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SEISMIC EXPLORATION WITHOUT EARTHQUAKES FROM LOCAL TO GLOBAL SCALE: TURNING SEISMIC NOISE TO SIGNAL

Deep internal structure of the Earth has been explored using earthquakes. Seismic waves in cold and stiff regions travel faster than those in hot and soft ones. Can we infer them without earthquakes? Yes. A method of seismic exploration without earthquakes, known as "seismic interferometry," has been developed in ten years. This method utilizes ambient vibrations recorded by seismometers, which were recognized as noise for earthquake observations.

The ambient noise consists of background seismic surface waves (Rayleigh and Love waves). They are excited by ocean swells at random in a frequency range from 0.005 Hz to 0.5 Hz. At low frequency around 0.01 Hz, they are also known as seismic hum, whereas at a higher frequency around 0.1 Hz, they are also known as microseisms. Their wavefields are so complicated that seismic exploration using the ambient noise seems to be difficult. However, a simple statistical processing of seismograms, cross-correlation analysis, enables us to explore the Earth's internal structure.

A cross-correlation function between a pair of stations exhibits an impulse response between them. The method is known as seismic interferometry. One origin of this method is day back to Aki's pioneer work in the 1950's, when he was at ERI. At that time, the method was applied for shallow (at depths of several meters) structure of the playground at the University of Tokyo. The method is revived in 2000's using modern dense networks of seismometers.

Our groups succeeded in imaging from local to global scales: (1) the structure beneath Mt. Asama: the magma chamber at a depth of about 5 km west of the summit, (2) the crustal structure beneath the Japan islands and (3) global upper mantle structure as shown in the figure.

This method has potential application for seismology on other planets. Although the Mars is expected to be tectonically inactive, seismic waves excited by atmospheric disturbances may probe the internal structure in the near future.

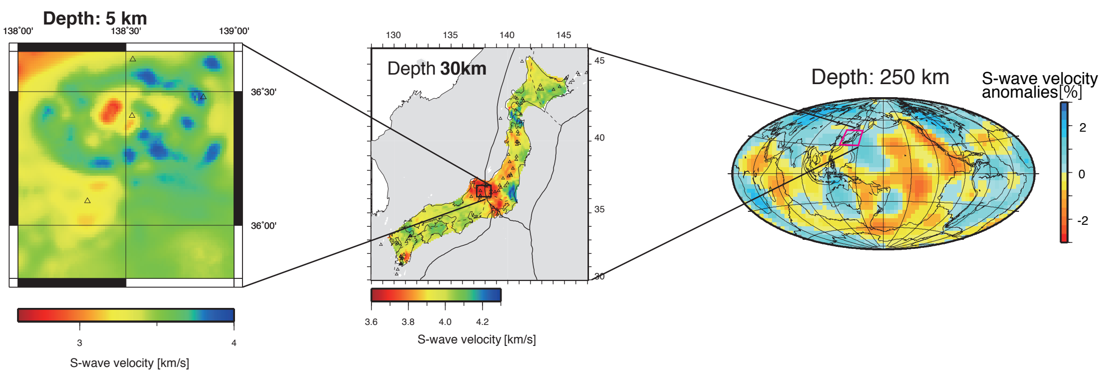
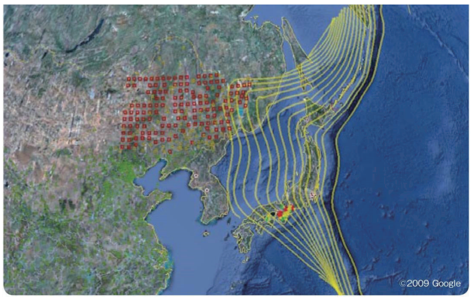
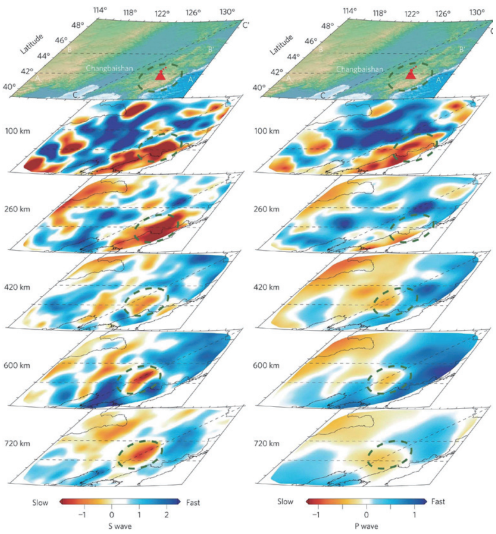


