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The age and intrusive relationships of granitoids of the Blue Tier Batholith, north-east Tasmania

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ABSTRACT

The south-east part of the Blue Tier Batholith in north-east Tasmania consists of several granodioritic to alkali-feldspar granitic plutons which intruded in five main phases. K-Ar and Rb-Sr dating indicates that the first three intrusive phases occurred between about 398 and 388 Ma and the fourth phase followed about 15 Ma later. The first three phases of intrusion can not be clearly distinguished by radiometric dating due to partial resetting caused by later intrusions and metasomatism. The plutons belong to four chemical suites related to the intrusive phases. The progressive change in the chemical character of the suites in order of intrusion may reflect different source rocks and a rising level of crustal melting.

INTRODUCTION

In north-east Tasmania granitoid bodies with compositions of hornblende-biotite granodiorite, biotite granite/adamellite and alkali-feldspar granite form the Blue Tier Batholith. These can be grouped into suites with distinctive chemical, isotopic (Sr) and petrographic character. The order and timing of emplacement of these suites is an important factor in any petrogenetic model for the formation of the batholith.

This paper describes the mapping evidence for the order of intrusion of the granitoid bodies, discusses the nature of these suites, reviews previous geochronological data and presents new K-Ar data from plutons of the Blue Tier Batholith that are exposed in the St Helens and neighbouring area. Previous geochronological work consists principally of K-Ar dating by McDougall and Leggo (1965), Rb-Sr dating by Cocker (1982), K-Ar and Rb-Sr dating by Turner *et al.* (1986) and Rb-Sr dating by Mackenzie *et al.* (1988).

GEOLOGY

The granitoids of the Blue Tier batholith intrude the folded Ordovician to Lower Devonian (Banks and Smith, 1968; Rickards and Banks, 1979) Mathinna Beds, which consist of interbedded quartzwacke, siltstone, and slate, regionally metamorphosed to slate

grade. The granitoid intrusion produced narrow contact metamorphic aureoles, and took place shortly after the regional folding of the country rocks, which is correlated with the Tabberabberan deformation of eastern Australia. The plutons are generally steep sided and elongated NNW in the general fold-trend.

In the following account rock bodies, where possible, will be referred to by the names used by Groves *et al.* (1977) and the locations of the main intrusive units and those of other features are shown on the geological sketch map (fig. 1).

In the St Helens area the Mathinna Beds have been intruded by a granitoid body ranging in composition from biotite hornblende granodiorite to biotite granite. It includes rock units previously described as George River granodiorite, Akaroa granodiorite and Grants Point granite (Groves *et al.*, 1977). These units are considered to be part of the same intrusion and will be included together under the term George River pluton. Another dominantly biotite-hornblende granodiorite mass (Gardens pluton) with minor areas of biotite granodiorite, outcrops on the coast at The Gardens and extends inland to the north-west. The George River and Gardens plutons are very similar in petrographic character and have the same attitude of mafic mineral foliation. It seems probable that these apparently separate masses are part of the same pluton.

North and west of St Helens a large biotite adamellite mass (Mt Pearson pluton) was intruded after the George River pluton. The order of intrusion can be demonstrated in the Launceston Creek area west of St Helens where quartz and feldspar pegmatitic patches, present in the marginal adamellite of the Mt Pearson body, intrude as thin veins into the granodiorite of the George River body. The truncation of the mafic mineral foliation in the George River and the Gardens bodies by the Mt Pearson mass also indicates that it was later than both bodies. The western part of the Mt Pearson pluton has been cut by a north-south fault and forms north and south extensions of the body.

A north-south trending biotite-hornblende granodiorite body (Scamander Tier dyke), stretching south from Binalong Bay to Scamander, is a later intrusion.

The area of outcrop immediately south-west of Binalong Bay is interpreted as part of the dyke rather than part of the George River body on the basis of its greater geochemical similarity to the rocks of the Scamander Tier dyke than to those of the George River pluton. This agrees with Groves *et al.* (1977) but differs from the St Helens map sheet (McClenaghan *et al.*, 1987).

A narrow east-west trending, dyke-shaped offshoot of the main dyke extends west from near the northern end, bisects the Mt Pearson pluton and connects to a broad patch of granodiorite outcrop in the Goshen area. Farther south in the Catos Creek area a broad north-south trending dyke of the same composition is considered to be part of the same intrusive phase. These bodies have been postulated (Turner *et al.* 1986) to be the hyperbyssal feeders to the St Marys porphyrite extrusive body which crops out in the St Marys Pass area. The dyke is chilled against the George River pluton near St Helens and also against the Mt Pearson pluton along the narrow east-west part of the dyke and on the eastern boundary of the broader mass farther west, thus demonstrating that it is later than both those bodies.

