

A PYROXENE SOLVUS SECTION

A. C. TURNOCK

*Department of Earth Sciences, University of Manitoba
Winnipeg, Canada*

ABSTRACT

An experimental determination of a solvus on the join $Mg_{0.2}Fe_{0.3}Ca_{0.5}SiO_3$ – $Mg_{0.4}Fe_{0.6}SiO_3$ for total pressure of 20 Kb, shows a two-phase region of augite \pm orthopyroxene. The maximum calcium content of the orthopyroxene on the solvus is $7 \pm 5\%$ Wo ($CaSiO_3$), and shows no change with increasing temperature in the range 800 to 950° C. The minimum calcium content of augite is $25 \pm 5\%$ Wo at 800° C, $15 \pm 5\%$ at 950°, so that with increasing temperature the stability field of augite is extended to a low $CaSiO_3$ content.

An intersection through the solvus has been experimentally determined for synthetic pyroxenes with compositions which lie along the join which is marked A–B in Fig. 1. The solvus section, which is presented in Fig. 2,

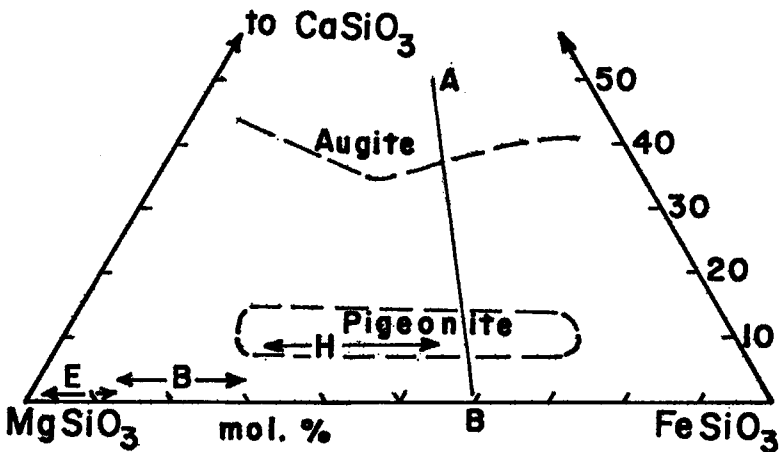


FIG. 1. The composition ranges of pyroxenes in the system $MgSiO_3$, $FeSiO_3$, and $CaSiO_3$, after the compilation of Deer *et al.* (1963). H = Hypersthene with blebs of exsolved augites. A–B is the section in Figure 2. Average trend lines for Enstatite (E) and Bronzite (B) are from Brown (1968).

shows the field of solid solution of augite and orthopyroxene, and the two-phase region between them. This join is not binary, but it is approximately binary in the subsolidus because it is laid out approximately parallel to known tie-lines between coexisting pairs of augite + hypersthene (divergence angle of about 10°, by comparison with the tie-lines

