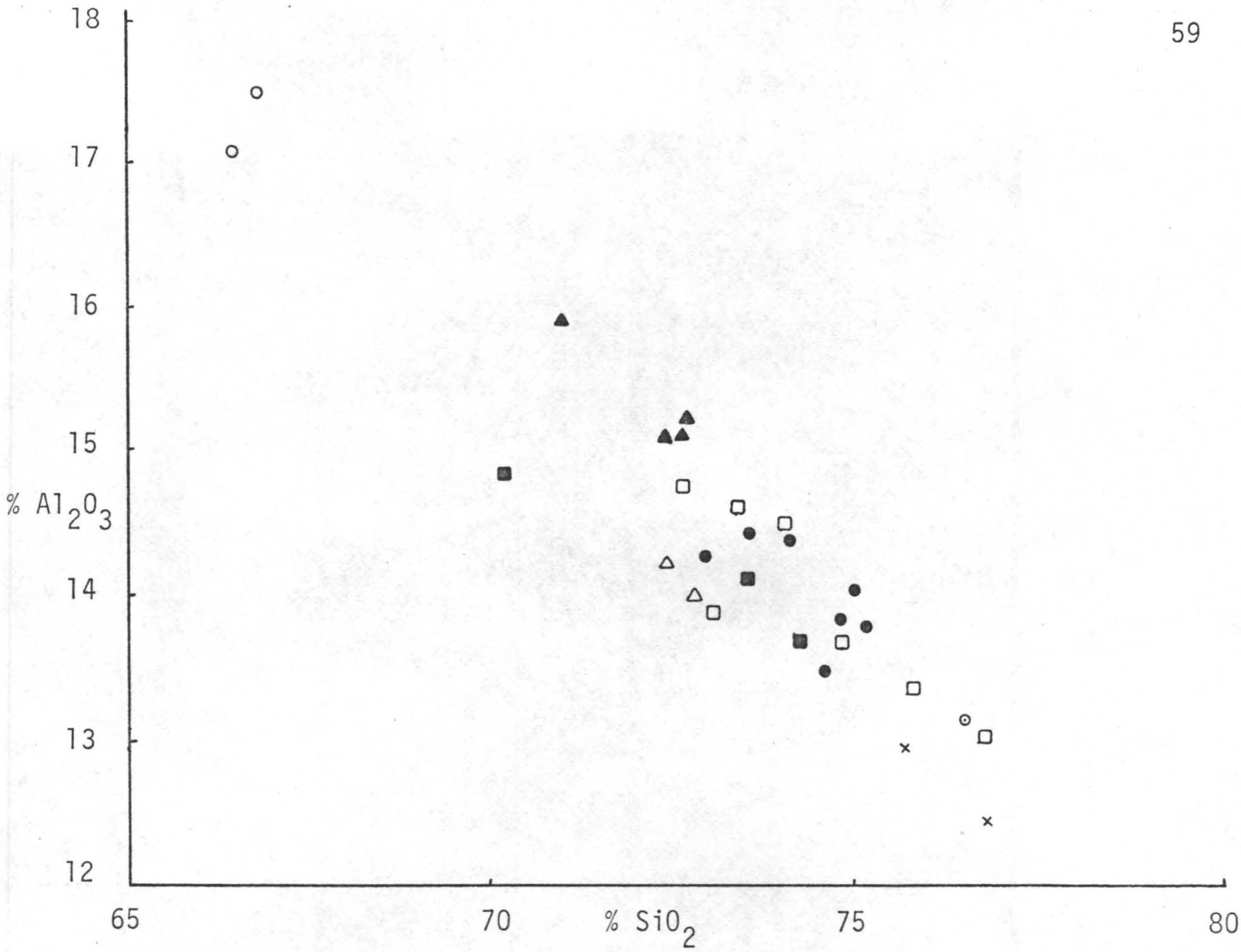
As analyses were made on Group 1 pegmatites only, this discussion, of necessity, will be limited to that group. Hence, further reference to pegmatites and microgranites implies Group 1 dikes only.

Jahns and Burnham (1969) maintain that coarse grained pegmatitic phases can be developed only in the presence of a discrete silicate saturated aqueous fluid. Indeed, they suggest that such rocks represent crystallization directly from only such a phase. This conclusion is consistent with the form of many of the smaller pegmatite viens. These intrusions extend for many meters of outcrop, yet have thicknesses of less than 1 cm in certain cases. It is difficult to envisage how a silicate melt of 10^6 - 10^7 poises viscosity could have intruded as such a thin sheet (Jahns and Burnham (1969)).

Such pneumatolytic viens contrast sharply with the silicate melt origin inferred for the microgranites (Carmichael et al. (1974)). However, the complete gradation in form from the microgranites, to microgranites with discontinuous pods of pegmatite, to intimately layered mixed intrusives, to pure pegmatite, suggests the derivation of the pegmatite from the microgranites. Further, this observed gradation suggests that such differentiation occurred within the dike system itself. Some support for this idea is provided by the intimate crosscutting and counter crosscutting relationships of the two, which suggests a close temporal relationship.

If this is true, how does it happen? As may be seen in the major element variation diagrams, and the Granite and Feldspar plots, the composition of the microgranites is very uniform over the entire area of

