EVOLUTION OF CLINOPYROXENE AND GARNET IN AN ECLOGITE NODULE FROM THE ROBERTS VICTOR KIMBERLITE PIPE

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The eclogite nodule studied is bimineralic and shows a variable texture, which may be crudely banded. One half of the nodule is dominated by very large clinopyroxene crystals (up to 6.0 cms) which are separated by narrow zones of granular garnets (2.0 to 5.0 mms). Internally these clinopyroxenes show numerous, prominent exsolution lamellae of garnet (up to 1.25 mm thick), and occasional more granular garnet inclusions. In the other half the texture is dominantly of granular type with roundish garnets (2-5 mm) and anhedral clinopyroxenes (4 to 20 mm): the large clinopyroxenes showing scattered exsolution lamellae. In the fine-granular part, the garnets again tend to surround individual clinopyroxenes. The bulk composition of the whole nodule shows wt.%: SiO_2 44.03, TiO_2 0.17, Al_2O_3 15.30, Cr_2O_3 0.05, Fe_2O_3 4.74, FeO 4.76, MnO 0.18, MgO 12.21, CaO 17.65, Na_2O 0.65, K_2O 0.23, P_2O_5 0.03.

There is a very wide spread of both garnet and clinopyroxene compositions. Individual garnet lamellae and granules show fairly constant compositions, except at the margins and in occasional apophyses of large granules. Individual clinopyroxene crystals show marked changes in composition with most particularly : Al_2O_3 gradually decreasing, and SiO_2 and MgO gradually increasing, as garnet (either lamellar or granular) is approached. These changes accord with the high Al_2O_3 and lower SiO_2 and MgO of garnet compared with clinopyroxene, and indicate the occurrence of granular as well as lamellar exsolution. It appears that the latter exsolution has been dominant in the coarse-lamellar part of the nodule, and the former in the fine-granular part. These differences may reflect initial variation in grain size within the rock, and it is probable that different initial proportions of garnet and clinopyroxene occurred in the two parts of the nodule. That some garnet must have been present in the rock initially is shown by the failure to homogenise the bulk rock composition (Fig.3), and accords with its high R_2O_3 content (cf. O'Hara, 1969).

Within the large clinopyroxene crystals, garnet lamellae of widely varying size are seen. Coarse lamellae may run continuously for several cms. and clusters of parallel fine lamellae tend to terminate adjacent to these coarse lamellae; suggesting the earlier development of coarse lamellae.

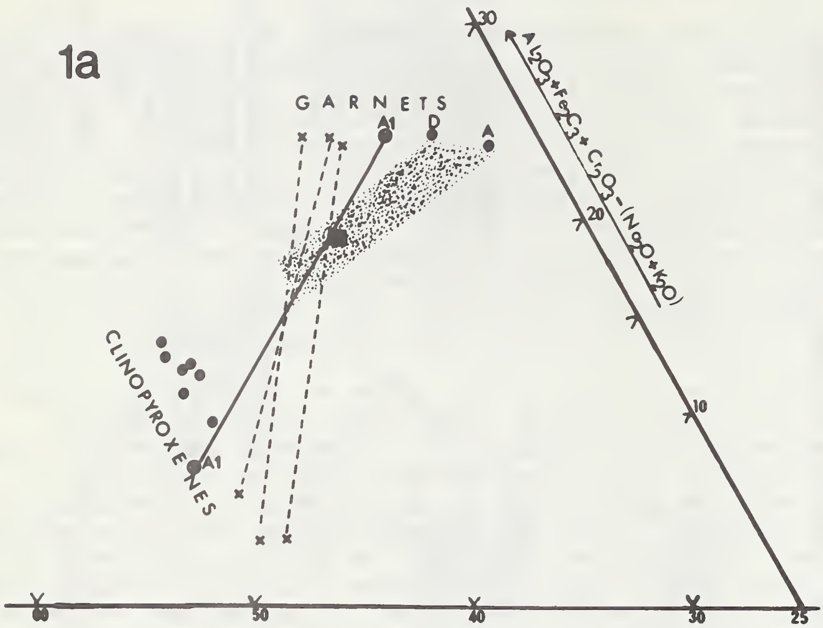
Despite the lack of chemical equilibrium within the rock on a large scale, it may be expected that the garnet exsolved at any one time would be in equilibrium with the clinopyroxene from which it was forming, and thus garnet and clinopyroxene in immediate contact would approximate to local chemical equilibrium. Fig.1 shows the composition (all Fe as FeO) of garnets and clinopyroxenes, with tie-lines joining garnet lamellae (classified according to size) and immediately adjacent clinopyroxene compositions in the coarse-lamellar part of the nodule.