The St Marys Porphyrite body is older than the Piccaninny Creek granite body to its south, as the latter cuts discordantly across the axial surface of a synclinal structure in the porphyrite (Turner *et al.*, 1986). The Piccaninny Creek body is also probably younger than the Piccaninny Point/Long Point granodiorite body lying to its south since it also cuts across the line of that body's western boundary (Turner *et al.*, 1986).

The large biotite adamellite Poimena pluton, centred on Poimena, clearly truncates intrusive and faulted boundaries between the Scamander Tier and Mt Pearson bodies, thus showing that it is later than them. In the Poimena area occur a number of minor adamellite intrusions in the Poimena pluton (McClenaghan and Williams, 1982) which are regarded as part of the Poimena pluton.

In the Haleys New Country area occurs biotite adamellite which was not subdivided on the St Helens map sheet (McClenaghan *et al.*, 1987). However the slightly more mafic character of the southern part of the body suggests that it may be composed of two bodies (fig. 1). The salient of Mathinna Beds (fig. 1) may mark the boundary between the two bodies. The northern body has similar petrographic and geochemical character to the Poimena pluton is continuous with it and thus is considered here as part of the Poimena pluton, whereas the southern body will be referred to as the Haleys New Country pluton. The Poimena pluton is clearly younger than a biotite granodiorite in the Pyengana area (Pyengana pluton), since it cuts across the boundary between it and the Mathinna Beds (fig. 1). It also appears to be younger than the Haleys New Country pluton since it cuts across that body's contact with the Mathinna Beds on its north-west margin (fig. 1).

In the Lottah area the Poimena pluton is intruded by an alkali-feldspar granite body (Lottah pluton) which is geochemically and petrographically very similar to the Mt Paris pluton farther west which also intrudes the Poimena pluton.

In the St Helens Head area the George River pluton is intruded by muscovite granite dykes which only occur in that body.

Dolerite dykes are spread widely throughout eastern Tasmania and the Furneaux Group of islands, intrude many of the plutons, and are particularly common in the Gardens and Poimena plutons. The dykes have been inferred to be of similar Devonian age to the granitoids, as on Flinders Island a dolerite dyke is crossed by a quartz-feldspar porphyry dyke (pers comm. P. W. Baillie and N. J. Turner, 1984) assumed to be comagmatic with the other granitoids.

The above suggests that most of the major plutons intruded in five phases (see fig. 2). The first consists of the George River and Gardens bodies which may have intruded as a single pluton (George River phase). The second phase consists of the Mt Pearson pluton (Mt Pearson phase). The third phase comprises the comagmatic Scamander Tier, Catos Creek and St Marys porphyrite (Scamander Tier phase). The fourth phase is the Poimena pluton and associated minor bodies (Poimena phase). The last phase consists of the Lottah and Mt Paris plutons (Lottah phase).

The Pyengana and Haleys New Country plutons are earlier than the Poimena pluton but their order of intrusion can not be related to the other bodies. The Piccaninny Point/Long Point pluton and the St Marys porphyrite appear to be earlier than the Piccaninny Creek pluton but their order of intrusion can not be otherwise related to the main phases or to each other.

GEOCHEMISTRY

The geochemical data from the plutons suggests that they can be grouped into four main chemical suites, the Gardens, Scamander Tier, Poimena and Lottah suites. The correspondence between intrusive phases and chemical suites is indicated in Figure 2. The geochemistry of the Lottah suite will not be discussed here as it has been described in a number of publications (McClenaghan *et al.*, 1982; McClenaghan and Williams, 1982; Higgins *et al.*, 1985; Mackenzie *et al.*, 1988).

The Gardens and George River plutons have been grouped together in the same suite because the coherence of their combined chemical trends and the similar attitude of their mafic mineral foliation suggest that they were originally a single body.

On the basis of geology, chemistry, petrology and age determinations the Scamander Tier, St Marys Porphyrite and Catos Creek bodies were comagmatic (Turner *et al.*, 1986; Higgins *et al.*, 1986) and so have been included in the same suite. The Mt Pearson pluton is also grouped with the Scamander Tier suite. This differs from its original assignment to the Musselroe suite (McClenaghan, 1989) and the change is based on a re-examination of the data which suggest that the geochemical trends shown by the Mt Pearson data are more consistent with the Scamander Tier suite bodies than with the Musselroe suite. The Musselroe suite units lie outside the study area and will not be considered further here.

The Poimena suite is represented by the single large Poimena pluton with data from the minor adamellite bodies excluded from the geochemical plots.

The Gardens, Scamander Tier and Poimena suites form generally well defined straight line relationships on two-component plots which are distinctly different for MgO-FeO* and CaO-FeO* (fig. 3). These show decreasing negative slopes with intrusive order whereas the Zr-FeO* plot (fig. 3) shows the opposite trend with slopes increasing with order of intrusion. For other element plots (e.g. SiO₂, TiO₂ and Y, fig. 3) the distinction between suites is less clear.

