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論 文 内 容 要 旨

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学位論文の 題　　　名	Characterization of heterogeneity in the lithosphere of the globe from transverse amplitude analyses of teleseismic P-waves （遠地Ｐ波のトランスバース振幅解析から推定される リソスフェアの不均質性の特徴）		

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Abstract

Heterogeneous structure of the lithosphere has been extensively studied using seismic waves generated by natural earthquakes and man-made sources to obtain precious knowledge on the dynamics and evolution of the earth. Seismic tomography techniques, refraction/reflection analyses and receiver function analysis have determined spatial variations of seismic wave velocities in the lithosphere with global or regional scales. However, the spatial resolutions obtained by tomography are generally in a few tens of kilometers, and the other two approaches suppose layered structures neglecting 3-D heterogeneity. Seismic coda wave analyses have stochastically characterized small scale heterogeneity of the crust and/or upper most mantle. However, the analyses are generally restricted in a regional scale so that few systematic global distribution of the heterogeneity has been examined by coda wave analyses. In the present study, we analyze transverse amplitudes in teleseismic P-waves which mainly originate from 3-D medium heterogeneity and are insensitive to layered structure. We analyze teleseismic P-waves not only from deep earthquakes but also from shallow earthquakes that can be recorded around the world in order to systematically characterize the lithospheric heterogeneity of the globe.

We use records of broadband seismic data from IRIS GSN network deployed around the world.

A total of 3378 bandpass filtered seismograms with high signal to noise ratio of $\geq$10 collected at 72 IRIS GSN stations contributes to the analysis. For each earthquake-station pair, we extract the three-component seismograms of the teleseismic P-waves for 10, 20 and 30 second from their onsets, respectively. We calculate the energy partition of direct P-wave and its coda into the transverse component and take its root mean square amplitude. We further average all the amplitudes over events at each station and call this hereafter "normalized transverse amplitude", which are calculated for the frequency bands of 0.5-1 Hz, 1-2 Hz and 2-4 Hz.

We first analyze transverse amplitude of teleseismic P-waves from deep (depth>300 km, *M*:5-7, period:1987-2000) and shallow (depth<35 km, *M*:5-6, period:1998-2002) earthquakes observed at stations in the western Pacific regions. Although source time functions of shallow earthquakes are much complicated, the normalized transverse amplitude of shallow earthquakes for each station is nearly equal to that of deep earthquakes. This strongly suggests that the normalized transverse amplitudes of teleseismic P-waves from shallow earthquakes are mainly affected by the heterogeneous structure beneath the stations and not by near around the source heterogeneity. Hence, we analyze teleseismic P-waves from shallow earthquakes to systematically evaluate the heterogeneity of lithosphere of the globe, because a lot of shallow earthquakes occur around the world.

We survey spatial variation of the normalized transverse amplitudes in the Eurasian continent and western Pacific regions, the American continents, the African continent and Antarctica. In the Eurasian continent and western Pacific regions, most of large normalized transverse amplitudes are observed at stations located on tectonically active regions such as along the Arabia-Eurasia plate boundary, the collision zone of the Indian and Eurasian plates, and along the island arcs in the western Pacific. Stations on the southern part of China and a polar station on an island located on the north Atlantic ridge-transform system also indicate large normalized transverse amplitudes. Small normalized transverse amplitudes are observed in mid Eurasia and Australia, which are tectonically quiet regions on stable continents. In the North and South American continents, large normalized transverse amplitudes are observed along the transform faults and the subduction zones distributed along the western coast. The southern, central and northern parts of North America including eastern South America also indicate large normalized transverse amplitudes. Small normalized transverse amplitudes dominate in eastern North America. In the African continent, large normalized transverse amplitudes are found along the rift valley. Small normalized transverse amplitudes dominate on the rest of the continent including Saudi Arabia. In Antarctica, large normalized transverse amplitudes are found at the South Pole station and in the western Hemisphere. Small normalized transverse amplitudes locate at stations in the eastern Hemisphere. These results indicate some correlations between the normalized transverse amplitudes and the tectonic settings of stations.