Fig.1 also shows the garnet and clinopyroxene compositions of points as far removed from the other phase as possible; and the calculated average bulk composition (A2) of a region of clustered fine parallel garnet lamellae within a large clinopyroxene crystal. Composition A_2 has 14.1 wt.% Al_2O_3, and the maximum Al_2O_3 content of actual clinopyroxene found in the rock is 13.82%; suggesting an initial content approaching 14.5%.

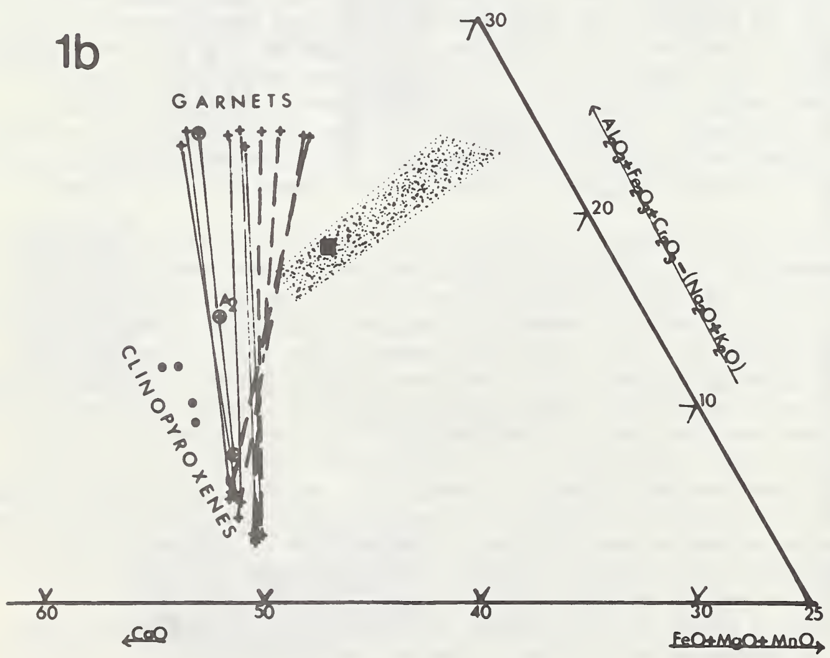
Fig.1 shows a swing in orientation of garnet-clinopyroxene tie-lines during the progressive exsolution of garnet, associated with an overall

FIG1

1a



1b



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variation of garnet C (atoms Ca/Ca+Mg+Fe+Mn) from 36.2 to 55.0 The change in tie-line orientation may be expected to occur with decreasing T. &/or increasing P.(O'Hara & Mercy, 1966; Lovering & White, 1969) The data indicate that a sufficiently CaO- and Al_2O_3- rich clinopyroxene (initially capable of co-existing with pyrope-rich garnet) may exsolve to yield clinopyroxene and garnet compositions related to those of grospydites (Sobolev et al, 1968).

Fig.2 shows Fe/Mg ratios of garnet lamellae and adjacent clinopyroxene (from Fig.1), together with approximations (A&D) towards the Fe/Mg ratios of co-existing garnet and clinopyroxene prior to exsolution. Point A is calculated using garnet A and clinopyroxene A2 of Fig.1, while point D is calculated from garnet D and the most aluminous clinopyroxene found in the region around garnet D. The distribution coefficient, K=Fe/Mg Garnet/Fe/Mg Clinopyroxene, shows a progressive increase during the course of exsolution, corresponding to decreasing T &/or increasing P (Banno, 1970) and is consistent with the change in tie-line orientation in Fig.1. Temperature rather than pressure is expected to have the major effect on K (op.cit).

Fig.3. summarises experimental data on a crushed large clinopyroxene complete with its exsolution lamellae. Data points are also shown for two runs on a starting material formed by the bulk rock composition (P.1). The large clinopyroxene with exsolution lamellae homogenises to clinopyroxene alone in a wedge shaped field adjacent to the solidus. Assuming that the initial eclogite (consisting of unexsolved clinopyroxene and initial garnet) formed by crystallisation from magma and was therefore in equilibrium with liquid, an initial T. and P. of formation of the nodule at approximately 1400°C and 34-38 kb. are indicated by Fig.3 (subject to variation in the composition of the liquid). The exsolution of garnet from clinopyroxene and the relations of Figs. 1 & 2 could then develop as a result of cooling to the geotherm at roughly constant depth.

