Imaging the Lithosphere-Asthenosphere boundary beneath circum-Pacific areas with the precursors of sP

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Lithosphere-asthenosphere boundary (LAB) is the negative upper mantle discontinuity. The lithospheric slabs with different subducting angles and velocities and stagnant slabs induce the different temperature and material anomalies into the deep Earth’ s interior, and the related dehydration and other volatiles are different in the processes, then affect the topography and characteristics of the LAB. Detecting the LAB in the Pacific subducting zone with seismic data will be helpful for understanding the interaction between the lithosphere and asthenosphere and the geodynamics of subducting slabs, and provides important geophysical parameters for recognizing the Earth’ s evolution.
The seismic waveform data recorded by the Chinese Digital Seismic Network, USArray, etc, are processed with the N-th root slant stack method to retrieve the seismic triplications or precursors of strong phases related to the LAB. The LAB is imaged and can be used to study the effects of the subducting slabs and related stagnant materials on the LAB. In the work, we found that: (1) The depth of LAB in the northern Lau Ridge is about 63 km with a range of 63 to 64 km, in the northwest is about 77 km with a range of 76 to 78 km and in the south is about 72 km; (2) The depth of LAB beneath Izu-Bonin is around between 58 and 65 km, and the average depth is 62 km; (3) In the western part of the south America, the LAB depths range between 60 and 63 km, with the average depth of 61 km and the topography of 3 km, while in the eastern part, the ones range between 78 and 82 km, with the average depth of 80 km and the topography of 9 km. We infer that the continental lithosphere may be subjected to the stronger erosions in the area near the trench, for the higher degree of partial melting and the more fertile melts in the asthenosphere; the one may be subjected to the weaker erosions in the area far from the trench, for the lower degree of partial melting and the less fertile melts in the asthenosphere.

Keywords: Lithosphere-Asthenosphere Boundary, N-th Root Slant Stack, Chinese Digital Seismic Network

Mid-lithosphere discontinuities beneath the western and central North China Craton

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We image the mid-lithosphere discontinuity (MLD) beneath western and central North China Craton (NCC) by a new approach —seismic daylight imaging (SDI), which analyzes P reflectivity extracted from stacked autocorrelograms for teleseismic events recorded by a dense array. The array across the NCC extended west-to-east for about 1000 km with average station interval of about 15 km, and was deployed by Institute of Geology and Geophysics, Chinese Academy of Sciences under North China Interior Structure Project (NCISP).

With higher and broader frequency band (0.5-4Hz) than used with receiver functions, the SDI approach reveals finer scale components of multi-scale lithospheric heterogeneity. The depth of the MLD beneath the western and central parts of the NCC ranges from 80-120 km, with a good match to the transition to negative S velocity gradient with depth from Rayleigh wave tomography. The MLD inferred from SDI also has good correspondence with the transition from conductive to convective regimes estimated from heat-flow data indicating likely thermal control within the seismological lithosphere.

Keywords: Mid-lithosphere discontinuity, Seismic daylight imaging, Autocorrelogram

Measurements of Rayleigh wave particle motions beneath the Japanese islands: Implications for the crust and uppermost mantle structures