Plutons for which only a small amount of data are available can be assigned tentatively to the main chemical suites. A sample from the Haleys New Country pluton and three samples from the Piccaninny Creek pluton (fig. 3) appear most similar to the Scamander suite rocks and so may be part of the same suite. The assignment of Haleys New Country pluton to the Scamander Tier suite is consistent with the indication that it intruded earlier than the Poimena pluton. Two samples from the Piccaninny Point/Long Point pluton have distinctly higher MgO values than the Gardens suite rocks at similar FeO* values, but other elements plot in the Gardens suite fields (fig. 3). On their FeO* and MgO content alone they may belong to a different unnamed suite.

The Pyengana pluton rocks are similar in composition to the Garden suite rocks for most elements. However, they can be distinguished from them on K₂O-FeO* and Rb-Sr plots (fig. 4). Possibly the greater Rb and K₂O content of the Pyengana pluton rocks compared to the Gardens suite rocks at similar FeO* values is due to their metasomatic alteration by fluids from the later nearby Lottah and Mt Paris plutons. Some of the Pyengana suite rocks are more oxidised than the Gardens suite (fig. 5) which is consistent with the presence of magnetite in some parts of the Pyengana pluton but not in the Gardens suite units.

GEOCHRONOLOGY

Results

Turner *et al.*'s (1986) K-Ar biotite, Rb-Sr biotite and Rb-Sr whole rock ages for the St Marys Porphyrite and related intrusives indicate that the Rb-Sr ages are within $\pm 2\%$ limits of the K-Ar data. New biotite K-Ar age data for other intrusives in the St Helens area are presented together with a compilation of K-Ar and Rb-Sr age data (table 1) from previous work (McDougall and Leggo, 1965; Cocker, 1982; Turner *et al.*, 1986; Mackenzie *et al.*, 1988).

The data have been grouped in terms of the major intrusive phases. Simple inspection of the data (fig. 6), suggests that:

- (1) there is considerable variation in age within the individual intrusive phases,
- (2) the average ages of intrusive units are not completely consistent with order of intrusion,
- (3) the average Rb-Sr ages of rocks of the same intrusive phase are approximately consistent with the K-Ar average ages (although generally a few million years younger), and
- (4) the Poimena intrusive phase is distinctly younger than the other intrusive phases.

Interpretation

The lack of consistency between the radiometric ages and the observed order of intrusion suggests the partial resetting of the ages of earlier bodies by the later intrusions. Patches of metasomatic alteration of granitoids in the area near St Helens (McClenaghan *et al.*, 1991) may also have been responsible for partial resetting. If resetting has taken place it is possible that it has occurred variably so that the oldest age for each phase may be a more reliable indicator of its age. In Figure 6b biotite K-Ar age ranges for the oldest sample from each phase are shown. These show the George River, Mt Pearson and Scamander Tier phases as having very similar age ranges and the Poimena phase again being distinctly younger. These age ranges are consistent with the four phases having been intruded in the observed order.

The biotite K-Ar ages for the George River phase are generally consistent, however there are several spurious younger ages. Sample GA489 (table 1) is much younger than the other samples. This may be an analytical problem since this result is much older than the other results and was produced by a different laboratory. Sample G1 is also somewhat younger than the other samples; however it comes from the northern part of the Gardens pluton (outside the area shown in fig. 1) and is distant from the other sample locations. The biotite Rb-Sr age (40523, table 1) for a sample collected from near the same point is also younger than the majority of the samples. This suggests that this is a real variation, possibly related to resetting by the later intrusion of the Poimena pluton. If the Poimena pluton were responsible for this resetting then it must be present at shallow depth in that area since the nearest surface occurrence is 5 km away.

Patches of metasomatically altered granodiorite occur within the George River pluton (McClenaghan *et al.*, 1991) and may have produced partial resetting although the samples collected did not come from these localities. The age of 397 ± 4 Ma obtained from a muscovite granite (MSH166, table 1) intruding the George River pluton is the same as the oldest age from the pluton thus confirming the reliability of the older ages for this phase. Weighted average ages (table 1) for the Rb-Sr and K-Ar data are almost the same and their error ranges overlap.

