Multi-scale Structure and Lithospheric Discontinuities

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The continental lithosphere is heterogeneous on a wide variety of scales and apparent seismic discontinuities arise from the interaction of the seismic wavefield with multiple-scale features. In consequence the character of such discontinuities is frequency-dependent. Nevertheless it is possible to track discontinuities within the lithosphere across closely spaced stations exploiting P-wave reflectivity extracted from stacked autocorrelograms at each receiver.
Although most inference of finer-scale structure is indirect, corroborative evidence comes from the geochemistry of xenoliths across southeastern Australia. There is a close correspondence between changes in chemistry and P-wave reflectivity in the neighbourhood of the xenoliths.

Keywords: Lithospheric Heterogeneity, Lithsopheric Discontinuities

Imaging Lithospheric Seismic Discontinuities beneath Cascadia using S-to-P Receiver Functions

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Strong, sharp seismic discontinuities in the 60 –110 km depth range are now frequently imaged and sometimes related to the lithosphere-asthenosphere boundary. However, determining the exact relationship has proven challenging, and interpretations diverge particularly between the continents and the oceans. Here we use S-to- P receiver functions recorded by the Cascadia Ocean Bottom Array and the western most Transportable Array to image crust and upper mantle discontinuity structure beneath the Juan de Fuca and Gorda Oceanic Plates and western North America. We handpick events from epicentral distances 55 –80 degrees away, choosing 5021 waveforms of which 343 are from ocean bottom seismometers. We use an extended time multi-taper technique to deconvolve the waveforms and migrate to depth in 3-D. We image a positive phase, or velocity increase with depth, that corresponds to an oceanic Moho at 6 –7 km depth and a continental Moho at 33 –37 km depth. We also image a negative discontinuity beneath the ocean plate that thickens with age from 25 –45 km depth beneath the oceans in general agreement with expectations from half-space cooling. Waveform and geodynamic modelling indicate that these are defined by melt. This suggests that melt exists at the base of the plate, defining it, and that melt is likely transported along the base of the plate towards the mid-ocean ridge. In addition, we image a deeper discontinuity at 55 –75 km beneath the continental lithosphere also likely related to the lithosphere-asthenosphere boundary.

Keywords: lithosphere-asthenosphere, seismic, receiver function, Cascadia, melt, ocean plate

Moho Depth Variations in the northeastern North China Craton Revealed by Receiver Function Imaging

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The North China Craton (NCC), one of the oldest cratons in the world, has attracted wide attention in Earth Science for decades because of the unusual Mesozoic destruction of its cratonic lithosphere. Understanding the deep processes and mechanism of this craton destruction demands detailed knowledge about the deep structure of the region. In this study, we used two-year teleseismic receiver function data from the North China Seismic Array, which consists of ~200 broadband stations deployed in the northeastern NCC, to image the Moho undulation of this region. A 2-D wave equation-based poststack depth migration method (Chen et al., 2005) was employed to construct the structural images along 19 profiles, and a pseudo 3D crustal velocity model of the region based on previous ambient noise tomography and receiver function study was adopted in the migration. We considered both the Ps and PpPs phases, but in some cases we also conducted PpSs+PsPs migration, analyzed images using different back azimuth ranges of the data, and calculated the theoretical travel times of all the considered phases to constrain the Moho depths. By combining the structure images along the 19 profiles, we got a high-resolution Moho depth map beneath the northeastern NCC. Generally, the Moho depths are distinctly different on the opposite sides of the North-South Gravity Lineament. The Moho in the west are deeper than 40 km and shows a rapid uplift from ~40 km to ~30 km beneath the Taihang Mountain Range in the middle. To the east in the Bohai Bay Basin, the Moho further shallows to ~30-26 km depth and undulates by ~3 km, coinciding well with the depressions and uplifts inside the basin. The Moho depth beneath the Yin-Yan Mountains in the north gradually decreases from ~42 km in the west to ~35 km in the east, varying much smoother than that to the south. Our results broadly consist with the pattern of previous active source studies [http://www.craton.cn/data], and show a good correlation of the Moho depths with geological and tectonic features. We systematically compared our results with other seismic observations and discussed correlations of Moho depths with lithospheric thickness, seismic anisotropy, surface geology, reginal tectonics, and gravity anomaly as well as petrographic and geochemical data in detail. Furthermore, we discussed possible mechanisms accounting for fundamental destruction of the NCC lithosphere in Late Mesozoic.

