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Metastable non-stoichiometric diopside and Mg-wollastonite: An occurrence in an interplanetary dust particle

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ABSTRACT

Interplanetary dust particles (IDPs) are the best samples available for the study of the dust that accreted in the early solar system to form protoplanets at 4.56 Ga. Chondritic aggregate IDPs have a matrix of (sub)-spherical units with variable amounts of micrometer-sized Fe,Ni-sulfides, Mg,Fe-olivines, and (Ca,Mg,Fe)-pyroxenes. The crystallographic and chemical properties of these materials can be modified by energetic thermal processes such as irradiation by energetic atoms (space weathering) and flash heating when an IDP decelerates in the Earth's upper atmosphere. Both thermal events have high heating and quench rates. Thermal alteration that occurs during atmospheric entry, or dynamic pyrometamorphic alteration, could obscure many details of earlier thermal modifications. Pure and TiO_2- or Al_2O_3-bearing, non-stoichiometric diopside and Mg-wollastonite in the IDP L2011K7 are the ultimate products of these thermal modifications, which were dominated by thermally induced loss of (Ca,Mg)O or mostly MgO in original Ca,Mg-clinopyroxene. The calculated oxygen deficiencies, O = 22 – 24 atoms per formula unit (afu) on the basis of Si = 8.00 afu, support a sequence of "anhydrous biopyriboles": diopside/Mg-wollastonite → anhydrous amphibole → (Si-rich) anhydrous smectite. This particular type of thermal modification, which is kinetically controlled, is unique to the constituents of IDPs. The extreme environmental conditions of high temperatures with high heating and cooling rates encountered by IDPs favor metastable equilibrium of the reaction products. That is, the kinetic, non-equilibrium processes, do not yield random reaction products but ones with predictable chemical compositions. The Ca,Mg-clinopyroxene compositions observed in this IDP were determined by the metastable eutectic in the enstatite-wollastonite system. The "anhydrous biopyribole" reaction sequence breaks down at calculated oxygen deficiency ($O < 20$ afu) in the vesicular, amorphous, amoeboid grains that could have been melted by atmospheric-entry flash heating.