CORRESPONDENCE

COEXISTING PYROXENES

SIR,—The dispute over the consequences of projecting tie lines of coexisting pyroxenes onto a triangular diagram first sprang up following the publication of the letter of Kretz (1961*a*) opposing Wilson's (1960) view concerning the concurrence of tie lines. This controversy has been frequently mentioned by subsequent workers dealing with the subject, but thoughtful and constructive comments or suggestions have seldom been advanced. The controversy still finds its place in current works devoted to coexisting pyroxenes (*e.g.* Leelanandam, 1967). Hence a discussion concerning this does not seem untimely.

The controversy essentially centres around whether the tie lines of different coexisting pyroxene pairs equilibrated under similar P–T conditions should be concurrent on a specified limb of the triangle. A corollary to this postulate is that the "point of concurrence" should be a function of temperature (and pressure). While Wilson (1960) contended in favour of this, Kretz (1961*a*, 1961*b*) objected. According to Kretz (1961*b*), the tie lines should not intersect at a point except when $K_D = 1$, the intersection point then being the apex of the triangle. It should be apparent from the discussions to follow that both of them are only partially correct.

The distribution coefficient (K_D) of Fe between clinopyroxene and orthopyroxene may be expressed as $\frac{X^c}{1-X^c} \cdot \frac{1-X^o}{X^o}$, where X^c = Fe/(Fe + Mg) in clinopyroxene etc. Plots of X^c vs. X^o describe the familiar Roozeboom curve. It may be noted that up to a certain compositional limit of the coexisting phases, the distribution curve is by and large linear. Within this compositional range, K_D may be expressed simply as X^c/X^o.

If the compositions of the two pyroxenes fall within this range, then the tie lines of different coexisting pyroxene pairs equilibrated under similar P–T conditions (and hence $K_D = X^c/X^o$ = constant, assuming ideal mixtures and ignoring the compositional effect on K_D) will be concurrent on a limb of the triangle. A similar case for garnet-biotite pairs has been discussed by Chakraborty & Sen (1967). That the tie lines will be concurrent, under the above mentioned conditions, can be easily proved geometrically.

In Figure 1, W = $CaSiO_3$, C – C′ = clinopyroxene solid solution and O – O′ = orthopyroxene solid solution. Fe/(Fe + Mg) at C and O = zero, and at C′ and O′ = 1. Consider two hypothetical pyroxene pairs having the same K_D (= X^c/X^o) value, say 0.5. This may be possible when X^c = 0.2, 0.3 and X^o = 0.4, 0.6. PB and QD (Fig. 1) are the tie lines corresponding to the first and second pair respectively. Thus, CB = 0.2, CD = 0.3 and OP = 0.4, OQ = 0.6. Let the tie line QD meet OW at A′ instead of A. Now, from the similar triangles ACB and AOP it follows that AC/AO = CB/OP = 0.5. Similarly, A′C/A′O = CD/OQ = 0.5. Therefore, AC/AO = A′C/A′O which is impossible unless A and A′ represent the same point. In other words, the two tie lines are concurrent on OW. Obviously, the tie lines for other pairs having K_D = 0.5 will also meet at A. When K_D = 1, the "point of concurrence" will be the apex, as indicated by Kretz (1961*b*).

It does follow then that tie lines corresponding to pyroxene pairs (or any other mineral pair that may be plotted in a triangular diagram in a similar fashion) within certain compositional limits *should be concurrent* provided the phases are equilibrated under similar P–T conditions (neglecting the factors causing K_D deviate from constancy). It also follows that the tie lines *will not be mutually parallel*; neither will they normally intersect each other within the triangle. (Parallel tie lines have been wrongly taken by several workers as an indication of equilibrium). In a special case only, when OO′/CC′ is equal to X^c/X^o (*i.e.* K_D), the tie lines will be mutually parallel. Tie lines MN and RS correspond to two hypothetical pyroxene pairs where X^c = 0.4, 0.6 and X^o = 0.2, 0.3 respectively. For these pairs K_D = 2.0, and OO′/CC′ in the present figure is also 2.0; it may be noted that these tie lines are parallel.

Inasmuch as K_D is a function of temperature (and pressure), the "point of concurrence" of different tie lines should also be a function of temperature (and pressure).

