**SHOCK MELTING OF MARTIAN BASALTS AND THE ENTRAPMENT OF ATMOPSHERIC GASES.** P. Beck[1], T. Ferroir[2], P. Gillet[2], G. Montagnac[2], M. Bohn[3] and M. Lesourd[4] [1]Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Ranch road NW, DC20015. [2]Laboratoire des Sciences de la Terre, CNRS UMR 5570, Ecole Normale Supérieure de Lyon, 46 allée d'Italie, 69364 Lyon Cedex 7, France. E-mail : ferroir@ens-lyon.fr, [3]Ifremer-Centre de Brest, (CNRS-UMR 6538), BP70, 29280 Plouzané Cedex, France. E-mail : Marcel.Bohn@ifremer.fr. [4] CNRS et SCIAM, Laboratoire d'Histologie, UFR de Médecine, Université d'Angers, 1 rue Haute de Reculée, 49045 Angers Cedex, France.

**Introduction:** Martian meteorites conserve the fingerprints of an intense shock event that probably occurred during their ejection from the parent surface. In addition to shock-induced mineral transformations and deformations, localized fusion of the stone is a characteristic feature of the shergottite subgroup (more than half of the Martian meteorites). Shock-melting is observed either as planar (shock veins) or as spherical areas (melt pockets), where rounded sulphurs and silicate glass testify of a past liquid stage. The mechanisms that produced the heterogeneous temperature distribution within shocked meteorites are still unclear. In the case of shock veins, frictional heating was proposed to have brought the necessary heat to initiate the melting process [1]. The generation of local hot-spots, the melt pockets, remains poorly understood. Interestingly, the most direct argument for a Martian origin of these meteorites relates to melt pockets, which were found to contain large volumes of Martian atmosphere [2].

We present here a systematic study of natural hollandite-type feldspar encountered in melt pockets from four shergottites. We show that this high-pressure phase is a widespread mineral and may result of whether solid-state transformations of pre-existing feldspar or by crystallisation from the melt. The occurrence of hollandite sets constrains on the shock pressure experienced and then the shock energy, which can be used to discuss a model for melt pockets formation from local energetic balance.

**Hollandite mode of occurrence:** Melt pockets from four shergottites were investigated by Raman microspectroscopy. Three basaltic shergottites were studied, Northwest Africa 480 (NWA 480), Northwest Africa 856 (NWA 856), Zagami, and one picritic shergottite Northwest Africa 1068 (NWA 1068). From our study, hollandite-type feldspar is a major component of SMV and MP mineralogy in shergottites. It appears dark grey in reflected light and three petrologic types can be distinguished. First type corresponds to SMV or MP rims, where maskelynite crystallized and adopted a hollandite structure. In some zone the former hollandite can be followed toward the interior of the melt pocket, where it breaks down into the CAS+Sti assemblage [3]. The second type corresponds to dark grey isolated rounded grains within MPs pr SMVs such as the ones presented in figure 2C. Type 2 size can be up to 50-60 µm. Microprobe analyses revealed that both type 1 and type 2 fall within the Albite-Anorthite joint. Their major element composition was found to be identical to that of maskelynite, which argues in favour of a solid-state transformation origin. The third type is always associated to stishovite crystals and was only observed in Zagami and NWA 480. This type was previously described by Langenhorst and Poirier [4]. This association is clearly observed in Zagami, with distinct K-hollandite and stishovite grain. The size of the observed crystals is 10 µm for each phase. In NWA 480, a 25 µm wide dark zone was observed in which Raman spectroscopy revealed the superimposition of stishovite and hollandite spectras, though the two phases were not distinguished at the higher magnification of the SEM. Chemical analyses showed that the zone has a composition consistent with a mixture of K-feldspar and $SiO_2$. The lack of K-feldspar in the untransformed parts of NWA 480 and Zagami argues in favour of whether a solidus or a liquidus origin for K-hollandite, since it cannot have formed through solid-state transformation.

