

**DISCOVERY OF A NEW HIGH-PRESSURE SILICATE,  $(\text{Mg,Fe,Ca})_4\text{Si}_3\text{O}_{10}$  WITH A SPINELLOID STRUCTURE, IN A SHOCK MELT POCKET FROM THE TISSINT MARTIAN METEORITE**

Chi Ma

Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, USA  
(chima@caltech.edu)

**Introduction:** The Tissint Martian meteorite is a highly-shocked, olivine-phyric shergottite. Olivine is often transformed to ringwoodite or ahrensite and, in melt veins or pockets, even to bridgmanite plus wüstite [1]. Plagioclase is transformed to maskelynite or even melted and partially crystallized to tissintite [2] or stöfflerite [3]. Chromite is transformed to xieite or chenmingite [4]. These responses to shock conditions on Mars provide clues to the nature of ejection events for Martian meteorites. New-to-science high-pressure phases discovered in meteorites can also inform the study of deep Earth systems.

Our ongoing nanomineralogy investigation of the Tissint shergottite has revealed the new high-pressure minerals ahrensite [1], tissintite [2] and chenmingite [4]. Reported here is the discovery of a new high-pressure silicate phase – “ringwoodite-Q-II”,  $(\text{Mg,Fe,Ca})_4\text{Si}_3\text{O}_{10}$  with a tetragonal spinelloid structure. Its structural formula is  $(\text{Mg,Fe,Ca,Si},\square)_2\text{SiO}_4$ . Scanning electron microscope (SEM), electron back-scatter diffraction (EBSD), and electron probe microanalysis (EPMA) were used to characterize its composition, crystal structure and petrography.

**Occurrence, Chemistry, and Crystallography:** In Tissint, this new silicate phase occurs as irregular to subhedral crystals,  $\sim 1 - 3 \mu\text{m}$  in size, at the rim of a shock melt pocket. The melt pocket is about  $100 \times 220 \mu\text{m}^2$  in the plane of the thin section. The high-pressure phases ahrensite, bridgmanite and wüstite are also found in or adjacent to this melt pocket, which is surrounded by olivine and pyroxene. Overall, the host rock consists mainly of pyroxene (mostly zoned pigeonite), ‘maskelynite’ (An58-69), and olivine (typically  $\sim \text{Fo}_{70}$  but ranging from  $\text{Fo}_{40}$  to  $\text{Fo}_{80}$ ), with minor ilmenite and chromite and trace pyrrhotite, magnetite, and merrillite. Melt pockets and veins are scattered throughout the meteorite [e.g., 1,2].

Chemical composition of this new silicate by EPMA (WDS) is (wt%)  $\text{SiO}_2$  43.68,  $\text{FeO}$  28.07,  $\text{MgO}$  17.44,  $\text{CaO}$  6.40,  $\text{Al}_2\text{O}_3$  3.03,  $\text{MnO}$  0.62,  $\text{Na}_2\text{O}$  0.50,  $\text{TiO}_2$  0.28,  $\text{Cr}_2\text{O}_3$  0.25, sum 100.26, giving rise to an empirical formula based on 10 oxygen *apfu* of  $(\text{Mg}_{1.72}\text{Fe}_{1.56}\text{Ca}_{0.45}\text{Na}_{0.06}\text{Mn}_{0.03}\text{Cr}_{0.01}\text{Ti}_{0.01})(\text{Si}_{2.90}\text{Al}_{0.24}\text{Ti}_{0.01})\text{O}_{10}$  with a general formula of  $(\text{Mg,Fe,Ca})_4\text{Si}_3\text{O}_{10}$  [i.e., one molecule of  $(\text{Mg,Fe})_2\text{SiO}_4$  plus one molecule of  $(\text{Mg,Fe,Ca})_2\text{Si}_2\text{O}_6$ ]. EBSD reveals that this silicate has a tetragonal  $I4_1/amd$  spinelloid structure, indexed using  $a = 5.92 \text{ \AA}$  and  $c = 8.34 \text{ \AA}$  from [5] (yielding mean angular deviations  $< 0.6^\circ$ ). Therefore, the empirical structural formula of this new silicate spinel based on 4 O is  $(\text{Mg}_{0.69}\text{Fe}_{0.62}\text{Ca}_{0.18}\text{Si}_{0.16}\text{Al}_{0.09}\text{Na}_{0.03}\text{Mn}_{0.01}\text{Cr}_{0.01}\text{Ti}_{0.01}\square_{0.20})\text{Si}_{1.00}\text{O}_4$ , with a general formula of  $(\text{Mg,Fe,Ca,Si},\square)_2\text{SiO}_4$ .

