DISCOVERY OF METEORITIC ERINGAITE, 
Ca₃(Sc,Y,Ti)₂Si₃O₁₂, THE FIRST SOLAR GARNET?

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Introduction: During a nano-mineralogy investigation of the Vigarano CV3 meteorite, eringaite Ca₃(Sc,Y,Ti)₂Si₃O₁₂ was identified in a cluster of ultra-refractory inclusion fragments within a shattered amoeboid olivine aggregate in VCM3. Eringaite is a newly-discovered garnet-group mineral in metasomatic rodingite-like rocks from the Wiluy River, Sakha-Yakutia Republic, Russia [1]. Reported here is the second natural occurrence of eringaite, as a new ultra-refractory mineral in a primitive meteorite, among the earliest solids formed in the solar nebula. Field-emission SEM, electron back-scatter diffraction (EBSD) and electron microprobe were used to characterize its composition and structure and associated phases.

Occurrence, Chemistry, and Crystallography: Eringaite occurs as irregular or subhedral grains, 0.5–2 μm in size, along with tazheranite, hexaferrum and MgAl-spinel within davisite and Sc-bearing diopside in a cluster of ultra-refractory inclusion fragments. The mean chemical composition of the eringaite is (wt%) SiO₂ 28.93, CaO 25.26, Y₂O₃ 12.37, Sc₂O₃ 11.04, TiO₂ 5.33, Ti₃O₅ 4.43, MgO 4.36, Al₂O₃ 4.34, ZrO₂ 2.38, FeO 0.63 V₂O₅ 0.42, sum 99.49, showing an empirical formula (Ca₂.31Mg₀.56Y₀.09Fe₀.05)(Sc₀.82Y₀.48Ti³⁺₀.32Ti⁴⁺₀.25Zr₀.10V₀.03Cr₀.01)(Si₂.₄₇Al₀.₄₄Ti⁴⁺₀.₀₉)O₁₂, where Ti³⁺ is calculated based on stoichiometry. EBSD analysis reveals that the eringaite has a garnet Ia₃d structure, identical to that of synthetic Ca₃Sc₂Si₃O₁₂ [2], showing a = 12.25 Å, V = 1838.27 Å³, Z=8.

Associated tazheranite (71wt% ZrO) is a special cubic zirconia with a formula (Zr₀.₆₁Sc₀.₁₈Y₀.₀₈Ti₀.₀₇Ca₀.₀₂Mg₀.₀₂Al₀.₀₁)O₁.₈₀, maybe expressed as (Sc,Y,Ti,Ca,Mg)₂Zr₃O₉. Fine-grained euhedral hexaferrum shows Fe₀.₅₅Os₀.₁₅Ir₀.₁₃Mo₀.₀₈Ni₀.₀₄Ru₀.₀₂ or Fe₀.₅₅Mo₀.₂₆Ru₀.₀₈Os₀.₀₄Ir₀.₀₂Ni₀.₀₂W₀.₀₂. Davisite (10 wt% Sc₂O₃) and diopside (6 wt% Sc₂O₃) are surrounded by forsterite.

Origin and Significance: Eringaite is a new Sc-rich ultra-refractory silicate and likely the first garnet formed in the solar system. Eringaite is Ti³⁺-rich, indicating highly reducing environments. Texturally, eringaite, tazheranite, spinel and hexaferrum formed early in this Vigarano ultra-refractory inclusion before the appearance of davisite and Sc-rich diopside. Molar Sc/Zr of eringaite (~8.2), tazheranite (~0.3), davisite (~3.6) and diopside (~7.7), are consistent with conservation of Sc/Zr in a reaction among eringaite, tazheranite, spinel and/or vapor to produce davisite and Sc-rich diopside. Forsterite condensed around the refractory inclusion at a later stage in the nebula.

Thortveitite (Sc₂Si₂O₇) identified in the Murchison ultra-refractory inclusion MUR1, is probably the first solar silicate, as an early condensate [3]. This discovery implies that eringaite may be the second solar silicate, followed by davisite.