

YAMATO 980459: THE MOST PRIMITIVE SHERGOTTITE? G. McKay¹, L. Le², C. Schwandt², T. Mikouchi³, E. Koizumi³, and J. Jones¹, ¹Mail Code SR, NASA Johnson Space Center, Houston, TX 77058, USA, Gordon.McKay@jsc.nasa.gov, ²Lockheed Martin, 2400 Nasa Road 1, Houston, TX 77058, USA, ³Dept. of Earth and Planetary Science, University of Tokyo, 7-3-1 Hongo, Tokyo 113-0033, Japan.

Introduction: The Antarctic Research Center of the Japanese National Institute of Polar Research (NIPR) recently announced the discovery of a new Martian shergottite, Y98(0459) [1]. This sample is a member of the subgroup of basaltic shergottites that contain abundant olivine phenocrysts, and are thus olivine-phyric.

Y98 may have special significance among the basaltic shergottites because (1) it appears to have been the most magnesian Martian magma yet found [e.g., 2,3], and thus can provide valuable clues to magma petrogenesis on Mars; (2) it contains no late-crystallizing phases, but instead contains ~30% interstitial glass [2,4,5], which can provide unambiguous incompatible element patterns of the parent melt; and (3) it carries an LREE-depleted signature similar to QUE 94201 [6], whose isotopic characteristics are the most primitive of all basaltic shergottites [e.g., 7].

A correlation has been noted between trace element/isotopic signatures and the oxidation state of the shergottite meteorites [8,9], with more depleted samples being more reduced and less depleted samples being more oxidized. Variation in oxidation state among the Martian meteorites, correlated with systematic trace element and isotopic variations, must have important implications for the redox state of the Martian crust and mantle and the overall differentiation of Mars. While QUE has primitive isotopic characteristics and is also the most reduced shergottite, it is quite Fe-rich, and thus is an evolved magma. In contrast, Y98 has a depleted REE pattern suggesting that it may have primitive isotopic characteristics, as well as a very primitive, olivine-rich major element composition. Thus it is important to determine whether Y98 is also highly reduced, as we might expect based on its depleted REE pattern.

This abstract and a companion abstract in this volume [10] report initial results of our experimental crystallization studies of this sample. In [10], we focus on the crystallization sequence of Y98. Here, we concentrate on using the variation of chromite compositions with redox conditions to estimate the approximate oxygen fugacity under which this chemically primitive sample crystallized.

Experiments: Experiments were run at oxygen fugacities near QFM and IW+1 using our usual wire loop technique. We ran both controlled cooling experiments, designed to mimic the crystallization of the

meteorite, and isothermal experiments, designed to approach equilibrium.

Quenching Difficulties. These experiments have proven perplexingly difficult. The high liquidus temperature and extremely olivine-rich composition invariably resulted in the formation of quench crystals during our usual air quenching.

Figs. 1 and 2 show cooling runs. Fig. 1 shows a run that was not drop-quenched, and Fig. 2 shows one that was. Other than the quenching speed, both charges had similar cooling histories. The drop-quenched charge

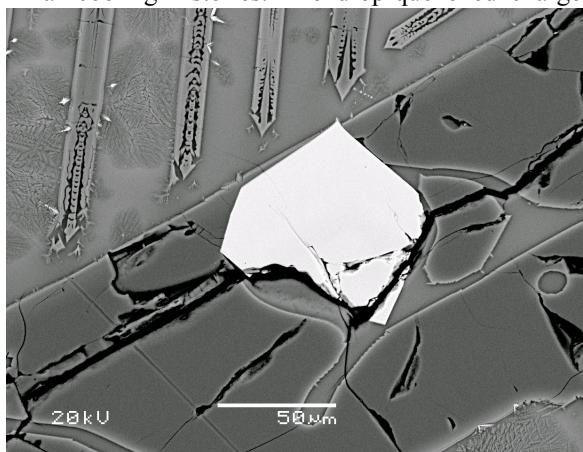


Fig. 1. BSE image of IW+1 run cooled from 1575 to 1330 °C at 10°/hr, then rapidly cooled to below the solidus by a power failure. White grain is chromite, dark skeletal grain is primary olivine grown during 10°/hr cooling, skeletal needles are olivine grown during rapid cooling, medium gray phase is glass, and patchy areas in glass are quench olivine and pyroxene.

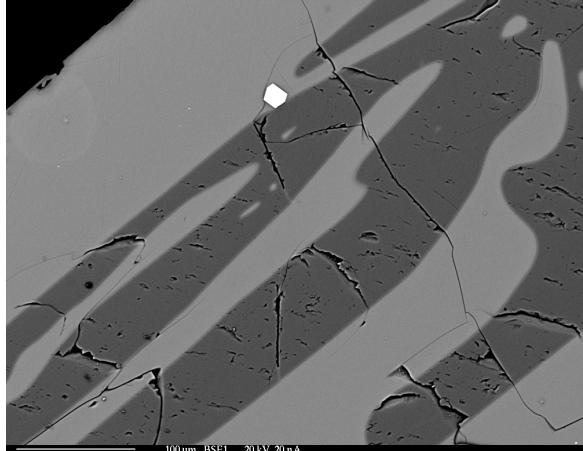


Fig. 2. BSE Image of IW+1 run cooled at 80°/hr from 1460 to 1380°C, held for about 15 hr, then drop quenched into water. Dark gray grain is mm-length olivine crystal (Fo₇₉). Light gray area is glass, and white grain is chromite. Note the absence of quench products.

contains only mm sized olivine grains (Fo83) and rare chromite, while the charge that was not drop-quenched also contains second-generation olivines and olivine-pyroxene intergrowths that clearly grew during the rapid cooling. As a result of the quenching problem, we have switched to drop-quenching into water in our later runs.