Figure: Maps of S-wave velocity structures at depths from local to global scale: (1) the structure beneath Mt. Asama: the magma chamber at depth of about 5 km west to the summit, (2) the crustal structure beneath the Japan islands, and (3) global upper mantle structure.

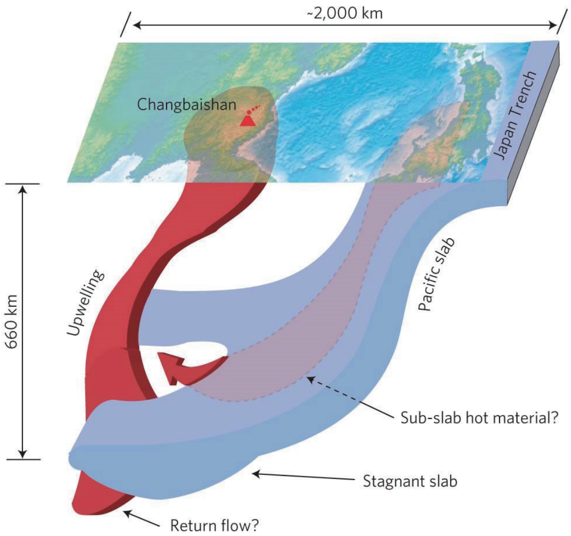
NECESSARRAY PROJECT: DYNAMICS OF EARTH INTERIOR SEEN FROM NORTHEAST CHINA



(1) Stations of NECESSArray are indicated by red. Yellow iso-depth contour lines show the trace of subducting Pacific slab.



2) S- and P-wave tomographic models. Changbaishan volcano is indicated in the map. Broken line circles trace the suggest conduit-like upwelling.



(3) Cartoon showing a possible scenario to associate the deep Pacific slab subduction and the upwelling, and the off-arc intraplate volcanism.

We have conducted, together with Chinese and U.S colleagues, a temporal deployment of over 120 broadband seismometers in northeast China (NorthEast China Extended SeiSmic Array, NECESSArray) from September, 2009 till August, 2011. NECESSArray covers the area about 600x1200km^2 and the largest such temporal deployment conducted by one research group. The purpose of the project is manifold: (1) elucidating the origin and dynamics of Chinese continent, (2) resolving the fate and role of Pacific stagnant slab beneath NE China, (3) probing deep earth's interior (CMB, core) using NECESSArray.

One of the biggest surprises was the finding of a gap (or absence) of the stagnant slab in the mantle transition zone beneath NE China, where previous tomographic models indicated the presence of a horizontally laying slab. Considering that Changbaishan (also known as Baitoushan) volcanic region, the largest currently active magmatic center in northeast China and a puzzling off-arc intraplate volcano, is located just east of this gap of the stagnant slab, we proposed their connection. Indeed both P- and S-wave tomographic models show consistently a slow region in the transition zone, and particularly the S-wave model shows a conduit like low-velocity anomaly connecting the gap and Changbaishan.

This result was recently published in Nature Geoscience.

High-quality recording of NECESSArray data was also used to reveled a detail heterogeneous structure of the core mantle boundary (CMB) and the inner core (the deepest part of the earth). While the project team is currently summering the results of data analysis in more than ten scientific papers, the NECESSArray data have become available to the scientific community from the Data Center of the Ocean Hemisphere Research Center of ERI (http://ohpdmc.eri.u-tokyo.ac.jp/).