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INTRODUCTION: Compositional models (e.g., *1, 2, 3*), based on element correlations observed in SNC meteorites and cosmochemical constraints, suggest that the Martian core is enriched in FeS. Whether the Martian core is liquid or solid is dependent on its thermal state and the melting behavior of the core materials. Accurate determination of melting temperatures in the Fe-FeS system at high pressure is required to assess the state of a sulfur-bearing iron-core. Melting in the system Fe-FeS at high pressure has been studied up to 10 GPa (*4, 5, 6*), far below the core pressures of Mars. The results above 5 GPa are still controversial. We have carried out high-pressure melting experiments on Fe-FeS mixtures in piston-cylinder and multi-anvil apparatus. In this paper, we present our melting data in the Fe-FeS system up to core pressures of Mars. We also report a new iron-sulfur compound (Fe_3S_2), synthesized above 14 GPa, which affects the melting behavior in the simple binary system. Finally, we discuss the state of the Martian core in light of our new experimental results.

EXPERIMENTAL APPROACH: The starting materials, Fe-FeS mixtures, were synthesized in sealed silica glass tubes which were evacuated, at 800 °C. The synthesized sample was then loaded in a MgO-platinum or a MgO-rhenium double-capsule. Experiments below 3 GPa were conducted in a piston-cylinder apparatus. At higher pressures, melting experiments were carried out in a multi-anvil apparatus, installed at the Geophysical Laboratory. The apparatus has been calibrated up to a pressure of 25 GPa for a 10-mm-edged octahedra and 3-mm TEL (truncation edge length) assembly at room temperature and 1200 °C. The 3-mm assembly consists of a rhenium heater with a lanthanum chromite sleeve serving as a thermal insulator. Temperatures were measured with a W26%Re-W5%Re thermocouple whose junction was placed along axial direction. Experiments at pressures between 7 GPa and 12 GPa were carried out by using a 10-mm-edged octahedra and 5-mm TEL assembly. In order to minimize the inconsistency in pressure calibration among different assemblies, experiments were performed at overlapping pressures. The quenched samples were examined with an optical microscope and an electron microprobe. Backscattered electron images, chemical composition maps, and quantitative chemical analyses were obtained with a JEOL-SUPERPROBE JXA-8900 electron microprobe. Melting of the samples was determined on the basis of quenched textures and composition maps. Irregular Fe grains embedded in a FeS matrix indicated that the sample was unmelted, whereas dendrites of FeS surrounded by a eutectic-like intergrowth of iron and troilite indicated that the sample melted.

RESULTS: The eutectic temperature in the system Fe-FeS was bracketed by at least two experiments above and below the melting point at each pressure. The temperature of the eutectic linearly decreases from 988 °C at 1 bar to 900 °C at 12 GPa, contrary to the results of Usselman (*6*) who reported a cusp in the eutectic curve at 5.2 GPa. Our eutectic temperature at 10 GPa is about 200 °C lower that of Usselman at the same pressure. The eutectic compositions in the melted experiments were determined by electron microprobe analysis. The sulfur content of the eutectic linearly decreases as a function of pressure, from 31 wt percent sulfur at 1 bar to 20.5 wt percent sulfur at 7 GPa, consistent with the results of Brett and Bell (*4*) and Ryzhenko and Kennedy (*5*). Above 7 GPa, the pressure has very little effect on the eutectic composition up to 12 GPa. However, the sulfur content of the eutectic determined by Usselman (*6*) is about 3 wt % higher than our results at pressures above 7 GPa, which may be related to the discrepancy in the eutectic temperature. A small amount of sulfur (about 2 wt %) was detected in iron in samples quenched from pressures higher than 7 GPa. The sulfur solubility in metallic iron at high pressure was further confirmed by x-ray diffraction data which indicated that the lattice parameter of the quenched iron is about 0.7 % larger than that of pure iron.