**Peak shock pressure:** Static experiments have shown that Na-Feldspar transforms into hollandite for $21 < P < 23$ GPa [5]. Since Ca-Na hollandite grains observed in the four meteorites formed by shock-induced solid-state transformation from the initial feldspar, the pressure had to be in the 21-23 GPa range. The observation of the (K-Na)-hollandite+stishovite assemblage puts additional constrains on P/T shock conditions underwent by the two meteorites in which it was found, i.e. NWA 480 and Zagami. In [6] experiments this association is observed for P>22.5 Gpa and T>2250 K. This is consistent with the previous 23 GPa estimation of peak shock pressure for Zagami shock veins [1].

The pressure recorded by the high-pressure mineralogy of the melt pockets is of the order 22 GPa for the studied meteorites. Because pressure heterogeneities should relax in a very short time (less than one ms) it is likely that the mineral assemblages encountered in shock veins and melt pockets record the continuum shock pressure.

**Melt pockets formation:** The past presence of porosity in shergottites cannot be evaluated; our sampling of Mars by meteorites is biased since these surface rocks had to be shock accelerated above 5 km.s$^{-1}$. It is well known that porosity can attenuate a shock wave by heating the material well above the non-porous Hugoniot. If the porosity is high, the temperature increase can be high enough to initiate melting. If melt pockets correspond to ancient porous areas, we can try to assess the local porosity which is necessary to have induced local melting. The simplest model for energy partitioning is found in [7]. This model hypothesize that the initial shock energy converts into temperature increase and melting enthalpy. We can calculate the pressure necessary to have produced local melting, as a function of the initial local porosity (Fig. 1). Results show that for the continuum pressure we estimated before, ~22 GPa, the value of the local porosity is as high as 0.43 (Fig. 1). A more sophisticated model, which takes into account the plastic energy dissipated by void collapse [8] leads to a slightly higher value (0.46) (Fig.1).

**Rare gases composition of melt pockets:** The presence of trapped Martian atmosphere gases was initially discovered in melt pockets from the EETA 79001 shergottite [2]. A trapped atmospheric component was further identified in impact glasses of the Zagami shergottite [9] and in the ancient cumulate ALH 84001 [10]. This component appears to be controlled by shock effects. In the case of shergottites, it has been shown than the atmospheric signature is carried by melt pockets [2, 9, 11].

Here, we propose that melt pockets corresponds to ancient porous areas that were compacted during the shock event that ejected shergottites. Because shergottites are superficial rocks the pores could have been connected with the Martian atmosphere. According to [2], 0.2 cm$^3$ of Martian atmosphere is trapped per gram of glass. Supposing that this volume corresponds to the pore volume present prior to the impact melting, a pre-existing local porosity of ~0.4 is obtained (Fig. 1). From our model, a 0.4 local porosity requires a shock pressure of 25 GPa for melting which is in good agreement with the peak shock pressure recorded by the melt pockets studied here (~22 GPa).

**Conclusion:** From our study, hollandite type feldspar appears as a widespread mineral in melt pockets from Martian meteorites, setting constrains on the peak pressure condition. More, we propose here that melt pockets could correspond to ancient porous areas that were compacted during the extraction from the parent planet. In order to generate local melting high local porosity were calculated (0.40) which explains the high amount of atmospheric gases trapped in melt pockets.

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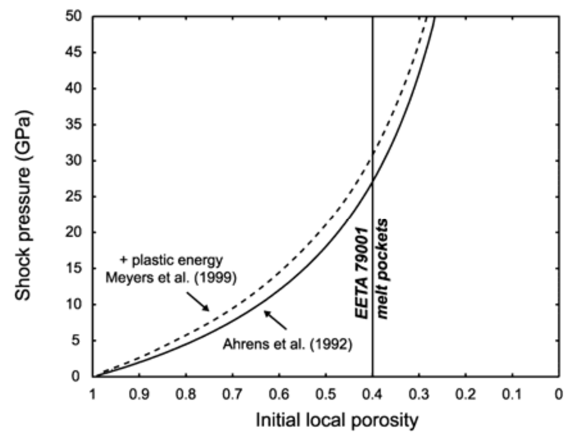


Figure 1: Shock pressure calculated for local melting as a function of the local porosity, using [7] and [8] models. The vertical line corresponds to the volume of atmospheric gases trapped in melt pockets of EETA 79001 converted in pre-existing local porosity [2].