



Pyroxenes in komatiites and lunar basalts: crystallization in the margins of anhydrous lavas

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The compositions and crystallization sequences of pyroxenes in Archean and Tertiary komatiites and in lunar basalts are similar in many ways. The spinifex-textured upper parts of komatiitic basaltic flows are composed dominantly of fine needles of pyroxene, oriented randomly in the uppermost part, then acquiring an orientation perpendicular to the flow top in underlying "stringbeef" spinifex. The needles are zoned with cores of pigeonite (or rarely orthopyroxene) and rims of augite and they lie in a matrix of devitrified glass or intergrown plagioclase and augite.

Basalts from Apollo 12 and 15, collected during missions in 1970 and 1971, have similar textures. Four samples were chosen for electron and ion microprobes studies, all of them providing extremely fresh crystals of zoned pyroxene. Samples 12021, 12052 and 15495 are coarse-grained pigeonite basalts, containing acicular phenocrysts of pyroxene (with pigeonite cores and augite rims, up to 1cm long) embedded in a groundmass of pyroxene, plagioclase, opaque phases and glass. Sample 15597 is a fine-grained pigeonite basalt, displaying small phenocrysts of zoned pyroxene, without preferential orientation, in a groundmass of silica glass.

The compositions of pyroxenes from a komatiite flow at Alexo in Canada were measured using electron and ion microprobes. Pigeonite in komatiites is highly magnesian with Mg# ($Mg/(Mg+Fe)$) up to 0.85. Augite has a wide range of compositions. The rims of zoned crystals have Mg# like those of pigeonite, with Wo contents that range from very low, in the sub-calcic field, to high. In matrix augite, Mg# drops sharply as Wo decreases slightly. Pyroxenes in lunar basalts have lower Mg# due to higher Fe in these basalts, but the Wo contents of pigeonite and augite are comparable. Parman *et al.* (1997, *Earth Planet. Sci. Lett.*, 150, 303) used the results of experiments conducted at 1atm and 0.2MPa and the compositions of pyroxene from South African komati-

ites to propose that these lavas had crystallized from hydrous magma in shallow-level intrusions. The Alexo augites with high Mg# and high Wo plot in Parman *et al.*'s wet 0.2 MPa experimental field but these pyroxenes cannot have formed at such pressure because they crystallized within a lava flow capped by hyaloclastite (Barnes, 1985, *Lithos*, 18, 241-270). The similar compositions of lunar pyroxenes, which crystallized from indisputably anhydrous magma (e.g. Canup & Asphang, 2001, *Nature*, 412, 708-712), support this interpretation. We tentatively attribute these compositions to crystallization at low temperatures in liquids that were strongly supercooled because of delay in nucleation of pyroxene.

The trace elements distribution in pyroxenes can also provide some important information on the crystallization processes. McSween *et al.*, (2001, *Nature*, 409, 487-489) studied pyroxenes in the Shergotty meteorite and showed that the Li and B contents, and Ce/Y ratios in late crystallizing augite were lower than those of early crystallizing pigeonite. They claimed that this abnormal behaviour of these elements resulted from degassing of originally hydrous magma during crystallization of the pyroxene. On the basis of our analyses on pyroxenes from komatiites and lunar basalts, we propose that water is not necessary and that the variation of trace element contents and ratios results merely from differences in element partitioning between the two types of pyroxene.