



VARIATION OF K/Rb RATIO IN THE MAJOR UNITS
OF THE GUICHON CREEK BATHOLITH
(92I)

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INTRODUCTION

Close geochemical association of potassium and rubidium has led to the extensive use of K/Rb ratios in petrogenetic analysis of igneous systems. Ionic radii of the two elements do not differ by more than 15 per cent ($K^+ = 1.33\text{\AA}$ and $Rb^+ = 1.47\text{\AA}$), and rubidium as a minor element substitutes extensively for K^+ sites in potassium-bearing minerals, especially in micas, in which K^+ sites are larger than in feldspars. Because of its geochemical similarity to potassium, the distribution of rubidium during magmatic processes is controlled mainly by the availability of K^+ sites. Being larger in size, rubidium accumulates in residual melts more rapidly than does potassium. Hence, with progressive differentiation the K/Rb ratio of rocks should decrease with increasing acidity. Therefore K/Rb ratios can indicate the extent or direction of differentiation in a suite of igneous rock. The K/Rb ratio of oceanic volcanic rocks decreases from 1 300 in oceanic tholeiites to about 350 in alkali basalts and is as low as 300 in trachytes (Engel, *et al.*, 1965). In orogenic andesites the K/Rb ratio also decreases with increasing potassium or acidity (Gill, 1978). For crustal rocks the K/Rb ratios range from 130 to 300 (Taylor, 1965).

The K/Rb ratio in igneous rocks can be used to recognize different magmatic processes that may have affected a particular suite; for example, processes related to source or parent magma and the extent and trend of magmatic differentiation.

Here we consider the distribution of K/Rb ratios in rocks of the Guichon Creek batholith. Since major element chemistry, field evidence, and phase equilibria show that the Guichon Creek batholith is a highly differentiated composite body ranging from quartz-diorite at the margin to quartz monzonite in the core (Northcote, 1969; McMillan, 1976; and others), the K/Rb ratio would be expected to decrease with increasing acidity. However, the K/Rb ratios of Guichon rocks do not follow this expected trend; instead, the ratio increases with increasing acidity (Fig. 133). Few similar K/Rb ratio trends have been reported in the literature, one example being the Blue Mountain nepheline syenite in Ontario (Payne and Shaw, 1967). As well as the anomalous trend, K/Rb

TABLE 1
VARIATION OF POTASSIUM (in weight per cent) AND RUBIDIUM (in ppm),
AND K/Rb RATIO IN GUICHON CREEK BATHOLITH ROCKS

	SiO ₂	K	Rb	K/Rb	K*	Rb*	K/Rb*	K**	Rb**	K/Rb**
Border Phase	58.9	1.33	39	341	1.66	33	503	1.78	38	468
Guichon Variety	61.8	1.73	52	333	2.01	48	419	1.80	38	474
Chataway Variety	64.2	1.75	47	372	2.01	50	402	1.81	37	489
Bethlehem Phase	65.2	1.85	38	487	1.89	47	402	1.93	38	509
Bethsaida Phase	73.7	2.83	34	832	2.70	73	370	1.89	37	511

NOTE: Starred columns contain values calculated from the Rayleigh fractionation model.
 *values represent K, Rb, and K/Rb ratio calculated using the actual modal mineralogy of Guichon batholith rocks
 **values are from adjusted mineralogy to produce the K/Rb ratio trend of batholith rocks