The Mt Pearson phase shows a considerable range of biotite K-Ar ages. Sample GA624 (table 1) is one of the younger ages and since it was dated by a different laboratory from the majority of the samples may differ from them because of different analytical conditions. The variation in the age of the other samples is difficult to understand since the younger ages do not appear to be close to later intrusions and are unlikely to have been reset. Sample MSH176 (table 1, fig. 1) lies closest to the younger Poimena pluton but has one of the older ages for the phase, whereas MP1 lies at a greater distance and has one of the younger ages. Sample MSH176 also came from close to the later Scamander Tier phase intrusion yet is older than samples more distant such as MSH180. Samples MP1 and MBT241 differ considerably in age though they came from nearly the same part of the Mt Pearson body. The anomalous variations in age may be related to metasomatic alteration since the southern margin of the Mt Pearson pluton shows considerable

Table 1. K-Ar AND Sr-Rb BIOTITE DATES FOR GRANITOID ROCKS IN THE ST HELENS AND NEIGHBOURING AREAS

Intrusive phase	Rock body	Sample no.	Grid ref.	Biotite-total rock Age (Ma)	Sr-Rb Initial ratio	Biotite K-Ar Age (Ma)	
George River	George River	GA489 ¹	FQ064178			375±10	
	George River	37851-1 ²	FQ068184	391±1.5	0.7084		
	George River	37851-2 ²	FQ068184	397±1.5	0.7084		
	George River	MSH168	FQ122291			394±3	
	George River	MSH186	FQ068183			397±4	
	George River	MSH173	FQ119320			390±2.8	
	George River	MSH167	FQ136297			398±4	
	Gardens	40523	EQ949661	383±1.5	0.7083*		
	Gardens	MBT258	EQ977560			389±8	
	Gardens	MBT257	FQ006452			389±2.8	
	Gardens	MBT256	EQ033433			394±2.8	
	Gardens	G1	EQ942667			380±8	
	<i>Average</i>				390.3±0.9		392.2±1.2
	Mt Pearson	Mt Pearson	GA624 ¹	EQ944291			373±10
Mt Pearson		40525-1 ²	EQ950290	383±1.5	0.7086		
Mt Pearson		40525-2 ²	EQ950290	382±1.5	0.7087		
Mt Pearson		40529 ²	EQ950290	383±1.5	0.709*		
Mt Pearson		MP1	FQ075362			375±6	
Mt Pearson		MBT241	FQ071347			393±2.8	
Mt Pearson		MSH174	EQ982326			388±4	
Mt Pearson		MBT242	EQ967357			378±2.8	
Mt Pearson		MSH180	EQ951246			376±3.6	
Mt Pearson		MSH192	EQ993215			383±4	
Mt Pearson		MSH176	EQ907282			391±3	
Mt Pearson		MSH179-1	EQ920167			392±4.4	
Mt Pearson		MSH179-2	EQ920167			396±4.4	
<i>Average</i>				382.7±0.9		386.0±1.2	
Scamander Tier	Scamander Tier	GA488 ¹	FQ063279	389	0.708	382±10	
	Scamander Tier	83/21 ³	FQ036153	386±3	0.7079		
	Scamander Tier	37791-1 ²	FQ057257	385±1.5	0.708		
	Scamander Tier	37791-2 ²	FQ057257	391±1.5	0.7077		
	Scamander Tier	37791-3 ²	FQ057257	386±1.5	0.7079		
	Scamander Tier	MP2	FQ025292			387±4	
	Scamander Tier	MSH183	EQ936306			390±4	
	Scamander Tier	MSH177-1	EQ922265			394±3.8	
	Scamander Tier	MSH177-2	EQ922265			397±3.4	
	St Marys	GA490 ¹	FQ026000			384±10	
	St Marys	GA491 ¹	FQ026000			380±10	
	St Marys	83/24 ³	FQ024031	388±3	0.7084		
	St Marys	83/27-1 ³	FQ034020	389±3	0.7075		
	St Marys	83/27-2 ³	FQ034020	387±3	0.7075		
	St Marys	83/29 ³	FP027998	389±3	0.7075		
	St Marys	83/30 ³	FP030983	387±3	0.7077		
	St Marys	83/33-1 ³	FP004957	386±3	0.7079		
	St Marys	83/33-2 ³	FP004957	388±3	0.7078		
	St Marys	83/31-1 ³	FP008970	391±3	0.7075	391±7.8	
	St Marys	83/312 ³	FP008970			395±7.9	
	Catos Creek	83/22-1 ³	EQ948087	388±3	0.7079		
	Catos Creek	83/22-2 ³	EQ948087	387±3	0.7079		
	Haleys New Country	MSH178	EQ881164			396±3.8	
	<i>Average</i>				387.6±0.6		392.3±1.6
	Poimena	Poimena	GA614 ¹	EQ831601			375±10
		Poimena	GA623 ¹	EQ912314			370±10
		Poimena	40561 ²	EQ800352	373±1.5	0.7112	
		Poimena	2012 ⁴		383±3		
Poimena		2017 ⁴		381±3			
Poimena		2109 ⁴		379±3			
Poimena		2008 ⁴		376±3			
Poimena		2004 ⁴		379±3			
Poimena		MSH182	EQ881320			381±6	
<i>Average</i>				376.7±1		377±4.6	
	Muscovite granite dyke intruded into the George River pluton	MSH166	FQ131283			397±4	
	Granitoid within 0.3 m of dolerite dyke and assumed to have been reset by the dolerite	MSH175	FQ002450			386±4.2	
		MSH171	FQ120320				
<i>Average</i>						387.4±2.2	
	Pyengana	40519 ²	EQ735371	377±1.5	0.7087		
	Pyengana	MAL2	EQ792295			389±2.6	
	Pyengana	MAL2 ⁺	EQ792295			384±4.4	
	Pyengana	MAL7	EQ848273			377±3.2	
<i>Average</i>				377±1.5		384±1.8	

