EVIDENCE FOR A MARTIAN D”-LIKE LAYER. A. Khan[1,2], D. Huang[1], C. Duran[2], P. Sossi[1], M. Murakami[1] and D. Giardini[2], [1]Institute of Geochemistry and Petrology, ETH Zurich, Switzerland, [2]Institute of Geophysics, ETH Zurich, Switzerland (akhan@ethz.ch, dhuang@ethz.ch, cduran@ethz.ch, psossi@ethz.ch).

Introduction: Mars is the second terrestrial planet after the Earth for which seismic data have been acquired [1] which have afforded us the rare opportunity to examine its interior [2,3]. While nearly 4 years of seismic monitoring as part of the InSight mission has unveiled the large-scale radial structure of crust, mantle, and core [4-8], a number of puzzling observations abound, including a core-diffracted P-wave that suggests a seismically slower lower mantle relative to expectations from current models [e.g., 6] and, from a cosmochemical viewpoint, a low mean core density (6-6.4 g/cm^3) [6-9] (Figure 1) that implies a total large light element budget (>20 wt%) in excess of what is cosmochemically considered feasible [9].

To address these issues, we report on the presence of a molten silicate lower-mantle layer overlying a dense liquid Fe-Ni-S-C-O-H core [10].

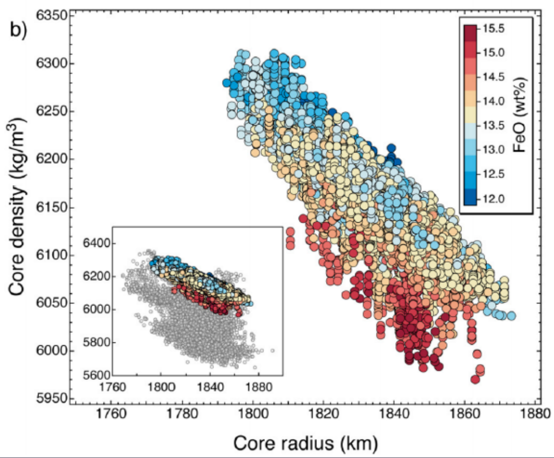

Figure 1: Relationship between core radius, core density, and mantle FeO content determined from InSight seismic and geophysical data [9]. Grey circles in the inset are the core properties from [6].

Method of analysis: We use a combination of 1) seismic and geophysical observations, 2) first principles calculations of silicate and Fe-Ni alloy liquids at martian core conditions, and 3) cosmochemical arguments.

Results: We first determined P-wave velocities and densities of multi-component Fe-Ni-X mixtures, where X=S, C, O, and H, for a range of pressure and temperature conditions consistent with Mars's core using the equation of state (EoS) of [11] (Figure 2). Relying on this EoS, we subsequently computed seismic profiles of P-wave velocity and density of the martian core for a whole range of compositions by randomly creating Fe-Ni-X mixtures. The set of seismic profiles were matched with the observed seismic profiles obtained from analysis of core-traversing P-waves [8]. The comparison revealed that while the seismic observations can be matched in the deeper parts of the martian core, the observations immediately below the CMB cannot be fit. This indicates that the region near the CMB, which had initially been identified as belonging to the core, represents the bottom of the silicate mantle as also suggested in geodynamic models [12]. Current geophysical and seismic observations [6,7,13] require both the silicate layer and underlying Fe-Ni-rich core to be liquid.

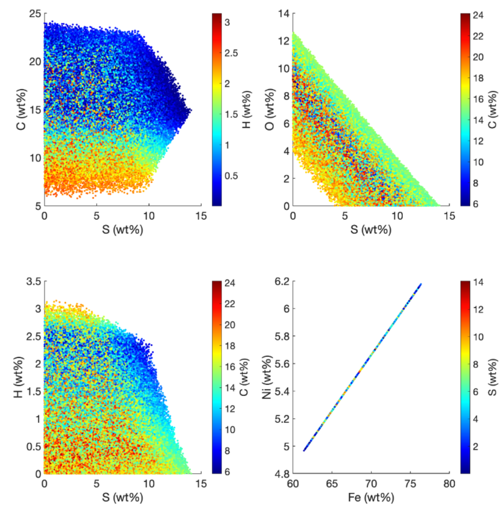

Figure 2: Distribution of Fe-Ni-S-C-O-H senary mixtures based on first principles simulations [11] that match the observed density and P-wave velocity in the core [8] immediately below the CMB.

Following this, we proceeded to re-invert the entire differential travel time data set obtained from the InSight mission [7,8,14] to determine the interior structure of Mars. For this purpose, we re-parameterized our spherically-symmetric model of Mars so that it consists of a crust, mantle, molten silicate layer, and liquid core. The crust is physically parameterized in terms of P-, S-wave speed, density, and Moho thickness, whereas mantle and core are parameterized through composition and temperature. Mantle and core seismic properties are computed using free energy minimization [15] and EoS methods [8], respectively.

Inversion of the InSight seismic body wave travel time data set shows that the latter is compatible with a silicate melt layer overlying a dense liquid core. In addition to thickness and seismic properties of the layer that point to a silicate composition, we are able to re-estimate the size and density of the core. Because of the presence of the layer, core size is reduced and mean core density increases relative to what had been predicted previously [e.g., 6], whereby the total light element budget is reduced to cosmochemically-reasonable values (11-14 wt%).

To provide observational evidence for our new model of Mars's interior structure, we performed synthetic waveform computations (Figure 3) to predict possible silicate-layer- and core-interacting phases. Of particular interest are multiply-diffracted P-waves along the solid mantle-liquid silicate layer and liquid silicate layer-liquid core interfaces that are absent in previous models [e.g., 6-8]. We subsequently searched for these phases in the InSight seismic data and relying on a large farside meteoroid impact [14,16,17], were able to make positive detections of the aforementioned multiply-diffracted P-waves as evidence in support of a martian D"-like layer and, ultimately, a new model of the interior structure of Mars.

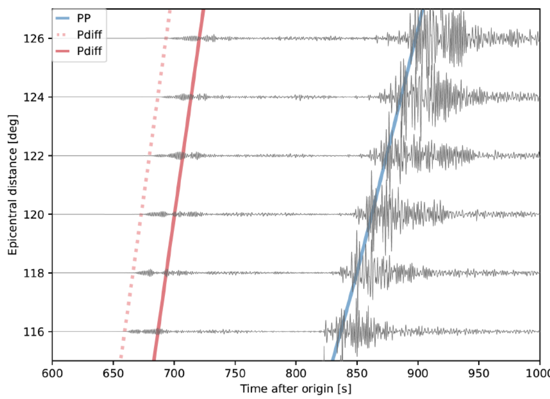

Figure 3: Synthetic vertical-component waveform section for a martian model [6]. Waveforms are computed with AxiSEM [18], assuming an isotropic source. Solid and dotted vertical lines indicate ray-theoretically predicted body wave arrivals.

Summary: We have found seismic evidence for a deep-seated liquid silicate layer at the bottom of the martian mantle that was previously considered to be the outermost core. As a consequence of the presence of this layer, core size decreases, while its density increases. The new bulk core properties determined here reconcile geophysical- and cosmochemical requirements for the light-element content of the Martian core.

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