Keywords: Moho discontinuity, North China Craton, Lithospheric destruction, Receiver function imaging

A Detailed Look at Pn Phases in the Western Pacific: Local Reverberations versus Scattering in the Deeper Lithosphere

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Oceanic Pn or Po phases propagate efficiently in old Pacific lithosphere. Their ability to propagate hundreds of km up a subducting slab and then travel thousands of km horizontally within the lithosphere while retaining their high frequency content indicates that there are strong, semi-horizontal heterogeneities within the plate that scatter and guide the waves (e.g., Kennett and Furumura, 2013). However, it is clear that reverberations within the water column and sediments contribute significantly to the coda of Po. In an attempt to sort out the relative contributions of local reverberations and lithospheric scattering to the coda, we examine in detail the waveforms of Po phases recorded on an array of ocean-bottom seismometers on 150-160 Ma seafloor south of Shatsky Rise. We separate Po into the upgoing and downgoing components by combining vertical and pressure records. Then stacking the auto- and cross-correlations of upgoing and downgoing records from many earthquake sources reveals the local reverberatory response. We model the stacked correlograms to infer local sediment/crustal structure using a reflectivity method. Reflections at the base of the sediments are just as important as reflections at the seafloor, but coherent multiple reflections are almost undetectable. Despite the relatively flat seafloor, changes in the stacked correlograms with back azimuth from individual stations indicate that variations in local sediment structure play a key role in randomizing the local response and minimizing coherent reverberations.

Keywords: Pn coda, Oceanic lithosphere

Microstructural & geochemical evolution of the deep arc lithosphere: implications for seismic discontinuities beneath continents

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Lower crustal and upper mantle xenoliths provide the only direct samples of deep lithosphere, and therefore play an essential role in understanding lithospheric structure. We examine the microstructural and geochemical evolution of peridotite xenoliths from the Sierra Nevada, a Mesozoic continental arc. These xenoliths represent an arc mantle column grading from depleted spinel peridotite characterized by strong orthorhombic olivine LPO to fertile garnet peridotite with weak axial-[010] LPO. In contrast to observed nominally dry axial-[010] LPO, intragranular olivine microstructures indicate deformation under hydrous conditions (in which the (001)[100] system is dominant). However, water contents in olivine are too low to account for E-type fabric. These seemingly contradictory results can be reconciled in the context of the Sierran peridotites' P-T-t path, which was found to consist of initial lithosphere formation via melt depletion at shallow (<2 GPa) depths followed by thickening, modal metasomatism (involving a hydrous melt), and final equilibration and rapid cooling (~5 My) at deep (>3 GPa) and cold (750 –800 C) conditions. We propose that melt infiltration and associated precipitation of fine-grained pyroxene and garnet facilitated grain-size sensitive creep, localizing deformation in fine-grained regions and resulting in weak, axial-[010] LPOs in the most metasomatized peridotites. So, even though (001)[100] slip may have been the dominant active slip system, E-type fabrics were not produced because the overall LPO was dominated by grain-size sensitive creep promoted by presence of melt. Subsequent cooling resulted in water loss from olivine owing to the drastic lowering of solubility with decreasing temperature. However, final temperatures were too low (750 C) to enable significant deformation –effectively preserving the relict intragranular (001)[100] microstructures. Our study has implications for seismic structure of subduction zones globally. We show that overriding plate lithosphere –an often overlooked aspect of the subduction system –is stratified in terms of composition and fabric. The transition from orthorhombic E-type to weak axial-[010] fabrics results in a significant decrease in Vp anisotropy. Seismic anisotropy in subduction zones is complex, and thus the interplay between compositional gradients and cooling histories of mantle lithosphere need to be considered when interpreting subduction zone structure.

Keywords: subduction, peridotite, xenolith, LPO

Layered anisotropic structure of the Huatung Basin oceanic lithosphere offshore eastern Taiwan

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We analyze ambient noise of continuous seismic waveform data recorded by ocean-bottom seismometers (OBS) deployed in the Huatung Basin and adjacent regions off the east coast of Taiwan. Taiwan is a young and active orogenic belt resulting from the oblique subduction and collision between the Eurasian Plate and the Philippine Sea Plate. Sitting on the westernmost edge of the Philippine Sea Plate, the Huatung Basin is directly involved in the subduction-collision processes. The structural characteristics of the lithosphere provide important constraints not only on its own history but the tectonic evolution in this complex region. We integrate data from OBS with those from land stations along the east coast of Taiwan to derive Rayleigh wave Green’ s functions from cross-correlation between all available station pairs, covering the majority of the Huatung Basin. We measure phase velocity dispersion at periods from 4 to 20 sec, and invert for 2-D anisotropic phase velocity maps based on a wavelet-based multi-scale inversion scheme. Our results reveal a distinct period-dependent variation in anisotropy. At periods of 4-8 s, the anisotropy is generally weak and the fast direction is aligned in N-S direction. In contrast, at periods of 12-20 s, stronger anisotropy is observed with fast direction in NW-SE. The N-S anisotropic pattern reflects characteristics at crustal depths, and is consistent with magnetic lineation suggesting past basin spreading direction. Therefore, what we observe is likely the fossil anisotropic fabric created during the development of the ocean basin. On the other hand, the mantle lithosphere is dominated by NW-SE anisotropy, a direction sub-parallel to that of the convergence between the Philippine Sea Pate and the Eurasian Plate. The coincidence implies that the Huatung Basin’ s mantle lithosphere is under the influence of asthenospheric flow induced by the plate motion of the Philippine Sea Plate.

Keywords: seismic anisotropy, ambient noise, ocean-bottom seismometer, Huatung Basin, Philippine Sea Plate, Multi-scale wavelet inversion