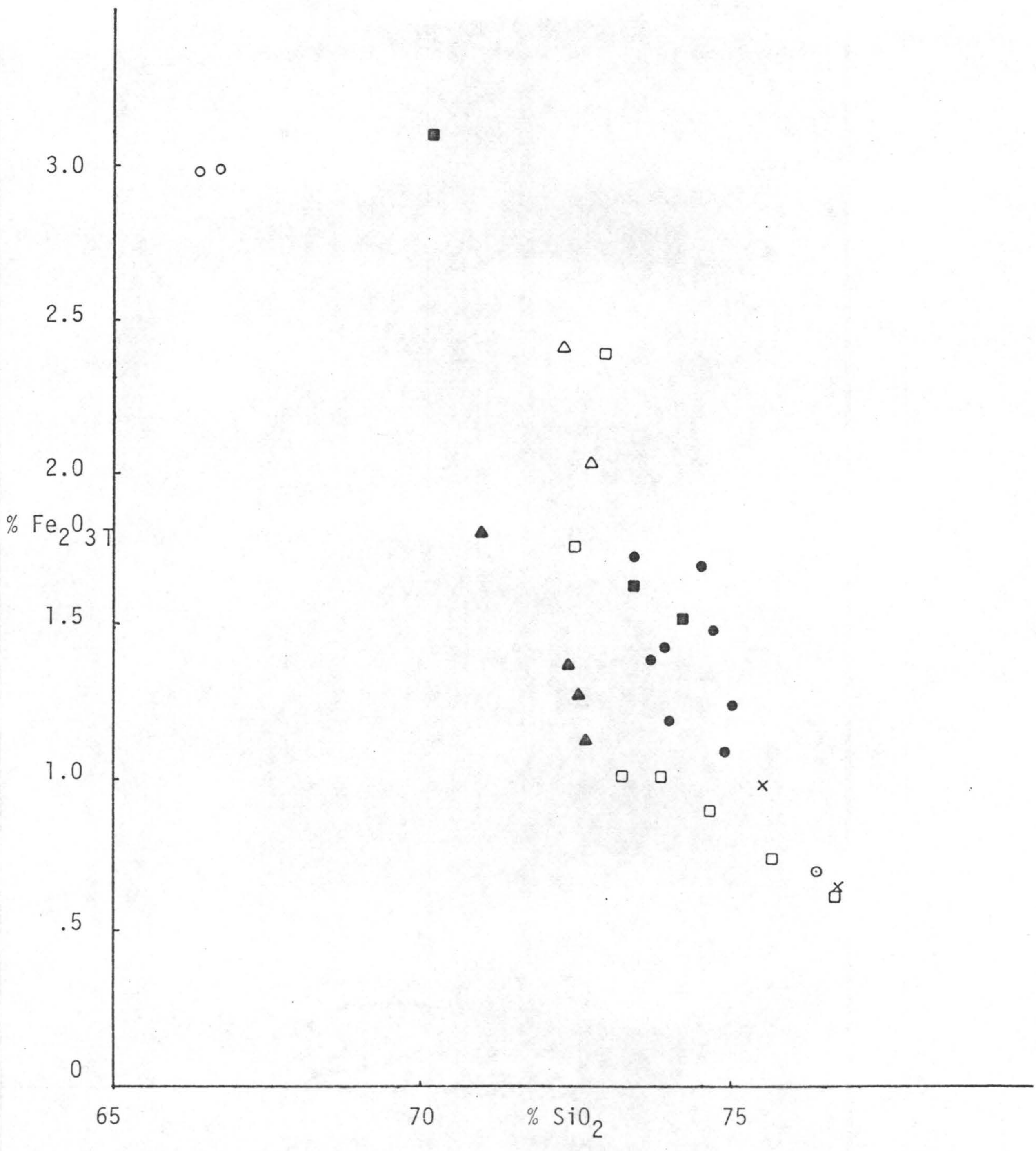
Fig. 36

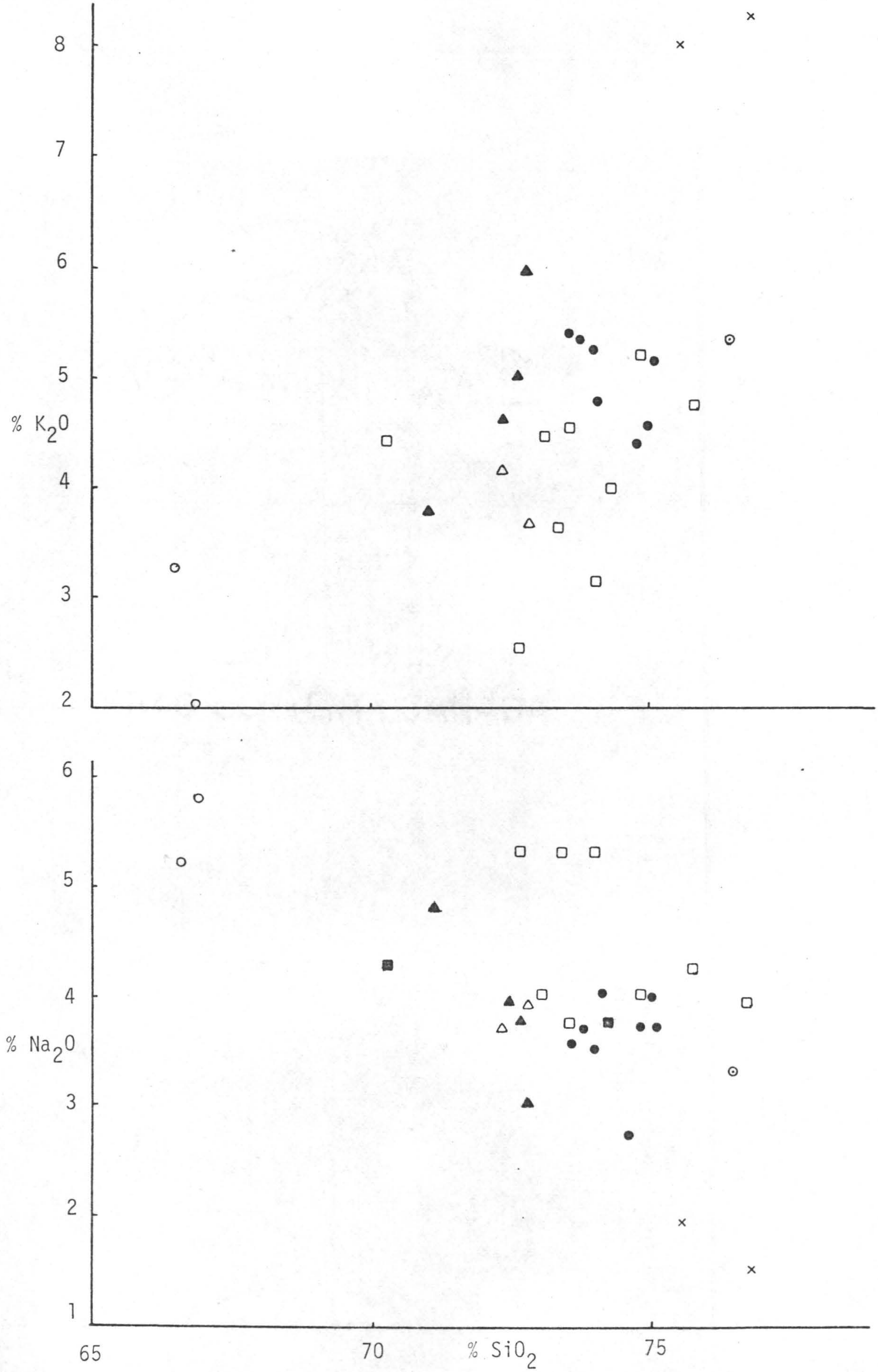


Symbols

Group 1	microgranites	●
	mixed intrusive	⊙
	pegmatites	×
Group 2	microgranites	▲
Group 3	microgranodiorites	△
Group 4	microgranodiorites	○
Dalles Pink		□
Austin		■

