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Seismic Attenuation and Source Parameters of the Swarm Region in Wakayama, Southwestern Honshu, Japan

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1. Introduction

Generally, earthquake swarms in Japan occur in regions closely related to volcanic activities. The earthquake swarm activity of Wakayama, however, is characterized by the long continuing activities of shallow earthquakes in a non-volcanic region far from the present volcanic front in Japan. For a model of occurrence of the Wakayama swarms, Wakita et al. (1987) proposed a diapiric rise of magma and the exclusion of water and volatiles from the magma cooling at the shallow crust in regional stress field. This model is basically similar to Kanamori's model (1972). In discussing the mechanism of occurrence of the swarm activity, it is important to make clear the structure and physical properties not only in the lower crust including the vicinity of the Moho discontinuity but also in the swarm region. In particular, it is important to examine attenuation property of seismic waves in the swarm region, because the structural weakening of the swarm region would be reflected on absorption attenuation due to injections of water and scattering attenuation due to cracks with various lengths in the region. On the other hand, it is also important to examine seismic source parameters in the swarm region.

2. Results

We estimated site responses, seismic attenuation and source parameters using S waves of surface rock-site records from an array observation for strong motions deployed in the swarm area of Wakayama. Magnitudes (M) of analyzed 35 events range from 2.1 to 4.5. Their focal depths are shallower than 10 km, and hypocentral distances range from about 3 to 39 km. First, from a linear inversion of S-wave spectra, we found that S-wave quality factor, i.e. a Qd-value, was approximated by the relation of Qd= 6.7f^ 1.5 for 2 to 10 Hz and Qd= 222 for 10 to 32 Hz. The S-wave attenuation (1/Qd) is characterized by the high attenuation and the clear disappearance of frequency dependence beyond about 10 Hz. Next, we separated the S-wave attenuation into scattering attenuation (1/Qs) and absorption attenuation (1/Qi) using the coda parts on the assumption that 1/Qd = 1/Qs + 1/Qi. For this analysis, we used the compact solutions for multiple scattered wave energy in time domain by Zeng (1991). Ts-p (S-P time) of used 16 events is less than 0.8 sec and the analyzed lapse-time interval is 4 to 9 sec. For 4 to 32 Hz, 1/Qs is significantly small compared with 1/Qi and 1/Qd roughly agrees with 1/Qi. For f = 2 Hz, however, 1/Qs is predominant in the total attenuation. On the other hand, coda Q-value, Qc, seems to be similar to Qd for 2 to 32 Hz. Such significantly high absorption attenuation suggests the presence of saturated or partially saturated fluids in cracks or pores, which is interesting in discussing the structural weakening of the swarm region.

As for the site response, we found that although the rock sites had their own site effects, i.e., amplification or deamplification, at frequencies more than about 3 Hz, this bias could be remarkably weakened by using the average over the stations as a reference and the relative site-amplifications obtained had nearly flat characteristics in the whole frequency rage. In order to estimate absolute site-response at the virtual observation station with the average site-response over the stations and source parameters, we applied a non-linear, non-reference-site inversion, assuming the omega-squared source model. The absolute site-amplification at the virtual station well converges to unity below 3 Hz, which shows that the separation between the site- and source-effects is precisely executed in the inversion. The relation between the seismic moment (Mo) and the corner frequency (fc) follows the scaling law, Mo is proportional to fc^-3 , and the stress drops are less than about 80 bars.