Empirical relation for *Q* factors of crack resonances and its use to estimate source properties of volcanic LP events

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Long-period (LP) seismic events are thought to arise from the oscillations of a fluid-filled resonator. The resonator geometry and fluid properties of LP sources have been estimated by comparing observed frequencies and *Q* factors to those calculated from a crack model (Chouet, *J. Geophys. Res.*, 1986). Taguchi et al. (*J. Geophys. Res.*, 2018) developed a method based on an analytical formula for the crack resonance frequencies proposed by Maeda and Kumagai (*Geophys. J. Int.*, 2017). This method enables us to estimate all the parameters of crack geometry and fluid properties. But the comparison of *Q* factors was conducted by numerical simulations of the crack model, which took extensive computational time, especially for LP events with large *Q* factors. So we systematically investigated the relation between *Q* factors and the crack model parameters by numerical simulations. It is known that *Q* factors of the crack resonances are proportional to α/a, where α is the *P* wave velocity of the solid and *a* is the sound speed of the fluid in the crack (Kumagai and Chouet, *J. Geophys. Res.*, 2000). We additionally found an empirical relation, indicating that the proportional constant depends on log(W/L), where *L* and *W* are crack length and width, respectively. To test the applicability of this empirical relation, we used it to analyze LP events at Galeras volcano, Colombia, in January 1993. These LP events have been thought to be generated by resonances of the crack filled with dusty gas. Our estimates of the crack model parameters displayed decreasing trends in both crack volume (*V*) and gas-weight fraction of water vapor (*n*) in the crack. These trends are similar to those shown by Taguchi et al. (2018). We further analyzed LP events at Galeras in May 1993 and December 2006 with the empirical relation for *Q* factors assuming dusty gas as the fluid in the crack. Because of their large *Q* factors, the determinations of crack geometry and fluid properties for these LP events with numerical simulations of the crack model were computationally expensive. The empirical relation for *Q* factors enables us to estimate all the crack model parameters for these LP events easily, and we found similar decreasing trends in both *V* and *n* to those in January 1993. This similarity implies that these variations during the individual periods of LP events were caused by the similar processes at this volcano.
These results demonstrate that the empirical relation obtained in this study is applicable to estimate all the parameters of LP sources, and may contribute to improved monitoring of fluid states under volcanoes and better understanding of LP source processes.