Fig. 37




8
7
6
5
% K_2O
4
3
2
6
5
4
% Na_2O
3
2
1
65
70
% SiO_2
75

Figs. 40, 41 and 42

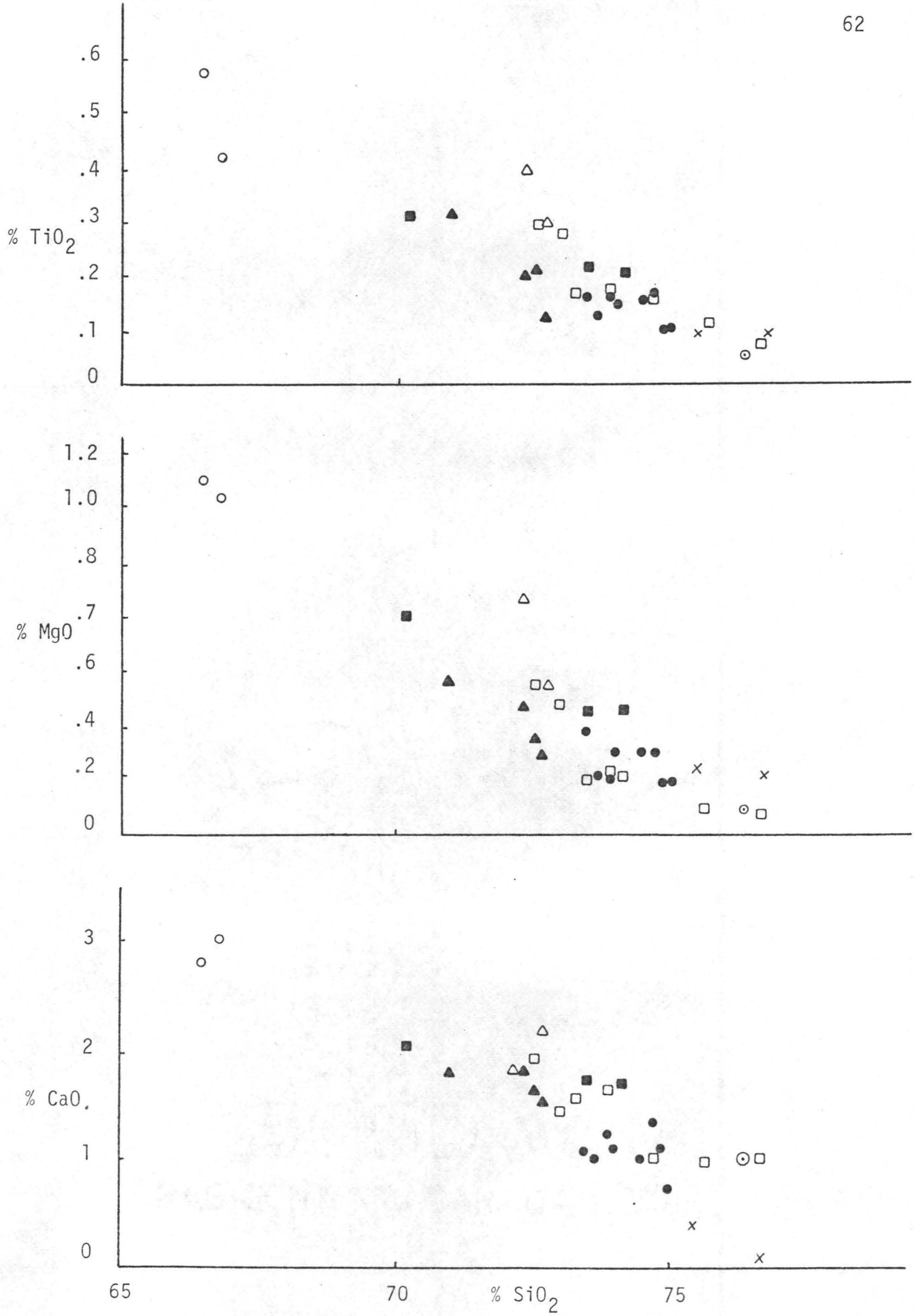


Fig. 43

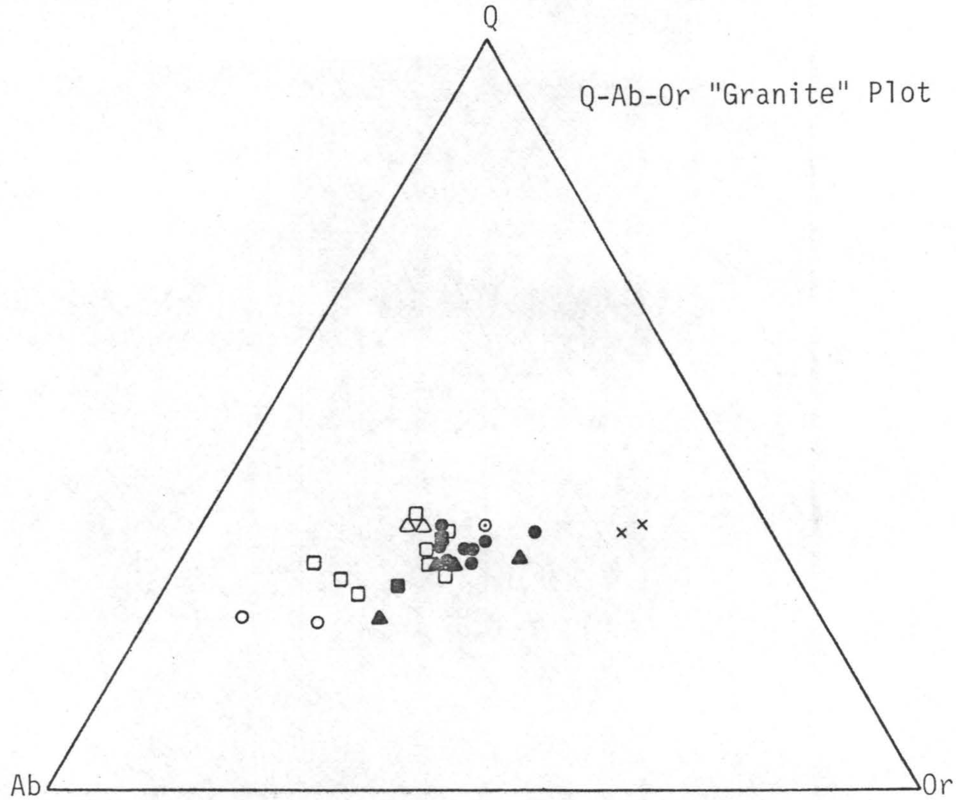
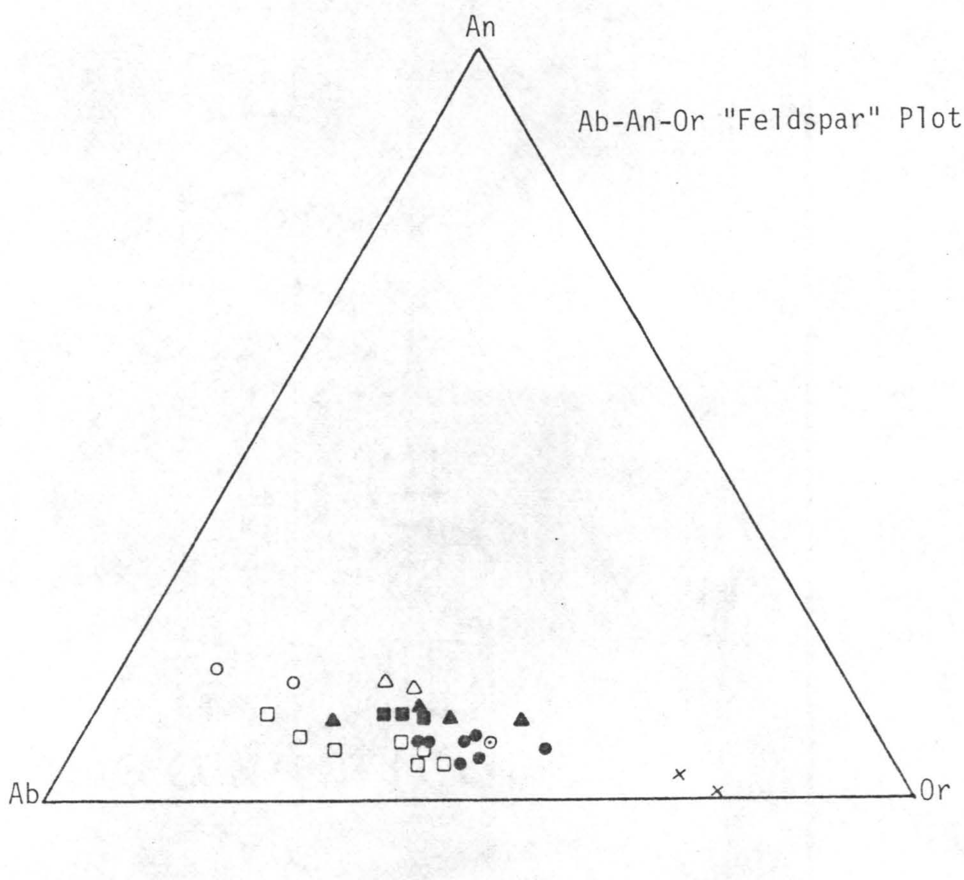


