Scandinavian Lithosphere Structure derived from Surface Waves and Ambient Noise

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The Scandinavian mountain chain runs approximately parallel to the western coast of Norway with topography up to 2500 m. Since this region lacks recent compressional tectonic forces, we can study the geodynamic evolution of crustal and upper mantle structures which were once participating in continental collision and are now deeply eroded. Together with the ScanArray network we use data from previous and permanent projects, in total more >220 stations, for a surface wave tomography of entire Scandinavia using both earthquake and ambient noise data.

Initially, we performed a beamforming of Rayleigh surface waves which yielded average phase velocities for the study region and several of its sub-regions. However, a remarkable sin(1Θ) phase velocity variation with azimuth is observed in northern Scandinavia and southern Norway/Sweden but not in the central study area. For periods >35 s a 5% deviation between the maximum and minimum velocities was measured for opposite backazimuths of 120° and 300°, respectively. Such a variation is incompatible with azimuthal anisotropy or weak heterogeneity and might be caused by an eastward dipping lithosphere-asthenosphere boundary (LAB), as is implied by the observations of low shallow velocities below southern Norway in previous studies.

In order to test this hypothesis, we carried out 2D full-waveform modeling of the Rayleigh wave propagation in a model with a steep gradient in the LAB in combination with a pronounced reduction in the shear velocity below the LAB. This setup resulted in faster phase velocities for propagation in the direction of shallowing LAB, and slower ones for propagation in the direction of deepening LAB, consistent with the observation. This effect is probably due to the interference of reflected surface wave energy.

From this observed azimuthal bias, we demonstrate that an isotropic distribution of earthquakes is vital for the tomography results, otherwise significant velocity artefacts occur.

Phase velocity maps were derived with the two plane wave method. We merge those ballistic surface wave observations at longer periods with tomographic maps constructed from inter-station phase velocities measured on ambient noise stacks. Finally, we use a 1D transdimensional
Bayesian method to invert the merged phase dispersion curves at each grid point for the $V_{SV}$ structure. Below the entire mountain belt a crustal root is absent consistent with previous studies. The Lofoten peninsula shows very low crustal and lithospheric $V_{SV}$ with a shallowing Moho towards the continental margin. The LAB is deepening from west to east with a sharp step both in the South (120 km depth) and the North (150 km depth). A high-velocity spot above the LAB in the North can be related to a gravity anomaly. The central area shows rather smooth varying structures from west to east. Additionally, we find low-velocity areas below 150 km depth beneath the Paleoproterozoic Baltic Shield in northern Finland. The sharp gradients in the LAB imaged in southern and northern Scandinavia are consistent with our $\sin(1\Theta)$ phase velocity variation with azimuth whereas the smoother velocity structure in the central study area explains the absence of $1\Theta$ phase velocity variations there.