GEOCHEMISTRY OF GRANITOID CLASTS FROM MACLEAN EXTENSION OREBODY, BUCHANS, NEWFOUNDLAND, AND IMPLICATIONS ON THEIR POSSIBLE SOURCE

by

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Abstract

Lithogeochemical analyses have been obtained from samples of the alkali feldspar phase of the Topsails granite, the Feeder Granodiorite and granitoid clasts from ore-horizon breccia-conglomerate beds in MacLean Extension orebody area. The peraluminous Topsails granite is from an A-type (anorogenic) magma which is chemically distinct from the clasts and cannot be their source. The peraluminous Feeder Granodiorite and granitoid clasts are both from I-type (orogenic) magmas and have many geochemical similarities and some differences. The Feeder Granodiorite may be a late-stage differentiate of the magmatic source of the clasts. Variable alteration of the clasts complicates lithogeochemical interpretations. A revised petrographic classification of clasts is presented.

Introduction

The volcanogenic sulfide ore deposits at Buchans occur as three types, stockwork ore, *in situ* ore and transported ore (Thurlow, 1981a; Thurlow and Swanson, 1981). These deposits are hosted by the Buchans Group of the Newfoundland Central Volcanic Belt (Kean et al., 1981), an Ordovician-Silurian sequence of subaqueous volcanic, volcaniclastic and sedimentary rocks.

The transported ore forms a series of sulfide-bearing breccia-conglomerate beds with diverse lithic clasts, including granitoids. These beds have been interpreted as the deposits of debris flows (Walker and Barbour, 1981; Binney et al., 1983).

The source of the granitoid clasts has been enigmatic. Two small intrusive bodies (Wiley's River and Little Sandy intrusions) have been interpreted to be comagmatic with the Buchans Group volcanic rocks and possible sources of the granitoid clasts. They have been collectively named the Feeder Granodiorite (Thurlow, 1981a,b).

Major and trace element analyses have been determined for 21 clasts collected from 20 Level of the MacLean Extension workings. Eight samples of the Wiley's River intrusion and one sample of the Little Sandy intrusion were analyzed for the same elements. Also, seven samples of the alkali feldspar phase of the Topsails granitic complex (Taylor et al., 1980; Thurlow, 1981b) from adjacent to the Buchans Group and the Wiley's Brook intrusion were analyzed for comparison.

Petrography

Thin sections of more than 150 granitoid clasts from ore horizon boulder breccia beds have been examined. More than 90 per cent of these were from MacLean Extension orebody, with the remainder from the Oriental orebody. A petrographic classification of granitoid types is presented in Table 1 and is considered more useful than the field classification proposed by Stewart (1983); the field clast groupings of Stewart (1983) lacked geochemical coherence or petrographic distinctiveness.

Primary mineralogy of the clasts is simple and relatively consistent, i.e. quartz, plagioclase, biotite (rarely preserved, now chlorite), opaque minerals (hematite, magnetite?), apatite, zircon and sphene (rare).

Detailed petrographic examination of clasts has demonstrated that color and mineralogical differences used in the earlier classification are primarily due to alteration. Textural differences are gradational and probably represent differences in the mode and timing of crystallization of a single magma. The clast types have been arranged to reflect these gradations, from those with the best developed crystallinity (Type 1) to the least developed (Type 5).

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Table 1: *Petrographic classification of granitoid clasts.*