Errors for individual determinations are at the 99% confidence level and averages are weighted according to these errors. ¹ data from McDougall and Leggo (1965), ² recalculated data from Cocker (1982), ³ data from Turner *et al.* (1986), ⁴ data from Mackenzie *et al.* (1988), * assumed value, + hornblende date. New determinations were performed by Dr A. Webb, AMDEL.

metasomatic alteration associated with a pink colouration of the K-feldspar and this is also patchily developed elsewhere in the body (McClenaghan *et al.*, 1991). The very coarse grain size of the Mt Pearson pluton may have facilitated the passage of metasomatic fluids. The hydrothermal fluids from the Mt Pearson pluton also produced the zoned mineralisation of the Scamander Mineral field in the area south of the Mt Pearson body (Ruxton and Plummer, 1984).

Age data from the Scamander Tier phase (table 1) is generally consistent suggesting that little resetting took place. The age of 396 ± 3.8 Ma for the Haleys New Country pluton is consistent with its assignment to the Scamander Tier phase in agreement with its chemistry.

The three samples from the Pyengana pluton all come from relatively close to the later Poimena pluton and sample 40519 (Table 1) also came from close to the Mt Paris pluton which was intruded as part of the youngest intrusive phase (Lottah). It seems likely that these dates have been partially reset by thermal or metasomatic effects and that the Pyengana pluton is older than is suggested by this data, possibly of a similar age to the George River phase which is chemically similar.

In an attempt to obtain the age of intrusion of the dolerite dyke suite, biotite was dated from two samples of granitoid collected adjacent (<0.3 m) to two dykes (table 1, fig. 6a) and samples of the same granitoid further away, so as to determine a resetting age based on the dyke intrusion. The biotite ages of the samples close to the dyke are in agreement within the limits of error and have a younger but not significantly different age from the granitoid more distant from the dyke. The ages suggest that the dolerites were intruded at about the same time as the granitoids which is consistent with the geological evidence.

DISCUSSION

The progressive change in slope of the linear trends on two-component chemical plots for the Gardens, Scamander Tier and Poimena suites, which follows the order of intrusion, suggests that this change in composition reflects some fundamental petrogenetic process. All three suites contain plagioclase with calcic core regions of approximately uniform composition surrounded by oscillatory and normal zoning (MacKenzie *et al.*, 1988; McClenaghan *et al.*, 1992) which are characteristics indicating the presence of restite material (Chappell *et al.*, 1987). This feature together with the linear chemical plots suggests that the restite model of White and Chappell (1977) may apply to the petrogenesis of the three suites. If following Chappell *et al.* (1987) the most basic granitoid composition is taken as indicating the source composition then different source rocks of progressively less basic character would have been melted at younger intervals. The source rock for the George River and Scamander Tier suites would have been granodioritic whereas for the Poimena suite it was adamellitic. This change in the source rock with time may have been produced by a progressive rise in the level of melting in the crust.

CONCLUSION

Geological field data indicates that the granitoids were intruded in five intrusive phases. The first three phases (George River, Mt Pearson and Scamander Tier) took place from 398 to 388 Ma but individual phases can not be clearly resolved by the K-Ar dating. The Poimena phase of intrusion followed about 15 Ma later. The age of the Pyengana phase is unclear but may be similar to the George River phase. Variations in the ages obtained from the George River, Mt Pearson and Pyengana plutons may have been due to resetting caused by later intrusions or metasomatism. There is a general correlation of the chemistry of the granitoids with age which may reflect a rise in the level of melting in the crust causing melting of progressively less basic source rocks.