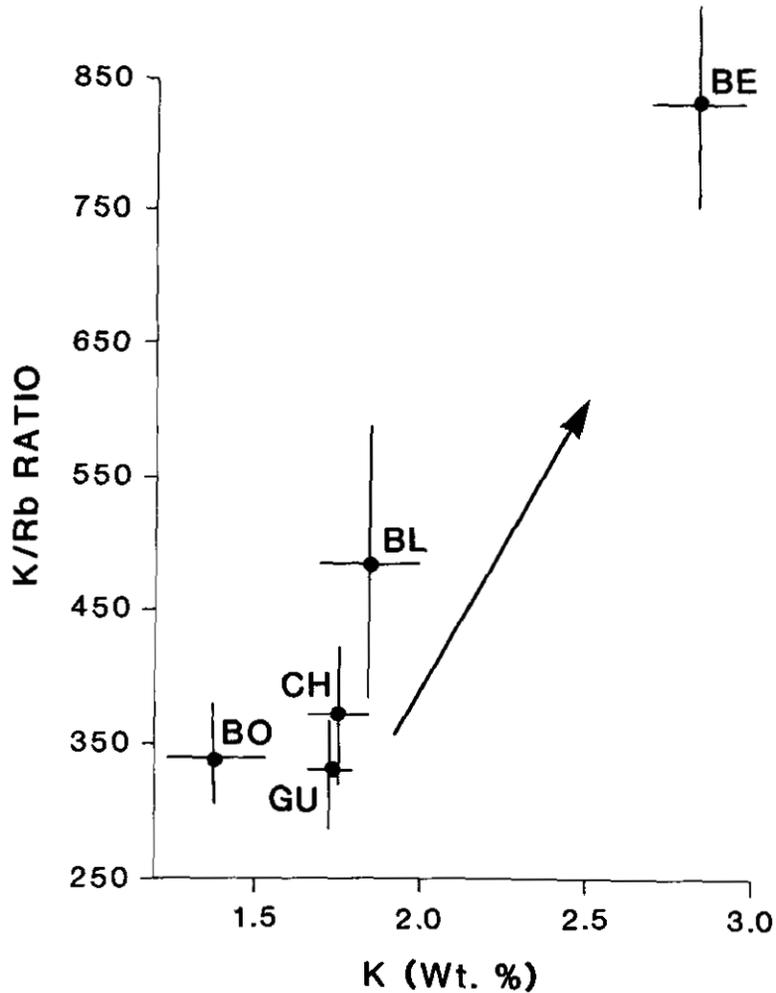


Figure 133. A plot of average K/Rb ratios of major units of the Guichon Creek batholith versus K (weight per cent).

ratio levels are abnormally high in the Guichon Creek batholith, ranging from 300 to over 800 (Table 1). Expected ranges of K/Rb ratios calculated from theoretical concentrations of potassium and rubidium using equilibrium fractionation models (Table 1) are narrower. Thus the range of the K/Rb ratio and its anomalous trend probably indicates the activity of processes other than crystal fractionation.

K/Rb RELATIONS IN GUICHON CREEK BATHOLITH ROCKS

Compositionally, the Guichon Creek batholith parent magma was approximately andesite, with SiO_2 about 63 weight per cent. The large lithophile elements, such as rubidium, show a very wide range of values in andesitic and other calc-alkaline rocks, dependent mostly on the source of the parent magma. For the Guichon Creek batholith average rubidium abundances range from 52 ppm in the Guichon variety to 34 ppm in the Bethsaida phase. The pattern is shown on Figure 134, which also shows that, in general, rubidium increases within phases as silica increases. This contrasts with the general trend for the batholith, where rubidium decreases as silica increases.