Clast type	Grain size (mm) (average/range)	Texture	Phenocrysts	Mafic mineral content	Distinguishing features
1	medium (1 / 0.2-3.0)	seriate porphyritic	abundant qtz + feldspar; qtz typically larger (to 5 mm)	rare biotite; mostly chlorite + opaques after biotite ± epidote (5%)	relatively coarse grained seriate texture, i.e. gradation in grain size of groundmass to phenocrysts
2	fine (0.5 / 0.1-2)	relatively equigranular	qtz + feldspar (to 2 mm)	rare biotite; mostly chlorite + opaques after biotite + epidote (0-5 vol. %)	relatively intermediate grain size and equigranular
3	fine to very fine (0.3 / 0.1-0.5)	hiatal porphyritic - rare microgranophyric areas	qtz + feldspar (1-8 mm) in clusters (especially feldspars)	chlorite + opaques ± epidote (5%)	hiatal porphyritic - large difference in size between phenocrysts and groundmass; abundant phenocrysts
4	very fine (0.2 / 0.1-0.4)	equigranular	rare qtz + feldspar (to 2 mm)	chlorite + opaques ± epidote zoisite (5%)	equigranular, fine grain size, lack of phenocrysts relatively minor microgranophyric areas
5	very fine to fine (0.5 / 0.1-2)	variable % of well developed microgranophyric patches	rare, mostly qtz (to 2 mm)	chlorite + opaques ± epidote (0-5%)	abundant microgranophyre; equigranular
6	very fine (0.2 / 0.1-0.4)	equigranular euhedral to subhedral feldspars	none	very abundant, especially opaques, biotite and chlorite (to 10%)	'lath-like' texture of feldspars; abundant mafic minerals - almost exclusively restricted to siltstone breccia, under ore horizon

Type 6 clasts are texturally and mineralogically distinct. They show a weakly developed felty texture with euhedral to subhedral plagioclase laths in a groundmass of anhedral plagioclase, quartz and opaque minerals. These clasts show a higher plagioclase/quartz ratio and a higher per cent of mafic and opaque minerals than the other clast types. This type is also chemically distinct (lower SiO_2, higher TiO_2 and CaO) and primarily restricted to the siltstone breccia unit which occurs several metres stratigraphically beneath the lower ore unit in the MacLean Extension area. However, rare clasts of this type have been found within the lower ore unit.

Staining with sodium cobaltinitrite for potassium feldspars suggests that all feldspars are plagioclase. The alteration and lack of twinning of feldspars have prevented petrographic determination of An content, but the major element geochemistry suggests that they are predominantly of albitic composition.

The dusty and pitted appearance of the feldspars and the presence of secondary minerals (sericite, calcite, epidote) in the feldspar crystals suggest that they have been saussuritized. Whether this is due to hydrothermal alteration or is a product of regional metamorphism is not known. The regional metamorphism of the Buchans Group is of the prehnite-pumpellyite facies (Henley and Thornley, 1981), and the alteration may have been a product of this metamorphism.

Geochemistry

The study was designed to assess the relationship among three sample populations: the granitoid clasts, Feeder Granodiorite (FG) (predominantly the Wiley's River intrusion), and Topsails granite. The present geochemical results are preliminary, but do suggest several points: (1) all rock types are silica-oversaturated and peraluminous; (2) the FG and the clasts are from I-type (orogenic) magmas, whereas the Topsails granite is from an A-type (anorogenic) magma; (3) trace element abundances show significant differences between the Topsails granite and the other two populations; (4) the magmatic relationship of the FG and the granitoid clasts cannot be conclusively established, or refuted with the present evidence; and (5) the clasts have undergone varying degrees of alteration, whereas the FG and the Topsails granite are comparatively unaltered. These points are examined in more detail below.

All clast samples were found to contain greater than 70% (wt.%) SiO_2 (anhydrous) with some clasts exceeding 80% SiO_2. Both the FG and the Topsails granite have a more restricted silica range of about 5% SiO_2, all above 70% SiO_2.

Because of the mobility of the alkali elements during alteration, their usefulness for classification of altered rocks is suspect. As will be discussed below, the alkali distributions in the clasts were affected by alteration. For this reason, plots after Irvine and Baragar (1971) and AFM plots are not presented; however, they suggest a calc-alkaline affinity for all populations. Strong (1977) and Thurlow (1981a) demonstrated that the Buchans Group is calc-alkaline.

