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Two generations of exsolution lamellae in pyroxene from Asuka 09545: Clues to the thermal evolution of silicates in mesosiderite

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Abstract

Mesosiderite meteorites consist of a mixture of crustal basaltic or gabbroic material and metal. Their formation process is still debated due to their unexpected combination of crust and core materials, possibly derived from the same planetesimal parent body, and lacking an intervening mantle component. Mesosiderites have experienced an extremely slow cooling rate from ca. 550 °C, as recorded in the metal (0.25–0.5 °C/Ma). Here we present a detailed investigation of exsolution features in pyroxene from the Antarctic mesosiderite Asuka (A) 09545. Geothermobarometry calculations, lattice parameters, lamellae orientation, and the presence of clinoenstatite as the host were used in an attempt to constrain the evolution of pyroxene from 1150 to 570 °C and the formation of two generations of exsolution lamellae. After pigeonite crystallization at ca. 1150 °C, the first exsolution process generated the thick augite lamellae along (100) in the temperature interval 1000–900 °C. By further cooling, a second order of exsolution lamellae formed within augite along (001), consisting of monoclinic low-Ca pyroxene, equilibrated in the temperature range 900–800 °C. The last process, occurring in the 600–500 °C temperature range, was likely the inversion of high to low pigeonite in the host crystal, lacking evidence for nucleation of orthopyroxene.

The formation of two generations of exsolution lamellae, as well as of likely metastable pigeonite, suggest non-equilibrium conditions. Cooling was sufficiently slow to allow the formation of the lamellae, their preservation, and the transition from high to low pigeonite. In addition, the preservation of such fine-grained lamellae limits long-lasting, impact reheating to a peak temperature lower than 570 °C. These features, including the presence of monoclinic low-Ca pyroxene as the host, are reported in only a few mesosiderites. This suggests a possibly different origin and thermal history from most mesosiderites and that the crystallography (i.e., space group) of low-Ca pyroxene could be used as parameter to distinguish mesosiderite populations based on their cooling history.

Keywords: Pyroxene, exsolution, mesosiderite, thermal history, cooling rate