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Aluminian low-Ca pyroxene in a Ca-Al-rich chondrule from the Semarkona meteorite

ALAN E. RUBIN*

Institute of Geophysics and Planetary Physics, University of California, Los Angeles, California, 90095-1567, U.S.A.

ABSTRACT

A Ca-Al-rich chondrule (labeled G7) from the Semarkona LL3.0 ordinary chondrite (OC) consists of 73 vol% glassy mesostasis, 22 vol% skeletal forsterite, 3 vol% fassaite (i.e., Al-Ti diopside), and 2 vol% Al-rich, low-Ca pyroxene. The latter phase, which contains up to 16.3 wt% Al_2O_3, is among the most Al-rich, low-Ca pyroxene grains ever reported. It is inferred that 20% of the tetrahedral sites and 13% of the octahedral sites in this grain are occupied by Al. Approximately parallel optical extinction implies that the Al-rich, low-Ca pyroxene grains are probably orthorhombic, consistent with literature data that show that Al_2O_3 stabilizes the orthoenstatite structure relative to protoenstatite at low pressure. The order of crystallization in the chondrule was forsterite, Al-rich low-Ca pyroxene, and fassaite; the residual liquid vitrified during chondrule quenching. Phase relationships indicate that, for a G7-composition liquid at equilibrium, spinel and anorthite should crystallize early and orthopyroxene should not crystallize at all. The presence of Al-rich orthopyroxene in G7 is due mainly to the kinetic failure of anorthite to crystallize; this failure was caused by quenching of the G7 precursor droplet. Aluminum preferentially enters the relatively large B tetrahedra of orthopyroxene; because only one tetrahedral size occurs in fassaite, this phase contains higher mean concentrations of Al_2O_3 than the Al-rich orthopyroxene (17.8 and 14.7 wt%, respectively). Chondrule G7 may have formed by remelting an amoeboid olivine inclusion that entered the OC region of the solar nebula during an episode of chondrule formation.