SHOCK MELT FEATURES IN LOS ANGELES AND TISSINT: A COMPARISON C. R. Kuchka[1], E. L. Walton[2], and C. D. K. Herd[1]. [1]Dept. of Earth & Atmospheric Sciences, University of Alberta, Edmonton, Canada, [2]Dept. of Physical Sciences, MacEwan University, Edmonton, Canada.

Introduction: In this study, we investigate two petrologically distinct Martian meteorites – highly differentiated Los Angeles and the more primitive olivine-phyric Tissint – with an emphasis on shock metamorphism. Los Angeles is thought to be derived from a highly evolved lava flow or shallow volcanic intrusion [1], while current studies suggest that Tissint is derived from a depleted mantle source into which olivine macrocrysts have accumulated [2]. Both meteorites contain abundant shock melt heterogeneously distributed throughout the host rock, formed by hypervelocity impact on Mars. Polished thin sections of Los Angeles stone 1 and Tissint were analyzed with a Zeiss Evo MA LaB_6 filament SEM equipped with an electron dispersive spectrometer. Raman spectra were acquired on the Los Angeles thin section only with a Bruker Senterra Spectrometer, using the 50 x objective of a microscope to focus the excitation laser (532 nm line of Ar+ laser) to a 3−4 μm spot size.

Results:

Igneous textures: Los Angeles is an aphyric microgabbro composed mainly of zoned pyroxene and plagioclase (now maskelynite) (Fig. 1). Minor minerals include titanomagnetite, ilmenite, pyrrhotite, merrillite, apatite, silica and pyroxferroite breakdown material, observed as fine-grained symplectic intergrowths of fayalite + hedenbergite + silica. Larger grains of silica (up to 1 mm) are found throughout the host rock, associated with plagioclase.

Tissint is composed of mm-size zoned olivine macrocrysts (up to 2.5 mm) and smaller more ferroan olivine (~0.5 mm) set in a groundmass of finer grained pyroxene and plagioclase (now maskelynite). Olivine is euhedral and contains abundant micro-inclusions of Fe-Ti-Cr oxides. The groundmass texture is trachytic. Minor minerals include chromite, pyrrhotite, ilmenite, and merrillite. Tissint is distinct from Los Angeles by the presence of coarse-grained olivine and the lack of abundant free silica, the latter of which is restricted to magmatic inclusions in the larger macrocrysts.

Shock metamorphism: Both Los Angeles and Tissint exhibit strong mosaic extinction and fracturing of pyroxene, complete conversion of plagioclase to maskelynite and the presence of shock melts. However, the microtexture and composition of shock melts are distinct between the two meteorites.

Shock melt pockets in Los Angeles can be divided into three broad types: (1) macroscopic (>1 mm) highly vesiculated with flow-textured glass, (2) microscopic (<1 mm) clast-poor, and (3) microscopic (<1 mm) clast-rich [3].

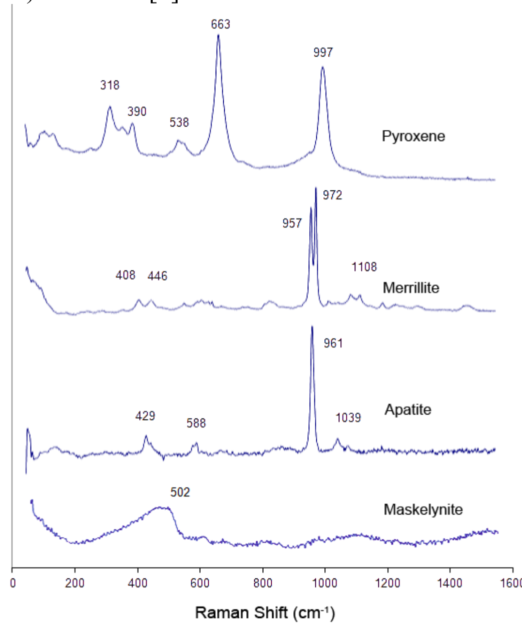

Figure 1: *Representative raman spectra for Los Angeles host rock.*

Raman spectroscopy was used to examine the structural state of silica in Los Angeles. Coesite, silica glass and stishovite have been identified within and adjacent to shock melts (Fig. 2). Coesite is identified by its characteristic Raman band at 520 cm^{-1} [5]. Silica glass is identified by the spectral shape and the presence of a "lip" on the hump at 450 cm^{-1} which suggests quenching at <12 GPa [6]. Stishovite is identified by the intense peak at 750 cm^{-1} [7]; however, the small size of these crystals compared to that of the laser meant that only mixed spectral signatures of stishovite + pyroxene could be obtained (Fig. 2). The mm-size macroscopic shock melt pockets are zoned with respect to silica polymorphs. Host rock pyroxene in direct contact with the now-quenched shock melt contains tiny (1 μm) bipyramidal stishovite crystals. Within the melt matrix, close to the margin, clasts of coesite and silica glass are observed. The interior of the pocket is characterized by abundant vesicles and pyroxene glass. Skeletal titanomagnetite and acicular phosphates have also been documented. Phosphates are identified according to intense peaks centered near ~960 cm^{-1} in Raman spectra [9]. In contrast the smaller microscopic shock melt pockets have quenched stishovite and pyroxene throughout the melt (i.e., they are not zoned in terms of their mineral assemblages).

