Constraints on chemical layering of Earth's mantle from topography of the 660-km discontinuity

With the support from the National Natural Science Foundation of China and Chinese Academy of Sciences as well as Ministry of Science and Technology of China, the research team led by Prof. Ni SiDao (倪四道) at the State Key Laboratory of Geodesy and Earth's Dynamics, Institute of Geodesy and Geophysics, Chinese Academy of Sciences, found the seismological evidence of small scale topography of the 660-km mantle discontinuity, which as published in *Science* (2019, 363: 736—740).

The globally observed 660-km seismic discontinuity defines the top of the lower mantle and is commonly understood to involve the phase transition of the mineral ringwoodite to bridgmanite and ferropericlase. Several lines of evidence support the boundary being due to the phase transition alone, which leads to whole mantle convection. However, other geochemical and mineralogical lines of evidence suggest a chemical interface, which requires some sort of dominantly layered or compartmentalized convection in order to maintain chemical differences between the upper and lower mantle. Seismic waves can be used to measure many features of the discontinuity related to the physical properties at the boundary, including sharpness, density, elasticity contrast, and topographic variations.

Topographic variation provides essential clues for understanding the nature of the 660-km discontinuity. The scale of roughness on a boundary provides insight into the dynamic process responsible for the topographic variations. Previous methods reveal the large-scale (~1 000 km) topography and intermediate-scale (~100 km). In order to determine the small-scale (~10 km) topographic variations of the 660-km and the 410-km seismic discontinuities, they use the scattering of short period waves. They choose seismic waveforms at small angular epicentral distances (e. g. 0°—40°), where asymmetrical scattering waves P′ • d • P′ are readily observable. The topographic variations of the 660-km discontinuity are constrained from the amplitudes of P′ • 660 • P′.

Small-scale topography of the 660-km boundary, or a less likely thin layer of volumetric heterogeneities, would best be explained with a chemical origin. Some regions lack small-scale topography of the 660-km interface, implying a globally discontinuous chemical layer. Their observations support simulations that describe subducting slabs as transient features of the transition zone, which eventually penetrate into the lower mantle. They also support a picture of partially-blocked upper to lower mantle circulation, which effectively alternates between layered and whole-mantle convection.

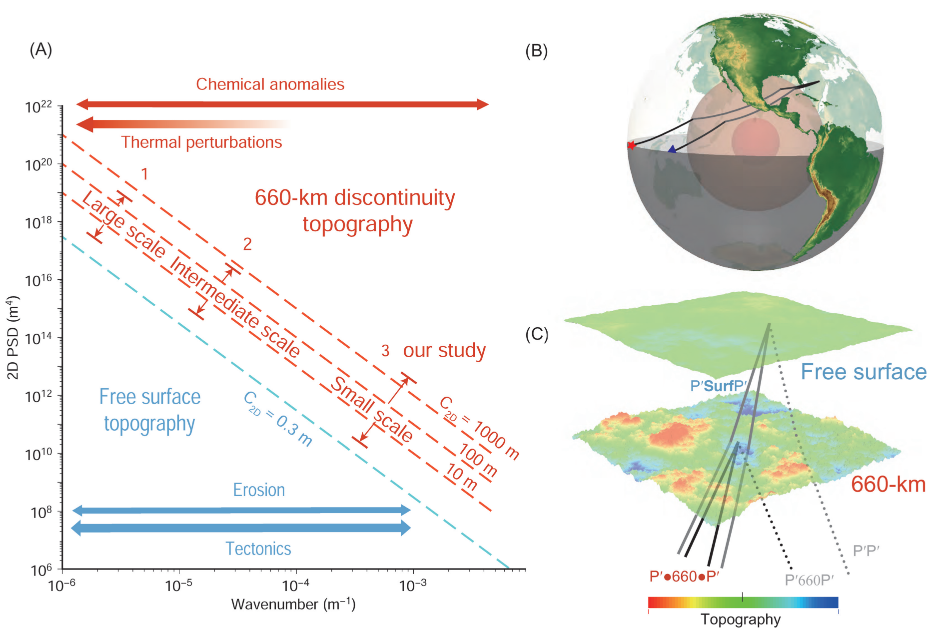

Figure Power spectral density of the free surface (ground surface) and 660-km interface as sampled by the ray path of seismic phase P'SurfP' and P′ • 660 • P′ respectively.