

MELT INCLUSIONS IN CHASSIGNITES: A CONNECTION BETWEEN MARTIAN METEORITES AND IN SITU EVOLVED ROCKS AT GALE CRATER. P. Wu¹, E. Gazel¹, and A. Udry² ¹Department of Earth and Space Sciences, Cornell University (pw443@cornell.edu, egazel@cornell.edu); ²Department of Geoscience, UNLV (arya.udry@unlv.edu).

Introduction: Understanding the compositional diversity of igneous rocks is the key to investigate conditions of melting and sources within the martian interior. Meteorites, our only martian samples, can be analyzed with the most advanced laboratory analytical techniques and thus has dominated our knowledge of martian igneous chemistry. Most martian meteorites are classified into three major categories, shergottite, nakhlite, and chassignite (SNC). As a type of olivine cumulates with abundant melt inclusions, chassignites can provide key information on the compositions of parental magmas, volatile budgets, and early crystallization processes. Chassigny, Northwest Africa (NWA) 2737 and Northwest Africa (NWA) 8694 are the only members of the chassignites that have been recovered.

The proposed parental magma composition calculated from Chassigny and NWA 2737 melt inclusions are similar [1-3]. The parental magma calculated based on chassignites has been suggested to have a connection with the surface Gusev crater basalts [2,4]. This possible linkage between chassignites and Gusev crater on Mars provides a connection between meteorites and *in situ* compositions collected on the martian surface.

The Mars Science Laboratory (MSL) Curiosity rover discovered diverse evolved rock compositions at Gale Crater [5]. This led to the hypothesis that some of the Gale felsic rocks may be analogous to the felsic building blocks of continental crust on Earth [5]. However, thermodynamic modeling shows that the felsic compositions discovered at Gale Crater could be formed by fractional crystallization of a Gusev basalt starting composition [6]. The Gusev basalts show a connection with both the chassignites and the Gale evolved rocks [2,4,6], which suggests a possible link between the chassignites and the evolved rocks.

Here we attempt to model the target felsic compositions through fractional crystallization of the parental magma composition proposed based on NWA 2737 bulk melt inclusions compositions. We used MELTS, a thermodynamic modeling software [7], to model fractional crystallization paths. A wide range of parameter variables were applied. Our models suggest that the Gale felsic compositions, Sparkle and Angmaat, which are interpreted as “early continental crust” can be obtained from NWA 2737 parental melt compositions through fractional crystallization.

Methods: We used six parental magma compositions calculated from NWA 2737 melt inclusions by He et al. [3] as starting compositions for the modeling. He et al. [3] analyzed nine melt inclusions in a single thin section of NWA 2737. Measured phase compositions and phase abundances are used to calculate the bulk composition of inclusions [3].

Among the nine melt inclusions, olivine, low-Ca pyroxene, kaersutitic amphibole, augite, apatite, chromite, sulfide, alkali-rich glass, and some Ti-biotite were identified [3]. Since MI-4 and MI-5 are likely off-center cuts and MI-6 includes some biotite and may represent composite grains, we excluded MI-4, MI-5, and MI-6 from our study. We recalculated the bulk compositions of MI-7 and MI-9 by removing chromites, which are located, at the edge of the inclusions, which are likely primary minerals co-trapped in the inclusion [8].

We first used *Petrolog3* [9] to reconstruct the six melt inclusion bulk compositions. We used the same FeO content of the parental magma (19 wt%) as He et al. [3], which is the average FeO content of the parental melt of Chassigny and the Gusev basalts Humphrey [2, 10] and a $K_D^{Fe/Mg_{Ol/melt}}$ of 0.35 [11]. The new reconstructed melt inclusion compositions agree well with the NWA 2737 parental magma composition proposed by He et al. [3].

We used alphaMELTS to perform fractional crystallization models from the six reconstructed melt inclusion bulk compositions. The MELTS algorithms facilitates thermodynamic modeling of equilibrium phase relations for magmatic systems by calculating the abundances of components among all known phases. The goal is to find the phase assemblage with the lowest thermodynamic potential at each temperature [7, 12]. We used alphaMELTS as a front end, and run the MELTS algorithm [12] with the Rhyolite-MELTS 1.2.0 calibration [13]. Rhyolite-MELTS is calibrated on various bulk compositions and is appropriate for modeling fluid-bearing silicic magmas. Rhyolite-MELTS is suitable for quartz and feldspar saturations and works better at pressures below 1 GPa [13]. The algorithm first calculated the liquidus temperature. With a cooling interval of 10 °C, Models stop at 600 °C. We assessed pressures from 5 to 9 kbar in our isobaric models. We evaluated the effect of water by normalizing the bulk compositions to various water contents ranging from dry to 2 wt%. We applied oxy-

gen fugacity values near the Fayalite-Magnetite-Quartz buffer.

Results: Liquid lines of descent starting from 2 selected melt inclusions are plotted under the same pressure and f_{O_2} (5 kbar, FMQ) with various water content in Fig. 1. Overall, crystallization paths are similar and most of them evolved toward the andesite and dacite fields. MI-9 started with a higher value of Na_2O and is the only starting composition evolving toward the trachy-dacite field and reached the Na_2O value of the Gale felsic rocks. None of the starting compositions reached the high Al_2O_3 , K_2O , and low CaO values of the Gale felsic rocks. The lower Al_2O_3 and higher CaO values in our models suggest that feldspar such as plagioclase were possibly accumulated in the Gale felsic rocks during crystallization [7]. Among all the parameters examined, f_{O_2} shows the greatest effect for the total alkali paths (Fig.2). For silicic liquid with 65% of SiO_2 , plagioclase, spinel, and clinopyroxene are the dominant phases (Fig. 3).

