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Quantifying the spatial distribution of phases in rocks – a new look at an old approach

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The spatial distribution of phases in polyphase materials is of great interest to a broad variety of earth and materials scientists. In particular, the phase distribution in igneous and metamorphic rocks can tell us much about nucleation and growth of crystals, about mechanisms that were active during deformation of such rocks, and about the rheology of crystalline materials. In the earth sciences much work has focussed on the distribution of phenocrysts and porphyroblasts in igneous and metamorphic rocks (e.g. Jerram et al., 1996) but less attention has been paid to the distribution of two or more phases forming the bulk of a rock. The spatial phase distribution of major rock constituents can for example be described using the concept of randomness and non-randomness (Kretz, 1969).

As part of a study of deformation mechanisms and microstructures in eclogites of the Tromsø Nappe of northern Norway the distribution of phases in three images from three different eclogite thin sections have been analysed using two variations of Kretz's "contact area" method. The first of these calculates expected grain and phase boundary fractions using the volume fraction of minerals, whereas the second uses the total grain surface area proportions of each phase to define the expected grain and phase boundary fractions. The images were selected to cover a good range of volume fractions of the eclogites' two main constituent phases, garnet and omphacite (garnet:omphacite approximately 3:7, 1:1 and 7:3). Interestingly, despite having very different volume fractions the three samples show quite similar total grain surface area fractions (with garnet grain surface area fractions ranging from 0.47 to 0.61).

The boundary fractions of all three samples show a significant departure from the expected values calculated from the volume proportions: In each case a higher phase

boundary proportion was observed than expected. Additionally, in the sample with a volume proportion garnet:omphacite of 1:1 both garnet and omphacite grain boundary fractions are less than expected, suggesting a regular/anticlustered distribution of garnet and omphacite. Contrastingly, in the samples with volume proportions garnet:omphacite of 3:7 and 7:3 lower grain boundary proportions in the phase with the greater volume fraction were observed, whilst the phase with the lesser volume fraction showed higher grain boundary proportions than expected. This observation suggests that the phase with the lower volume percentage tends to form clusters, yet at the same time the observed higher fraction of phase boundaries suggests a regular/anticlustered distribution of garnet and omphacite. Together these observations might be interpreted as small clusters of the phase with the lower volume fraction being regularly distributed throughout the sample.

When comparing the observed boundary fractions with the expected values calculated using the total grain surface area proportions we note that the observed values lie closer to the expected. Indeed the sample with a volume fraction ratio garnet:omphacite of approximately 3:7 and with garnet contributing 47% to the total grain surface area does not appear to depart significantly from the expected curve. The other two samples (with volume fraction ratios 1:1 and 7:3 and corresponding garnet grain surface area fractions of 51% and 61% respectively) on the other hand show significant departures from the expected values. Again we note higher phase boundary fractions than expected. In both cases there are fewer omphacite and garnet grain boundaries than expected. These observations suggest that the distribution of garnet and omphacite is regular/anticlustered.

Altogether the analysis of these eclogite samples suggests a non-random distribution of their major constituent phases. This conclusion though strongly relies on the assumed expected boundary proportions of a two-phase mixture with randomly distributed phases as being correct. Computer-simulated crystalline microstructures with random distributions of two phases will be used to test this assumption.

References

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