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# THE INTERDEPENDENCE OF ELEMENTS IN THE HYDROTHERMALLY ALTERED STRZELIN AND BORÓW GRANITES

**Abstract:** Comparative analyses of fifteen pairs of elements that should show linear dependences of their contents in hydrothermally altered granite were carried out for the Strzelin and Borów granites. Only K/Rb, Fe/V, Al/Ga, Ti/V, K/Ba and Ba/Rb show positive correlations. Interdependence is questionable for: Ba/Sr, Y+REE/Na. It is also dubious for the hydrothermal primary minerals laumontite, prehnite, feldspar and chlorite. No interdependence was found for the elements in the pairs: $SiO_2$/K, $SiO_2$/Rb, Ca/Sr, $SiO_2$/Fe, Mg/Cr, Cr/V and Y+REE/Ca, despite suggestions in the literature.

**Keywords:** geochemistry, hydrothermal stage, element ratio, granite

## INTRODUCTION

Rock-forming elements in the Earth's crust are mainly distributed according to the rock-forming processes. The geological history of any rock can therefore potentially be reconstructed from its geochemistry. The chemical composition of rocks becomes commonly modified, however, by processes such as hydrothermal activity. Such activity may change the mineralogical and geochemical composition of granites. Nevertheless some pairs of elements tend to show a linear interdependence due to the magmatic processes and hydrothermal stages of granite formation.

The interdependence of elements is mainly a result of their crystallochemical affinities, the mobility of the element, and the thermodynamic conditions under which the elements coexist, *e.g.* a temperature decrease of hydrothermal fluids, or pH changes caused by the crystallization sequence of the main minerals during successive stages of post-magmatic processes.

The relatively high concentrations of some trace elements in hydrothermally altered granites depend also on the frequency of the minerals in which these trace elements are dissipated, and is therefore related to the presence of particular minerals: granite with a graphic texture contains, for instance, feldspars that are enriched in Pb, and hydrothermally formed albite contains more Ba and Sr than pneumatolytic albite (Kowalski 1967). Additionally, the chemical composition of the wall rock and individual regional, geochemical conditions clearly influence the elements' concentrations.

Based on a theoretical approach (Hall 1990; Hall *et al*. 1993; Polański 1988; Faure 1998; Rudnick *et al*. 2004) and on the geochemistry of the Strzelin and Strzegom-Sobótka massifs (Kowalski 1967; Gadomski 1968; Szpila 1967; Walenczak 1968), a linear dependence should be shown by the following pairs of elements (silicon is expressed as $SiO_2$, and La, Ce, Nd as REE): K/Rb, $SiO_2$/K, $SiO_2$/Rb, K/Ba, Ba/Rb, Ca/Sr, Ba/Sr, Fe/V, $SiO_2$/Fe, Mg/Cr, Cr/V, Al/Ga, Ti/V, Y+REE/Na, Y+REE/Ca.

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The aim of the present contribution is to prove such an interdependence for the above-mentioned pairs of elements during the hydrothermal stage of granite alteration. Data are based on the geochemistry of the hydrothermally altered Strzelin and Borów granites (Ciesielczuk 2000b).

The dependences were calculated on the basis of bulk rock chemical analyses (main and trace elements). These were perfomed for the slightly, intermediately and strongly altered Strzelin granite and for the highly altered Borów granite. Data for four hydrothermal minerals crystallized in veins in the Strzelin granite (feldspar, chlorite, prehnite and laumontite) were added for comparison. The XRF analyses were made in the laboratory of the Department of Earth Sciences at Keele University, UK.

## INTERDEPENDENCE OF ELEMENTS DURING THE HYDROTHERMAL STAGE OF GRANITE FORMATION

The concentrations of some elements in the unaltered granites from the Sardinia, Strzelin and Borów are given in Table 1 pointing at convergence for main elements and divergence for trace elements contents. The values of unaltered granites are compared with the mean values of these elements in hydrothermally altered the Strzelin and Borów granites. The mobility of the elements, having been calculated for mean values, is shown in columns 5 and 6.

Table 1. Chemical composition of unaltered the Sardinia (Hall *et al*. 1993), Strzelin and Borów granites, compared with the mean values in hydrothermally altered the Strzelin and Borów granites (Ciesielczuk 2000b). Arrows indicate the behaviour of elements during alteration. The table contains only the elements used for the analyses of interdependence.

