

PARTIAL MELTING OF A MARTIAN MANTLE; Constance Bertka and John R. Holloway, Geology and Chemistry Depts., Arizona State University, Tempe, AZ 85287

An understanding of the nature of Martian volcanic products can begin with an explanation of their production in an upper Martian mantle. We are using results from partial melting experiments on a proposed mantle composition to estimate primary melt compositions. This approach has been applied to the mantle composition derived by Morgan and Anders (1) from cosmological arguments.

Patera (2) used thermodynamic calculations on reactions in the $\text{CaO-MgO-Al}_2\text{O}_3\text{-SiO}_2$ system to determine stable phase assemblages in an upper Martian mantle. His results suggest that in a 20 to 30 kb range the Morgan-Anders bulk composition gives a stable phase assemblage of garnet + clinopyroxene + orthopyroxene + olivine. Wood and Holloway (3) have organized a thermodynamic data base for the system $\text{Na}_2\text{O-FeO-CaO-MgO-Al}_2\text{O}_3\text{-SiO}_2$ in a free energy minimization program which is used to calculate the stable phase assemblage, the phase composition and the mode for a chosen bulk composition at a given pressure and temperature. The composition of Martian mantle phases at 20kb and 1200°C have been obtained from an application of the program to a Morgan-Anders mantle composition. Starting materials for the experiments were chosen so as to approximate the predicted phase compositions. The garnet and clinopyroxene were separated from ultramafic nodules; the olivine is from a megacryst and the orthopyroxene synthesized at 1200°C and 1 atmosphere in a gas-mixing furnace. These minerals were combined in a proportion such that all phases were present in major amounts. The resulting bulk composition differs from the Morgan-Anders one because of the greater amounts of orthopyroxene, clinopyroxene and garnet compared to olivine (see Table I). However, the ratios of phases is unimportant to this study provided the phase assemblage remains the same.

The experimental setup used is a modification of the basalt-peridotite sandwich method of Takahashi and Kushiro (4) with the addition of an iron wustite C-O-H fluid buffer system after Jakobsson (5; described in Holloway and Jakobsson, 6). The sample, consisting of the crystalline assemblage capped by a starting basalt composition is placed in a graphite capsule. This graphite capsule is placed in a Pt capsule along with an iron, stearic acid, and water mixture. The resulting buffer controls oxygen fugacity as well as fluid composition and eliminates iron loss problems. Ideally, any melt generated from the peridotite assemblage equilibrates with the basalt composition at the top of the capsule, which results in an area large enough for analysis and free of quench crystal modification. An electron probe analysis of run products produced in a solid-media piston cylinder at 20kb and 1200°C after 10 hours is shown in Table I. The grains analyzed, clinopyroxene and olivine, were those which crystallized near the capping basalt.

The difference in composition between the starting olivine phase and the run product suggest this phase was tending towards equilibrium. Also, the mg# of the run product olivine is in close agreement with the mg# calculated for olivine. The starting clinopyroxene differs from the run product clinopyroxene largely in CaO and Al_2O_3 content and also approaches the calculated composition (see Table I). The measured MgO/FeO partitioning between melt and olivine (.38) as well as the similarity between starting and run melt compositions suggests the melt has not fully equilibrated with the peridotite phases. However, a decrease in melt TiO_2 concentration can be correlated with an increase in TiO_2 concentration in clinopyroxene suggesting the melt is reacting with the phases towards an equilibrium composition.

Further experiments with variations in starting basalt compositions will enable the primary melt composition to be isolated.

The calculations for the subsolidus phase assemblage yield the important result that a Martian mantle with a Morgan-Anders composition is very close to the boundary between garnet lherzolite (OL+CPX+GT+OPX) and spinel-garnet lherzolite (OL+CPX+GT+SP). The calculations predict about one wt% orthopyroxene. During small amounts of partial melting the orthopyroxene will most likely be consumed, leaving an olivine + clinopyroxene + garnet residue. In contrast to the Earth's upper mantle, this residue will not buffer silica activity at the olivine + orthopyroxene levels.

REFERENCES

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TABLE I

BULK COMPOSITION			STARTING COMPOSITIONS					RUN PRODUCTS			
MA*	EX**		OL	CPX	GT	OPX	#3048 BASALT	OL	CPX	MELT	CPX*
SiO ₂	41.9	46.3	40.2	53.4	40.9	56.3	46.0	38.3	51.2	45.3	52.2
TiO ₂	.3	.1	.0	.2	0	0	3.0	0	1.2	2.4	-
Al ₂ O ₃	6.4	9.6	.1	2.3	22.5	0	14.7	.1	6.8	16.5	5.4
FeO	15.0	12.7	12.5	6.7	15.1	13.5	12.2	21.4	6.9	12.6	6.4
MgO	30.0	23.8	46.7	14.1	13.9	30.2	9.1	39.8	14.6	8.8	16.0
CaO	5.2	7.2	.2	22.4	6.9	0	8.1	.1	18.0	8.9	19.5
Na ₂ O	.1	.2	0	1.0	0	0	3.6	.1	1.1	4.0	.54
K ₂ O	0	0	0	0	0	0	3.4	0	0	1.3	-
MnO	.2	.2	0	0	.4	0	0	.2	.2	.2	-
NiO	-	.1	0.3	0	0	0	0	0	0	0	-
Mg#	77	77	87	79	62	80	57	77	79	56	82
		wt%	20	20	40	20					

* Morgan and Anders

** Starting bulk composition

* Calculated composition