Using the granitoid classification scheme of White and Chappell (1983), the granitoid clasts and the Feeder Granodiorite crystallized from I-type magmas and the Topsails granite from an A-type magma (Figure 1). Figure 1b is probably a more reliable plot that Figure 1a which uses alkali elements. The elements Ga and especially Al are considered to be relatively immobile during alteration, unlike the alkali elements. High contents of highly charged cations such as Ga, Zr and Y (see Figures 1b and 2) are considered diagnostic of A-type magmas (White and Chappell, 1983). A-type granitoid bodies in eastern Australia are associated in space and time with volcanic rocks, as is the Topsails granite (Whalen and Currie, 1983). The presence of miarolitic and granophyric textures further substantiates the designation of the Topsails granite as an A-type intrusion (White and Chappell, 1983, page 30).

Although I-type magmas are usually subaluminous, the Feeder Granodiorite and granitoid clasts are peraluminous. This may indicate a minimum-temperature melt or a highly fractionated I-type melt (White and Chappell, 1983, page 28). This allows the possibility that FG is the more fractionated parent of the granitoid clasts, but this has not yet been demonstrated.

Plots of paired immobile elements (Figure 2) have been shown to be effective in distinguishing different magma series and their tectonic settings (Pearce and Cann, 1973; Wood et al., 1979; Palacios et al., 1983). The distinctiveness of the Topsails granite is obvious while the correlation between the clasts and the FG is suggested. Bailey (1981) proposed that Zr and Y enrichment distinguishes anorogenic andesites from orogenic andesites, which supports the anorogenic setting of the Topsails granite. The slight enrichment of the FG in Zr and Y relative to the clasts is suggestive of a late stage differentiate (Taylor, 1965).