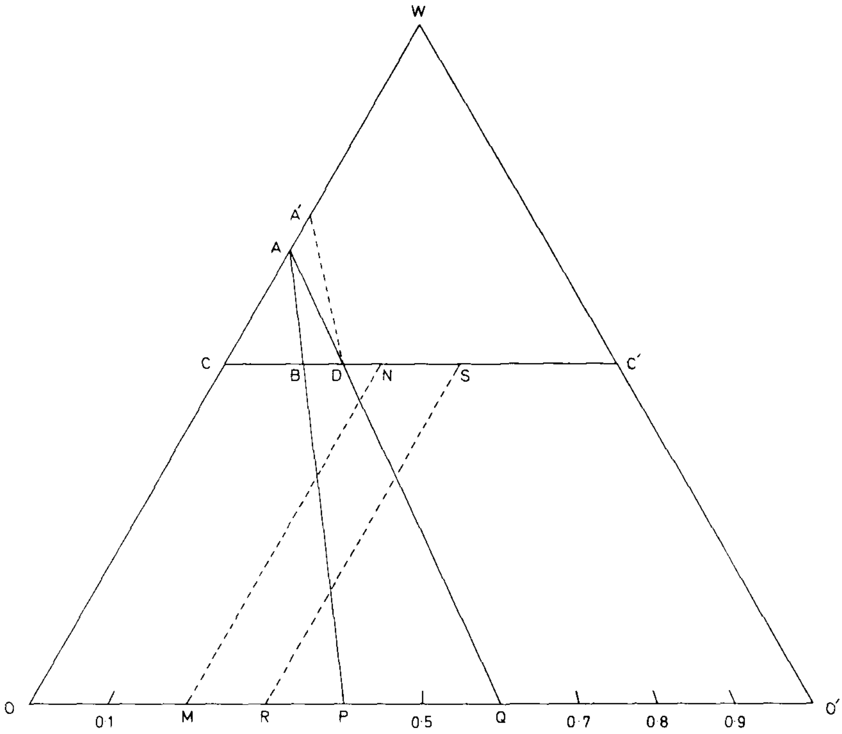

FIG. 1.–For explanation see text.

If the tie lines corresponding to different pairs supposedly crystallised under similar P–T conditions do not meet at a point (in that case, tie lines may be intersecting), the influence of variable concentration of other elements in the phases, lack of equilibrium etc. may be suspected. The "point of concurrence" thus qualitatively behaves like K_D. But, since the distribution curve *will be linear only under special cases* (*e.g.*, when $K_D = 1$, or within certain compositional limits), *the tie lines should not normally be expected to be concurrent.* In other words, when K_D has to be expressed as $\frac{X^c}{1-X^c} \cdot \frac{1-X^o}{X^o}$, which generally is the case, *the tie lines will not be concurrent*, and the configuration of the tie lines will be similar to those demonstrated by Kretz (1961*b*, Fig.10). Consequently, in this case the tie lines alone will not be capable of providing any information regarding the nature of element distribution, attainment of equilibrium, crystallisation temperature etc.

It is concluded, therefore, that the tie line operation for discussing element distribution is not really worthy of the popularity it has gained; nevertheless, in certain cases, this operation may not be as "meaningless" as Kretz (1961*a*) contemplated.

This note has been prepared during the tenure of NRC post doctoral fellowship.

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15th January, 1969.

STRATIGRAPHICAL SUB-DIVISIONS OF THE SKIDDAW SLATES OF THE LAKE DISTRICT

SIR,–In the chapter on the Skiddaw Slates in the recently-published *Memoir* of the Geological Survey of Great Britain (The Geology of the Country around Cockermouth, Eastwood and others, 1969), a comparison is made in Figure 4 between the sequence in the Skiddaw Slates for the district under description and that in the ground to the south around Keswick and Buttermere, the latter after Rose (1954) and Jackson (1961). Much of the sequence shown for the latter area agrees with that put forward by the writer in a summarized account (*The Geology of the Lake District* by S. E. Hollingworth and others, 1954) of work which involved detailed mapping on the six-inch scale of the whole of this area (the full results of this work are not yet published). It is not made clear in the recent memoir, however, that the term "Hope Beck Slates" used in the section in Figure 4 should be ascribed wholly to Jackson.

The term "Hope Beck Slates" was introduced by Jackson (1961) to denote a distinct formation of slates claimed by him to underlie the Loweswater Flags and to outcrop in an area south-east of Lorton on the northern and western flanks of Dodd and near Scaw Gill. The detailed work by the writer, however, does not confirm the existence of a discrete group of slates in this stratigraphical position. The new palaeontological evidence obtained by Jackson (1962) does no more in this connection than confirm the existence of the lowest fauna (*Didymograptus deflexus*) so far recognized beyond doubt in the Skiddaw Slates (both in this area and in the ground covered by the Cockermouth Memoir) as being present at Scaw Gill. The only evidence of the possible presence of a lower zone in the ground south-east of Lorton is the provisional assignment by Jackson (1964) of a single specimen to the *Tetragraptus approximatus* group. In the view of the writer, therefore, the grounds on which the term "Hope Beck Slates" have been introduced are insecure and the term should not be retained.

Generally over the Keswick-Buttermere area the writer believes that on stratigraphical grounds the lowest rocks exposed are probably arenaceous and gritty beds, forming the lower part of the Loweswater Flags. As yet, however, palaeontological evidence is lacking. These beds do include some coarse grits and can probably be correlated with the "Grit" group, the lowest of the subdivisions proposed in the Cockermouth *Memoir.* The general conclusions of the writer from his work in the Keswick-Buttermere area agree closely with those reached by the Geological Survey in the Cockermouth area; they do not support the subdivision of the Skiddaw Slates recently put forward by Simpson (1967).

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