PETROLOGIC CONSTRAINTS ON THE PRESSURE, TEMPERATURE, TIME AND COMPOSITION OF THE MATRIAN INTERIOR: SAMPLES AND EXPERIMENTS.

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Petrologic analysis of surface samples has been used to deduce pressure and temperature conditions existing in the crust and upper mantle at specific times in the Earth's history, as well as to estimate the chemical and mineralogical composition of the crust and upper mantle. The same techniques can be applied to samples of the Martian surface to provide P, T, time and composition constraints of the Martian interior. Estimates of P and T conditions existing at a given time would, in turn, provide strong constraints on the thermal evolution of Mars. Knowledge of the chemical and mineralogical composition of the Martian interior is of fundamental importance in assesing the early histroy of the solar system. In this abstract I outline the general petrological approach, describe the kinds of sample required, summarize our current understanding of the Martian interior based on experimental petrology, and outline some of the important experiments needed to allow a full petrologic interpretation of Martian samples. *Xenoliths* in lavas and pyroclastics often contain mineral assemblages which can be used to calculate P and T with high precision using available thermochemical models (1). However, xenoliths are volumetrically rare on the Earth's surface and it is unlikely that they will be found by initial Martian expeditions. The most common surface rocks on Mars are lavas and so these are the samples which will have to be used in a petrologic analysis to deduce pressure, temperature, mineral assemblage and chemical compositions of the interior of Mars. *Primary magmas* are most useful because, by definition, they have not undergone fractionation since leaving their source region. Primary magmas are identified by the atomic ratio of Mg/(Mg+Fe), the mg#. Comparison of the composition of a primary magma with experimentally determined compositions identifies the phase assembalge of the source region which is used to estimate pressure (2). The experimentally determined solidus is then used to estimate temperature. The source region phase assemblage helps constrain the chemical composition. Terrestrial primary magmas are most often found in monogenetic cones and associated flows. These too are uncommon and not all monogenetic cones are formed from primary magmas. It is thus probable that primary magmas will not be sampled in initial expeditions. *Fractionated magmas* almost certainly form the major volcanic features on Mars and so are the most probable type of sample to be obtained. In favorable instances the composition of the primary magma parent of a fractionated magma can be estimated. The strongest constraints are a combination of the observed chemistry with experimentally determined crystallization sequences. If the primary magma composition can be estimate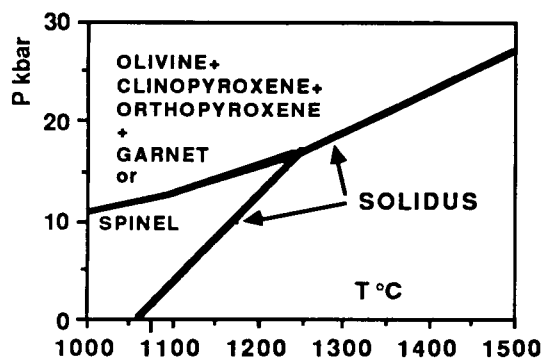d in this way then the technique outlined above can be used. This more convoluted path introduces greater uncertainty in the estimated mantle conditions, but has been used sucessfullly to estimate the P T conditions in the source regions of mid-ocean ridge basalts on Earth (3). Making those estimates required several samples of the same general rock type. The utility of any of the possible sample types is seriously degraded by secondary alteration or weathering. The sample size must be large enough to ensure homogeneity, so it is proportional to grain size.

Current assesments of the chemical composition of the Martian interior are based on the primary constraints of mean density and moment of inertia, together with experimentally determined mineral densities, and chemical models using either chondritic

Figure 1. Garnet-spinel transition (7) and solidus (6) for Martian mantle with mg# =78.

meteorites (4) or SNC's (5). For the most recent estimates of mantle density based on refined moment of inertia values there is very good consistency between the chemical models. Those models result in significaltely lower mg#'s for Mars compared to the Earth, and slightly higher (Fe+Mg)/Si.

Experiments on volatile (H_2O and CO_2)-free compositions show that the mantle mineral assemblage is olivine + clinopyroxene + orthopyroxene + aluminous phase to depths of >200 Kms (6). The aluminous phase is either spinel or garnet depending on pressure (Fig.1). Experimental determination of the minimum melt composition for a volatile-free Martian mantle ar 23 kbar shows that the liquid is low in Si and Al and high in Fe and Mg with a low mg# (Table 1). These low melting fraction liquids will show REE paterns characteristic of equilibration with garnet only for degrees of melting ≤ 2-5 wt% liquid. Similiar results for minimum melt compositions are not available for the spinel field, but by analogy with terrestrial systems they will have higher Si/(Fe+Mg). As the melting fraction increases, the liquid will show a decrease in mg# and a slight increase in (Mg+Fe)/Si.

Table 1		
Minimum Melt Compositions*		
Oxide	Mars	Earth
SiO_2	41.	45.
Al_2O_3	12.	12.
FeO	23.	15.
MgO	12.	25.
P(kbar)	23.	35.
Ref.	(6)	(8)

* In equilibrium with garnet, olivine, clinopyroxene and orthopyroxene.

An important consequence of the unusually high Fe and low Si content of Martian primary liquids is a very high melt density. Preliminary experimental results show that pyroxene and olivine float in minimum melt compositions at 23 kbar (13). This phenomenum will have major consequences for phase stratification in the Martian mantle, quite possibly preventing magmas from rising in the garnet stability field. The more silica-rich magmas from the spinel stability field are less dense and presumably could rise to the surface.

Additional experiments will be needed to provide a useful data base for the understanding of Martian samples. Determination of the subsolidus mineralogy is needed for Martian mantle composition in the spinel field and also at pressures equivalent to the core-mantle boundary. Ultra-high pressure systems are now available for subsolidus and melting studies up to 25 GPa, the approximate pressure of the core-mantle boundary (9). There is theoretical (10) and direct (11) evidence that the Martian mantle is at least as rich in volatiles and the Earth's. Dissolution of volatiles such as H_2O and CO_2 at high pressures are known to cause drastic changes in the composition, density and viscosity of primary magmas (12) and so we must evaluate the effects of those volatiles on Martian mantle compositions. Finally, the observation that the most common of the mantle minerals float in some Martian primary magmas points out the necessity of accurate measurements of melt density over as wide a range of pressure as possible.

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