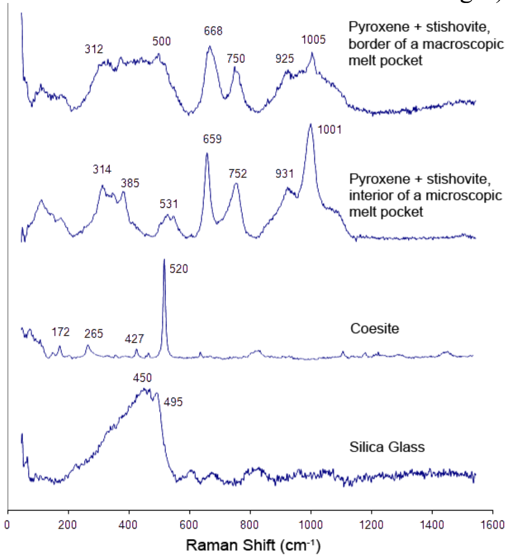

Figure 2: Representative *Raman spectra for minerals found in Los Angeles shock melt pockets.*

The post-stishovite polymorph, seifertite, has been observed in Los Angeles. Due to the beam sensitivity of this mineral its presence could not be confirmed by Raman, but was identified in BSE images by its distinct cross-hatched texture of orthogonal lamellar intergrowths of bright (seifertite) and dark (dense SiO_2 glass) [8]. Seifertite is restricted to those grains in the host rock associated with plagioclase, and has not been observed within or adjacent to shock melts.

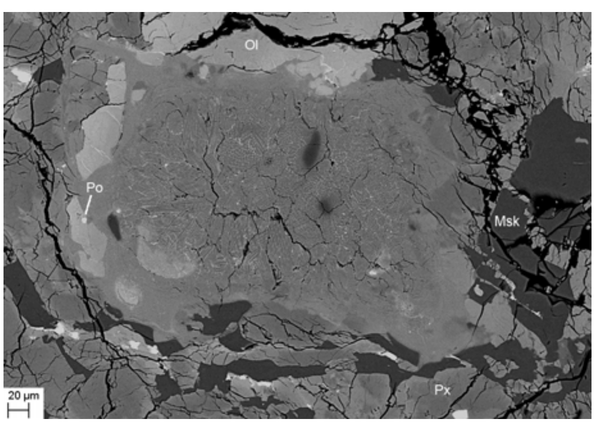

Figure 3: *Clast-poor shock melt pocket in Tissint. White grains and stringers are chromite.*

Shock melt pockets in the Tissint thin section are generally clast-poor, characterized by chromite stringers interconnected between a network of tiny silicate crystallites (≤3 µm). These shock melts are largely devoid of pyrrhotite spheres, most likely reflecting the paucity of igneous pyrrhotite in this section. The margins of shock melt pockets are difficult to distinguish, as they have gradational contacts with groundmass pyroxene. Shock veins cut across and penetrate grains, extending several cm. These veins occasionally contain entrained clasts of host rock minerals. The shock vein matrix shows flow textures and have coarser interiors, fining towards their margins.

Discussion: Shock melts form *in situ* from void collapse or shock impedance contrasts, cooling by conduction of heat to the colder host rock [10]. In Los Angeles, the size of the shock melt pockets dictates the distribution of silica polymorphs. In those melt pockets large enough to have extant melt remain liquid long enough to show flow-textured glass and vesicles, silica polymorphs crystallizing from the melt can be used to map pressure and temperature conditions. The thermal dependence of crystallizing stishovite with a bipyramidal habit, observed along within host rock pyroxene adjacent to these melts, indicates formation conditions ~12 GPa and <600 °C [11]. Inside the melt pocket, coesite and silica glass formed at lower pressure (<12 GPa). Hence, shortly following shock melt generation by shock, crystallization of high-pressure phases began at the borders of larger pockets as heat was lost to the surrounding host rock. The high-pressure phase seifertite is not observed within or adjacent to shock melts, consistent with their crystallization after the peak pressure. For microscopic pockets, crystallization was much faster, with stishovite crystallizing to the center of those pockets. These smaller shock melts likely represent true high pressure melts.

The bulk chemistry of Tissint and Los Angeles are distinct, leading to different behaviors of melt features between the two meteorites. Melt features in Tissint commonly incorporate and grade into groundmass pyroxene, and are typically clast-poor. Majorite-pyrope garnet and a high-pressure variant of pyrite have been documented in shock melt veins in Tissint [12, 13]. These minerals will be useful for constraining peak shock conditions in future studies.

References: [1] Rubin et al. (2000) Geol. 28, 1011-1014. [2] Irving et al. (2012) LPSC. XLIII #2510. [3] Walton & Spray (2003) MAPS 38, 1865-1875. [4] Chennaoui Aoudjehane et al. (2005) MAPS 40, 967–979. [5] Boyer et al. (1985) Phys Chem Miner. 12, 45-48. [6] Polsky et al. (1999) J. Non-Cryst. Solids, 248, 159-168. [7] Hemley et al. (1986) Phys Chem Miner. 13, 285-290. [8] El Goresy et al. (2008) Eur. J. Miner. 20, 523-528. [9] Jolliff et al. (1996) LPSC XXVII 27, 613-614. [10] Walton & Herd (2007) GCA 71, 5267-5285. [11] Sclar et al. (1964) Sci. 144, 833-835. [12] Lin et al. (2012), LPS. XLIII #5131. [13] Moyano-Cambero et al. (2012) MAPS #5058.