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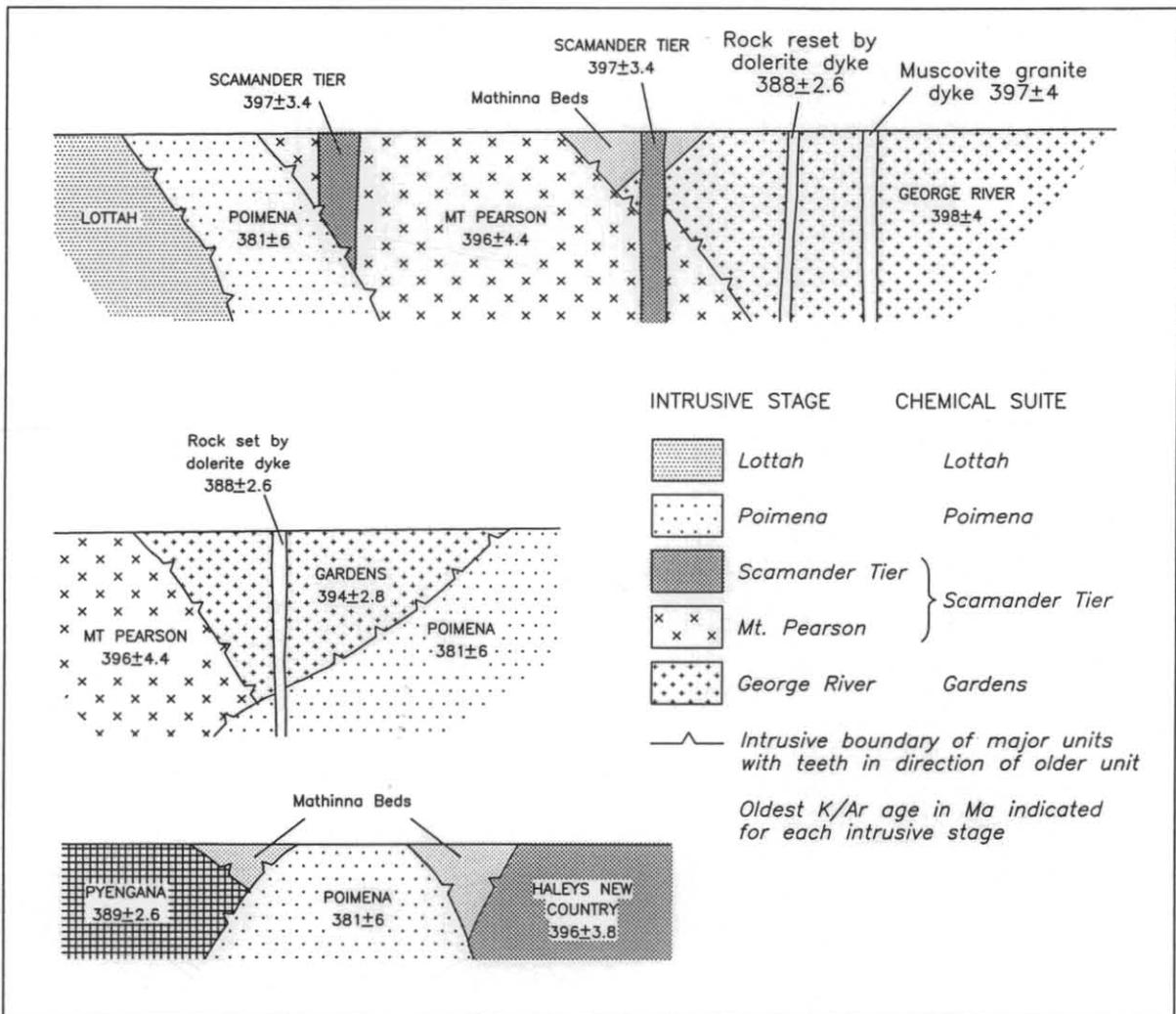


Figure 2. Geological cartoon showing intrusive order of major phases.