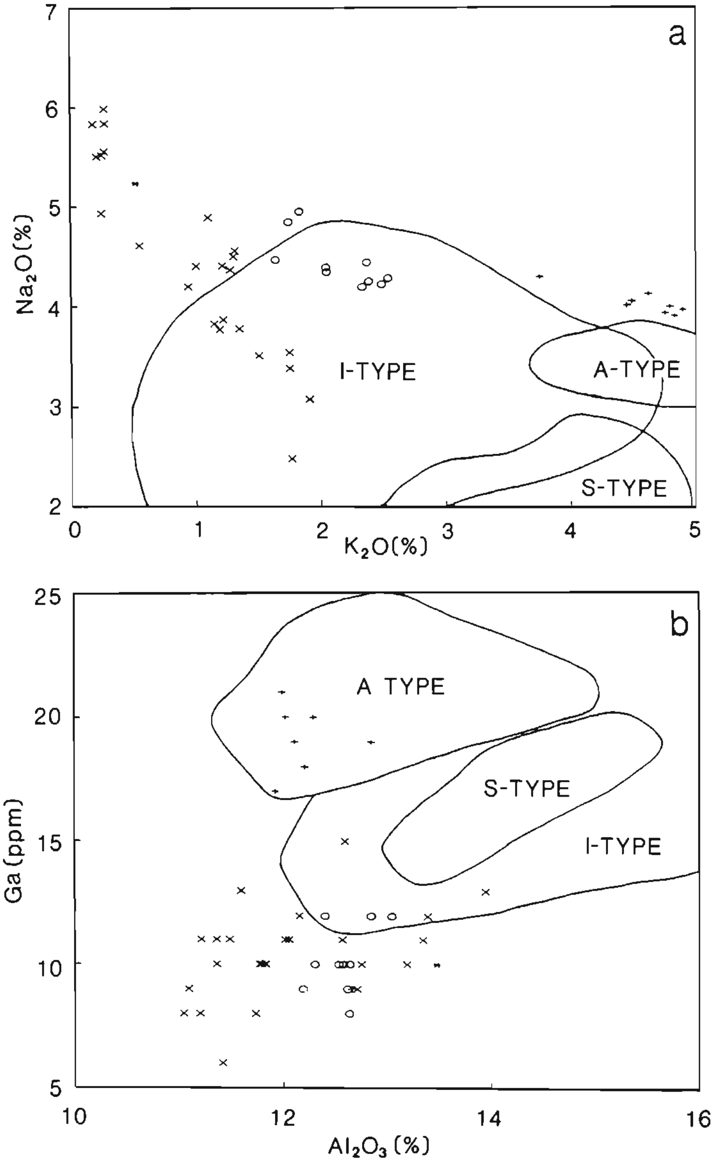

Figure 1: *Discriminant diagrams for granitoid magma series from White and Chappell (1983):* ***(a)*** *K_2O vs. Na_2O;* ***(b)*** *Al_2O_3 vs. Ga. The 'x' represents a granitoid clast sample from MacLean Extension orebody, 'o' represents a Feeder Granodiorite sample, the '+' represents a Topsail (alkali feldspar) granite sample, and the '*' represents the sample from the Little Sandy Intrusion.*

Alteration

The most common expression of hydrothermal alteration is the production of hydrous minerals from the primary anhydrous minerals. Therefore, the loss on ignition (LOI) provides a qualitative means to judge the degree of alteration. Although the LOI may be a mixture of H_2O, CO_2 and sulfur-bearing gases, for evaluation of the degree of alteration, LOI is considered to be mainly H_2O and CO_2.

The variable degree of alteration of the clasts is apparent in Figure 3. A positive correlation between both CaO and K_2O with loss on ignition is shown in Figures 3b and c. The feldspars are partly altered to sericite (or muscovite) and calcite, indicating that these chemical variations probably reflect alteration. The very high barium content of the clasts in general, and the presence of barite as secondary veins and disseminations in the clasts is also in accord with the weakly defined positive correlation between Ba and LOI in Figure 3d. Magnesium values scatter around a weak positive correlation (Figure 3a). Variable amounts of chlorite and magnesium in the clasts could indicate an alteration, rather than a metamorphic origin for the chlorite. Alteration is indicated mineralogically by the saussuritization of feldspars, chloritization of biotite (no other primary mafic mineral, or relicts of other mafic minerals have been recognized) and introduction of barium and calcium as barite and calcite. The elevated Ba values in the clasts probably indicate that their alteration is related to the mineralizing event at Buchans (Thurlow, 1981a) or to migration of Ba from barite in the breccia-conglomerate beds during or after consolidation (*op. cit.*, page 285). The presence of calcite ± barite veins in some samples analyzed could add to LOI scatter and mask the chemical effects of rock alteration.

Ca and Sr are considered to behave similarly under many conditions (Taylor, 1965; Mason, 1966). This behavior and the contrasting dissimilar behavior of Rb and Sr are demonstrated in Figure 4. Sr content shows a corresponding increase with Ca content (Figure 4b), whereas Rb and Sr has a negative correlation (Figure 4a). The increase of Ca and Sr contents in the clasts is believed due to the introduction of calcite during alteration. Rubidium contents remain relatively constant in the clasts though Sr values increase. Unless Rb was uniformly depleted, which conflicts with the generally variable nature of the alteration, it was apparently unaffected by the alteration.

Figure 5 presents evidence which possibly conflicts with FG being the parent of the clasts. If it were the parent, then it should have had a similar K_2O content, prior to the alteration of the clasts. If, as is indicated in Figure 3c, K_2O increased with degree of alteration (along with

