Inland repeating earthquakes in the vicinity of low frequency earthquakes around Hakodate, Hokkaido

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Strength reduction due to pore pressure increase plays an important role for the generation of earthquakes. Earthquake swarms in central Tohoku activated after the 2011 Tohoku-Oki earthquake are examples of this; they are estimated to be caused by the upward fluid migration due to the decrease of WNW-ESE compressional stress after the earthquake (Yoshida & Hasegawa, 2018a and b). Inland deep low frequency earthquakes are also considered to be closely related to the fluids (e.g., Hasegawa & Yamamoto, 1994), but their detailed mechanism is poorly understood. In this presentation, we introduce our recent study on earthquakes occurring in Hakodate, Hokkdaido, which are covered by a dense seismic network installed by the Association for the Development of Earthquake Prediction (ADEP) (Noguchi et al., 2017). In this area many low frequency earthquakes are occurring, shallow ones of which occur in the immediate vicinity of ordinary earthquakes. This provides a unique opportunity to investigate the relationship between the diversity of fault motions and the fluid behavior.

We start by relocating hypocenters of ordinary earthquakes and low frequency earthquakes by applying the double-difference location method (Waldhauser & Ellsworth, 2002). We used precise differential arrival time data of P- and S-waves obtained by the waveform cross-correlation following Yoshida & Hasegawa (2018), which largely improved the accuracy of relative hypocenter locations. We relocated hypocenters of 198 earthquakes for the period from 2003 to Oct. 2018, which are listed in the JMA unified catalog or in the ADEP catalog; 22 of them are ordinary earthquakes and 176 are low frequency earthquakes. Relative locations of ordinary earthquakes are very precisely determined due to the similarity of waveform, but those of low frequency earthquakes are almost controlled by the manually picked arrival time data because of the diversity of their waveforms.

Relocated hypocenters show that low frequency earthquakes are distributed in a plate shape dipping eastward with focal depths from 5 to 35 km, which are confirmed by the S-P times obtained at the stations just above their epicenters. Low frequency earthquakes occurring in the shallow part of the crust are located in the immediate vicinity of ordinary earthquakes. We found that the initial parts of P- and S-waves of these low frequency earthquakes have similar waveform characteristics with those of the nearby ordinary earthquakes. Furthermore, ordinary earthquakes occurring near the low frequency earthquakes have very similar waveforms themselves. They turned out to be inland repeating earthquakes based on the hypocenter relocations using precise differential arrival times obtained by the waveform cross-correlation. Other repeating earthquake sequences were also found based on the template matching method (Shelly et al., 2013). Some earthquakes in one of those repeating earthquake sequences occur with a time interval of about ten minutes or so. Similar repeating earthquake occurrences with such a short time interval have been found in an induced seismicity of a recent fluid-injection experiment (Lengline et al., 2014), which suggests that natural repeating earthquakes are also caused by a similar mechanism to the fluid injection induced seismicity; slips are repeatedly caused in the same locations due to successive reduction in frictional strength by the pore pressure increase.

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