EVOLVING MODELS FOR THE PETROGENESIS OF MAGMATIC ROCKS IN GUSEV CRATER, MARS. H. Y. McSween[1] and T. Usui[1], [1]Department of Earth & Planetary Sciences, University of Tennessee, Knoxville, TN 37996, mcsween@utk.edu and tusui@utk.edu.

Introduction: Spirit rover has analyzed a suite of picritic and alkaline volcanic rocks, making Gusev the most thoroughly characterized igneous province on Mars. These rocks were previously hypothesized [1] to have formed by crystal fractionation of primitive Adirondack-class picritic basalt at different pressures. However, large degrees of fractionation are required to achieve the high alkali concentrations in some rocks. Here we explore the possibility of using other primitive magma compositions derived from melting experiments on the Dreibus-Wänke (DW) Mars mantle [2].

Method: Phase relations for primitive, multiply saturated Martian melts - Humphrey, an Adirondack class rock [3], and experimental melts from various degrees (~10-30%) of partial melting of the DW mantle [4] - are shown in Fig. 1. Our fractionation calculations use all these compositions (Table 1). A MELTS calculation closely follows the experimental liquid line of descent for Humphrey only until pyroxene saturation occurs [3], so we restrict our MELTS models to the crystallization interval for olivine and spinel. Calculated runs under various conditions show that changes in P (1 bar to 5 kbar), H_2O (0 to 1 wt.%), and fO_2 (QFM to QFM-3) do not significantly alter the liquid line of descent, and equilibrium versus fractional crystallization only matter later in the sequence. Changes in physical and chemical parameters affect liquidus temperatures and mineral stabilities, but not compositional trends of liquids when only olvine and spinel are crystallizing (except for Cr, which varies with fO_2). We attempt to reproduce the bulk chemical compositions of Adirondack, Backstay, Irvine, and Barnhill class rocks, which do not show evidence for aqueous alteration [1], petrologic mixing (as for the Wishstone class [5]), or crystal accumulation (as seen in the Algonquin class [6]).

Results: Calculated liquid lines of descent for the various primitive magmas show very limited changes in SiO_2 abundances (Fig. 2) but significant changes in MgO (Fig. 3), so we use MgO as an index of fractionation. Only magmas formed by lower degrees (~10%) of partial melting than Humphrey can reach the high alkali contents of Backstay, Irvine, and Barnhill class rocks (e.g. Na_2O in Fig. 3) during fractionation. Abundances of most elements can be readily explained by fractionation of olivine and spinel from these primitive magmas (e.g. Al_2O_3 and TiO_2 in Fig. 3). This suggests that all the Gusev basaltic rocks (picritic and alkaline) could have formed by different degrees of melting of the same DW mantle. Differences in degree of melting may reflect temporal or spatial changes in adiabatic upwelling beneath Gusev crater.

A few elements (CaO, P_2O_5, Ni) are not well modeled (e.g. CaO in Fig. 3). The significance of this discrepancy is unclear. These elements might have been disturbed by alteration of rock surfaces (all these rocks were brushed but not ground by the RAT). Ca-phosphate is readily attacked by acidic fluids [7]; leaching should lower P_2O_5 as well as CaO, but P_2O_5 contents are higher than calculated values. Alternatively, low CaO contents (Fig. 3) might reflect heterogeneous mantle sources [8], perhaps more depleted in clinopyroxene than the DW mantle, although this should not affect P_2O_5. Ni contents of Gusev rocks show no relationship to the proportion of fractionated olivine.

Conclusions:

(1) A variety of primitive melt compositions, derived from experiments that partially melted the DW mantle to various degrees, are possible parental magmas for Gusev rocks.

(2) Variations in physical and chemical conditions do not significantly alter the calculated liquid lines of descent for these magmas, because spinel and olivine remain the liquidus phases.

(3) Incompatible element oxides like Na_2O and TiO_2 in the Gusev rock suite are better modeled by fractionation of lower-degree partial melts than Adirondack-class magmas.

(4) A few elements (CaO, P_2O_5, Ni) are not adequately modeled, and require some other explanation, perhaps alteration or heterogeneous mantle sources.

The complicated petrogenesis required for these volcanic rocks (not to mention Wishstone pyroclastic rocks that may be associated with carbonatite magmas [5]) is not surprising for an alkaline province. Mars may be as complex as Earth, and simplified igneous models are unlikely to stand the test of time and data.

References: [1] McSween H. Y. et al. (2006) *JGR* 111, doi:10.1029/2006JE002698. [2] Dreibus G. and Wänke H. (1985) *Meteoritics* 20, 367-382. [3] Monders A. G. et al. (2007) *Meteor. & Planet. Sci*. 42, 131-148. [4] Bertka C. and Holloway J. (1994) *Contr. Mineral. Petrol.* 115, 323-338. [5] Usui T. et al. (2007) *LPS XXXVIII*, Abstract #1272. [6] McSween H.Y. et al. (2008) *JGR*, in press. [7] Hurowitz J. A. (2006) *JGR* 111, doi:10.1029/2005JE002515. [8] Schmidt M. et al.