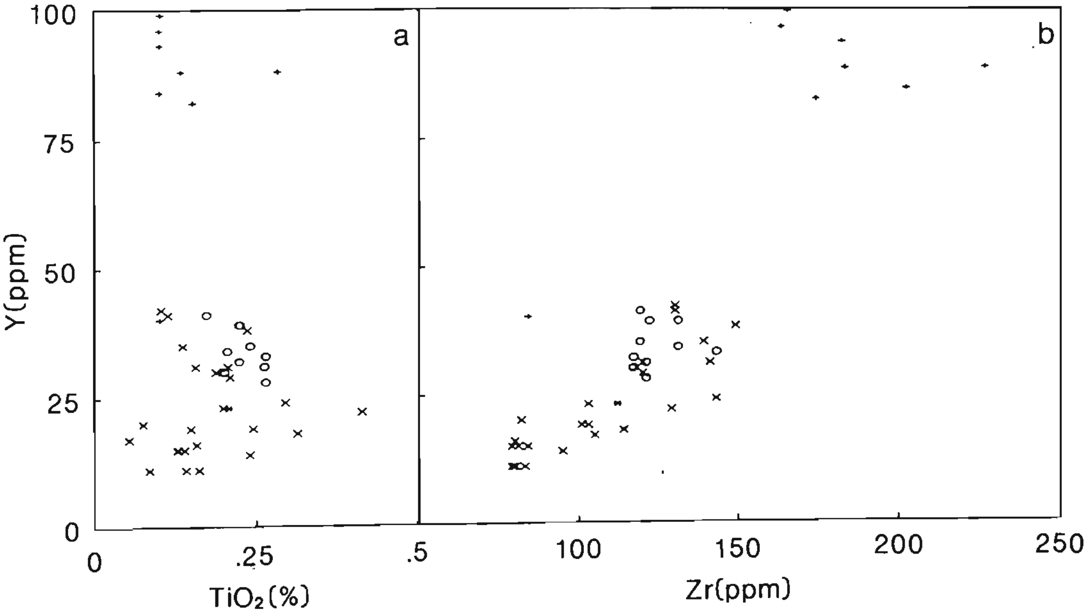

Figure 2: *Plots of relatively immobile elements: (a) TiO_2 vs. Y; (b) Zr vs. Y; after Palacios et al., 1983. For symbols see Figure 1.*

increasing Sr (Figure 4)) then the clasts in Figure 5 should plot toward the upper left part of the diagram and not the lower left part as indicated. Even if the FG is a later differentiate of the same magma and has a higher initial K_2O content, the observed trend still cannot be resolved. This underlies the difficulities in determining the changes in element contents during alteration. Work is in progress to try to resolve this problem.

The lack of apparent alteration of the FG and the Topsails granite is obvious from Figures 3 and 4. The fields for the Topsails alkali feldspar phase and the FG of Bell and Blenkinsop (1981) are shown in Figure 4a for comparison.

One of the samples designated as a Topsails granite plots consistently outside the cluster of other Topsail samples. This is a sample of a dike which closely resembles the Topsails granite megascopically. The trace element chemistry suggests that it was possibly modified by contamination from the FG during emplacement (see Figure 2a and b, especially).

The single data point for the Little Sandy intrusion is insufficient to permit any rigorous conclusions. The data do suggest, however, a closer affinity to the clasts than to the FG itself. Further analyses of samples from this body are currently in progress.

Conclusions

A few preliminary conclusions can be drawn. The Topsails granite can be clearly separated petrographically and lithochemically from the Feeder Granodiorite and granitoid clasts. This is consistent with the established geological and age relationships for the Topsails granite (Thurlow, 1981b; Bell and Blenkinsop, 1981; Whalen and Currie, 1982 and 1983). As first demonstrated by Thurlow (1981a), the FG has many geochemical similarities to the clasts and may have crystallized from the same magma reservoir which produced the clasts. Other element combinations suggest that the FG and clasts are geochemically distinct and not genetically related. Further work remains to be done before this problem can be resolved.

The FG and Topsails granite are both unaltered to weakly altered, whereas the clasts are variably altered. K_2O, CaO, MgO, Ba and Sr contents of the clasts increase erratically with increasing alteration.

