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 I41/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 (Mg3(SiMg)Si3O12) with the I41/a structure was synthesized [e.g., 1] and found later in the Tenham chondrite [2,3]. Tetragonal almandine-pyrope phase (TAPP) with the I-42d structure was reported to occur as inclusions in lower-mantle diamonds [4]. We present here the first occurrence of tetragonal almandine with the I41/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 μm² 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%) SiO₂ 48.17, Al₂O₃ 13.09, FeO 18.40, CaO 9.25, MgO 7.16, Na₂O 2.85, MnO 0.55, TiO₂ 0.39, Cr₂O₃ 0.08, K₂O 0.07, total 100.01, giving rise to an empirical formula of (Fe₁.16Ca₀.75Mg₀.61Na₀.42Mn₀.03K₀.01)(Al₁.16Si₀.63Mg₀.19Ti₀.02)Si₃O₁₂. The general formula is (Fe,Mg,Ca,Na)₃(Al,Si,Mg)₂Si₃O₁₂. The end-member formula is Fe₃Al₃Si₃O₁₂. Electron backscatter diffraction indicated this phase has a garnet-related structure. Synchrotron X-ray diffraction revealed that this garnet has actually a tetragonal structure (I41/a) with unit cell dimensions: a = 11.585(9) Å, c = 11.63(4) Å, V = 1561(7) Å³, 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.


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