DISTRIBUTION OF COBALT, VANADIUM AND CHROMIUM BETWEEN COEXISTING BIOTITE AND GARNET IN GRANULITE FACIES ROCK SAMPLES

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The distribution coefficients of cobalt, vanadium and chromium were determined in biotite-garnet pairs of granulite facies rock samples. The sample areas are Lapland, West Uusimaa and Sulkava. The distribution of cobalt between biotite and garnet is linear, K_D being 1.7. The distribution points of vanadium fall close to a straight line, the slope of which is 9.8. The chromium distribution points are scattered. A relationship, however, is apparent between the chromium distribution coefficient and the atomic ratio Mg/Fe + Mg + Mn of garnet. The distribution coefficient decreases with an increase in the Mg/Mg + Fe + Mn of garnet.

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Introduction

The distribution coefficients of trace elements between coexisting garnet, biotite and hornblende have been determined, e.g. by Kretz (1959). The thermodynamics of the distribution of trace elements between coexisting phases has been discussed by McIntire (1963). When considering the distribution of trace elements between coexisting minerals, the fundamental principle is an application of the Berthelot-Nernst distribution law: $\frac{x_1}{x_2} = K_D$. In the equation x_1 and x_2 are the concentrations of the trace element in mineral phases 1 and 2. If the distribution of the trace element is ideal and if two phases coexist at equilibrium, the distribution coefficient is a function of temperature and pressure alone. However, variations in the chemical compositions in the coexisting phases may have an influence on the distribution coefficient. If this is the case, the distribution coefficient may also depend on a third mineral phase.

Garnet-cordierite gneisses are very common rocks in the Precambrian of Finland. Some garnet-cordierite gneisses belong to the granulite facies, like the cordierite granulites of Lapland (Eskola 1952) and the lutogenites of West Uusimaa (WUC) (Parras 1958). This paper presents the distribution of cobalt, vanadium and chromium between coexisting biotite and garnet in garnet-cordierite gneisses of the granulite facies.

Samples

The samples of this study were taken from the granulite area of Lapland, from the charnockite area of the WUC and from the garnet-cordierite area of Sulkava.

The samples from Lapland are cordierite granulites. According to Eskola (1963), cordierite is not one of the granulite facies minerals. The cordierite granulites of Lapland may, however, be considered as members of a subfacies of the granulite facies. The samples contain the following mineral assemblage: quartz-potash feldspar-biotite-garnet-cordierite-sillimanite \pm placioclase.

According to Parras (1958), all the rocks of the WUC originated by ultrametamorphism, mineral assemblages attaining their equilibrium under conditions of the granulite facies. The Ca-content of the metamorphosed rock was a main factor controlling the crystallization of hypersthene, instead of garnet and cordierite. The mineral assemblages of the WUC samples are: quartz-potash feldspar-biotite-garnet-cordierite-sillimanite \pm placioclase and quartz-placioclase-biotite-garnet (sample no. 17).

The rocks of the Sulkava sample area in eastern Finland (Korsman and Lehijärvi 1973) are predominantly garnet-cordierite gneisses migmatized by potash granite. In addition, hypersthene gneisses and metamorphosed hypersthene-bearing granodiorites and quartz diorites occur in the area. The increasing Ca-content of the rock has also favoured the crystallization of hypersthene in the Sulkava area. The samples contain the mineral assemblages: quartz-potash feldspar-biotite-garnet-cordierite-sillimanite \pm placioclase and quartz - placioclase - biotite - garnet - hypersthene (samples nos. 61 and 66 a). According to the mineral assemblages, the garnet-cordierite gneisses of Sulkava crystallized under the conditions of the biotite-cordierite-almandine-granulite subfacies.

Biotites and garnets were separated from crushed and sieved material by heavy liquids, isodynamic separator and hand picking.

Results

Table 1 presents the Co, Cr and V contents of the minerals and the distribution coefficients. The distribution points are plotted in Figs. 1—3 on logarithmic scales. If the distribution follows the Berthelot-Nernst distribution law, the slope of the distribution line is 45° on such a plot.



Fig. 1. Distribution of cobalt between coexisting biotite and garnet. Scale is logarithmic. Symbols are: open circles-Sulkava samples, open circles with crosses-hypersthene-bearing Sulkava samples, solid circles-WUC samples, inclined crosses-cordierite granulites of Lapland.



Fig. 2. Distribution of vanadium between coexisting biotite and garnet. Scale is logarithmic. Symbols are as in Fig. 1.

