Development of a technique for automatic determination of volcanic earthquakes with unclear onsets - Application to Mt. Asama -

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Some of volcanic earthquakes have clear P and S-wave onsets, and other has unclear onsets. In the traditional classification of volcanic earthquakes, the former is called A-type, VT, or HF earthquakes, and the latter is called B-type, LP, or LF earthquakes. The source process of the former is thought to be the rock rupture due to the stress changes in the volcanic edifice. For the latter, various source processes involving volcanic fluids such as gas, hot water or magma, have been proposed.

Numerous B-type earthquakes are often detected by the seismic network near the active volcanic vent of a volcano even if the activity level of the volcano is not high. In addition, a sharp increase in the number of B-type earthquakes is often observed when volcanic activity increases. Because shallow B-type earthquakes reflect the state of the magma plumbing system or the shallow hydrothermal system, constant monitoring of their activity is important. However, since B-type earthquakes are numerous and it is difficult to read their onset by human eyes, manual processing is not easy. Therefore, it is necessary to develop a automatic method to detect the event and to determine the hypocenter location. For events with unclear onsets, various methods, such as obtaining travel time differences by using waveform correlation, using particle motion, using spatial distribution of amplitude, etc., have been proposed so far. In particular, methods using waveform amplitude are widely used for hypocenter determination of B-type earthquakes due to their excellent performance.

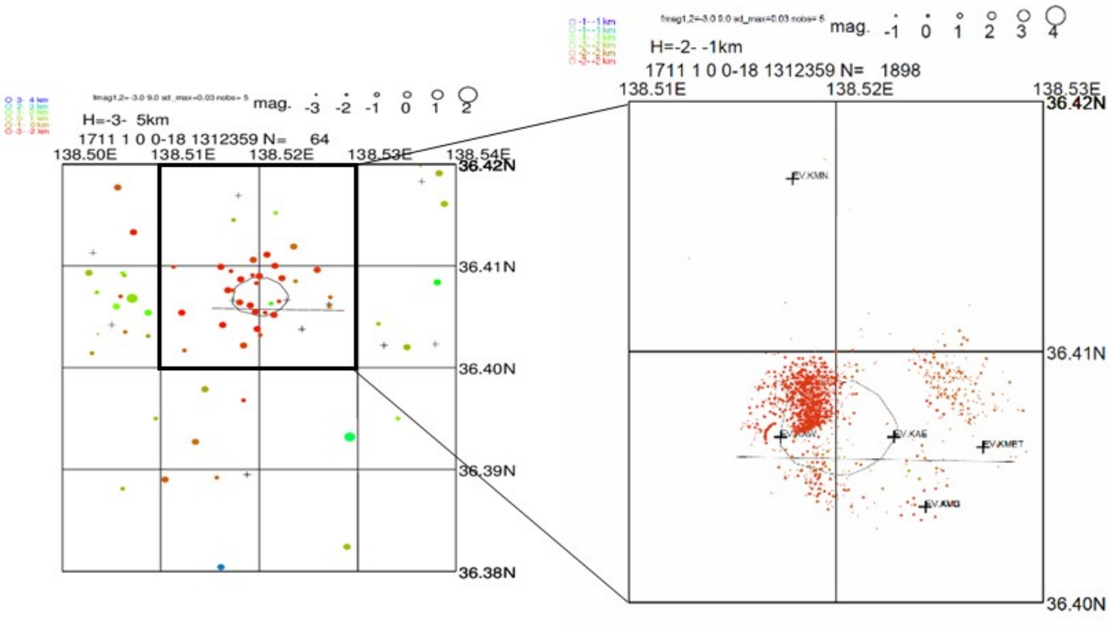
In this study, we first examine how effective the Horiuchi et al. (2010)'s method for hypocenter determination of volcanic earthquakes with unclear onset. This method has been used in hypocenter determination of non-volcanic earthquakes. The basic idea of this method is, first, to define an evaluation function that imitates the comprehensive judgment of experienced human beings, then, to optimize the parameters of the evaluation function automatically so that the results of automatic readings approach the human readings. Furthermore, the influence of noise is reduced by giving a higher score values to observation stations where the difference between the theoretical and the observed travel times is smaller and by choosing a solution with the sum of the score values of all observation stations is maximum. In order to further improve signal-to-noise ratio, S-waveforms are appropriately rotated before reading S-arrival.

When we applied the method in its original form to Mt. Asama data, the accuracy of the result was poor. Possible reasons would be, in addition to difficulty in onset reading itself, the influence of various factors such as poor human readings which are the basis of parameter optimization, and high noise level of the data. In order to improve the performance of the method, we have tried various remedy such as improving onset reading, utilizing amplitude, reducing noise, etc. and have finally reached the stage where automatic determination is satisfactory. The measures we have taken and their results are as follows.
1) If the conventional automatic reading method is applied as it is, the accuracy of S-reading is not good enough. We examined a method in which an approximate hypocenter location is determined first using the waveform amplitude, then the S-wave arrival is read using the correlation. In order for improving the accuracy of S-reading, we used the correlation of the S-waveform envelope. We then computed the hypocenter location by using both the amplitude and the travel time. But the high accuracy of the

S-reading was not reached. We abandoned this approach.
2) The hypocenters were determined by using both the automatic reading of S-arrival and amplitude, but accuracy was not satisfactory.
3) We performed following four remedy first: "To avoid reading noisy waveforms", "To discriminate between distant earthquakes and local volcanic earthquakes", "Not to use readings with low signal-to-noise ratio", "To remove amplitude data with inconsistent S-arrival". We then carried out hypocenter determination by using waveform amplitude alone. The results obtained by this procedure were most satisfactory.

When we apply above-mentioned improved method to the data for three months from November 2017 to January 2018, we could determine hypocenters of about 1900 events near the summit of Mt. Asama. The number of events that was determined manually during the same period was less than 100 events. Although we need to investigate more about the accuracy of the obtained hypocenter location, we believe that the improved version of this method is fairly promising.

Keywords: volcanic earthquakes, hypocenter determination, amplitude of waveforms, unclear onset



Manual pick

Auto pick