A new iron-sulfur compound with composition Fe_3S_2 was synthesized at pressures above 14 GPa. This finding has a significant effect on the melting relations in the system Fe-FeS at high pressure. The simple binary system with an eutectic changes to a binary system with an intermediate compound which melts incongruently. The sulfur content of the eutectic decreases

to 18 wt % at 14 GPa, whereas the sulfur content of the peritectic is about 20.5 wt %. The eutectic temperature increases with increasing pressure above 14 GPa, but it is about 500 °C lower than that extrapolated from Usselman's data (*6*) at 21 GPa. Figure 1 shows schematic melting relations at different pressures with the eutectic and peritectic points determined in this study.

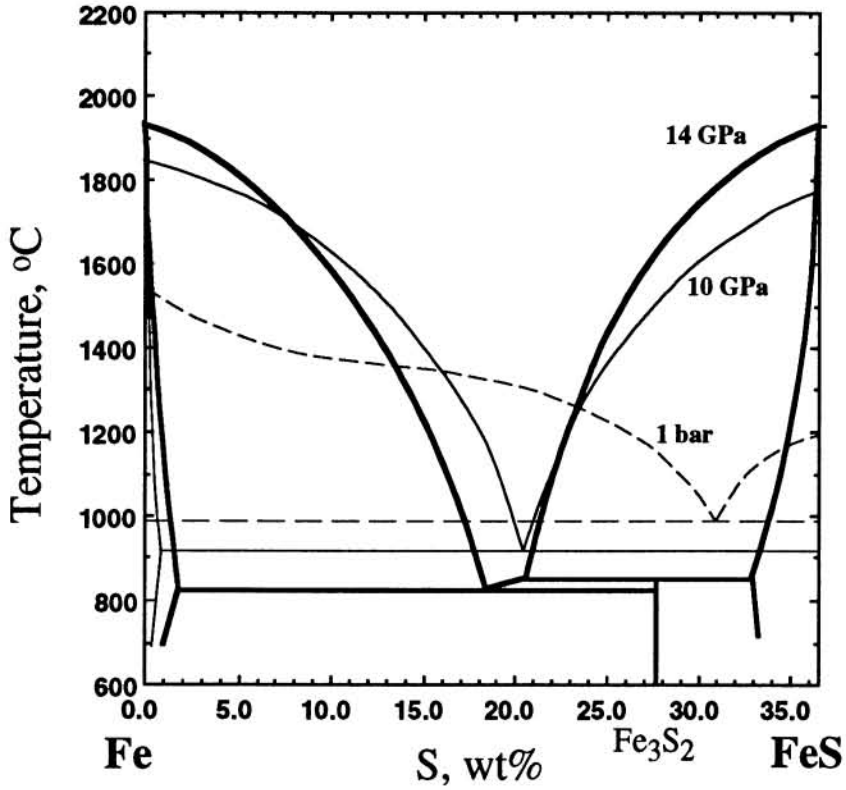

Fig. 1. Melting relations in the system Fe-FeS at pressures of 1 bar (dashed lines), 10 GPa (thin lines), and 14 GPa (thick lines). An intermediate compound with composition Fe_3S_2 forms at pressures above 14 GPa. The eutectic and peritectic points were determined in this study.

DISCUSSION: The Martian core contains about 14 wt % sulfur based on the model composition of Dreibus and Wänke (*1*). Our results indicate that the sulfur content of the eutectic at the core/mantle boundary pressure of Mars (Bertka and Fei, this volume) is about 17 wt %. This value slightly decreases with increasing pressure. The sulfur content in the Martian core could coincide with the eutectic composition in the Fe-FeS system, which would have important implications for the core formation processes. The eutectic temperature at core pressures determined in this study is much lower than previous estimates based on extrapolation of Usselman's data. Our new experimental results indicate that for any marstherm derived from thermal models (e.g., *7, 8, 9*), Mars has a completely fluid core; if the current estimates of the composition of the core are reasonable. A completely fluid core that is only weakly convecting would be consistent with the existence of the very weak Martian magnetic field (*8, 9*).

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