Fig. 44



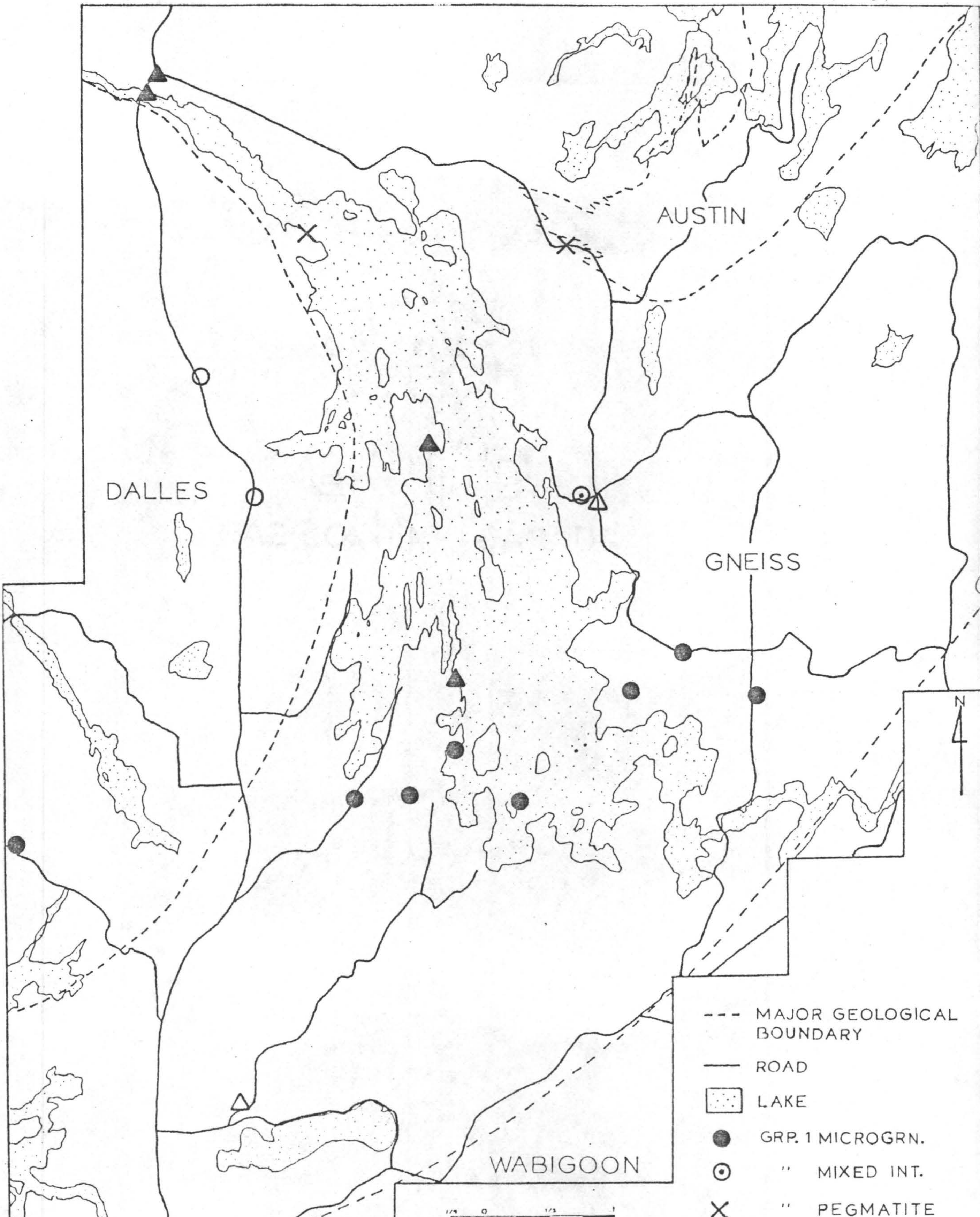


Fig. 45. Location of Samples

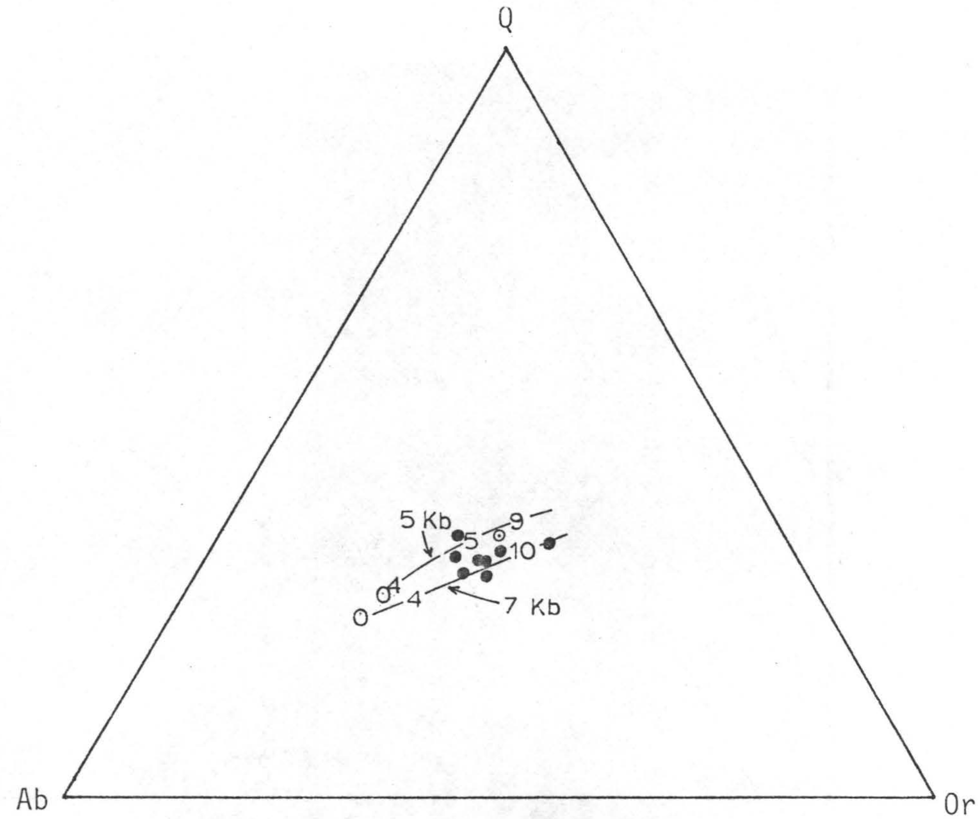
study. This suggests, that rather than small multiple sources, the wellspring of the microgranites is a single large differentiating system. Indeed, the very constancy of the composition and its closeness to that of the "average" granite suggests that the melt represents the residual phase of that system (Winkler (1976)).

In this context, it is interesting that the chemical analysis of F187 is very similar to those of the microgranites. Examination of the Granite and Feldspar plots shows that this sample (mixed intrusive) plots almost within the microgranite fields. This is significant as F187 is composed of finely intergrown quartz, alkali feldspar and plagioclase with the development of myrmakitic and graphic textures. According to Marmo (1971) such textures may be characteristic of crystallization of a melt of eutectic composition.

The textural characteristics of the microgranites, particularly the tattered emboyed nature of the plagioclase feldspars, suggests that the melts were not of eutectic composition for their conditions of crystallization. However, the above observation suggests that they may have been close.

Comparison of the microgranite composition to experimentally determined eutectic melts in the system Q-Ab-Or-An-H_2O (water excess) yields a pH_2O estimate of 5-7 Kbs. Although the microgranite composition is only close to a true eutectic composition, this pressure is much too high. Eutectic melts cannot be moved far from their environment of formation without crystallizing. Hence, a eutectic melt at 7 Kb could never reach the 3-4 Kb pressure conditions envisaged for emplacement of the dikes.

Fig. 46



Comparison of the microgranite compostions to the eutectic compositions of the system Q-Ab-Or-An-H_2O (water excess) for confining pressures of 5 and 7 kb. The small numbers denote the An proportion of the eutectic composition. From Winkler (1976)

Winkler (1976) points out that such discrepancies between natural residual melt compositions and the experimental eutectics are the rule rather than the exception. This is because the experiments are conducted under conditions of pH_2O = p Total, while natural granitic melts commonly are undersaturated with respect to H_2O (Wyllie et al. (1976)). Hence, the source melt of the microgranites appears to have been an undersaturated residual phase of near eutectic composition. That this melt contained some water and may even have been water rich (6-8%, Jahns and Burnham (1969)) is evident from the high degree of alteration of the plagioclase feldspars.

As noted in the section on petrography, this alteration is not ubiquitous. Coexisting Group 3 and Group 4 dikes do not develop it. Hence, rather than being related to a large scale metasomatic event, the alteration appears to be tied to the compositions of individual dikes.

The reactions of plagioclase to epidote, calcite and hematite as well as muscovite require Fe, K_2O and H_2O (Spry (1969)). Given the above consideration, this suggests that the dike melts must have had a considerable water content, which was left as a post crystalline residual fluid. The source of the Fe was probably the country rock with introduction by circulating residual fluids. This conclusion is supported by the observed colour control exerted by the country rock. In tonalitic country rocks, the dikes tend to be reddish, with development of magnetite. While in amphibolitic country rocks, the same dike tends to be whitish or yellowish with the development of Fe sulphides. At G103 a thick (10 m+) intrusive has a pronounced meter wide reddish band parallel to one margin. This could be interpreted as the front of inwardly migrating Fe. As potassium tends to increase in differentiation, its presence in a residual fluid is to be expected (Goldschmidt (1954)).

According to Jahns and Burnham (1969) progressive crystallization of such undersaturated water rich (6-8%) melts will produce a discrete aqueous fluid phase after 50-10% crystallization respectively. Hence, considering that the microgranites are volumetrically superior to the pegmatites, derivation of the pegmatite forming fluids by progressive crystallization of larger amounts of microgranite seems reasonable.

Concentration of such residual fluids to form discrete dikes may have occurred in the following fashion. A granitic melt flowing through a dike conduit eminating from the homogeneous source, would constantly decrease in volume as successive layers of microgranite were accreted onto the dike margins. In this way a magna which had travelled a great distance, and crystallized out a large amount of material may have become unsaturated and exsolved a discrete volatile phase. This phase would resist crystallization and hence would concentrate at the core of the dike, crystallizing the pegmatitic layers of a mixed intrusive. Eventually if such a melt progressed far enough, all of the silicate melt will have crystallized out leaving only the aqueous fluid to form pegmatite veins.

In addition to the spatial relationships the geochemical data is not inconsistent with this model. Maaloe and Wyllie (1975) have found that for the system Q-Ab-Or-An-H_2O the presence of a discrete aqueous fluid has a strong depressing effect on the quartz, alkali feldspar liquidis relative to that of plagioclase.

Examination of the variation diagrams, shows good correlation with the above considerations. In all elements there is good continuity and the progressive depletion of plagioclase relative to alkali feldspar and quartz is indicated. Further the one sample of mixed intrusive analysed has an intermediary composition to the two end members.

This observation by Maaloe and Wyllie (1975) also explains the tattered embayed nature of the plagioclases. If the drop in temperature during crystallization could not quite keep up with the depressant effect of the increased pH_2O, the melt may have slipped off the plagioclase liquidi resulting in resorption.

Interpretation of the trace element data is somewhat more difficult due to the distinct possibility of metasomatic redistribution. However, the bulk of the microgranite samples do have very similar Rb/Sr, K/Rb and Ca/Sr values, which suggests minimal contamination. Further, their K/Rb ratios are within the main igneous trend as defined by Shaw (1968).

The two samples of microgranite with higher than average Rb concentrations will be discussed later.

The trace element composition of the pegmatites is very similar to those of the microgranites and on a Rb/Sr plot they occur within the main microgranitic field. However, this is not what one would have expected. The pegmatites are enriched in K and depleted in Ca. Hence, K/Rb ratios are greater than the microgranites and the Ca/Sr ratios are much lower.

