

Apollo 12 Clinopyroxenes: Chemical Trends, Epitaxy,

Exsolution, and Phase Transitions

by

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Clinopyroxenes from rocks 12021, 12022, 12037, and 12052 have been studied by electron microprobe and room- and high-temperature X-ray diffraction techniques. Based on these studies, we make the following observations and interpretations:

1. Pigeonite was the first pyroxene to crystallize in rocks 12021 and 12052. The crystallization sequence is pigeonite → pigeonite + augite → iron-rich clinopyroxene.
2. In addition to tetrahedral aluminum accommodated by the $R^{2+}TiAl_2O_6$ substitution, octahedral aluminum is present in pyroxenes from rocks 12021, 12022, and 12052. No detectable octahedral Al was observed in 12037 pyroxenes.
3. In rocks 12021 and 12052 augite forms epitaxial overgrowths on pigeonite. In 12052, pyroxenes sectioned normal to \underline{c} show that the augite overgrowth is not complete and that pigeonite continues to grow parallel to [010] and becomes increasingly calcic.
4. Single-crystal X-ray diffraction studies of 12052 pyroxenes demonstrate that the plane of structural matching between pigeonite and the augite overgrowths is (100).

5. In rock 12021 primary pigeonites exsolve augite on both (001) and (100) with reflections of the latter being more diffuse. Augites exsolve pigeonite mainly on (001).
6. X-ray diffraction data for 12021 pyroxenes plotted on a (Wo-En-Fs) nomogram based on the unit cell dimensions b and β indicate that significant subsolidus phase separation has taken place between high and low Ca-pyroxenes over a wide range of Fe-Mg compositions.
7. At temperatures between 500° and 1100° C pigeonites transform with increasing temperature from $P2_1/c$ to $C2/c$ symmetry. The transition temperature decreases with increasing (Fe,Ca) in the pigeonite.
8. The $P2_1/c$ to $C2/c$ transition temperature decreases significantly (up to 200° C) with heat treatment. This may be due, in part, to partial homogenization of the augite-pigeonite intergrowths and/or disorder of Mg and Fe between the pyroxene M1 and M2 sites.