Low Shear Velocity Zones (LSVZ) in the Martian Upper Mantle Highlighted by Sound Velocity Measurements

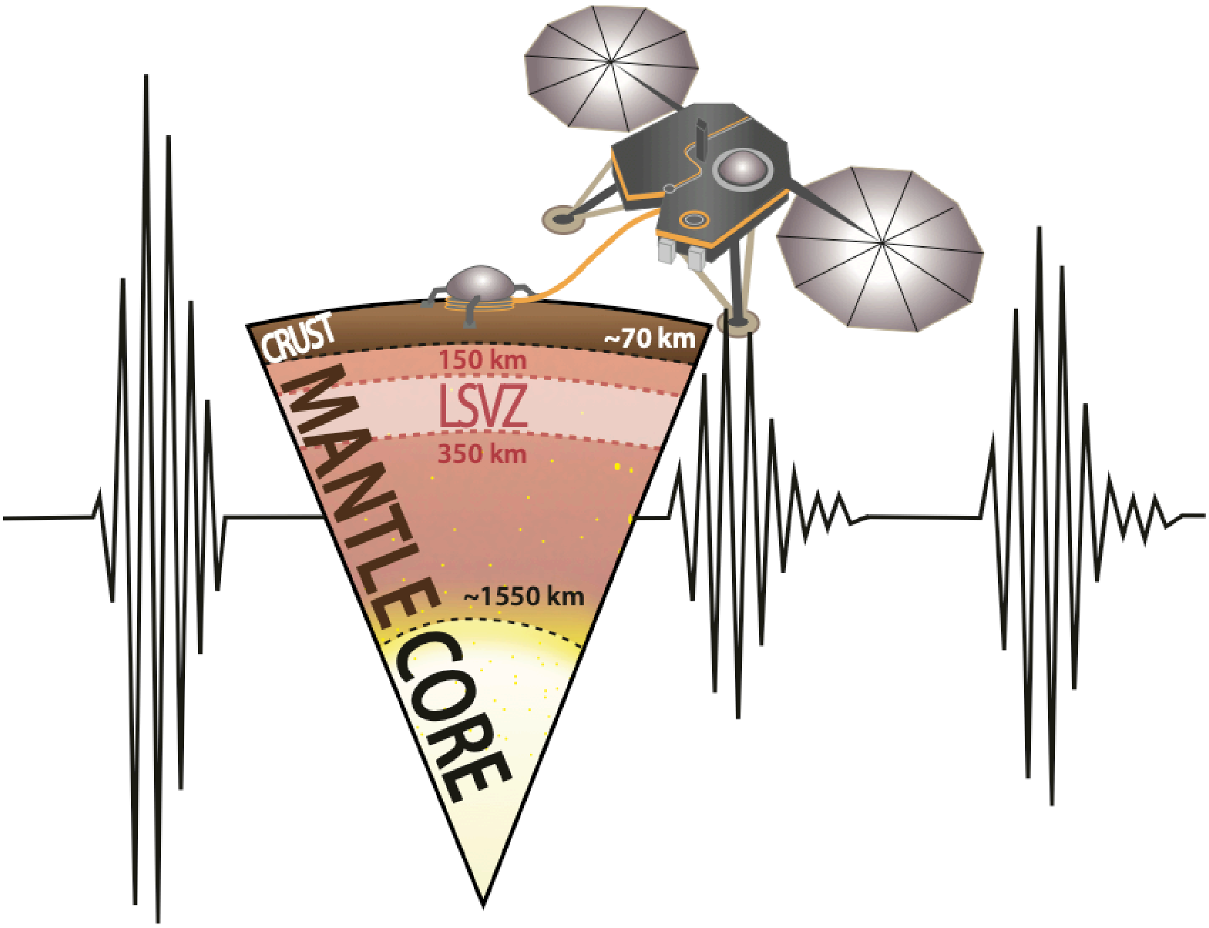
A collaborative work conducted by researchers at the Geodynamics Research Center (GRC) and Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie (IMPMC) suggest the existence of low shear seismic velocity regions between 150 and 350 km depth in Mars mantle. The experimental results presented in this study are consistent with recent observations from the InSight mission and could give important clues on Mars' mantle mineralogy and internal structure. The scientific article presenting and discussing these results was published on September 21 in the journal Geophysical Research Letters.

Since its landing on Mars in late 2018, the **InSight** (**In**terior exploration using **S**eismic **I**nvestigation, **G**eodesy and **H**eat **T**ransport) mission has been monitoring the red planet's seismic activity. To date, the deployed seismometer has recorded more than 600 distinct events, of which over 60 present characteristics that allow interpreting them as relatively distant quakes. Around ten of these latter carry information of Mar's interior (Knapmeyer-Endrun et al., Science 2021; Khan et al., Science 2021; Stähler et al., Science 2021). Interpretation of seismic observations and inversion of P- and S-wave velocities in terms of planetary structure and mineralogical composition requires the knowledge of the physical properties of the minerals and rocks constituents, at the relevant pressure and temperature conditions. These data are however still scarce for materials and aggregates expected to comprise the Martian mantle, especially lacking high-temperature sound velocity measurements.

The researchers at IMPMC, co-investigators and collaborators of the InSight Mission, investigated the nature and abundance of the mineral phases stable at Martian mantle P and T conditions. They used a laser levitation furnace to fabricate unique glass starting materials under various oxidation states representing some possible redox of Mars' mantle. These glasses were then compressed and heated in a multi-anvil apparatus, at pressure and temperature conditions that approach those of Mars's interior. Analysis of equilibrium mineralogy revealed the stability of magnetite, an Fe^{3+}-rich mineral not reported in previous studies but a likely candidate in Mars' oxidized mantle environment.

The researchers at GRC conditioned these Martian rock samples and prepared devices for the ultrasonic experiments. The compressional (VP) and shear (VS) velocities, as well as the density of the synthesized Martian rock aggregates were then investigated in Japan, within the framework of the **P**remier **R**esearch **I**nstitute for **U**ltra-high **P**ressure (**PRIUS**) program at GRC. The joint GRC-IMPMC team conducted together, several high-pressure experiments using a combination of ultrasonic techniques and a large volume press apparatus at the beamline BL04B1 in SPring-8 (Hyogo, Japan). The obtained data allowed researchers to propose forward velocity and density profiles that provide guidance to the interpretation of InSight seismic observations .

In particular, the measured pressure and temperature derivatives of VP and VS, once coupled with predicted areotherms (pressure and temperature profiles for increasing depth within Mars) showed a clear temperature-induced reduction of seismic wave speeds between 150 and 350 km depth. The reduction is particularly large for shear velocities (VS) and would dominate over pressure-induced effects at Mars' shallow mantle conditions for all the predicted areotherms. Interestingly, the existence of such low-shear-wave-velocity layer would be independent from mineralogy as revealed by further thermodynamics modelling conducted by the study's co-authors. These findings are consistent with recent observations from the InSight mission on Mars and should greatly contribute to further constrain the Martian mantle mineralogy and thus understanding the planet's internal structure and dynamics.



Reference:

Low Velocity Zones in the Martian Upper Mantle Highlighted by Sound Velocity Measurements, 2021, Xu F., Siersch N.C., Gréaux S., Rivoldini A., Kuwahara H., Kondo N., Menguy N., Kono Y., Higo Y., Plesa A.-C., Badro J. and Antonangeli D., **Geophysical Research Letters**, In Press. doi.org/10.1029/2021GL093977

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