
X-ray study. Twelve at random picked clino pyroxene grains (~0.1 mm in size) from a fractionated sample provided by Hafner (1) were studied using a 12 kW X-ray generator and a focussing Ge-monochromator (Guinier-Johansson type). This sample was reported to be well homogeneous (\(\text{W}^{06-14}\)En56-64Fs26-34) as observed by microprobe analysis (1). Precession photographs reveal strong heterogeneities of the grains and indicate chemical disequilibrium in submicroscopic dimensions. Two remarkable examples are presented here.

Besides the wellknown exsolution of augite on (001) and (100) from pigeonite two host pigeonites P1 and P2 are observed which correlate after Nakazawa (1) with the exsolved augites: P1-A(001), P2-A(100). A splitting of the a*-axes of P1 and P2 \((0^{\circ}-1^{\circ})\) is observed. The correlation mentioned above seems to be ascertained even in our high resolution photographs. Phenomena resulting from nonequilibria in submicroscopic scale can clearly be seen on precession photographs of a grain 'twinned' on (100), (Fig.1). Individual I shows only a weak splitting into P1 and P2 on c*, individual II shows a distinct splitting of 0.65°. Intensities of P1-reflections are clearly higher than those of P2 in I, whereas those of P1 and P2 are practically the same in II. The intensities of corresponding augite reflections are equal in both individuals. There are streaks between reflections of A (001) and P1 in I, however none in II. All these observations can only be explained by chemical inhomogeneities in the melt on submicroscopic scale. They could enable 2 pigeonites to crystallize. Considering that after Ross et al. (2) the miscibility gap does not close it seems quite understandable that two different clinopyroxenes crystallize as reported by Bence and Papike (3) and Ross et al. (2).

The other grain shows a host pigeonite onto which an augite has grown in such a way that as well the c-axes of pigeonite and augite as the a-axes form an angle of 1.2°. This value corresponds to 1/2 \((B_{\text{A}-B_{\text{p}}})\) and is characteristic of 'epitaxial overgrowth' after Ross et al. (2), (Fig.2). The lattice parameters in \(\text{Å}\) are for P1,2: \(a=9.667, b=8.897, c=5.213, \beta=108.55^\circ\); for A (001):9.673, 8.897, 5.263, 105.87°; for A (100):9.75, 8.897, 5.214, 106.6°; for Aep:9.746, 8.897, 5.255, 106.15°; for Pep:9.729, 8.897, 5.211, 108.62°. It is pointed out that \(a\) of Aep and A (100) and \(c\) of Aep and A (001) are the same within the accuracy of measurement. Aep has preserved its very own

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Fig. 1: Schematic drawings of details from monochromatic high resolution precession photographs of a 'twinned' grain showing reflection groups a) 600 b) 002

Fig. 2: Schematic representation of reflection groups 202, 102 and 002 of a grain with 'epitaxial' characteristics

lattice parameters, it has those of an augite 'free of strain' mentioned by Morimoto (4), proving well that it is not a lamellar exsolution. The host pigeonite exsolves as usual in 14053 pyroxenes an augite on (001) and (100). Although the reflections of the latter 'phase' are extremely diffuse, their positions do well correspond to those of A(100) reflections. Because of their extreme diffuseness this 'phase' is estimated only 1 or 2 cells thick. The pigeonite reflections show a tendency to split into P1 and P2. The epitaxial augite Aep exsolves only pigeonite Pep on (001). Additional streaks relating host and epitaxial systems (Fig.2) are observed. They indicate a transition zone, probably caused by a chemical gradient.

Transmission electron microscopy (TEM) has been done on three clinopyroxene grains of pigeonitic (grains K1,K2,K3) and one of augitic (grain G1) composition from 14053. The purpose of this TEM study is to supplement the X-ray investigations.
with an independent information on the submicroscopic textures and to see to which extent the results of both methods are consistent. Specimens suitable for TEM with 100 keV were prepared by crushing. By this method, numerous small fragments of one grain are obtained. All grains show the well-known submicroscopic unmixing into pigeonite (P-lattice) and augite (C-lattice) which commonly occurs as lamellar intergrowth approximately along (001) and (100) (5). Pigeonite is predominant in K1, K2, and K3. The volume ratio pigeonite to augite in G1 is about 1:1. In K1 and K2, the augite lamellae on (001) are typically 200-400 Å, the pigeonite lamellae 500-2000 Å in width. Only the pigeonite lamellae contain additional augite lamellae on (100) which are a few lattice constants thin and have a spacing of 200-400 Å. It is concluded that the augite on (100) exsolved after the unmixing on (001). In the grain K3 (= crystal No 23 from Dr. Nakazawa who did X-ray studies on it), the augite lamellae on (001) are thinner (100-250 Å) and less frequent than in K1 and K2. Augite lamellae on (100) are the prominent feature in K3. It has been repeatedly stated that the thermal history of rocks may be revealed by studying the submicroscopic textures of their clinopyroxenes. A major obstacle in reaching this goal is the difficulty to obtain the chemical composition of the very area studied by TEM. One way is to investigate grains previously analyzed by the electron microprobe (5). Another possibility is the elemental analysis by an energy dispersive X-ray spectrometer which can be directly combined with TEM. Such a system was recently attached to our microscope. The smallest electron beam probe presently used by us is 0.3 μm in diameter. Therefore, individual pigeonite and augite lamellae could not yet be analyzed. A few preliminary qualitative analyses showed that fragments from K1 and K2 contain about 2-4 Mol % in CaSiO3 content more than those from K3 which have a composition of about Wo10–Wo12. K3 has a significantly higher MgSiO3 and lower FeSiO3 content (reaching En65 and Fs 25) than K1 and K2. A detailed discussion of the TEM results in comparison with the X-ray studies is planned for the Proceedings.

References