DISCOVERY OF METEORITIC ERINGAITE, $Ca_3(Sc,Y,Ti)_2Si_3O_{12}$, THE FIRST SOLAR GARNET?

Chi Ma. Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, USA. E-mail: chi@gps.caltech.edu

Introduction: During a nano-mineralogy investigation of the Vigarano CV3 meteorite, eringaite $Ca_3(Sc,Y,Ti)_2Si_3O_{12}$ 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%) SiO_2 28.93, CaO 25.26, Y_2O_3 12.37, Sc_2O_3 11.04, TiO_2 5.33, Ti_2O_3 4.43, MgO 4.36, Al_2O_3 4.34, ZrO_2 2.38, FeO 0.63 V_2O_3 0.42, sum 99.49, showing an empirical formula $(Ca_{2.31}Mg_{0.56}Y_{0.09}Fe_{0.05})(Sc_{0.82}Y_{0.48}Ti^{3+}_{0.32}Ti^{4+}_{0.25}Zr_{0.10}V_{0.03}Cr_{0.01})$ $(Si_{2.47}Al_{0.44}Ti^{4+}_{0.09})O_{12}$, where Ti^{3+} is calculated base on stoichiometry. EBSD analysis reveals that the eringaite has a garnet *Ia3d* structure, identical to that of synthetic $Ca_3Sc_2Si_3O_{12}$ [2], showing a = 12.25 Å, V = 1838.27 Å^3, Z=8.

Associated tazheranite (71wt% ZrO) is a special cubic zirconia with a formula $(Zr_{0.60}Sc_{0.18}Y_{0.08}Ti_{0.07}Ca_{0.02}Mg_{0.02}Al_{0.01})O_{1.80}$, maybe expressed as $(Sc,Y,Ti,Ca,Mg)_2Zr_3O_9$. Fine-grained euhedral hexaferrum shows $Fe_{0.55}Os_{0.15}Ir_{0.13}Mo_{0.08}W_{0.04}Ni_{0.03}Ru_{0.02}$, or $Fe_{0.62}Mo_{0.20}Ru_{0.08}Os_{0.04}Ir_{0.02}Ni_{0.02}W_{0.02}$. Davisite (10 wt% Sc_2O_3) and diopside (6 wt% Sc_2O_3) 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 Ti^{3+}-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 refectory inclusion at a later stage in the nebula.

Thortveitite ($Sc_2Si_2O_7$) 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.

References: [1] Galuskin I.O. et al. 2010. *Miner. Mag.* 74, 365-373. [2] Quartieri S. et al. 2006. *Am. Miner.* 91, 1240-1248. [3] Ma C. et al. 2011. *MAPS* 46, S1, A144.