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The amplitude ratio of horizontal and vertical components of Rayleigh waves can be used to investigate the relatively shallow Earth structure, such as the crust and uppermost mantle. Most of the earlier studies using surface wave are primarily based on the measurements of phase and/or group speed dispersion, and the Rayleigh wave ellipticity (or H/V ratio), which is more sensitive to shallow subsurface structure, has rarely been applied to the construction of the large-scale velocity structure. It has been well-known that such H/V ratios can be used to infer the internal structure of the Earth, but the spatial distribution of the H/V ratios of long-period Rayleigh waves with dense seismic arrays has yet to be investigated.
In this study, we analyzed the H/V ratios of intermediate to long period (30 –200 s) Rayleigh waves for all stations of the Japanese broadband seismic network (F-net), and discuss their relation with the crust and upper mantle structure beneath the Japanese islands.
The frequency-dependent variations of observed H/V ratios for each station are relatively mild. This reflect that the H/V ratios of Rayleigh waves are far more sensitive to the near surface structure irrespective of frequency even in the long period. Still, some slight changes in H/V ratios as a function of frequency can be observed, which is likely to reflect the large-scale structure in the uppermost mantle, since the sensitivity kernels of H/V ratios have a secondary peak below the Moho. Our results show that the observed H/V ratios in the shorter period than 60 s become larger than the regional average, particularly in the south of Hokkaido, the south of Kyushu and Kanto areas, while those in the south-western Japan show relatively smaller values. In general, high H/V ratios can be found in a region with strong vertical velocity gradients; for example, sedimentary areas above relatively fast velocity bedrock. Our results reflect such features well in shorter period range, and also coincide well with the velocity anomalies in the upper crust based on ambient noise analysis (Nishida et al., 2008); i.e., high H/V ratios in slow velocity regions, and low H/V ratios in fast velocity regions. In the longer period at around 100 s, the H/V ratios become large in Tohoku and Kyushu areas, just above the subducting plates. This may reflect the effects of secondary peak of the sensitivity profile of Rayleigh wave ellipticity. These results indicate that the Rayleigh wave ellipticity has a good potential to constrain the crustal and uppermost mantle structure, if we use them in conjunction with the conventional phase speed data.

Structural Variations of Inner Lithospheric Discontinuities beneath the North China Craton: Implications of the craton stability and destruction

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The North China Craton (NCC), namely the Sino-Korean Craton, is one of the ancient Archean cratons with the crust rocks as old as ~3.8 Ga. Similar to other Archean cratons worldwide, the western part of NCC has retained its cratonic nature and stability over long periods of geological time, and presently is characterized by a thick and cold root with a negative mid-lithosphere discontinuity (MLD) marking the vertical heterogeneity of the mantle lithosphere. However, the detailed structural features of the MLD and the related low-velocity layer (LVL) below remain unclear. On the other hand, the eastern NCC has experienced server destruction since Mesozoic, as manifested by the transformation from a thick, cold and refractory lithosphere in the Paleozoic to a thin, hot and fertile one in the Cenozoic. Thus the NCC is an ideal laboratory to investigate the influences of the MLD on the evolution, particularly destruction of cratons.

The implementation of numerous portable seismic array observations in the past two decades within the NCC makes it possible to obtain more high-resolution images of the deep structure of the region than ever. In this study, we used the seismic data from 8 linear portable arrays of densely-deployed stations and the network of ~300 permanent stations within the NCC and surrounding areas to image the elaborate lithospheric structure with various seismological methods. Our results show that a negative MLD and an underlying LVL widely exists within the mantle lithosphere of the Ordos Block, namely the cratonic nuclei of the western NCC. The depth of the MLD varies mainly in the depth range of 80-120 km, uncorrelated with the depth variations of the Moho and LAB. An obvious deepening of the MLD and the LVL was observed beneath the orogenic belts surrounding the Ordos Block, which may reflect the modification of the lithospheric mantle structure by the associated orogenic processes. The depth of the MLD beneath the Ordos Block is comparable to that of the LAB in the eastern NCC where the lithosphere has been thinned and destroyed. Based on this observation, we propose that the MLD and the LVL may have acted as a mechanical weak layer in the lithospheric mantle, facilitating the destruction of the eastern NCC. Finally, we also observed a LVL in the mid-crust of the Ordos Block. It may be another clue to decipher the evolution of the craton.