Considering that the compound distribution coefficient of K/Rb

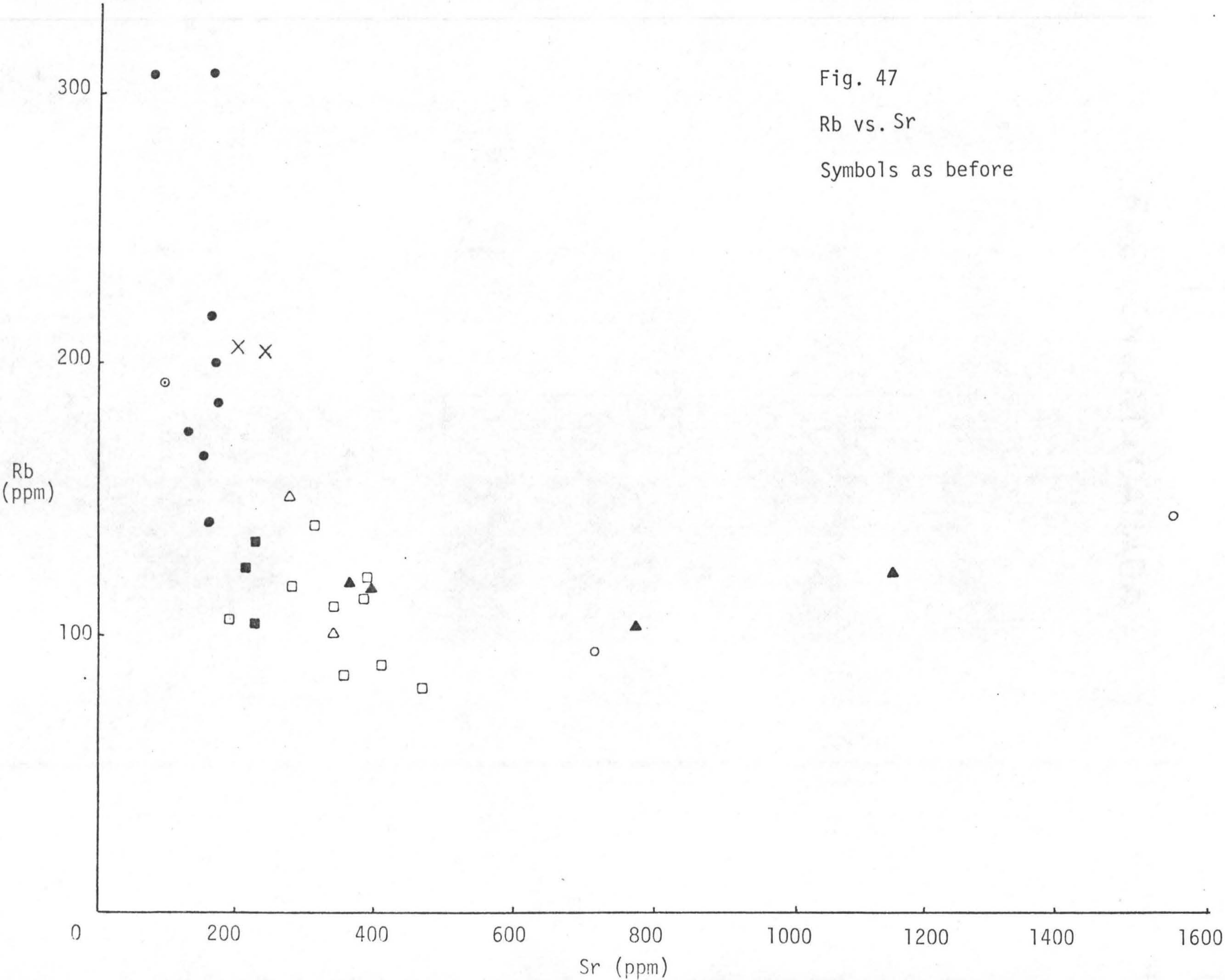
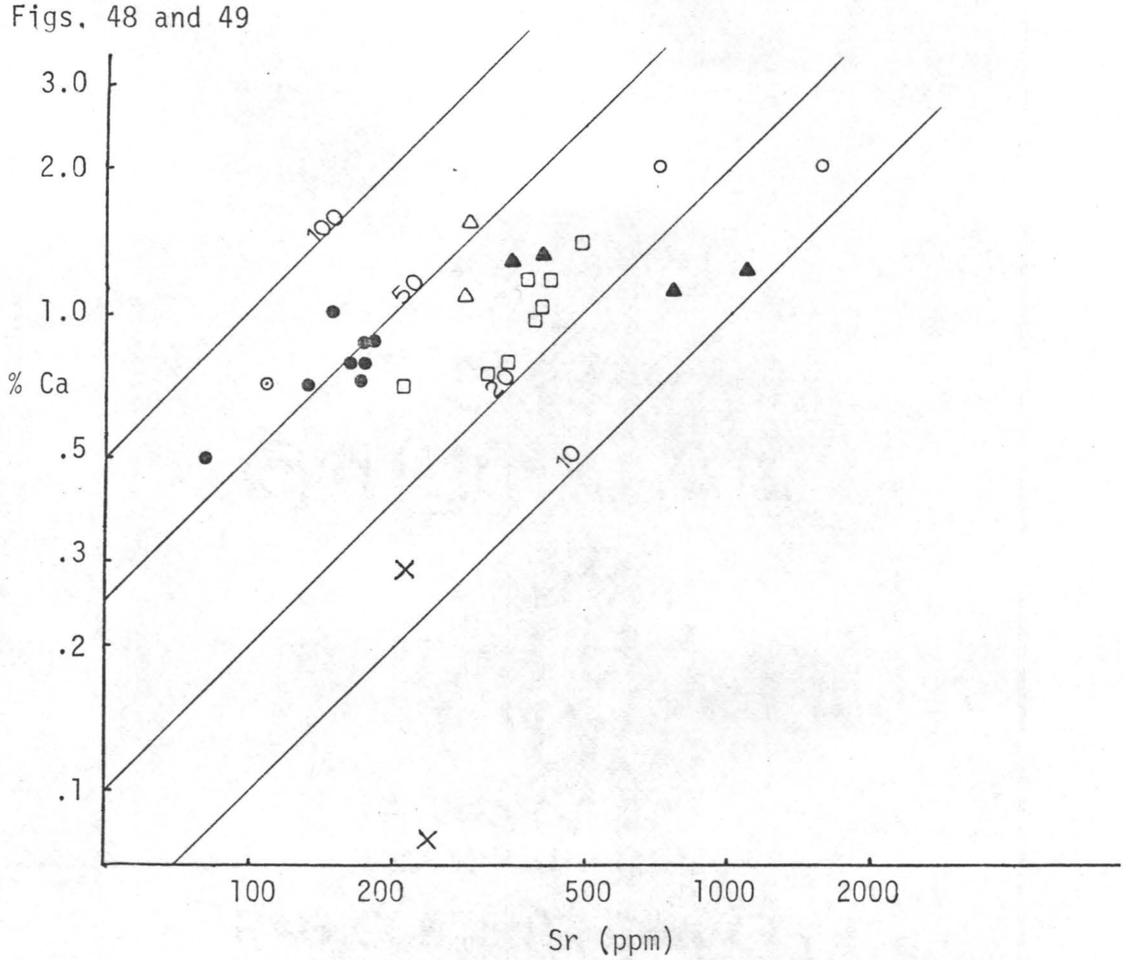


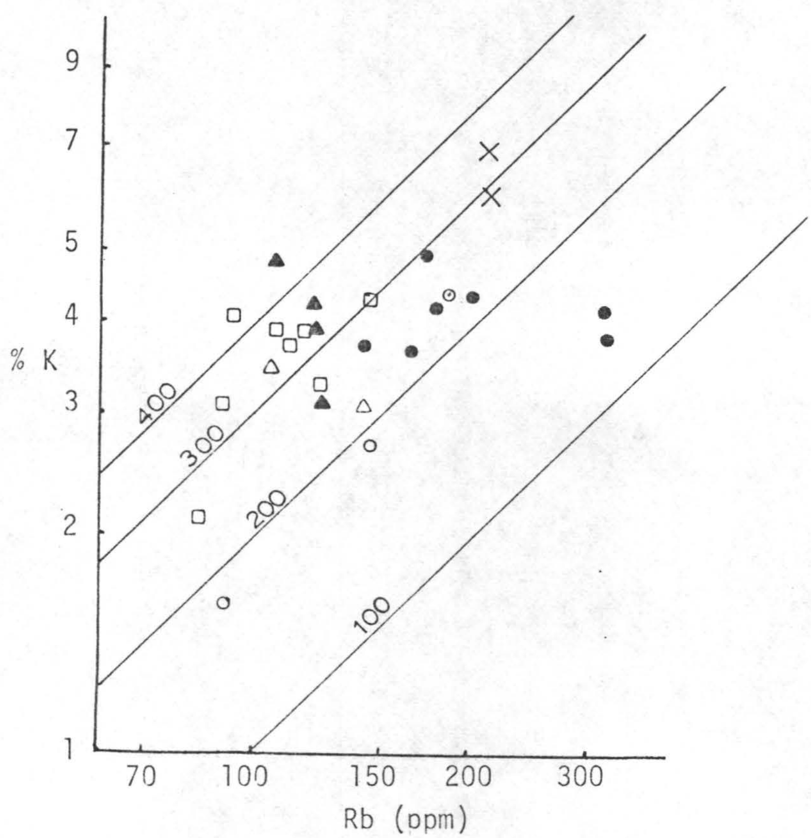
Fig. 47

Rb vs. Sr

Symbols as before

Figs. 48 and 49





for alkali feldspar is much less than one (Beswick (1973)) and that of Ca/Sr for both plagioclase and alkali feldspar is much greater than one (Beswick (1973)) and that of Ca/Sr for both plagioclase and alkali feldspar is much greater than one (Berlin and Henderson (1968)), these trends are anomalous.