To quantitatively discuss the normalized transverse amplitudes with the tectonic settings of stations, we examine the seismic activity around each station. We evaluate the seismic activity by counting the number of shallow earthquakes (depth≤100 km, $M\geq5$) within 300 km distance from each station for the past 30 years from 1973 to 2003. We find that seismically active regions are always characterized by large transverse amplitudes. On the other hand, in tectonically inactive regions where the seismicity is low, both of large and small normalized transverse amplitudes are observed. This implies that the normalized transverse amplitudes are able to detect lithospheric heterogeneity that is not attributed to recent seismic activity which is often used for characterizing the tectonic settings. Using the relation between the normalized transverse amplitudes and seismic activities, we classify the lithospheric heterogeneity into fours categories: Category A is the region with low seismicity and small normalized transverse amplitude; Category B is the region with low seismicity but large amplitude; Category C is the region with high seismicity and large amplitude; Category D is the region with highest seismicity and large amplitude.

We further discuss the origins of the heterogeneity around stations classified into Category B. Several plausible candidates are related to the large normalized transverse amplitudes at low seismic activity regions: (1) small numbers of earthquakes of $M\geq5$ around stations (ENH, TLY, ULN in western Pacific regions, FURI and KMBO in Africa, CPUP, LPAZ in South America and PMSA in Antarctica); (2) microseismicity of $M\geq3$ around stations (ALE and HKT in North America, XAN in south of China); (3) Holocene volcanoes (close to MDJ in east of China); (4) very low Bouguer gravity anomaly around station (BDFB in Brazil); (5) thick sedimentary layer (HKT in Texas, United States and ENH in south of China). However, no seismic or volcanic activities as well as other specific anomaly in the structure are recognized at 3 stations (BILL in Russia, FFC in Canada and SPA at South Pole). The origins of heterogeneity around these stations are still unknown but may be related to ancient activities of the lithosphere.

We apply a theoretical scattering model based on the Markov approximation for a plane P-wave propagating through the random medium characterized by a Gaussian autocorrelation function. This model presumes an impulsive source time function, hence we analyze teleseismic P-waves from deep earthquakes occurring along the western Pacific regions. We measure the ratios of peak intensity of transverse components to that of the sum of the three components, to determine the randomness $z\varepsilon^2/a$ where ε, a, and z are the fractional fluctuation, correlation distance and thickness of the heterogeneous structure, respectively. On the assumption of z =100 km, the ratio ε^2/a are estimated to be from 0.000053 km^{-1} to 0.000549 km^{-1} at 0.5-1 Hz, 0.000060 km^{-1} to 0.001870 km^{-1} at 1-2 Hz, and 0.000084 km^{-1} to 0.001796 km^{-1} at 2-4 Hz, which are in good agreement with the results of previous studies using different methods.

Although the ratios of peak intensity are not measurable for the teleseismic P-waves from shallow earthquakes because of complicated source time function, the root mean square of the ratios of peak intensities measured from deep earthquakes are proportional to the normalized transverse amplitudes for the data of western Pacific regions. This strongly suggests that the normalized transverse amplitudes from shallow earthquakes, which are well correlated with the normalized transverse amplitudes of deep earthquakes, can be used for estimating the randomness $z\varepsilon^2 / a$.

We compare our results with the spatial distribution of heterogeneity from previous studies to discuss the structure of the lithosphere and to understand the dynamics of the earth. The consistency between the spatial distribution of the normalized transverse amplitudes with Lg coda Q variation in five different continents and global S-wave velocity perturbation at 80 km depth suggests that the heterogeneity extends from shallow crust to upper mantle.

The present study has succeeded in systematically evaluating the heterogeneity of lithosphere on the globe by analyzing teleseismic P-waves of shallow earthquakes, and discussed the spatial distribution with tectonic settings. Applying the method used in the present study to dense seismic network data in various tectonic settings will deepen our knowledge on the lithospheric structure as well as the properties of seismic scattering waves from heterogeneity.