unsatisfactory on purely energetic grounds it does, however, represent the overall reactions that have taken place. Moreover, it seems to fit the facts best at Keno Hill, mainly because native sulphur is common in the oxidized zones, especially near residual nodules of sphalerite, and the present oxidizing solutions are neutral or slightly alkaline, a condition that favours the formation and preservation of the native zinc.

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COEFFICIENT OF ACCUMULATION. A MEASURE OF THE TOTAL TRACE ELEMENT CONTENT OF A MINERAL OR A ROCK

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ABSTRACT

The coefficient of trace element accumulation R is a measure of the overall concentration of trace elements in geological materials. If the concentration of element i is k_i and its crustal abundance is K_i, then

$$R = \frac{1}{n} \sum_{i=1}^{n} k_i / K_i$$

for the n trace elements determined. Structurally necessary major elements are excluded. Some applications of the coefficient are discussed.

INTRODUCTION

When a number of trace elements have been determined in a rock of mineral, each element is normally interpreted from the point of view of crystal chemical factors. If a comparison of two or more samples is made it is often evident that one is relatively poor in many elements, but this fact cannot be expressed directly because the levels of abundance are of different orders of magnitude. For example, consider two pyroxenes containing respectively 8.0 ppm Co, 1500 ppm Mn and 88 ppm Co, 2800 ppm Mn. The difference between the Co values has probably more significance than the difference between the Mn concentrations, but if one were to add the trace element contents of each sample such differences would be obscured.

The concentrations can be put on an equivalent basis by dividing each k_i by its crustal abundance K_i, to obtain the ratio r_i for element i. These ratios may then be summed and averaged for all the elements n determined, to obtain R. Thus

$$R = \frac{1}{n} \sum_{i=1}^{n} k_i/K_i.$$

It is proposed to call the quantity R the coefficient of trace element accumulation, or more briefly the *coefficient of accumulation*. An example of its application is given by Moxham (1960).

CALCULATION

The coefficient will be useful only inasmuch as the crustal abundances chosen and the analyses used are reliable. Use of data from different laboratories should evidently be undertaken with caution.

It is recommended that metals which are major (that is, structure-forming) constituents should not be included in the calculations, since their presence is necessary and more or less invariable. A special problem arises with elements for which the analysis gives "trace" or "*n.d.*" In the former case a concentration of half the sensitivity limit is a reasonable assumption: in the second case the writer has used one-tenth of the sensitivity limit, but this has little to recommend it. At all events one should not ignore such elements, since absence is as important a feature as presence.

An example of the calculation of R is given in Table 1.

APPLICATIONS

The coefficient R for the lithosphere is 1.00 by definition. Any value greater than 1.00 thus indicates an overall relative concentration greater

TABLE 1. CALCULATION OF R FOR A
PYROXENE

	Analysis	Abundance	
	ppm	ppm	r_i
Be	*	2	0.05
Ga	*	19	0.05
Cr	300	100	3.00
Ti	3400	10000	0.34
Ni	93	80	1.16
Co	88	23	3.82
Cu	320	70	4.58
V	570	100	5.70
Zr	80	156	0.51
Mn	2800	1000	2.80
Sc	200	15	13.33
Y	90	40	2.25
Sr	200	450	0.45
Ba	40	250	0.16
Sum			38.20

$R = 2.73$

*n.d. Be and Ga taken as 0.1,1.0 ppm respectively.
Crustal abundances chosen from the literature.
Augite from basalt, No. X4-149, in Cornwall & Rose (1957). *Geo. et Cosmochim Acta*, **12**, 209–224.

than in the crust, and conversely. The coefficient obscures individual crystal-chemical features of course, but where the data are available one can calculate partial coefficients such as R_Y for all the trace elements in 6-fold co-ordination (Y-position) in a mineral.

One interesting application was to demonstrate quantitatively the relative purity of skarn pyroxenes with respect to basic igneous ones (Moxham, *op. cit.*). Thirty-eight skarn pyroxenes showed a range of R-values from 0.32–1.86 with a mean of 0.66, whereas 8 igneous pyroxenes (Skaergaard, Keweenawan flows, Madras charnockites) had a range of 0.99–3.02 with a mean of 2.02. The relative purity of the skarn pyroxenes reflects their origin from marbles.

Another application is to emphasize the relative powers of different minerals to accommodate trace elements. A norite from the Southern California batholith, whose constituent minerals have been studied by Sen, Nockolds, & Allen (1959) showed the following coefficients: plagioclase and quartz, 0.30; hypersthene, 1.14; augite, 1.88; biotite, 2.21; magnetite, 14.51; ilmenite, 1.57. The tolerance of magnetite for trace elements (mostly ferrides) is clearly brought out.

A final example concerns three rock series studied by Nockolds &

Allen (1953, 1954, 1956). These are Hebrides tertiary tholeiites (main trend), the Southern California batholith, and the Hawaii alkali basalt series. It is evident from inspection of the analyses that the last series contains greater amounts of many trace elements than the former two. This fact is expressed concisely by the R-values, whose ranges are (respectively) 0.86–1.20, 0.61–1.39, 0.86–2.00, and whose means are 1.03, 0.86, and 1.21. The R-values in the individual series show no clear trends, however, with respect to increasing degree of differentiation.

CONCLUSIONS

The coefficient of accumulation is a quantitative descriptive index, which expresses the overall trace element of geological materials, and which may prove helpful also in resolving genetic problems. It will be more fully discussed in a forthcoming article (Shaw, in press).

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THE CRYSTAL STRUCTURE OF METAROSSITE

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Somewhere between the proofs and publication of our recent paper (Kelsey & Barnes, 1960) on the crystal structure of metarossite a few of the data disappeared from Table 4, p. 459. The first four lines in the left-hand column of this table should read

$$
\begin{array}{ll}
O_1{}^*-V_I-O_1{}' & 78 \\
O_2-V_I-O_1{}' & 75 \\
O_1{}^*-V_I-O_5 & 94 \\
O_1{}^*-V_I-O_6 & 108 \\
\end{array}
$$

REFERENCE

KELSEY, C. H., & BARNES, W. H. (1960): The crystal structure of metarossite, Can. Mineral., 6, 448–466.