S116-P006 **Room: Poster Session Hall** **Time: May 15**

Long-Period Strong Ground Motions in Tomakomai during the 2003 Tokachi-oki Earthquake: Why the Tomakomai western port so shaken?

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We successfully reproduced some important features of long-period (6.5 to 15 s) strong ground motions observed in the Yufutsu basin, Hokkaido, Japan during the 2003 Tokachi-oki, Japan, earthquake (Mw8.0; Japan Meteorological Agency) by numerical simulations of wave propagation. We found that the effective factors that controlled their features were not only deep bedrock structures but also shallow sedimentary layers. This earthquake generated the large amplitudes of long-period strong ground motions in some sedimentary basins in Hokkaido and especially the Yufutsu basin was subjected to the strongest long-period shaking during this earthquake. These ground motions excited large liquid sloshing in the large oil storage tanks in the city of Tomakomai located in the center of Yufutsu basin and some of the tanks were so severely damaged that fires broke out from two tanks and floating roofs sank into oil in several tanks. These severely damaged tanks had their natural periods of the fundamental mode of sloshing from 7 to 12 s and were concentrated in a refinery in the Tomakomai western port area adjacent to the downtown area. The Japanese dense nation-wide strong ground motion networks, such as the K-NET and the KiK-net, recorded the ground motions at many sites in the Yufutsu basin, showing strong spatial variation of long-period ground motions inside the basin. Those records revealed that the long-period shaking in the Tomakomai western port area was the strongest among all the areas inside the Yufutsu basin. To study how this observational feature can be explained using the available underground structure data, we simulated the wave propagation by calculating the 2-D wave-field with a period range between 6.5 and 15 s. The computational code of the FDM with velocity-stress staggered grids, was used assuming the underground structure models derived from microtremor array measurements in the Yufutsu basin [Kanno et al.(2005)]. Because the uncertainty in the source model and the underground model of propagation path about 200 km long may disturb our simulation purpose, we evaluated the incident wave-field from the seismogram at the site located around the basin's entrance along the propagation path, instead of full calculations from the source model to the basin. The source box technique [Alterman and Karal(1968)] was applied to giving the incident waves to the basin structure model. Our calculated waveforms well agree with the observed ones including the peak ground velocities. The features of the underground model assumed here are that the bedrock with an S-wave velocity over 3 km/s decreases its depth to about 4 km around the Tomakomai western port, while its depth increases down to 6 km, where long-period ground motions had less amplitudes than those of the Tomakomai western port area. On the other hand, the low-velocity sedimentary layers existing close to the ground surface become the thickest around the Tomakomai western port area. We therefore recognized that the shallow underground structure with the depth less than 1 km rather than the bedrock depth contributed to the excitation of the strongest long-period (6.5 to 15 s) ground motions in the Tomakomai western port area during the 2003 Tokachi-oki earthquake. The above findings suggest that we should be careful not only to the comprehensive structure of sediments such as the bedrock depth but also the detailed structure including the shallow part close to the ground surface for accurate prediction of long-period strong ground motions.