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Spatial distribution of low-frequency earthquakes suggestive of geofluid among the aftershocks of the 2008 Iwate-Miyagi Nairiku Earthquake in northeastern Japan

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Example seismograms of low-frequency aftershocks of the 2008 Iwate-Miyagi Nairiku Earthquake in northeastern Japan.

Introduction

- In northeastern Japan, inland low-frequency earthquakes (LFEQs) occur preferentially at depths deeper than the brittle-ductile transition, which suggests a generation mechanism of LFEQs other than the sudden slip of faults.
- Recent observations show that relatively low-frequency earthquakes occur even in the upper crust as well.
- Investigation of the generation mechanism of shallow LFEQs is quite important because it is directly related to the mechanism of closely located high-frequency earthquakes in the upper crust.
- Here we investigated the LFEQs among aftershocks of the 2008 Iwate-Miyagi Nairiku Earthquake (M_W 6.8) located to the west of the 2011 great Tohoku earthquake.



Study area



The 2008 Iwate-Miyagi Nairiku Earthquake(Mw 6.8) occurred in the central part of Tohoku district on June 14, 2008, and caused severe damage by mainly landslides.



Classification of events by Frequency Index

We detected LFEQs by using the frequency index (FI) defined by the logarithm of a ratio of high- and low-frequency spectral amplitudes. We used 2–4 Hz and 10–20 Hz bands for the low- and high-frequency ranges.



Correction of Frequency Index

- We analyzed more than 4000 events observed by a dense temporary seismic network deployed just after the mainshock.
- Frequency Index (FI) shows magnitude dependence.
- For the following analyses, we will use FI values corrected for the dependence by a straight-line fitting (top figure).
- The number distribution of FI values shows negatively skewed distribution than the normal distribution (red line), showing the relative abundance of low-frequency earthquakes (bottom figure).



Epicenter distribution



Hypocenter distribution of FI values is heterogeneous; there are some clusters of low-frequency earthquakes. We used hypocentral parameters determined by Okada et al. (2012) using the DD location technique.



Depth distribution: northern part



Depth distribution of aftershocks shows a complex fault system; westward dipping mainshock fault (e.g., Suzuki et al., 2020), and eastward dipping conjugate fault.

LFEQs are distributed near the top and bottom of the mainshock fault, and the upper part of the conjugate fault.

Depth distribution: southern part



LFEQs are distributed near the top of the mainshock fault.

In the southernmost part of the aftershock zone (sections from N–N' to P–P'), the earthquakes occur in a very shallow depth range, where LFEQs are dominant.

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Comparison with after slip and calderas



- There are four LFEQs dominant clusters in the aftershock zone (LF1–LF4).
- The area of LF1 overlaps the areas of postseismic slip detected by GNSS observation.
- LF3 is located in a probably hightemperature zone around the volcano, where the aftershock seismicity is low.
- LFEQs in LFE4 are located in Hanayama caldera and have shallow focal depths.

Black lines: cluster of LFEQs Purple lines: contour of postseismic slip (max = 30 cm, linuma et al., 2009) Green broken lines: caldera rim



Temporal variation: northern part (B–B' section)¹⁰



✤ In the northern part (LF1), LFEQs occurred in the shallower part.

The occurrence of LFEQs is limited in the early stage of aftershock activity.



Temporal variation: LF2 near the mainshock

- The LFEQs are distributed mainly along the conjugate plane.
- Maeda et al. (2019) found that the focal mechanisms along the conjugate plane have N–S trending P-axes, which is inconsistent with the relative motion of the subducting Pacific plate.
- The hypocenter of LFEQs seemed to migrate with time from deeper to the shallower part of the plane (right panel).



Left and right figures are the plot in the order of increasing and decreasing FI.

Discussion

- LFEQs in the area LF2 occur along the conjugate plane, where the focal mechanisms are systematically different from those of the surrounding region.
- Maeda et al. (2019) interpreted the anomaly by a local stress change due to the mainshock applied to a neutral stress field.
- The idea of neutral stress is based on their estimation of high Vp/Vs ratio and hence high pore pressure in the area of the conjugate plane.
- Hypocenters of LFEQs show temporal variation in the areas of LF1 and LF2, where the high pore pressure is suggested.
- These observations imply that the existence and movement of geofluid are responsible for the occurrence and hypocenter migration of LFEQs.



Conclusions

- We investigated the LFEQs among aftershocks of the 2008 Iwate-Miyagi Nairiku Earthquake (Mw 6.8) in northeastern Japan and found there are four LFEQs dominant clusters (LF1–LF4).
- LF3 and LF4 are located near the Kurikoma volcano and the Hanayamain caldera, where high temperature, volcanic fluids, and geological structures are the candidate factors affecting LFEQs.
- Hypocenters of LFEQs show temporal variation in the areas of LF1 and LF2, where the high pore pressure is suggested by the postseismic slip and the neutral stress field.
- Thus, the distribution of LFEQs plays a crucial role in understanding the contribution of geofluids not only to the seismogenic processes of aftershocks but to the faulting mechanism in the upper crust.

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