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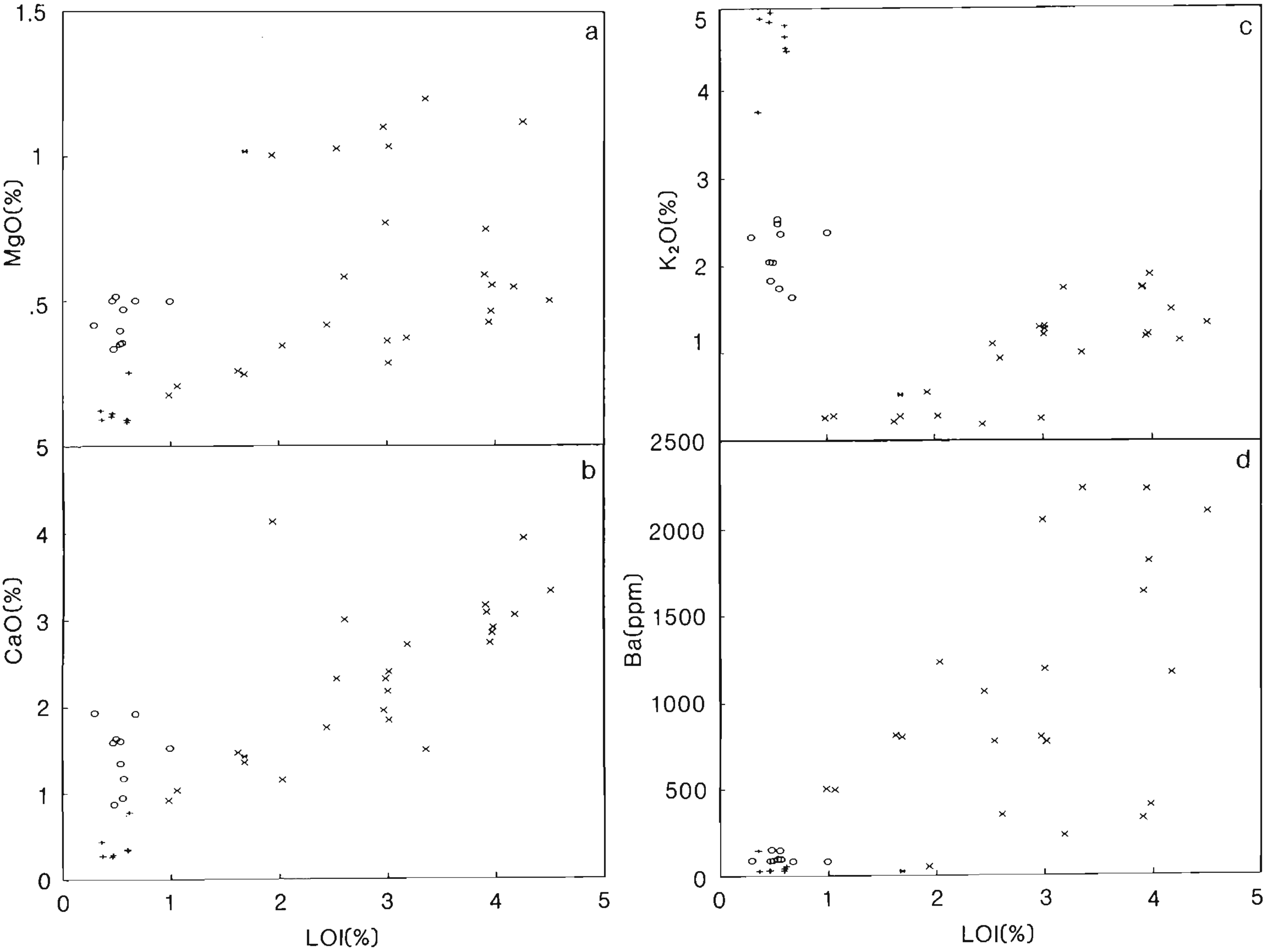

Figure 3: *Diagrams illustrating the effects of alteration on particular elements:* ***(a)*** *loss on ignition (LOI) vs. MgO;* ***(b)*** *LOI vs. CaO;* ***(c)*** *LOI vs. K_2O;* ***(d)*** *LOI vs. Ba. For symbols see Figure 1.*