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Keywords: North China Craton, Mid-Lithosphere discontinuity

Lithospheric structures beneath Chinese Mainland: Insights from S receiver functions

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A rigid lithosphere floating over the viscous asthenosphere is the basic model of continental drift. The displacement of lithosphere-asthenosphere boundary (LAB) provides important clues of lithospheric deformation. However, because the LAB is not a sharp discontinuity but marked in many places by a smooth velocity gradient, it is difficult to determine the precise depth of LAB with body waves. It can be also complicated by another relatively sharp discontinuity, named as mid-lithosphere discontinuity (MLD), which may result from deformation at mineral grain boundaries (Karato et al., 2015).
The Chinese Mainland is tectonically shaped in the Cenozoic by the collision with the Indian plate on its southwestern side and the subduction of the Pacific and Philippines oceanic plates on the eastern side. Investigation of the LAB under mainland China can help us understand its geodynamic evolution and the mechanism controlling intraplate seismicity and volcanism in China.
We have integrated the dataset from ~1000 permanent seismic stations of the Chinese seismic network and dataset from ~700 stations of IRIS in west China to obtain more than 300 thousands S receiver functions. We use these results to investigate the lithospheric structures beneath the Chinese mainland. The preliminary results indicate a low velocity layer between 60~150 km, which represents the LAB or MLD. The results show clear differences of the crustal and lithospheric structures between east and west China, the deformation of LAB between different blocks, the subduction of India Plate, the depth variations of LAB and the relationship between LAB and the seismicity of strong earthquakes. We will discuss the implications of these results on the Cenozoic tectonic evolution in mainland China. This work is supported by National Natural Science Foundation of China (Grant 41274093 and 41574077) and the Basic Research Project of Institute of Earthquake Science of CEA (Grant 2014IESLZ03).

Keywords: lithosphere-asthenosphere boundary, S receiver functions, Chinese mainland, mid-lithosphere discontinuity

Lithospheric thinning in the Cathaysia block (South China) from joint inversion of receiver function, surface wave dispersion, and P-wave velocity

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Cratons are stable geological blocks, whose thickness is typically more than 200 km. However, the lithosphere in the North China Craton is believed to have been modified since Mesozoic. More recent geochemical studies show that the lithosphere in eastern China has been destructed. Nevertheless, the study of the lithospheric structure in the Cathaysia block (South China) is rare. In this study, we use a new joint inversion method to focus on the lithospheric structure below a dense seismic array in the Cathaysia block, where the P-wave receiver functions, surface wave dispersions, and P-wave velocity are available. The layered S velocity and Vp/Vs ratio are obtained simultaneously. The thin lithospheric thickness (60-70 km) is comparable with the thickness in eastern North China Craton, which provides clear evidence of lithospheric thinning in the Cathaysia block. The low S velocity and high Vp/Vs in the middle crust indicate possible partial crustal melting. The lithospheric thinning and the consequent crustal melting could be possible reason for the widely distributed granitoids in South China.

Keywords: Lithospheric thinning, Joint inversion, South China, Partial melt

Velocity structure of the mantle transition zone beneath the southeastern Tibetan Plateau

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P-wave triplications related to the 410 km discontinuity (the 410) were clearly observed from the seismograms of three intermediate-depth earthquakes that occurred in the Indo-Burma Subduction Zone (IBSZ) and were recorded by the Chinese Digital Seismic Network (CDSN). By comparing the observed triplications with synthetic waveforms, we obtained the best-fit models for four azimuthal profiles to constrain the P-wave velocity structure near the 410 beneath the southeastern Tibetan Plateau (TP). We find that there is a ubiquitous low-velocity layer (LVL) atop the mantle transition zone (MTZ). The LVL is characterized by a thickness of 35-45 km, and the P-wave velocity decreased by up to 4.1-4.7%. We attribute the LVL to the partial melting induced by water or other volatiles released from the subducted Indian Plate and the stagnant Pacific Plate. A high-velocity anomaly of up to 1% is detected at a depth of 500 km, providing additional evidence for the remains of the subducted Pacific plate within the MTZ. There is a clear transition in the velocity decrement and the depth of the 410. We therefore infer that the mantle structure beneath the southeastern TP is primarily controlled by the southeast extrusion of the Plateau to the north, combined with the eastward subduction of the Indian Plate to the south.

Keywords: seismic triplication, low-velocity layer, mantle transition zone, southeastern Tibetan Plateau