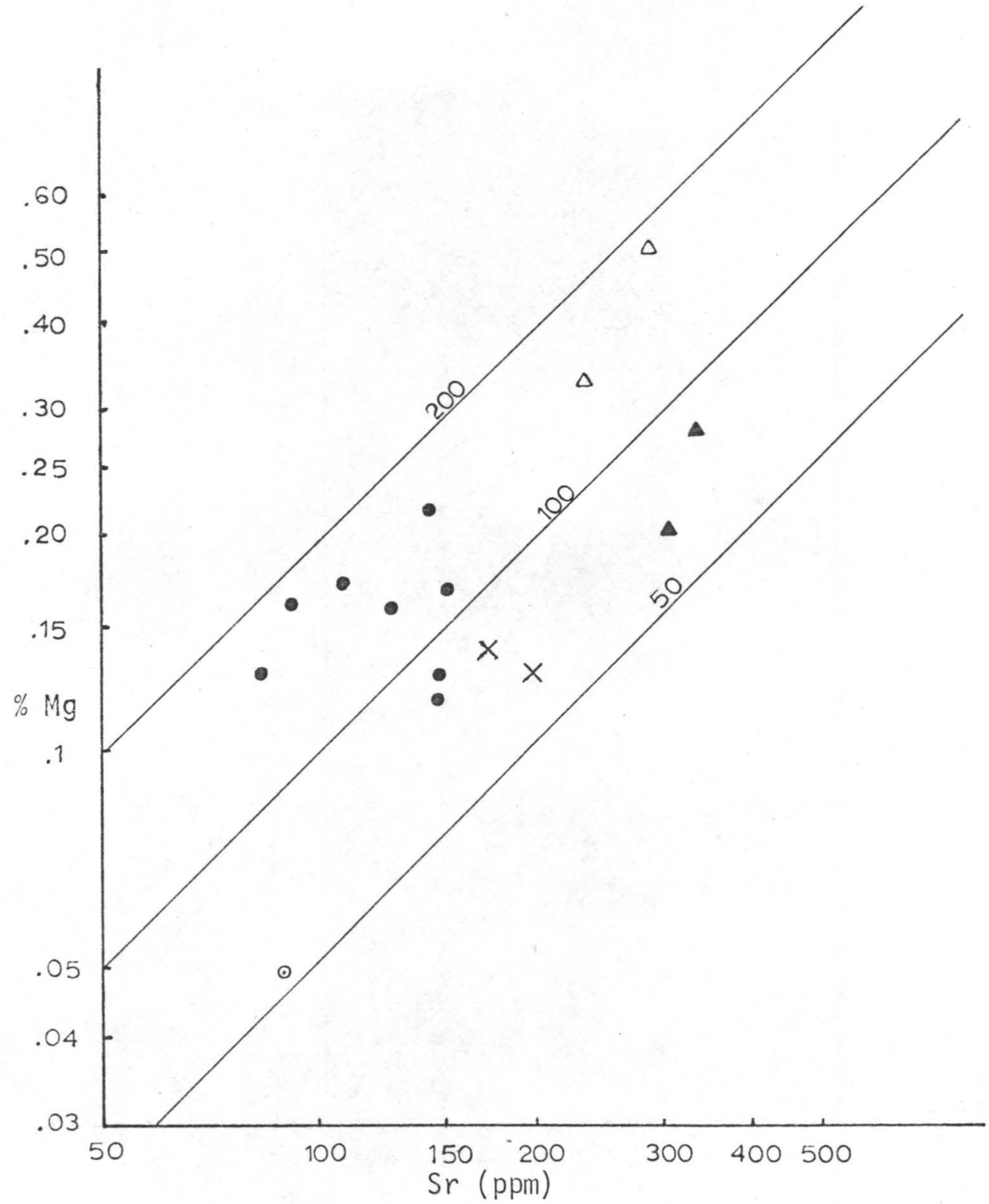
However, they are anomalous only if the feldspars are the controlling mineral phases. Studies by Beswick (1973) on K/Rb fractionations between phlogopite (an analogue for biotite) and aqueous chloride vapours has shown that the compound distribution coefficient is only slightly greater than one. Therefore, in a system where the main trace element concentration is in biotite, progressive crystallization will not result in a melt enrichment in Rb. Admitedly, the biotite content of the microgranites and pegmatites is low, between .5 and 2 percent, hence the effect should not be large. However it is a possibility.

The extremely low Ca/Sr values of the pegmatites suggests either that the pegmatites are derived from a separate strontium rich source, or that Sr does not follow Ca during the fractionation of the pegmatite from the microgranites.

While possible, the first point is not consistent with the morphological, spatial, temporal and major element compositional considerations presented up to this point. Hence, it will be pursued no further.

As to the second point, biotite may be again involved as an alternate controlling mineral phase. According to Goldschmidt's rules the large Sr^{+2} cation could substitue for the K^{+1} cation (radius difference 15%) along with the substitution of an Al^{+3} for an Si^{+4} to

Fig. 50


.60
.50
.40
.30
.25
.20
.15
% Mg
.1
.05
.04
.03
50
100
150
200
300
400
500
Sr (ppm)
200
100
50

balance the charge. Some evidence to support this idea is provided by a plot of Mg vs. Sr. If Mg composition may be taken as a measure of biotite abundance (assuming constant mineral composition) the close ratio correlation between the pegmatites and the micrograrites is significant. Further, the sample of mixed intrusive which is depleted in Mg shows a similar depletion in Sr maintaining the same ratio. This would tend to suggest that biotite is exerting some influence on the Sr distribution, and may be responsible for the anomalous concentrations.

The uniform low values for Nb and Y suggest that these elements were below concentration necessary for quantitative analysis, hence are of little value.

The variation of the Zr values for the microgranites and pegmatites are similar. However, the presence of discrete minute zircons in biotites indicates that Zr is not behaving as an ideal trace element. Since it occurs in its own stoichiometric phase, fractionation effects with respect to the other phases should be minimal. Therefore, the consistent decline in Zr between the microgranites and the pegmatites is consistent with continuing crystallization of the zircon phase.

Although some difficulties are presented by the trace element data, the concept of along dike fractionation of a water rich melt to produce pegmatite dikes is in agreement with the author's observation and analyses.

General Petrogenesis

Having determined that the pegmatites are indeed derived from the microgranites, let us now consider the origins of the microgranitic and microgranodioritic melts themselves.

From the previous discussion, it is clear that the emplacement of all the dike groups has been intimately related to the late stages of the intrusion of the Dalles body. Indeed, it was suggested that the earlier dike groups represent deformed equivalents of the Group 1 dike suite.

This conclusion is entirely consistent with the petrography and geochemistry of the Group 2 and 3 dikes. The minerology, textures and primary form of these dikes is identical to those of Group 1. Examination of the major element variation diagrams shows that, although they are distinct, there is a great deal of overlap and continuity between the three groups. Indeed, given the temporal relationship of the Group 2/3 dikes to the Group 1 dikes, their tendency to higher Al_2O_3, CaO, and lower SiO_2 is consistent with the progressive differentiation trend of the residual phase of a magmatic system (Carmichael et al. (1974)).

Considering the close spatial and structural relationships discussed above, this system should be the Dalles. Ramberg (1970) has noted that many diapiric bodies, which intrude as highly viscous masses, are probably not wholly solid, containing some residual magmatic phase. Indeed, according to Gower (Pers. Comm.) the Dalles body, although homogeneous on the large scale, is often composed of two discrete phases. A grey tonolite (Dalles grey) which is viened with irregular patches of reddish grenitic material (Dalles pink).

When chemical analyses of the Dalles pink provided by C. Gower are compared to the Groups 1-3 dikes, the correlation is striking. With the exception of slightly higher Na_2O values, the analyses of the Dalles pink have near identical ranges to those of the Groups 1-3 dikes. Therefore, it is possible that the source magna for the microgranites and microgranodiorites may have been the Dalles pink.

Given this hypothesis, what mechanisms can then be developed to explain the differentiation trend observed.

As may be seen, the trend in both the late intrusives and the Dalles pink is to increase SiO_2, K_2O, decrease Al_2O_3, Na_2O and only slightly decrease CaO. These trends are represented on the Granite and Feldspar plots by a slight increase in quartz and a strong decrease in albite.

Considering that the Dalles is largely a tonolitic body with normative quartz of approximately 25% (Gower, Pers. Comm.) and that its residual melt may not have been of eutectic composition (system Q-Ab-Or-An-H_2O), the increase in K_2O relative to Na_2O may be explained by differentiation of the melt along the cotectic away from the Q-Ab join of the Granite system (Tuttle and Bowen (1959)).

However, in this trend one would expect to see a slight decrease in quartz, or at least relatively little change. As noted above, quartz increases.

This poses no great difficulty if we remember that the Dalles is not a static body, but rather a mobile one. Further, as the mass of material progressed upwards towards the surface, the pressure would have continually decreased. Tuttle and Bowen (1959) noted that such decreasing pressure conditions continually shift the ternary eutectic of the Granite system towards the quartz end. Hence, a melt differentiating down the cotectic can be made to increase in quartz as it follows the shifting eutectic.

Further, actual mobility could be augmented by a second effect. The presence of rotated angular inclusions and stoping, suggests that the magmas may have been under a considerable overpressure relative to that of the environment of emplacement. If the Dalles was intruded from depth (7-10 Kb) with a solidified outer pressure seal, such an internal overpressure could be developed. Entry of the body into the brittle crustal regiem during the late stages of emplacement, would then cause cracking of the pressure seal allowing both emplacement of the dike series and polybaric fractionation of the residual melt.

