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Shallow Crustal Structures of Mars Beneath the InSight Landing Site Revealed by Frequency-Dependent P-wave Particle Motions

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Exploring the shallow crustal structure of Mars can offer valuable insights into the planet's geological evolution and climate history. The ambient wavefield data and marsquake records from NASA's InSight mission have enabled the characterization of both fine-scale near-surface structures (less than 200 meters) and large-scale crustal structures (greater than a few kilometers) on Mars. However, the exploration of intermediate-scale structures has remained limited. In this study, we introduce a novel varying-parameter approach that integrates principal component analysis with receiver function techniques. This method allows for the effective extraction of P-wave particle motions across various frequencies from the InSight low-frequency marsquake data, facilitating the inversion for the S-wave velocity structure within the topfew kilometers beneath the lander. Our resulting models reveal a distinct discontinuity at a depth of approximately 0.7 km, marked by a sharp increase in S-wave velocity from about 1.4 km/s to roughly 1.9 km/s. This discontinuity is characterized by a sharp transition, approximately 0.1 km thick, rather than a wider gradient zone. Our models are generally consistent with existing data on Mars' near-surface and large-scale crustal structures, effectively bridging these datasets. When combined with previous geological and seismic observations, the newly identified discontinuity may signify the top of less affected basaltic bedrock, and the overlying structures are interpreted as a composite of Noachian- to early Hesperian-aged sediments and Hesperian to Amazonian basalts. These insights provide new perspectives on the stratification at the InSight landing area, enhancing our understanding of Martian geological history.