References

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FIG.1. Molecular plot of bulk rock composition (■), and clinopyroxene and garnet compositions. Tie-lines join garnet lamellae and immediately adjacent clinopyroxene compositions: ✖ indicates coarse garnet lamellae, ✚ indicates intermediate and fine garnet lamellae (solid tie-lines join points occurring in clusters on fine garnet lamellae. Al ⊗ represent an exceptionally coarse garnet lamella and adjacent clinopyroxene. ⊕ represent the average compositions of garnet and clinopyroxene (including all clinopyroxene occurring in between lamellae) in a scan across a cluster of fine garnet lamellae, with A2 being the overall bulk composition. ● (unlabelled) in 1a are clinopyroxenes as far removed from garnet as possible; and in 1b are clinopyroxenes midway between clusters of fine garnet lamellae. ● (A&D) are the centres of large granular garnets in the coarse-lamellar and fine-granular parts of the nodule respectively. The dotted area indicates the probable location of garnet-clinopyroxene tie-line(s) before exsolution.

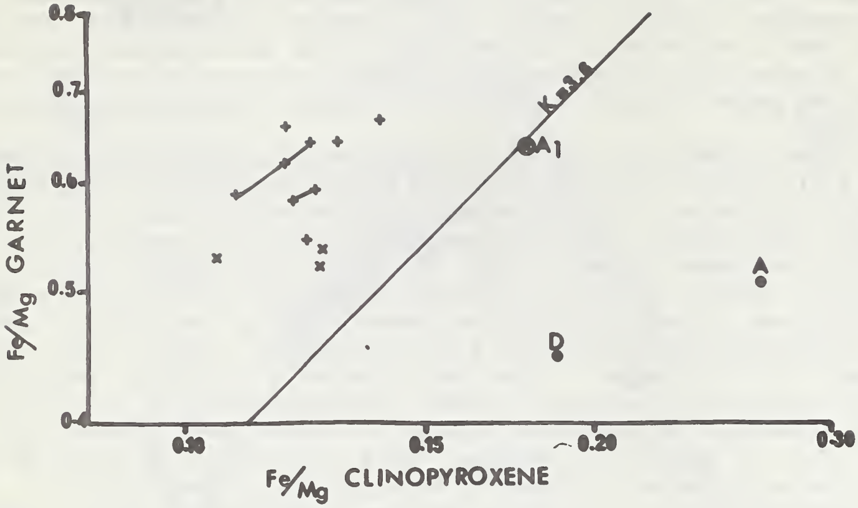

FIG. 2. Fe/Mg distribution in garnet and associated clinopyroxene. Symbolism as in FIG.1. The short lines join points occurring in the same cluster of fine garnet lamellae. The line K=3.6 is from Banno (1970,p.409) for Roberts Victor eclogites .

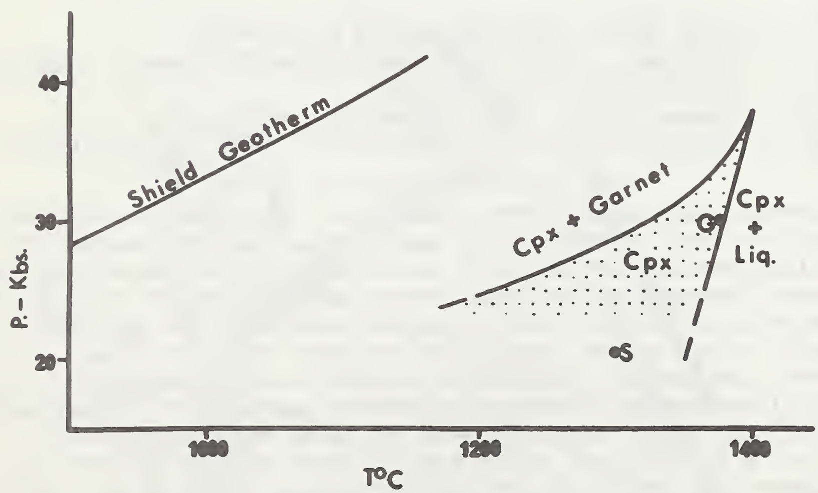

FIG. 3. Summary of experimental data on the composition of a large clinopyroxene crystal (with included garnet lamellae), showing an extensive field (dotted) of homogenisation to clinopyroxene only. The points G and S represent runs on the whole rock bulk composition showing cpx + garnet + glass, and cpx + spinel + ? garnet + ? glass respectively.