The model of derivation of the Groups 1-3 late intrusives from a polybaric fractionation residual phase of the Dalles intrusion is also consistent with the trace element data. Comparison of values provided by Gower (Pers. Comm.) shows that the Dalles pink has Rb/Sr, K/Rb and Ca/Sr values very similar to the Group 3 samples and two of the Group 2 samples. The two anomalous Group 2 samples have high Sr concentrations which may be due to contamination during metamorphism and deformation from adjacent Sr rich amphibolitic portions of the gneisses (Gower, Pers. Comm).

The slightly higher Ca/Sr and lower K/Rb values of the Group 1 microgranites may be explained in terms of the previously mentioned compound distribution coefficients of Berlin and Henderson (1968) and Beswick (1973). Since the compound K/Rb coefficient is less than one and that of Ca/Sr greater than one, progressive fractional crystallization of a magmatic system should enrich the residual melt in Rb and deplete it in Sr, relative to K and Ca. If, as suggested by the major element chemistry, the Group 1 microgranites represent later stage fractionations than the Groups 2 and 3 dikes, the above trends are consistent. Continued fractionation and melt enrichment in Rb could also explain the high Rb concentrations of two Group 1 micro-granite samples. These rocks are not markedly different from the bulk of the microgranites in terms of K_2O contents, hence have much lower K/Rb ratios. However, if the Group 1 microgranites as suggested, represent a near eutectic composition (system Q-Ab-Or-An-H_2O), progressive fractionation will not result in a drastic change in the residual melt composition. Hence the melt may be strongly enriched in Rb with no apparent increase in K_2O.

The range in Zr compositions of the late intrusives is also well within the range of values determined for samples of the Dalles pink (Gower, Pers. Comm.), further suggesting derivation of the dikes form that source.

Up to this point I have been considering the Dalles pink as the only possible source for the Groups 1-3 dikes. However, there is the Austin Granite in the area as well. Examination of the chemical composition of analysed samples of the body provided by Gower (Pers. Comm.) shows that they to overlap those of the late intrusives. However, given that there is no close spatial association of late intrusives to the Austin body itself and the fact that it is crosscut by underformed Group 1 dikes only, this body may be interpreted as a distinct expression of the same fractionating magmatic system as that which produced the late dikes. That is, as the brother of the Groups 1-3 dikes, rather than the father.

Unlike the Groups 1-3 dikes, the origin of the melts which produced the Group 4 dikes is unknown. The chemistry, petrography and morphology of these dikes is clearly distinct from that of the later intrusives and not consistent with derivation by fractionation of a residual Dalles phase. Gower (Pers. Comm.) has noted the presence of synkinematic mafic dikes of fairly late development in the area and it may be that the Group 4 dikes represent a late developing phase of that system. However, comparison of the Group 4 dike compositions with the mafic dikes does not show a strong correlation.

CHAPTER IV

CONCLUSIONS

1. The late synkinematic and post kinematic dikes of the Jaffray-Melick area were emplaced at environmental conditions of 450°-500°C temperature and 3-4 Kb confining pressure.
2. The emplacement of the dikes was controlled by the structures developed in the later stages of emplacement of the elliptical Dalles body, resulting in an inhomogeneous areal distribution and preferred dike concentrations. Further, emplacement of the dikes occurred during the intrusion of the Dalles producing synkinematic dike groups with complete gradation in deformated style.
3. The origin of the melts for Groups 1-3 dikes was a residual magnatic phase of the Dalles, similar to the Dalles pink. Entry of the Dalles body into the brittle upper regiems of the crust caused cracking of an outer pressure seal, fused at depth, which allowed emplacement of the early Group 2-3 dikes into the solidified outer portion of the Dalles body and the country gneisses. The decreasing pressure accompanying such emplacement resulted in polybaric fractionation of the residual Dalles phase which produced the observed Granodioriate-Granite fractionation trend between the Groups 2-3 and Group 1 dikes.
4. Individual batches of undersaturated residual Dalles material were fractionated by an along dike progressive crystallization process which continually increased the water content of the residual melt.

Sufficient crystallization would result in production of a discrete aqueous fluid phase which would form successively, the core of a mixed intrusive and a pegmatite dike.

5. The Group 4 microgranodionates are unrelated to these processes and may instead be related to the late synkinematic mafic intrusives of the area.

Suggestions for Further Work

1. The late intrusives on the west side of the Dalles body should be mapped to determine if the structural correlation developed in the east is valid.
2. Mapping studies of other such diaperic bodies of the gneiss belts may clarify some of the arguments presented above.
3. The author strongly suggests that workers in the gneissic terraines of the Canadian Archean should not ignor the minor late intrusions. They do have a place in the development of the geology of a region and are not ubiquitous. Estimates of % areal contribution to outcrop, strike and dip of the major trends and limited selected sampling takes little time and may yield excellent results. Further, it is a job which can be done by a junior.

REFERENCES

1. Barth, T.F.W. (1959), Principles of Classification and Norm Calculations of Metamorphic Rocks, J. Geol., 67, 135-152.
2. Berlin, R. and Henderson, C.M.B. (1968), A Reinterpretation of Sr and Ca Fractionation Trends in Plagioclase from Basic Rocks, E.P.S.L., 4, 79-83.
3. Beswick, A.E. (1973), An Experimental Study of Alkali Metal Distributions in Feldspars and Micas, Geoch. et Coschem. Acta., 37, 183-207.
4. Breaks, F.W., Bond, W.D., McWilliams, G.H., Gower, C.F. and Stone, D. (1975), Operation Kenora-Sydney Lake; Ontario Div. Mines, Preliminary Map, p. 1030, Geol. Ser. Scale 1 inch to 1 mile or 1:63, 360, Geology, 1974.
5. Carmichael, I.S.E., Turner, F.J. and Verhoogen, J. (1974), Igneous Petrology, McGraw-Hill, New York.
6. Deer, W.A., Howie, R.A. and Zussman, J. (1966), An Introduction to the Rock-Forming Minerals, Longmans. Group Ltd., London.
7. Fyfe, W.S. (1970), Some Thoughts on Granitic Magmas in Mechanisms of Igneous Intrusion, ed. Newall and Rast, Gallery Press, Liverpool.
8. Goldschmidt, V.M. (1954), Geochemistry, Clarendon, Oxford.
9. Gower, C.F. (1975), The Geology and Tectonic Evolution of the English River Gneiss Belt in the Jaffray-Melick Area, Near Kenora, Northwest Ontario, Tech. Memo. 75-78, Dept. of Geology, McMaster University, Hamilton, Ontario.

10. Jahns, R.H. and Burnham, C.W. (1969), Experimental Studies of Pegmatite Genesis. A Model for the Derivation and Crystallization of Granitic Pegmatites, Econ. Geol., 64, 843-864.

11. Maaloe, S. and Wyllie, P.J. (1975), Water Content of a Granitic Magma Deduced from the Sequence of Crystallization Determined Experimentally with Water-Undersaturated Conditions, Contrib. Min. Pet., 52, 175-191.

12. Marchand, M. (1973), Determination of Kb, Sr and Rb/Sr by XRF, Tech. Memo. 73-2, Dept. of Geology, McMaster University, Hamilton, Ontario.

13. Marmo, V. (1971), Granite Petrology and the Granite Problem, Elsevier, Amsterdam.

14. Price, N.J. (1969), Fault and Joint Development in Brittle and Semi Brittle Rocks, Pergamon, Oxford.

15. Ramberg, H. (1970), Model Studies in Relation to Intrusion of Plutonic Bodies in Mechanism of Igneous Intrusion, ed., Newall and Rast, Gallery Press, Liverpool.

16. Shaw, D.M. (1968), A Review of K-Rb Fractionation Trends by Covarience Analysis, Geoch. et Coschem. Acta., 32, 573-601.

17. Spry, A. (1969), Metamorphic Textures, Pergamon, Oxford.

18. Stauffer, M.R. (1966), An Empirical-Statistical Study of Three Dimensional Fabric Diagrams as Used in Structural Analysis, Can. Jour. Earth Sci., 3, 473-498.

19. Turner, F.J. (1968), Metamorphic Petrology, McGraw-Hill, New York.

20. Tuttle, O.F. and Bowen, N.L. (1959), Origin of Granite in Light of Experimental Studies in the System $NaAlSi_3O_8$-KA/Si_3O_8-SiO_2-H_2O, Geol. Soc. Am. Mem. #74.

21. Winkler, H.G. (1976), Petrogenesis of Metamorphic Rocks, 4th ed., Springer-Verlag, New York.

22. Wylie, P.J., Wuu-Liang Huang, C.R. Stern and S. Maalöe (1976), Granitic Magnas, Possible and Impossible Sources, Water Contents and Crystallization Sequences, Can. Jour. Earth Sci., 8, 1007-1019.

Appendix 1

GEOCHEMICAL DATA

Part A. Major Elements

Analytical Error

Computation of chemical compositions from the raw data was accomplished using the method of P. Gunn.

