

Estimation of frequency of volcanic eruptions at subduction zones in Japan

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Frequency of volcanic eruptions is a fundamental parameter to evaluate volcanic activity. For example, it can be used to calculate probability of volcanic eruptions. Furthermore, together with mass of ejecta, it gives long-term magma discharge rate, providing an insight into material circulation through volcanoes. Calculation of frequency of eruptions is, however, a challenging problem due to the difficulty of estimating the amount of under-recording of volcanic eruptions. The mechanism of under-recording may vary in different geological and geographical conditions. In this study, therefore, under-recording of events in each Japanese sub-region (subduction zone) was considered and frequency of volcanic eruptions was estimated. In addition, long-term magma discharge rate in each sub-region was also calculated and compared with the previous studies to validate the estimated frequency of eruptions.

The investigated datasets consist of age and magnitude, M , of volcanic eruptions ($M \geq 2$), which occurred in the Hokkaido, Tohoku, Izu, Central, and Kyushu regions in Japan in recent about two million years. Under-recording of volcanic eruptions was estimated by modeling a trend of recording rate of volcanic eruptions decreasing with time. The estimated magnitude-frequency relationships show that the frequency of eruptions ($M \geq 2$) in those regions varies more than one order of magnitude. For larger eruptions ($4 \leq M \leq 6$), frequency of eruptions decays by a factor of about 10 for each successive eruption magnitude category. On the other hand, frequency of smaller eruptions ($2 \leq M \leq 4$) decays by a factor of about 1.5 - 2.6, showing that the smaller eruptions are less frequent than the frequency expected from the magnitude-frequency relationship of the larger eruptions. One possible explanation of this feature is that smaller batch of magma is less buoyant and is more likely to be stuck in the crust. When the frequencies of eruptions in these Japanese sub-regions are normalized with the length of the subduction zones, they do not vary significantly, suggesting that the difference of tectonic settings is insignificant for frequency of eruptions at subduction zones.

As a validation of the estimated magnitude-frequency relationships, long-term averaged magma discharged rates were calculated on the basis of the estimated relationships and compared with previous studies. The long-term magma discharge rates, normalized by the length of those subduction zones, show similar value ($\sim 2 \times 10^{10}$ kg/ka/km) in the Kyusyu, Central, Tohoku and Northern Izu regions. This result is concordant with the previously reported discharge rate estimated from the volume of volcanic ejecta, showing that the estimated magnitude-frequency relationships are reliable. On the other hand, when entire Izu region was considered, the length-average long-term magma discharge rate is about one third of those of the other regions. This is probably because, under-recording of events was not successfully estimated due to the geological and geographical conditions of this region; the Izu region consists of submarine volcanoes where no eruptions are recorded and of small volcanic islands where wide-spread tephra deposits are less likely to be preserved and hence almost no large eruptions ($M \geq 6$) are reported. Furthermore, the length-average long-term magma discharge rate in the Hokkaido region is also smaller than those of the other regions, maybe reflecting low magma production rate caused by an oblique subduction of the Pacific plate beneath the North American plate although it may be the result of insufficient estimation of under-recording of events as well.

These results show that difference of geological and geographical conditions must affect under-recording of volcanic eruptions. It was also suggested that difference of tectonic setting of subduction zones does not significantly affect magnitude-frequency relationship of volcanic eruptions.

Keywords: eruption database, under-recording of eruptions, frequency of eruptions, long-term magma discharge rate, subduction zone