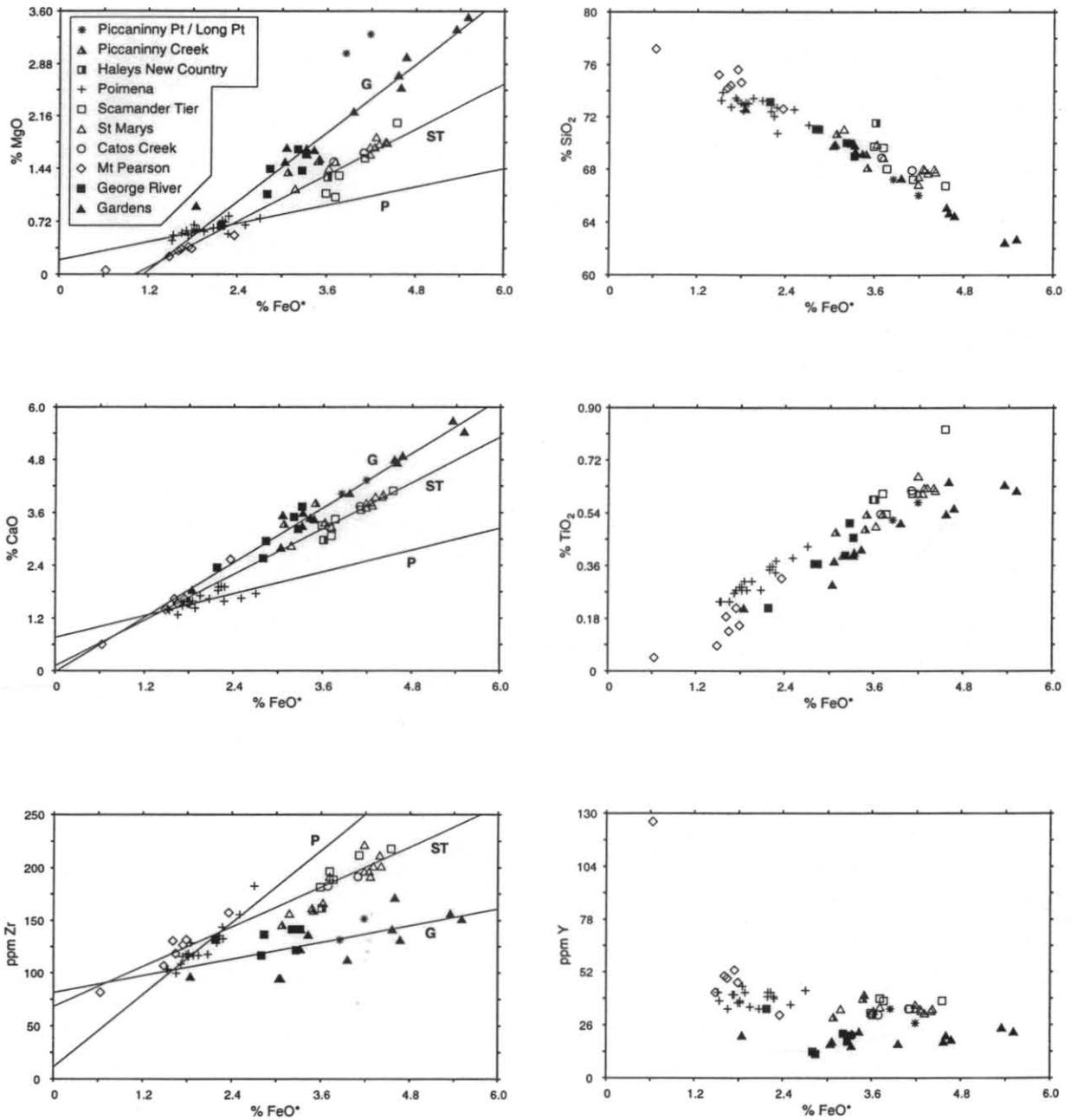
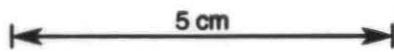


Figure 3. Plots of various oxides and elements against total iron as FeO (FeO^{*}). Best fit lines for the suites drawn on some plots. Sources of data on this and other geochemical plots, 20 analyses from Turner *et al.*, 1986; 10 analyses from McClenaghan *et al.*, 1992; 18 analyses MacKenzie *et al.*, 1988; 8 analyses M. P. McClenaghan (unpublished), 16 analyses McClenaghan, 1984; 1 analysis Baillie, 1986; 3 analyses Higgins (unpublished); 1 analysis Higgins *et al.*, 1985. Suite trend lines marked, Gardens (G), Scamander Tier (ST) and Poimena (P).



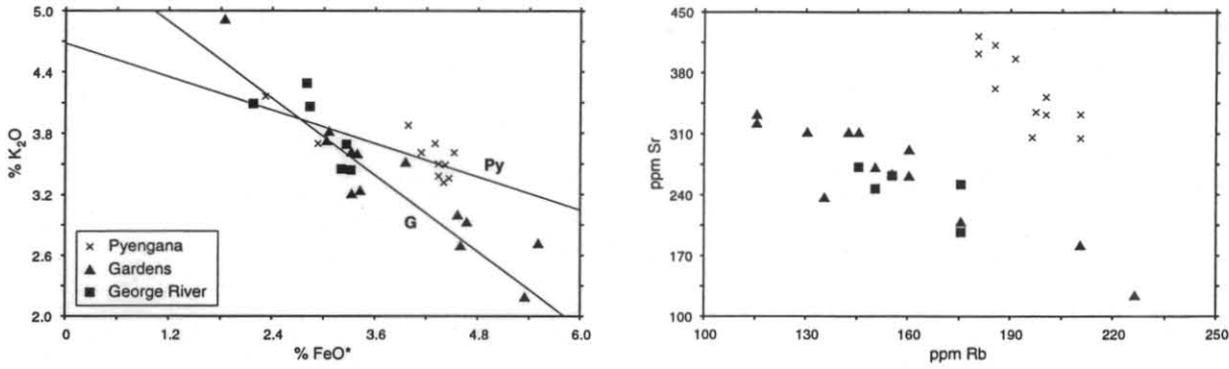


Figure 4. K₂O-FeO* and Sr-Rb plots for the Pyengana and Gardens suite rocks.