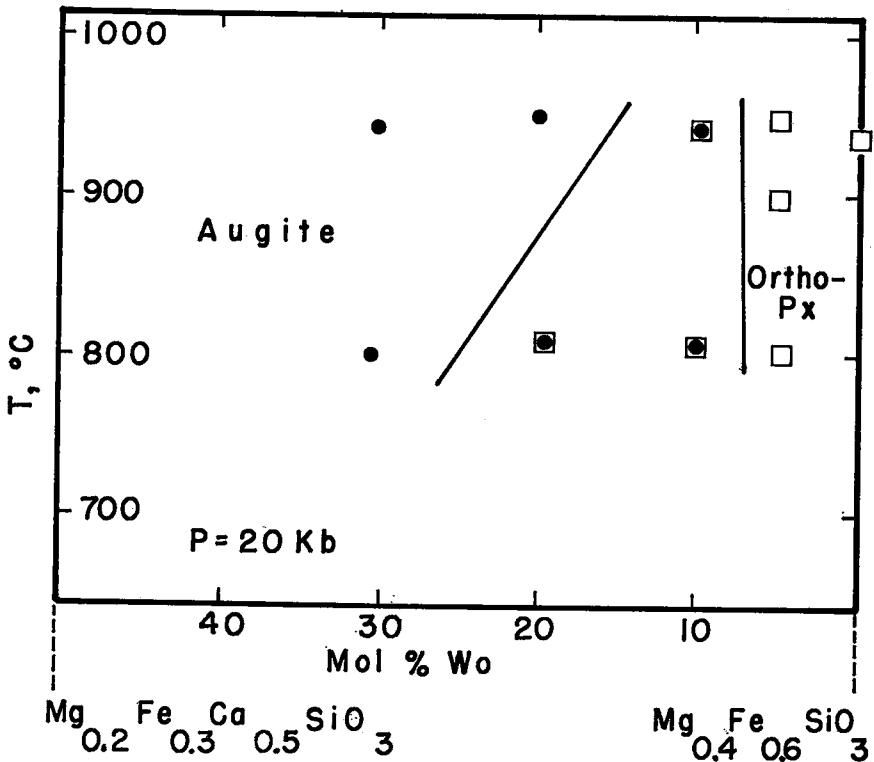


FIG. 2. T-X section across the pyroxene quadrilateral (A-B in Fig. 1) at P total = 20 Kilobars. ● = augite. ◻ = orthopyroxene. ◼ = 2 phases.

shown for natural pairs by Brown (1968, p. 348) and by Deer *et al.* (1963, p. 127).

Starting materials for the experiments were clinopyroxenes, synthesized at P total = 1 atm, with compositions as marked in the figures. Those with contents of calcium greater than 25 mol. % Wo (CaSiO₃) had an XRD pattern similar to augite, but those with less than 25% Wo had an XRD pattern with a reflection (231), and are referred to as pigeonites.

Experiments of the heat-quench-examine type were performed in a 2-stage press. About 0.1 g. of starting material was loaded into a silver capsule, with a pressure-sealed lid. This was fitted into a press furnace assemblage which included a talc pressure medium and a graphite cylinder furnace, designed by Boyd & England (1963). Pressures of 20 ± 1 kilobars and temperatures of 800 to 960 ± 15° C were maintained for about 12 hours. Quenching was performed simply by switching off the power, whereupon the temperature would decrease by 500° in 20 seconds.

The heating time of 12 hours exceeded the time for recrystallization of pigeonite to augite, orthopyroxene, or both. The results, shown in Fig. 2, are as follows. Pigeonite with a low calcium content of $Wo = 5\%$, reacted to form orthopyroxene. Pigeonite with 10% Wo reacted to form 2-phase mixtures of orthopyroxene + augite. Pigeonite with 20% Wo reacted to augite + orthopyroxene at 810° , but to augite alone at 950° . Augite with $Wo = 30\%$ only reacted by minor recrystallization, increasing the average grain size from 5 to $10 \mu\text{m}$.

The maximum amount of calcium that will go into solid solution in orthopyroxene is 7 ± 5 mol. % Wo , and the vertical alignment of the solvus indicates only small changes with temperature. In contrast, the stability field of augite is enlarged by temperature; at 950°C the composition of augite can extend to calcium contents of less than 20% Wo .

The enlargement of the augite field at the expense of the two-phase region indicates that a "low-Ca-augite" could form as a hypersolvus pyroxene. In view of the work of Smyth (1969), which showed that an orthopyroxene with composition $\text{En}_{30}\text{Fs}_{70}$ could be converted by heating at temperatures above 1050° to a high temperature polymorph with the augite $C2/c$ structure, it appears that there may be a complete series of augite solid solutions from $Wo = 50$ to $Wo = 0$ at pressures high enough to separate the solidus from the solvus.

The reaction of pigeonite to low-Ca-augite and orthopyroxene, and the extension of the augite solid solution range with temperature, leads to the suggestion that there may be no stability fields for pigeonite or protohypersthene at the P-T-X conditions shown in Fig. 2. Pigeonite, both in nature and in the products of experiments (*i.e.* Brown (1968), found pigeonite to be the high-temperature polymorph of orthopyroxene $\text{En}_{48}\text{Fs}_{43}\text{Wo}_9$) may be explained as forming as a quench-product on the cooling of low-Ca-augite in place of the more stable orthopyroxene. This has been observed by Smyth (1969), and this theory would explain the observation of Brown (1968), that pigeonite crystals produced in what he called the "clinopyroxene" P-T field were in part polysynthetically twinned; this twinning is a feature of quench-product pigeonite. This theory might explain the common occurrence of twinning in pigeonite (Deer *et al.* 1963, p. 150), but fails to explain the occurrence of any pigeonite crystals, especially phenocrysts in lava, which are large and have sharp extinction.

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