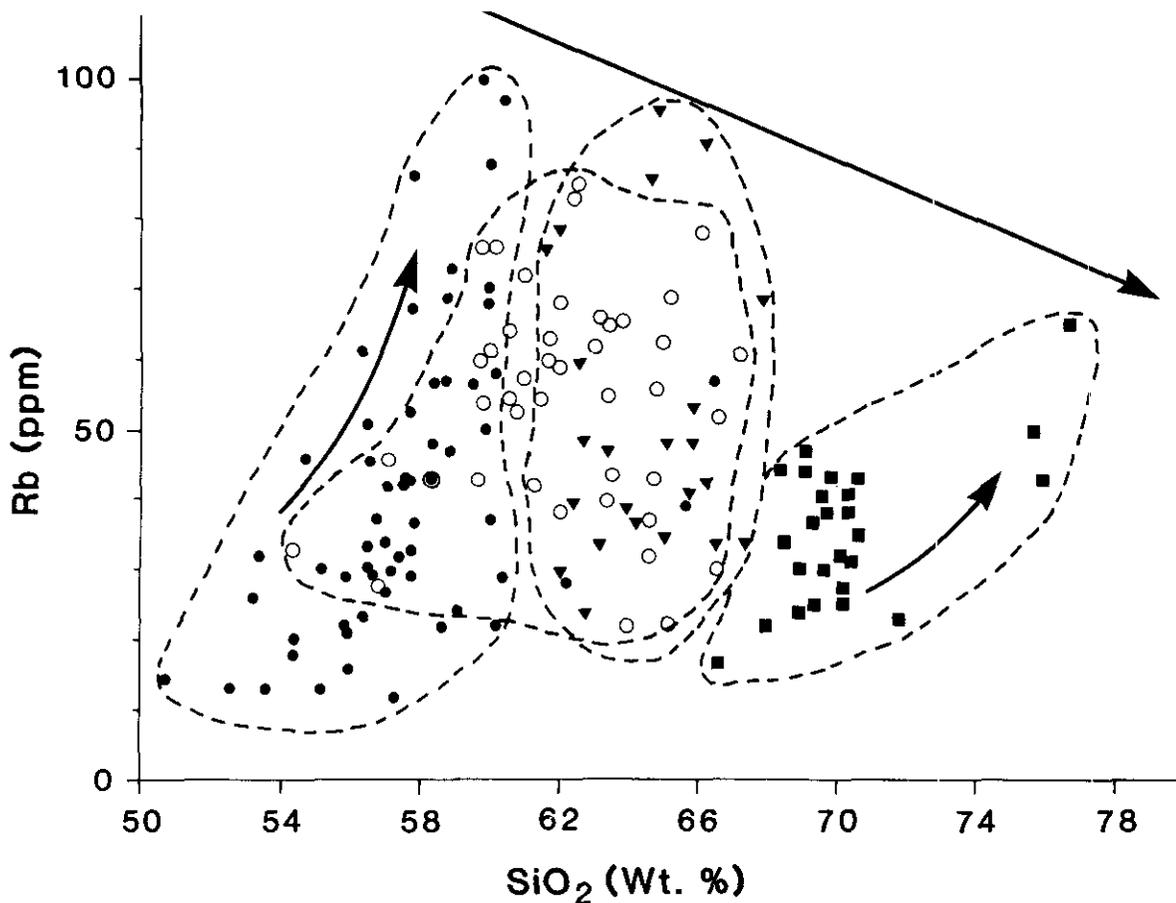


Figure 134. Rb versus SiO_2 , Guichon Creek batholith.

DISCUSSION

Several mechanisms have been suggested that could fractionate potassium and rubidium and lead to an increase in K/Rb ratio with progressive differentiation:

- (1) mica crystallization,
- (2) olivine, clinopyroxene, and garnet crystallization (Jakes and White, 1970),
- (3) amphibole crystallization (Harts and Aldrich, 1967), and
- (4) the effect of an aqueous phase (Payne and Shaw, 1967).

TABLE 2
ORIGINAL MODAL MINERALOGY USED IN CALCULATING K/Rb TREND

Minerals	Border Phase	Guichon Variety	Chataway Variety	Bethlehem Phase	Bethsaida Phase
Plagioclase	55	50	54	49	52
K-feldspar	3	10	11	10	11
Quartz	18	18	21	21	29
Biotite	7	9	5	3	6
Hornblende	10	8	7	4	0.4
K/Rb	503	419	402	402	370

MINERAL MODES AFTER PROPORTIONS WERE ADJUSTED TO PRODUCE K/Rb TREND OF BATHOLITHIC ROCKS

Plagioclase	50	50	50	48	50
K-feldspar	3	10	7	7	6
Biotite	9	6	3	2	2
Hornblende	38	34	40	43	42
K/Rb	468	474	489	509	511

Considering these possible mechanisms, the second does not apply to the Guichon Creek batholith because the minerals specified are either not present or occur as very minor phases. Processes (1) and (3) were modelled theoretically using distribution coefficients of andesitic rocks for these elements. The distribution coefficients of potassium and rubidium used in modelling are 5.63 and 3.26 in biotites and 0.33 and 0.014 in hornblende respectively (Philpotts and Schnetzler, 1970). From these figures, comparative K/Rb ratios are about 2 for biotite and 23 for hornblende. Therefore, mica fractionation could not lead to any appreciable increase in K/Rb ratio, and cannot account for the observed K/Rb variation of the Guichon rocks. With a larger K/Rb ratio, variation in amphibole content could indeed lead to systemic changes in K/Rb ratio. However, the changes in modal mineralogy of Guichon Creek rocks needed to produce the observed trend requires much higher fractions of amphibole than are observed (Table 2). This data suggests that changes in the K/Rb ratio in Guichon rocks could reflect the result of the combined biotite-hornblende fractionation but requires some other process to

account for the magnitude of the changes. Process (4), the effect of an aqueous phase, may be the cause. The effect of an aqueous phase is very difficult to document quantitatively because distribution coefficients for potassium and rubidium between silicate melt and an aqueous phase are not available. However, the relative distribution of these two elements can be inferred from their general chemistry. Rubidium has lower melting and boiling points than potassium. Hence, rubidium gasifies more readily than potassium [$Rb(s) > Rb(g)$] and enters the volatile phase more readily. Thus, development of a vapour phase could cause separation between potassium and rubidium. The more ready partitioning of rubidium into a volatile phase depletes the residual melt of rubidium, causing an increase of K/Rb ratio in the residual melt with progressive crystallization. Because of the behaviour of the volatile phase, rapid formation and release, for example, the K/Rb ratio could vary widely and have high and erratic ratios; both these features are observed in the Guichon Creek batholith.

CONCLUSION

Though experimental verification is needed to confirm empirical evidence about the effects of an aqueous phase on K/Rb ratios in magmatic systems, it seems likely that the value and trend of the ratio can be used to indicate whether there was volatile phase activity in the magma. For the Guichon Creek batholith, the trend of K/Rb ratios suggests that the magma contained a high water content that resulted in early saturation; hence, the K/Rb ratio is an indirect indicator of relative degree of differentiation. In the Guichon Creek batholith, the initial water content is estimated to have been between 2 and 3 weight per cent. Saturation was reached after about 72 per cent crystallization, which coincides with completion of crystallization of the Highland Valley phase. The timing of volatile phase release during magmatic differentiation is consistent with that determined independently based on zoning in plagioclase (Westerman, 1970) and formation of dykes, breccias, and mineral deposits (McMillan, 1976).

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