

Discovery of meteoritic calzirtite in Leoville: A new ultrarefractory phase from the solar nebula

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During a nanomineralogy investigation of the Leoville CV3 carbonaceous chondrite, calzirtite ($\text{Ca}_2\text{Zr}_5\text{Ti}_2\text{O}_{16}$) was identified in an ultrarefractory inclusion within an amoeboid olivine aggregate, using field-emission scanning electron microscope (SEM), energy-dispersive X-ray spectroscopy (EDS) and electron back-scatter diffraction (EBSD) analyses. Reported here is the discovery of calzirtite in a primitive meteorite, as one of first formed solids in the solar system.

Calzirtite occurs as irregular grains (0.5 – 1.5 μm in size), in zirconolite, along with hexaferrum and perovskite (Fig. 1), occupying the core area in an ultrarefractory inclusion with a rim consisting of Zr,Sc-rich grossmanite, surrounded by olivine. The chemical composition of calzirtite by SEM-EDS is (wt%) ZrO_2 68.8, TiO_2 14.4, CaO 9.1, Y_2O_3 6.8, Sc_2O_3 1.0, giving rise to an empirical formula (based on 16 O atoms *pfu*) of $(\text{Ca}_{1.50}\text{Y}_{0.50})\text{Zr}_{5.00}(\text{Ti}^{4+}_{1.32}\text{Zr}_{0.17}\text{Ti}^{3+}_{0.34}\text{Sc}_{0.12}\text{Y}_{0.05})\text{O}_{16}$, with Ti^{4+} and Ti^{3+} partitioned on stoichiometry. EBSD analysis revealed that calzirtite has a tetragonal $I4_1/acd$ structure, identical to that of synthetic $\text{Ca}_2\text{Zr}_5\text{Ti}_2\text{O}_{16}$, showing $a = 15.21$ \AA , $c = 10.11$ \AA and $Z = 8$.

Calzirtite joins other Zr-rich minerals from carbonaceous chondrites, including allendeite, tazheranite, lakargiite, zirconolite, kangite, panguite, baghdadite, zirkelite, and baddeleyite. Calzirtite probably formed by condensation or crystallized from a refractory melt in the solar nebula.

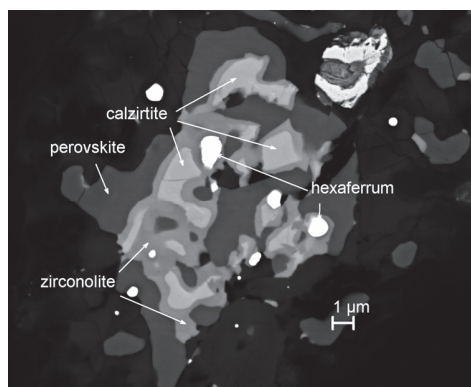


Figure 1: Back-scatter electron image showing calzirtite with zirconolite, hexaferrum and Y-rich perovskite in Leoville.