What causes the spatial variation in long-period strong ground motions within a sedimentary basin?

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The 2003 Tokachi-oki earthquake (Mw8.0) and the 2004 Kii-hanto-nanto-oki earthquake (Mw7.5) left recordings of long-period (several seconds to 20 s) strong ground motions (LPGM) at many stations of the K-NET, the KiK-net, and other strong-motion networks. Large-amplitude, long-period ground motions, which are a characteristic of large earthquakes, were not widely and densely recorded at many sites in Japan until the 2003 event. These datasets manifest significant spatial variation of LPGM with a small distance of several kilometers within the sedimentary basin. Although such spatial variation may not beyond expectation, it is of great significance that it was demonstrated by observations. In the Yufutsu basin during the 2003 event, the velocity response with the damping factor (h) of 1 % at the period of 7 s of the east-west component of the observed ground motions was 1.9 m/s at the Tomakomai west port, while it was just 0.9 m/s at the oil storage base that is located 13 km east of the port. Around the Nagoya port during the 2004 event, it was observed that the pseudo-velocity response (h = 0.5 %) around the period of 5.5 s was different by four times (0.7 and 0.16 m/s) between two sites 5 km distant mutually. It is important in aiming at more precise prediction of LPGM to study the control factors of spatial variation of LPGM. We here discuss the relation between the spatial variation observed within the Yufutsu basin during the 2003 event and the characteristics of the underground structure of the basin, thorough reproducing the observed recordings by seismic-wave propagation simulations.

The array measurements of microtremors conducted within the Yufutsu basin revealed the following features of the underground structure of the basin: (1) The depth to the bedrock with the S-wave velocity (Vs) over 3 km/s is 4 km beneath the Tomakomai west port, while it increases to 6.5 km beneath the oil storage base, where the LPGM was weaker than in the port area; (2) The thickness of the near-surface low-Vs (0.8 km/s) sediments is 1 km beneath the port, while it decreases to 0.3 km beneath the oil storage base. The ground motions observed at each station within the basin can be reproduced well by the seismic-wave propagation simulation of the 2003 event for the two-dimensional underground model of the basin including these features. We therefore consider that the thickness of the near-surface soft sediments rather than the bedrock depth governed the spatial variation of the long-period (7 to 8 s) shaking in the Yufutsu basin during the 2003 event. These findings suggest the need for understanding the detailed structures of near-surface soft deposits as well as the deep basin structure such as bedrock depth for predicting precisely LPGM in deep sedimentary basins.

The Yufutsu basin and the Ishikari basin extending north of the Yufutsu basin are bounded in the eastern and western sides by mountains, and the Tomakomai west port is located near the western edge of the Yufutsu basin. We simulated the seismic-wave propagation of the 2003 event for a simple three-dimensional underground basin model in which the above features are particularly expressed. The results show an area with larger amplitudes of LPGM near the Tomakomai west port. In the animation of wave propagation, it seems that this area is a result of the constructive interference of the surface waves propagating in the basin from the source direction toward north-west (direct surface waves) with the laterally refracted surface waves generated by the direct surface waves being incident on the western basin boundary. This result suggests a possibility that the western basin boundary had a significant influence on the spatial variation of LPGM within the basins during the 2003 event. This might mean the importance of understanding the detailed structure of the position and the shape of the basement particularly in basin edges for precise prediction of LPGM near basin edges.