**Origin and Significance:** This new silicate phase in Tissint is a shock-induced, high P – high T, vacancy-stabilized silicate spinel  $(\text{Mg,Fe,Ca,Si},\square)_2\text{SiO}_4$  (ringwoodite-Q-II) with a tetragonal metric, structurally similar to the vacancy-stabilized silicate spinel  $(\text{Mg,Fe,Si})_2(\text{Si},\square)\text{O}_4$  (ringwoodite-Q, derived from  $(\text{Mg,Fe})_3\text{Si}_2\text{O}_7$ ) in Tenham and Suizhou ordinary chondrites [5]. It is also structurally related to vacancy-stabilized tetragonal silicate spinel  $(\text{Fe,Mg,Cr,Ti,Ca},\square)_2(\text{Si,Al})\text{O}_4$  (ahrensite-Q) in Tissint [6]. This new silicate phase is a new-to-science material. Its composition, in the form of  $(\text{Mg,Fe,Ca})_4\text{Si}_3\text{O}_{10}$ , can be derived from a mixture of 50% olivine  $(\text{Mg,Fe})_2\text{SiO}_4$  and 50% pyroxene  $(\text{Mg,Fe,Ca})_2\text{Si}_2\text{O}_6$ .

In the melt pocket that contains this new silicate, like other melt pockets in Tissint, ahrensite formed through solid state transformation of olivine. Bridgmanite and wüstite, which are also found in the melt pocket, formed from the decomposition of olivine. Textures in the region suggest that this silicate grew through crystallization from the shock-induced melt of olivine and pyroxene. Formation of those phases occurred at high P and T during the Tissint impact event on Mars. For example, the formation of bridgmanite implies a peak P of at least 23-25 GPa with T on the order of 2200-2400 K [7]. This silicate may have crystallized during cooling so that peak P-T conditions are maxima for its formation.

Since both olivine and pyroxene and their high-pressure analogs are abundant in the Earth’s mantle, it is possible that silicates  $(\text{Mg,Fe,Ca})_4\text{Si}_3\text{O}_{10}$  and  $(\text{Mg,Fe})_3\text{Si}_2\text{O}_7$  are modally significant minerals within the Earth. The stability of  $(\text{Mg,Fe,Ca})_4\text{Si}_3\text{O}_{10}$  and  $(\text{Mg,Fe})_3\text{Si}_2\text{O}_7$  for typical bulk compositions in the Earth’s mantle is unknown but their possible occurrence should be taken into account in the study of deep Earth systems.

**References:** [1] Ma C. et al. (2016) *Geochimica et Cosmochimica Acta* 184:240–256. [2] Ma C. et al. (2015). *Earth and Planetary Science Letters* 422:194–205. [3] Ma C. et al. (2022) *LPSC* 53<sup>rd</sup>, Abs. #2332. [4] Ma C. et al. (2019) *American Mineralogist* 104:1521–1525. [5] Ma C. et al. (2019) *Meteoritics & Planetary Science* 54:1907–1918. [6] Ma C. et al. (2019) *LPSC* 50<sup>th</sup>, Abs. #1460. [7] Tschauner O. et al. (2014) *Science* 346:1100–1102.