CONSTRAINING COMPOSITION OF MARS USING GEOPHYSICAL CONSTRAINTS AND MINERAL PHYSICS DATA. Yi Wang, Lianxing Wen and Donald J. Weidner, (Department of Geosciences, State University of New York, Stony Brook, NY 11794-2100, yiwang1@ic.sunysb.edu, Lianxing.Wen@sunysb.edu, Donald.Weidner@sunysb.edu) .

Introduction: Compositions of the mantle and core of the terrestrial planets are important for us to understand the formation and evolution of the planets. There are two hypotheses on the evolution of the planets. One hypothesis suggests that the different mean densities of the terrestrial planets indicate different Fe/Si ratio in the planets. Because the terrestrial planets have different distance from the Sun, different mean density of the planets suggests a Fe/Si fractionation in the solar nebula [1, 2]. The other hypothesis suggests that the terrestrial planets all have the bulk composition with the same nonvolatile element abundances as those of C1 carbonaceous chondrite [3]. Later, this hypothesis is revised to that the terrestrial planets consist of two chondritic components, one is completely reduced and the other is oxidized, but both components have the same bulk composition of C1 chondrite [4]. Based on this hypothesis, the terrestrial planets have the same Fe/Si ratio, but the ratios between metallic Fe and the total Fe are different. Understanding the composition of terrestrial planets can help us distinguish these two hypotheses.

Method: Recent space missions to Mars, such as the Pathfinder Lander [5], provide us precise measurements of the hydrostatic gravity field, flattening factor and moment of inertia of Mars. These geophysical properties are all controlled by the density distributions in Mars and can be used to place constraints on mantle and core compositions in Mars.

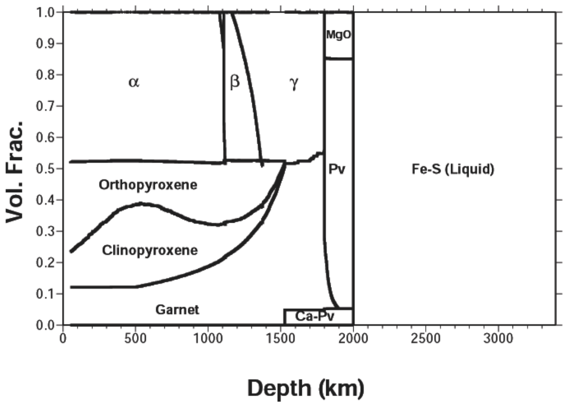

Figure 1. An example phase assemblage based on a Mars composition model in the mantle proposed by Dreibus and Wanke [4] and a Mars temperature profile by Fei and Bertka [14]. α denotes olivine; β wadsleyite; γ ringwoodite; Pv perovskite; MgO magnesiowustite.

Recent progress in mineral physics field allowed us to quantitatively predict velocity and density profiles in the interior of Mars, based on different mantle composition, core composition and temperature profiles in the planet. We consider both olivine and garnet components and their chemical interactions in our mineral physics calculation of velocity and density profiles in the mantle. We use stable assemblages (see an example in Figure 1) determined using phase equilibria data, chemical composition for each mineral determined using cation distribution data, and current estimates of elastic properties for each mineral to predict mantle velocity and density profiles (see an example in Figure 2) [6-9]. We use the measurements of elastic properties of pure liquid Fe [10] and liquid Fe with 10% S [11, 12] and a linearly assumption of elastic properties changing with S content to predict core density for different S contents.

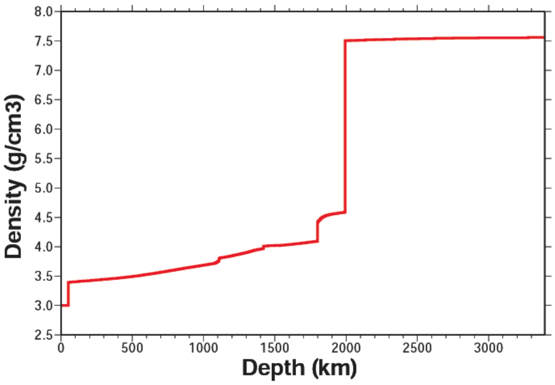

Figure 2. An example density profile in Mars based on the example compositions and temperature profile in Figure 1, with a pure liquid Fe core.