| element | granite Sardinia unaltered | Strzelin granite | | mobility of element | | Borów granite | |
|---|---|---|---|---|---|---|---|
| | | unaltered | altered | | | unaltered | altered |
| $SiO_2$ | ? | 70.41 | 66.87 | ↓ | ↓ | 73.34 | 72.44 |
| $TiO_2$ | 0.32 | 0.40 | 0.29 | ↓ | ↓ | 0.32 | 0.28 |
| $Al_2O_3$ | 14.79 | 15.13 | 15.96 | ↑ | ↑ | 13.32 | 14.09 |
| FeOtotal | 2.52 | 2.69 | 1.85 | ↓ | = | 2.48 | 2.48 |
| MgO | 0.80 | 0.80 | 0.44 | ↓ | ↑ | 0.19 | 0.24 |
| CaO | 2.09 | 2.61 | 3.74 | ↑ | ↓ | 1.42 | 0.10 |
| $Na_2O$ | 3.78 | 4.32 | 4.14 | ↓ | ↑ | 3.75 | 3.94 |
| $K_2O$ | 4.13 | 3.11 | 4.68 | ↑ | ↑ | 4.40 | 5.62 |
| Cr | 9 | 17 | 15 | = | = | 7 | 7 |
| Ga | 20 | 19 | 20 | = | = | 17 | 19 |
| Rb | 196 | 102 | 160 | ↑ | ↓ | 181 | 160 |
| Sr | 139 | 240 | 143 | ↓ | ↓ | 86 | 49 |
| V | 34 | 32 | 21 | ↓ | = | 17 | 16 |
| Y | 24 | 19 | 25 | ↑ | ↓ | 35 | 29 |
| Ba | 537 | 793 | 682 | ↓ | ↑ | 535 | 747 |
| La | 33 | 28 | 47 | ↑ | = | 44 | 40 |
| Ce | 60 | 67 | 99 | ↑ | ↓ | 98 | 79 |
| Nd | 24 | 40 | 39 | = | ↓ | 43 | 36 |

? no data, = immobile element, ↓ loss, ↑ increase of element content during hydrothermal alteration of the granite

It appears from the data in Table 1 that the geochemical effect of alteration is mostly divergent in both granites. During the hydrothermal stage the Strzelin granite was lost in barium, for instance, and enriched in caesium, yttrium and rubidium which is in contrast to the situation for the Borów granite. This may be ascribed to the hydrothermal history of the Strzelin and Borów granites, which was slightly different (Ciesielczuk, Janeczek 2004; Ciesielczuk 2000a, b).

Moreover, diagrams showing the relationship between the concentrations of the selected element pairs have been constructed. Some representative diagrams are presented in Fig. 1. It was expected that the mobility of the elements, as calculated for the mean values of the element content marked by the arrows in Table 1, would be compatible with the pairs of elements that show a linear dependences such as Fe versus V, which show the same tendencies (the amount of both decreased in the Strzelin granite, and was immobile in the Borów granite). In some cases, however, the interdependence of the elements' concentrations can be proved in the diagram only if a trend line is drawn, *e.g.* K/Ba.

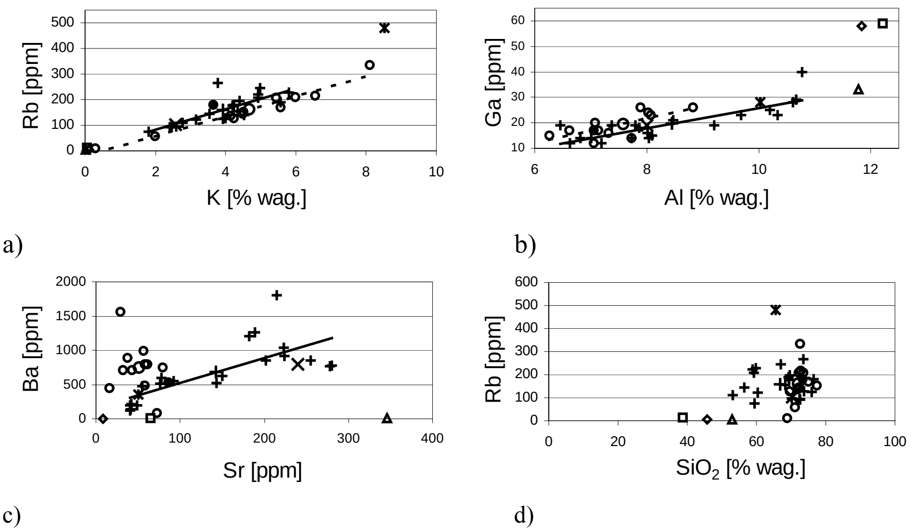


Fig. 1. The interdependence between elements: a) K/Rb, b) Al/Ga, c) Sr/Ba, d) $SiO_2$/Rb. Cross – unaltered; plus – altered Strzelin granite; full circle – unaltered; empty circle – altered Borów granite; asterisk – feldspar; square – chlorite; diamond – prehnite; triangle – laumontite. Solid line – tendency line for the hydrothermally altered Strzelin granite; dashed line – for the Borów granite.

## CONCLUSIONS

Comparative analyses of geochemical data for the hydrothermally altered Strzelin and Borów granites prove the existence of a linear interdependence for the following pairs of elements: K/Rb (Fig. 1a), Fe/V, Al/Ga (Fig. 1b), Ti/V. An interdependence has also been confirmed for K/Ba and Ba/Rb, but there is a considerable scattering of the plotted points in the diagrams. These pairs of elements also show interdependence for the magmatic stage of granite formation, as the projection points for unaltered granites are located close to the trend lines.

As interdependence between Ba/Sr (Fig. 1c) and Y+REE/Na was found only for the Strzelin granite, the probability of interdependence of these element pairs is questionable for the hydrothermal stage of alteration.

Usage of geochemistry of the hydrothermal minerals: laumontite, prehnite, feldspar and chlorite is also questionable, as some projecting points are partly close, and partly at significant distance to the trend line.

No interdependence could be established for the elements in the following pairs: $SiO_2$/K, $SiO_2$/Rb (Fig. 1d), Ca/Sr, $SiO_2$/Fe, Mg/Cr, Cr/V and Y+REE/Ca, although such an interdependence has been suggested in the literature.

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