Determination of Fe⁺³: The MELTS program [11] predicts that the composition of chromite, a near-liquidus phase, will vary significantly as oxygen fugacity changes from IW+1 to QFM. Most notably, Fe⁺³-bearing magnetite will increase with increasing oxygen fugacity. This suggested to us that it might be possible to estimate the oxygen fugacity under which Y98 crystallized, based on the composition of its chromite. We adopted the following strategy: we estimated the amount of Fe⁺³ in natural Y98 chromites by stoichiometry from careful microprobe analyses. We iteratively adjusted the concentration of Fe⁺³ until the cation sum equaled three when normalized to four oxygen atoms [e.g., 9]. We then compared Fe⁺³ in the natural chromites with Fe⁺³ from the IW+1 and QFM experiments. Determination of Fe⁺³ by stoichiometry is difficult and requires great care. We always analyzed both synthetic and natural chromites in the same microprobe run. Our analytical precision for Fe⁺³ on a homogeneous chromite standard is better than ± 0.25 wt% Fe₂O₃, but accuracy is much more difficult to assess. In any case, the high analytical precision allows small differences in Fe⁺³ content between chromite grains to be assessed (Fig. 3).

Experimental Results: Fig. 3 shows compositions of natural and synthetic chromites projected into the (Mg,Fe)Cr₂O₃-(Mg,Fe)Al₂O₃-(Mg,Fe)Fe⁺³₂O₃, or Chr-Sp-Mt prism. The IW+1 spinels have nearly the same proportion of magnetite as the natural spinels, while the QFM spinels have distinctly greater magnetite contents. While additional experiments will be required to understand the detailed compositional variations, these preliminary results clearly support the idea that Y98 crystallized under reducing conditions, more like those of QUE than those of Shergotty [8, 9].

Conclusions: Calculations by MELTS, as well as independent calculations based on regressions of olivine partition coefficients, suggest that Y98 liquidus olivine compositions will closely match the Y98 phenocryst cores. This constitutes strong evidence that Y98 is a melt composition, without accumulated olivine. Thus, it is one of the most primitive Martian magmas in terms of major element composition. Combined with its strongly LREE-depleted [6] mantle-like [7] REE pattern makes it a candidate for the most primitive Martian magma. Experimental evidence presented here supports the proposition that Y98 also

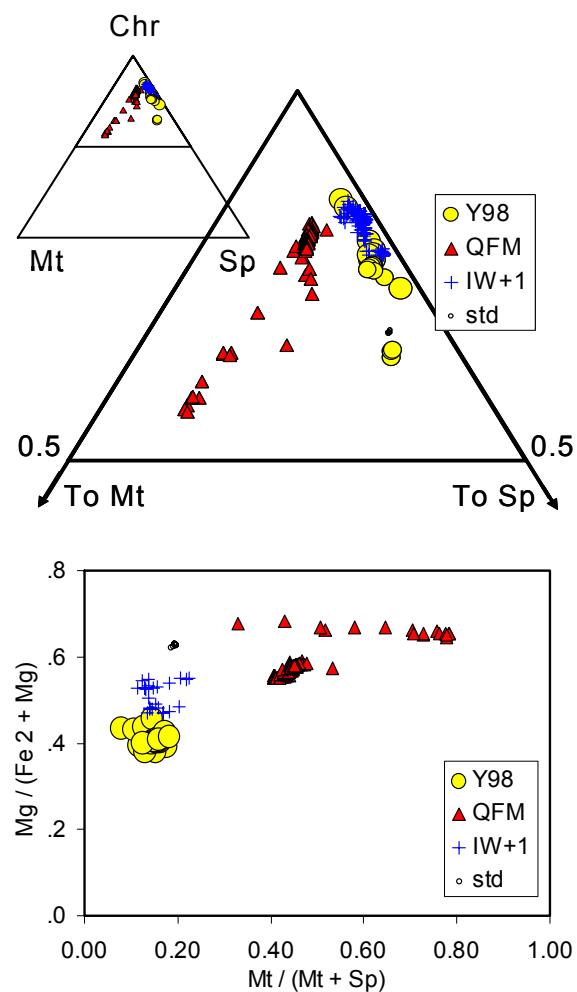


Fig. 3. Top: Projection of chromite compositions from ulvöspinel onto Magnetite-Chromite-Spinel face of spinel prism. Bottom: Projection onto floor of prism. Red triangles are chromites from runs at QFM. Blue crosses are chromites from runs at IW+1. Yellow circles are natural chromites from Y98. Tiny black dots are repeat analyses of homogeneous chromite standard, and indicate excellent analytical precision.

crystallized under very reducing conditions, like those of QUE. These results are thus consistent with derivation of this sample from a highly reduced mantle [7, 9].

References: [1] Misawa (2003) *NIPR Symp.*, 84. [2] Mikouchi *et al.* (2003) *NIPR Symp.*, 82. [3] McKay and Mikouchi (2003), *NIPR Symp.*, 76. [4] Greshike *et al.* (2003) *NIPR Symp.*, 29. [5] Ikeda (2003), *NIPR Symp.*, 42. [6] Shirai and Ebihara (2003), *NIPR Symp.*, 127. [7] Borg *et al.* (1997) *GCA* 61, 4915. [8] Wadhwa (2001) *Science* 291, 1527. [9] Herd *et al.* (2002) *GCA* 66, 2025. [10] Koizumi *et al.* (2004), this volume, [11] Ghiorso and Sack (1995) *Contr. Min. Pet.* 119, 197.