Previous studies [e.g., 13] using the moment of inertia factor and mineral physics data to constrain Mars composition assumed a solid core and fixed the mantle composition. Recent studies, however, have suggested a liquid core in Mars [14, 15]. In this study, we adopt a liquid Fe-S system in the core and test a variety of mantle compositions. Our mineral physics modeling method allows us to systematically search for possible compositions in the mantle and the core. We also use the observed hydrostatic geoid and flattening factor to place further constraints on the composition of Mars.

We construct 1-D density models of the interior of Mars for a series of mantle compositions, core compositions, and a temperature profile from Fei and Bertka's study [14], and then adopt the second-order internal theory of equilibrium of a self-gravitating and rotating planet to calculate the hydrostatic gravity, moment of inertia and flattening factor. Comparing the predictions with the observations, we place constraints on mantle and core compositions in Mars.

Conclusions: Increasing S content in the core would decrease core density. For a fixed mantle composition, it would require a larger core radius to fit the total mass and result in a larger moment of inertia factor. So the moment of inertia factor and core radius increase with an increasing S content in the core. Increasing Fe content in the mantle would increase mantle density. It would require a smaller core radius to fit the total mass and result in a lager moment of inertia factor. So the moment of inertia factor increases and core radius decreases with an increasing Fe content in the mantle. Based on the constraints of possible core radii of 1520-1840 km [16], total mass and moment of inertia factor (0.3662 ± 0.0017) [5] of Mars, we find that the Fe content in the mantle is between 11% and 15.5%, and the S content in the core is between 5% and 13.5% (Figure 3).

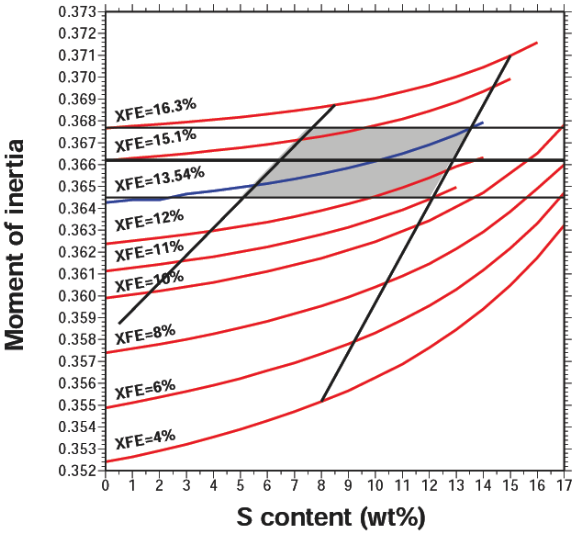

Figure 3. The moment of inertia factor calculated based on a variety of Fe contents in the mantle and S contents in the core. Heavy horizontal black line represents the observed moment of inertia factor value and two thin horizontal lines indicate the error bar. Vertical black lines represent the results based on the upper and lower bounds of the core radius (1520 and 1840 km), inferred recently by Yoder et al [16]. The shadow region represents the range of possible Fe contents in the mantle and S contents in the core, which can fit the observed total mass and moment of inertia factor of Mars.

Al content in the mantle also has effect on the moment of inertia. The Al content affects the volume ratio between pyroxene and garnet. Because garnet has a larger density than that of pyroxene, increasing Al content in the mantle would increase mantle density and a decrease of core radius would be required to fit the total mass resulting in a larger moment of inertia factor. The effect of Ca content is small.

We also discuss the constraints of the hydrostatic geoid and flattening factor, and implications of these mantle and core compositional models to the understanding of formation and evolution of the planet.

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