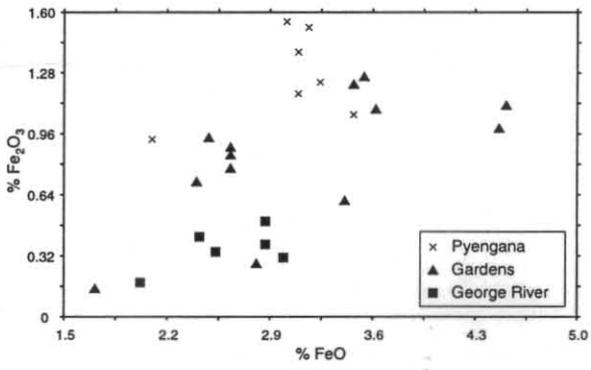
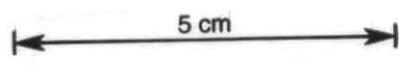


Figure 5. Fe₂O₃-FeO plot for the Pyengana and Gardens suite rocks.



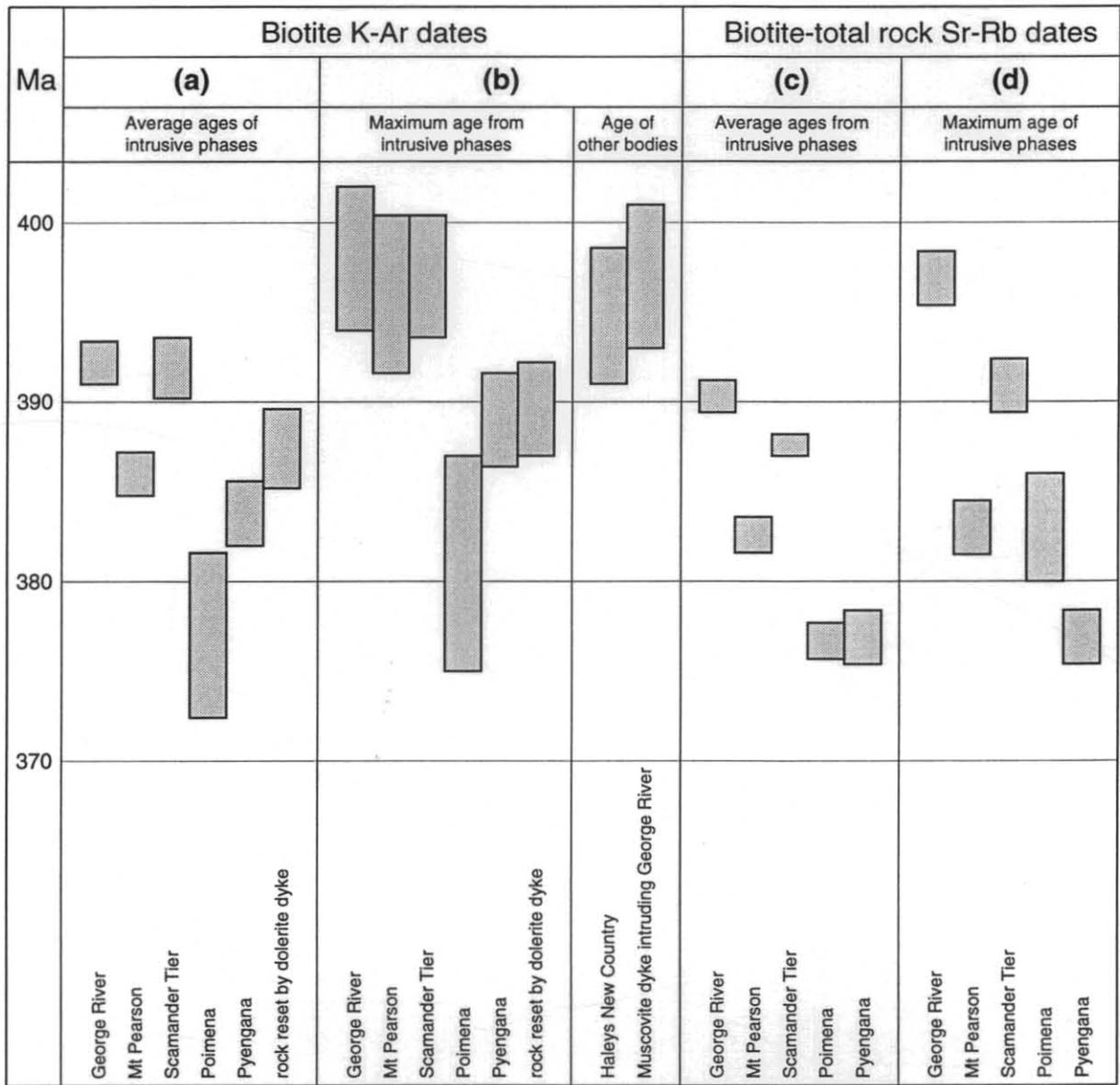


Figure 6. Bar chart of K-Ar and Sr-Rb biotite dates showing maximum range at 99% confidence level, for granitoid rocks in the St Helens and neighbouring areas.