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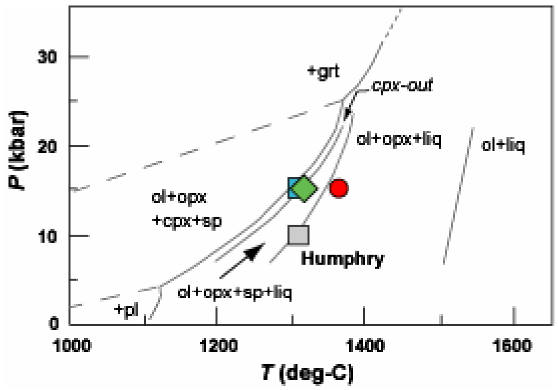

Fig. 1. Phase relations for Humphrey (an Adirondack-class basalt [3]) and experimental melts in equilibrium with ol+opx+cpx+sp (blue), ol+opx+sp (green), and ol+opx (red) for the DW Mars mantle composition [4].

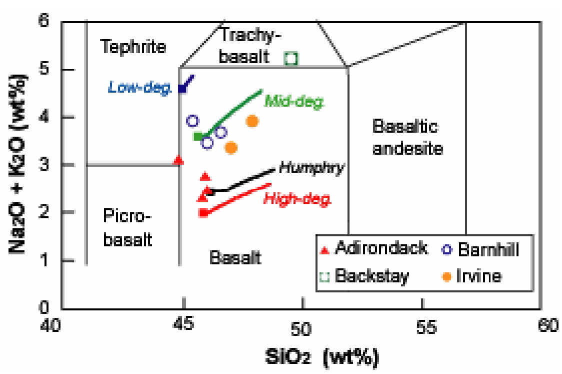

Fig. 2. Alkalis-silica diagram showing the calculated liquid lines of descent for various primitive Martian magmas (symbols as in Fig. 1). K_2O contents for experimental melts were assumed using Na_2O/K_2O ratios similar to Gusev basalts.

Table 1: Melt compositions.

Melt	Humphrey	SMR-5	SMR-6	DWF-27
P (kbar)	10	15	15	15
T (°C)	1320	1300	1300	1360
Ref.	[9]	[4]	[4]	[4]
(wt%)				
SiO_2	45.9	45.0	45.8	45.9
TiO_2	0.58	1.5	0.86	0.47
Al_2O_3	10.4	13.0	9.6	7.49
Cr_2O_3	0.67	0.14	0.49	0.63
FeOtotal	18.7	17.0	18.4	19.5
MnO	0.42	0.38	0.42	0.56
MgO	10.7	9.10	12.8	16.2
CaO	8.2	9.59	8.09	7.0
Na_2O	2.4	3.83	3.02	1.67
K_2O	0.09	-	-	-
P_2O_5	0.59	0.5	0.51	0.51
FeS	0.83	-	-	-
Mg#	50.5	48.8	55.4	59.7

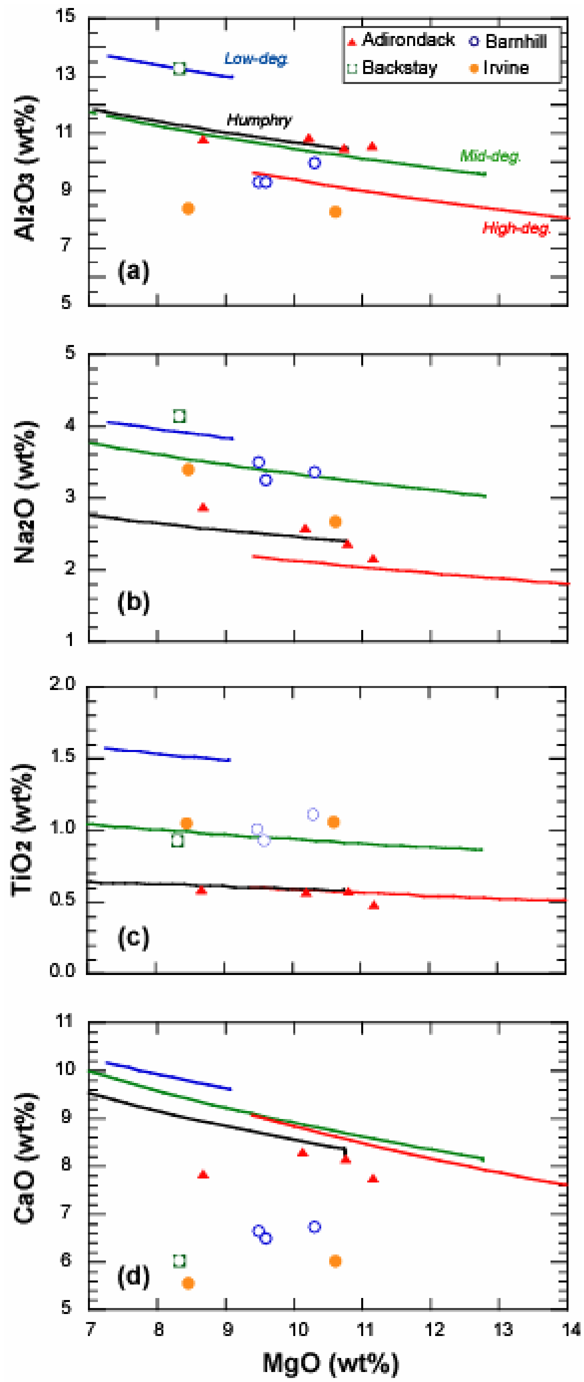

Fig. 3. Calculated liquid lines of descent for various Martian magmas (plotting at the high-MgO ends of the lines) compared to measured compositions of Gusev rock classes. Color code for liquids as in Figs. 1 and 2.