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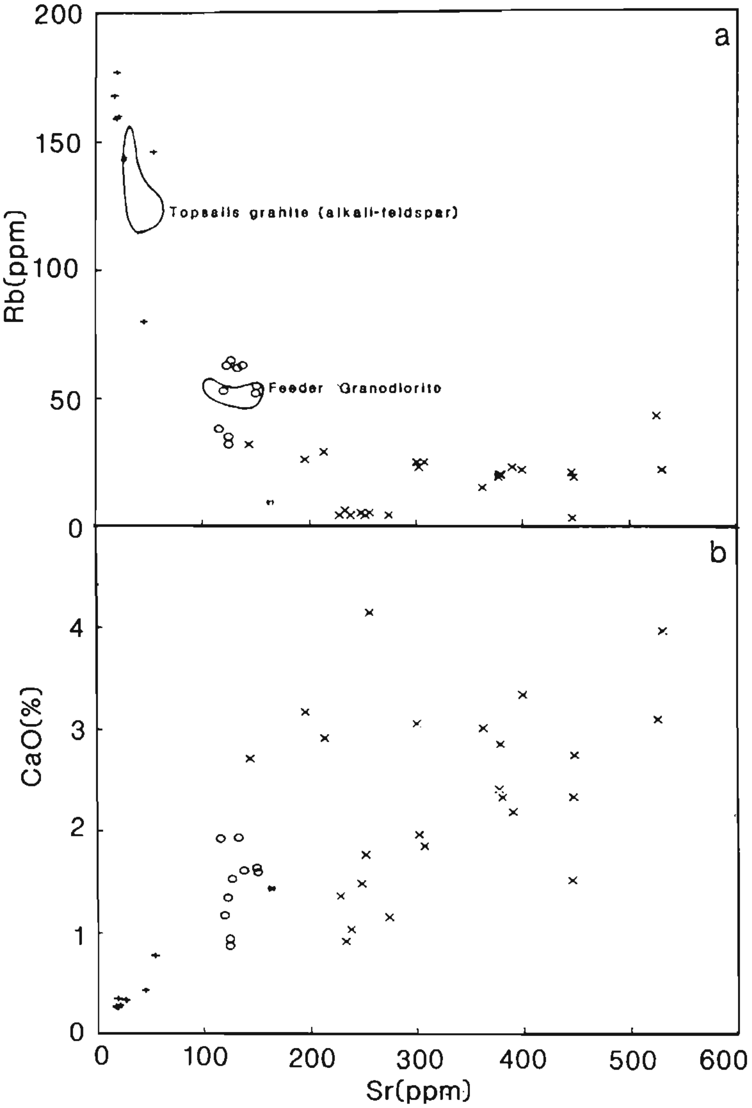

Figure 4: *Correlation diagrams: (a) Sr vs. Rb, fields after Bell and Blenkinsop, 1981; (b) Sr vs. CaO. For symbols see Figure 1.*

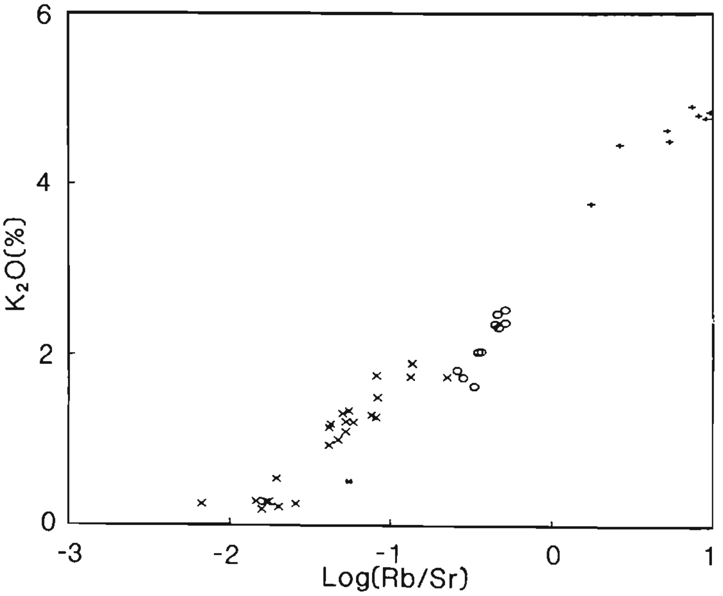

Figure 5: *Rb/Sr expressed logarithmically vs. K_2O. For symbols see Figure 1.*

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