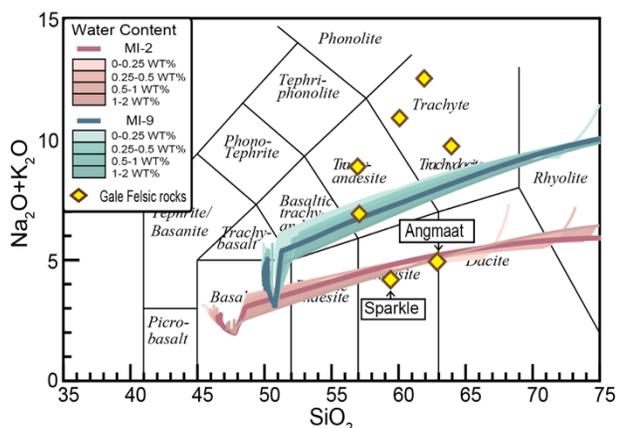


Fig. 1 Modeled liquid lines of descent for total alkali versus silica. Water content from dry to 2 wt.% were applied. The two felsic rocks proposed as “early continental crust”, Sparkle and Angmaat, are labeled. Data sources: Gale crater felsic rocks [5].

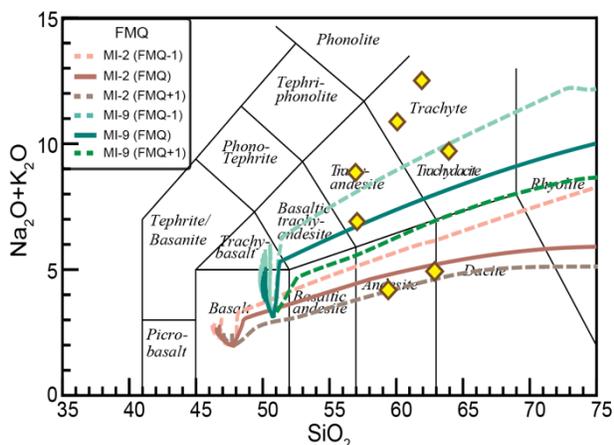


Fig. 2 Modeled liquid lines of descent for total alkali versus silica. Effect of f_{O_2} is shown.

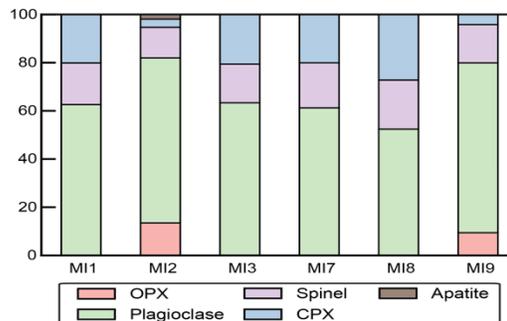


Fig. 3 Modeled phase abundances for liquid lines of descent at 65% SiO_2 . Models are calculated at 5kbar, FMQ, and 1wt.% water.

Discussion: We suggest a system containing two types of magma ascending mechanisms. A mantle-derived magma can either be trapped at the base of the crust or ascend directly to the surface with low-degree fractionation on its way up. The trapped melt cools down and starts to crystallize, forming the cumulus assemblage of chassignites. Trapped melt inclusions preserve the parental magma compositions. The residual liquid would contain high silica and alkali due to the fractionation of cumulus grains. When residual liquid leaves the system and ascends to the surface, the base of the crust will be enriched in cumulus minerals low in SiO_2 and high in MgO , and the felsic compositions will reach the surface (Gale felsic-like composition). Nevertheless, it is also possible that the parental liquid ascended to the surface without significant fractionation. In this scenario, the basaltic composition can also rise to the surface. The fact that evolved compositions are obtained after higher degrees of fractional crystallization implies that the volume of the felsic compositions is relatively small compared to the volume of the basaltic composition.

References: [1] Johnson, M. C., Rutherford, M. J. & Hess, P. C. (1991) *Geochim. Cosmochim. Acta*, 55, 349–366. [2] Filiberto, J., Treiman, A. H. & Le, L. (2008) *Meteorit. Planet. Sci.*, 43, 1137–1146. [3] He, Q. et al. (2013) *Meteorit. Planet. Sci.*, 48, 474–492. [4] Nekvasil, H., Filiberto, J., McCubbin, F. M. & Lindsley, D. H. (2007) *Meteorit. Planet. Sci.*, 42, 979–992. [5] Sautter, V. et al. (2015) *Nat. Geosci.*, 8, 605–609. [6] Udry, A., Gazel, E. & McSween, H. Y. (2018) *JGR*, 123, 1525–1540. [7] Ghiorso, M. S. & Sack, R. O. (1995) *Contrib. to Mineral. Petrol.*, 119, 197–212. [8] Roedder, E. (1979) *Bull. Mineralogie*, 102, 487–510. [9] Danyushevsky, L. V. & Plechov, P. (2011) *Geochemistry, Geophys. Geosystems*, 12, Q0702. [10] Gellert, R. et al. (2006) *JGR*, 111, E02S05. [11] Filiberto, J. & Dasgupta, R. (2011) *EPSL*, 304, 527–537. [12] Asimow, P. D. (1998) *Am. Mineral.*, 83, 1127–1132. [13] Gualda, G. A. R., Ghiorso, M. S., Lemons, R. V. & Carley, T. L. (2012) *J. Petrol.*, 53, 875–890.