DISCOVERY OF TETRAGONAL ALMANDINE, $(Fe,Mg,Ca,Na)_3(Al,Si,Mg)_2Si_3O_{12}$, A NEW HIGH-PRESSURE MINERAL IN SHERGOTTY

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Introduction: During a nanomineralogy investigation of the Shergotty meteorite, we have identified a new shock-induced high-pressure silicate, majoritic almandine with a tetragonal $I4_1/a$ structure, in an impact melt pocket. Field-emission scanning electron microscope, electron back-scatter diffraction, electron microprobe and synchrotron diffraction were used to characterize its chemical composition, structure, and associated phases. Tetragonal majorite ($Mg_3(SiMg)Si_3O_{12}$) with the $I4_1/a$ structure was synthesized [e.g., 1] and found later in the Tenham chondrite [2,3]. Tetragonal almandine-pyrope phase (TAPP) with the *I*-42*d* structure was reported to occur as inclusions in lower-mantle diamonds [4]. We present here the first occurrence of tetragonal almandine with the $I4_1/a$ structure in a shocked meteorite from Mars as a new high-pressure phase.

Occurrence, Chemistry, and Crystallography: Tetragonal almandine in Shergotty occurs as aggregates of subhedral crystals, 0.8 – 2.5 µm in diameter, along with stishovite in the central region of a shock melt pocket (Fig. 1). The shock melt pocket is ~ 450×1000 μm^2 in size, surrounded by pyroxene and maskelynite. The rock consists of mainly clinopyroxene and maskelynite, plus fayalite, silica phases, Ti-bearing magnetite, ilmenite, baddeleyite, chlorapatite, merrillite, and pyrrhotite.

The mean chemical composition of tetragonal almandine by electron microprobe analysis is (wt%) SiO_2 48.17, Al_2O_3 13.09, FeO 18.40, CaO 9.25, MgO 7.16, Na_2O 2.85, MnO 0.55, TiO_2 0.39, Cr_2O_3 0.08, K_2O 0.07, total 100.01, giving rise to an empirical formula of $(Fe_{1.16}Ca_{0.75}Mg_{0.61}Na_{0.42}Mn_{0.03}K_{0.01})(Al_{1.16}Si_{0.63}Mg_{0.19}Ti_{0.02})Si_3O_{12}$. The general formula is $(Fe,Mg,Ca,Na)_3(Al,Si,Mg)_2Si_3O_{12}$. The end-member formula is $Fe_3Al_2Si_3O_{12}$. Electron back-scatter diffraction indicated this phase has a garnet-related structure. Synchrotron X-ray diffraction revealed that this garnet has actually a tetragonal structure ($I4_1/a$) with unit cell dimensions: a = 11.585(9) Å, c = 11.63(4) Å, V = 1561(7) $Å^3$, and Z = 8.

Origin and Significance: Tetragonal almandine is the polymorph of cubic almandine, a new high-pressure garnet mineral, formed by shock metamorphism via the Shergotty impact event on Mars. It apparently crystallized from Fe-rich shock-induced melt under high-pressure.

References: [1] Angel R.J. et al. 1989. *American Mineralogist* 74:509–512. [2] Xie Z. & Sharp T.G. 2007. *Earth and Planetary Science Letters* 254:433–445. [3] Tomioka N. et al. 2016. *Science Advances* 2:e1501725. [4] Harris J. et al. 1997. *Nature* 387:486-488.

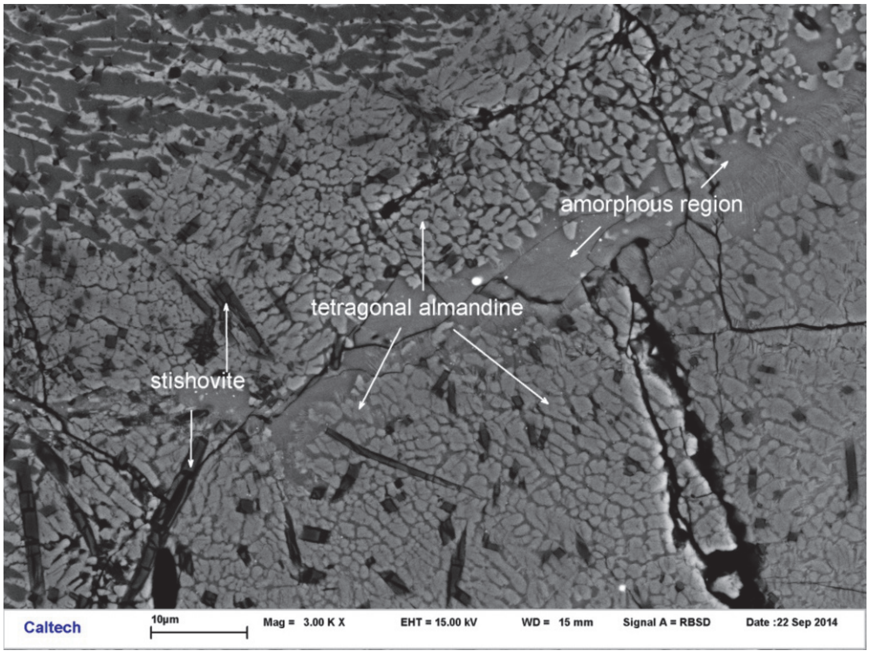

Fig. 1. Back-scatter electron image showing tetragonal almandine with stishovite in a Shergotty melt pocket.