To check the accuracy of the compositions thus determined, several known standards (B3, SY1, JB1 and GA) were run as unknowns and compared to the literature values (Abbey (1973)). The results for GA are tabulated below.

	GA (Literature)	GA (Unknown)
SiO_2	70.74	70.49
Al_2O_3	14.67	14.70
$Fe_2O_{3_T}$	2.89	2.89
MgO	0.96	0.99
CaO	2.48	2.46
Na_2O	3.59	3.80
K_2O	4.07	4.07
TiO_2	0.38	0.39
MnO	0.09	0.09
P_2O_5	0.12	0.12

As may be seen, the agreement is fair. The heavier elements (Fe, Ca, K, Ti, Mn) show excellent correlation, with almost no difference. Si and Al have differences of approximately .5 and .2% respectively which is acceptable. However, the lighter elements Mg and Na have differences of 4 and 6% respectively which is high. Examination of the other standards shows similar slight overestimates for these two elements. Hence, the calculated compositions for Na and Mg should be considered accurate to only ± 5%.

To determine the analytical precision in preparation of the fussion pellets, three separate pellets were made from sample FA7 and two from sample F424A. The results are tabulated below.

	$F177_1$	$F177_2$	$F177_3$	$F424_1$	$F424_2$
SiO_2	75.51	75.34	75.50	71.00	70.91
Al_2O_3	12.95	13.15	12.96	15.89	15.88
$Fe_2O_{3_T}$	0.98	0.99	0.97	1.81	1.82
MgO	0.12	0.24	0.30	0.60	0.55
CaO	0.39	0.40	0.39	1.76	1.78
Na_2O	1.92	1.85	1.83	4.81	4.80
K_2O	7.99	8.04	7.90	3.70	3.78
TiO_2	0.09	0.10	0.09	0.29	0.31
MnO	0.04	0.05	0.04	0.05	0.05
P_2O_5	0.01	0.01	0.01	0.10	0.11

As may be seen the error is negligible.

Abbey, S. (1973), Studies on Standard Samples of Silicate Rocks and Minerals, Part 3: Extension and Revision of Useable Values, GSC, Paper 73-36.

TABLE A(a)

MAJOR ELEMENT ANALYSES

(NORMALIZED)

IN WEIGHT PERCENT OXIDES

Sample	F101A	F139	F148	F158	F160	F177	F187	F190A	F201B	F203	F263A	F359
SiO_2	74.71	66.42	66.74	72.38	72.58	75.34	76.40	72.74	73.67	73.93	74.01	74.92
Al_2O_3	13.79	17.03	17.46	15.07	15.12	12.98	13.13	14.47	14.44	14.23	14.38	14.00
$Fe_2O_{3_T}$	1.49	3.01	3.01	1.39	1.29	0.99	0.70	2.05	1.39	1.43	1.19	1.09
MgO	0.29	1.29	1.24	0.47	0.35	0.24	0.09	0.55	0.21	0.20	0.29	0.18
CaO	1.38	2.83	3.01	1.85	1.58	0.40	1.01	2.18	1.10	1.22	1.11	1.13
Na_2O	3.71	5.20	5.78	3.92	3.75	1.85	3.30	3.90	3.69	3.51	4.04	3.97
K_2O	4.38	3.27	2.01	4.64	5.01	8.04	5.28	3.68	5.32	5.23	4.76	4.56
TiO_2	0.16	0.57	0.42	0.19	0.22	0.10	0.05	0.29	0.12	0.16	0.14	0.10
MnO	0.05	0.06	0.07	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05
P_2O_5	0.02	0.33	0.25	0.05	0.05	0.01	0.00	0.08	0.02	0.03	0.03	0.01
	●	○	○	▲	▲	×	⊙	△	●	●	●	●

Key to symbols on page 59.

TABLE A(b)

MAJOR ELEMENT ANALYSES

(NORMALIZED)

IN WEIGHT PERCENT OXIDES

	F424A	F435	F490	F544A	F581	F830	F924
SiO_2	70.91	74.52	75.04	72.67	72.34	76.74	73.48
Al_2O_3	15.88	13.46	13.75	15.23	14.22	12.39	14.40
$Fe_2O_{3_T}$	1.82	1.70	1.25	1.14	2.42	0.65	1.74
MgO	0.55	0.29	0.22	0.29	0.86	0.22	0.37
CaO	1.78	1.02	0.72	1.56	1.80	0.12	1.07
Na_2O	4.80	2.72	3.71	3.02	3.67	1.50	3.29
K_2O	3.78	6.06	5.14	5.90	4.16	8.25	5.39
TiO_2	0.31	0.15	0.10	0.12	0.39	0.09	0.16
MnO	0.05	0.05	0.05	0.04	0.05	0.04	0.06
P_2O_5	0.11	0.03	0.02	0.03	0.09	0.00	0.04
	▲	●	●	▲	△	×	●

PART B. Trace Elements

Analytical Error

Computation of the trace element compositions from the raw count data, was accomplished using the stock "Rubidium Strontum" and "XRFMBO" programs of the McMaster University Geology Department.

To check the accuracy of these methods standards were again run as unknowns and compared to literature values (Abbey (1973)). The results for JG-1 and NIMG are tabulated below.

	JG-1 (literature)	JG-1 (unknown)
Sr (ppm)	185	181.2
Rb	185	177.6
	NIMG (literature)	NIMG (unknown)
Y	120	115
Ar	260	262
Nb	40	38

Again the agreement is only fair. The difference of Rb, Y and Nb suggests that values determined by these methods should not be considered accurate to less than $\pm$ 4%.

Abbey, S. (1973), Studies on Standard Samples of Silicate Rocks and Minerals, Part 3: Extension and Revision of Useable Values, GSC, Paper 73-36.

To check the precision and reproducability of these methods duplicate pellets made for F177 were analysed. The results are tabulated below.

	$F177_1$	$F177_2$
Rb	206	207
Sr	206	206
Y	4	3
Zr	54	54
Nb	13	11

The error is negligible.

TABLE B. TRACE ELEMENT ANALYSES

(ppm)

	Sr	Rb	Y	Nb	Zr	
F101A	150	168	2	16	76	●
F139	1570	146	1	12	190	○
F148	717	91	8	11	200	○
F158	404	119	5	12	138	▲
F160	370	120	1	9	65	▲
F177	206	206	4	13	54	×
F187	108	186	4	11	79	⊙
F190A	287	152	4	17	159	△
F201B	175	199	2	11	83	●
F203	173	186	3	13	127	●
F263A	177	307	0	17	127	●
F359	164	141	1	13	85	●
F424A	1166	127	3	11	175	▲
F435	131	175	3	15	102	●
F490	80	305	8	14	106	●
F544A	789	104	4	11	118	▲
F581	348	103	0	1	144	△
F830	240	203	0	10	93	×
F924	169	219	2	12	120	●

Key to symbols on page 59.

Part C. Mesonormative Values MESONORMS

TABLE C(a)

Sample	F101A	F139	F148	F158	F160	F177	F187	F190A	F201B	F203	F263A	F359
Q	31.29	17.04	18.06	26.02	26.38	31.87	32.62	29.44	27.54	28.93	27.90	29.80
Or	25.21	15.47	8.34	26.15	28.62	46.65	31.24	20.23	30.95	30.46	27.36	26.52
Ab	33.62	46.34	51.38	35.30	33.81	16.72	29.94	35.30	33.33	31.78	36.41	35.84
An	6.78	11.80	13.17	8.88	7.55	1.90	5.07	10.38	5.36	5.91	5.33	5.57
C	0.54	0.63	0.98	0.39	0.85	0.79	0.17	0.33	0.73	0.72	0.70	0.55
Bi	1.47	5.94	5.47	2.17	1.78	1.35	0.47	2.71	1.08	1.13	1.40	0.92
Mt*	1.05	2.09	2.09	0.98	0.91	0.69	0.50	1.45	0.98	1.01	0.84	0.77
Ap	0.04	0.69	0.52	0.10	0.11	0.02	0.00	0.17	0.04	0.06	0.06	0.02
	●	○	○	▲	▲	×	⊙	△	●	●	●	●

* FeO was estimated at .33 $Fe_2O_{3_T}$ from analyses by Gower (Pers. Comm.) of FeO/Fe_2O_3 of the Dalles and Austin intrusions.

Key to symbols on page 59.

TABLE C(b) MESONORMS

Sample	F424A	F435	F490	F544A	F581	F830	F924
Q	23.44	31.40	30.15	27.33	29.42	34.20	29.50
Or	20.02	35.42	29.92	34.28	22.26	49.09	31.05
Ab	43.06	24.78	33.55	27.33	33.25	13.74	29.82
An	8.06	4.94	3.47	7.61	8.42	0.61	5.10
C	1.10	0.71	0.91	1.22	0.69	0.86	1.44
Bi	2.85	1.47	1.08	1.37	4.07	1.04	1.78
Mt	1.26	1.21	0.88	0.80	1.71	0.46	1.23
	▲	●	●	▲	△	×	●