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Sample No. V Cr Co $K_D(V)$ K_D(Cr) KD (Co) Lapland 01a/KK/70** biotite 1 000 630 50 9.1 2.0 2.3 garnet 110 320 22 01b/KK/70** biotite 760 580 24 8.4 1.8 1.1 garnet 90 330 21 01d/KK/70** 840 biotite 510 54 8.4 1.7 1.6 garnet 100 300 33 01e/KK/70** biotite 860 37 650 11.3 2.5 1.5 garnet 76 260 25 02b/KK/70** biotite 1 300 920 34 7.6 2.7 1.8 garnet 170 340 19 WUC 01/KK/69** 1 100 biotite 1 100 130 8.5 3.7 1.9 garnet 130 300 68 02/KK/69** biotite 730 800 86 12.2 4.2 1.8 garnet 60 190 48 017/KK/69** biotite 600 560 56 11.5 3.3 1.5 garnet 52 170 37 018/KK/69** biotite 800 820 82 11.1 4.6 1.5 garnet 72 180 54 020/KK/69** biotite 660 700 67 12.7 5.0 1.6 garnet 52 140 41 Sulkava 21/IL/61* biotite 1700 1 200 42 10.0 3.6 1.8 garnet 170 330 24 307/KV/63* biotite 1 400 790 79 8.8 3.0 1.6 garnet 160 260 50 20a/KK/67* biotite 1 600 870 74 8.4 3.8 1.8 garnet 190 230 41 61/KK/69** 700 biotite 230 51 (5.0)1.6 2.1 garnet 140 140 24 64/KK/69** biotite 1 300 1 200 51 10.0 5.5 1.5 garnet 130 220 34 65/KK/69** biotite 850 780 64 8.5 4.3 1.7 garnet 100 180 38 66a/KK/69** biotite 340 100 48 (4.9)0.9 1.6 garnet 70 110 30

TABLE 1 Emission spectrometric determinations of cobalt, vanadium and chromium (in parts per million) in biotite and garnet and distribution coefficients

arithmetic mean

* Anal. Ringa Danielsson.

** Anal. A. Löfgren.

In general the distribution points of cobalt fall close to a straight line, the mean value of the distribution coefficient being 1.7. The distribution coefficients of samples 01a, 01b and 61 deviate markedly from this mean value. The causes of the scattering may be as follows: the mineral fractions contained impurities, the samples were unhomogenous, equilibrium was not attained between biotite and garnet or the deviating samples crystallized at pressures and temperatures different from those of the other samples.

The distribution of vanadium between biotite and garnet is also regular. The mean value of K_D is 9.8. The distribution coefficients of the hypersthene-bearing Sulkava samples are markedly lower than those of the other Sulkava samples. If the distribution of vanadium between biotite and garnet in the mineral assemblage biotite-garnet is different from that in garnetbiotite-hypersthene, changes in the chemical compositions of the mineral pairs must indicate a change in the distribution coefficients.

The distribution points of chrome are scat-

1.7

9.8

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tered. The distribution coefficients of the Sulkava hypersthene-bearing samples are much lower than the K_D values of the other Sulkava samples. This may be because the biotites of the hypersthene-bearing samples are much lower in Cr than are the biotites of the other Sulkava samples.

The distribution coefficients of the Lapland



Fig. 3. Distribution of chromium between coexisting biotite and garnet. Scale is logarithmic. Symbols are as in Fig. 1.



Fig. 4. Influence of the magnesium atomic ratio on the distribution coefficient of chromium in biotite-garnet pairs. Symbols are as in Fig. 1.

samples deviate considerably from those of the other samples. Table 2 lists the results of Fe- and Mg-microprobe determinations of the garnets. From Fig. 4 it is seen that the chrome distribution coefficients decrease with the increasing atomic ratio Mg/Fe+Mg+Mn of garnet.

The regular distributions of cobalt and vanadium indicate that chemical equilibrium was attained in the biotite-garnet pairs and that the distributions follow the Berthelot-Nernst distribution law. It may be possible, however, that changes in the chemical compositions of the mineral pairs influence the vanadium distribution coefficient. This is indicated by the low K_D values of the hypersthene-bearing Sulkava samples. A correlation exists between the chromium distribution coefficients and the atomic ratio Mg/ Mg+Fe+Mn of garnet. This is also in agreement with the supposition that equilibrium was attained between garnet and biotite. It is not known how the distribution coefficients depend on crystallization temperature and pressure, nor what crystallization temperature is implied by the cobalt distribution coefficient 1.7 and the vanadium distribution coefficient 9.8.

TABLE 2

FeO-, MgO- and MnO-microprobe determinations of garnets. Anal. B. Saltikoff

Sample No.	Fetot as FeO	MgO	MnO	Mg
				Fe + Mg + Mn
Lappi				
01a/KK/70	31.5	9.7	0.5	0.35
01b/KK/70	30.6	10.3	0.5	0.37
01d/KK/70	32.2	9.9	0.5	0.35
01e/KK/70	31.3	8.8	0.5	0.33
02b/KK/70	32.6	8.0	0.5	0.30
WUC				
01 /KK/69	32.5	6.4	0.9	0.26
02 /KK/69	32.8	5.1	0.8	0.21
017/KK/69	33.7	6.9	0.6	0.26
018/KK/69	33.3	4.6	0.7	0.19
020/KK/69	31.4	5.1	0.7	0.22
Sulkava				
21/IL/61	32.8	6.4	0.6	0.26
20a/KK/67	34.6	4.0	0.5	0.17
64/KK/69	31.8	5.5	0.5	0.23
65/KK/69	35.2	4.9	0.5	0.20
65/KK/69	35.2	4.9	0.5	0.20

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