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Long-period events at Purace volcano, Colombia, generated by the interaction between magma and hydrothermal systems

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Purace volcano is located in the northwestern Coconucos Volcanic Chain between the Huila and Cauca departments. Characterizing the volcanic structure and understanding the mechanisms of magmatic and hydrothermal activity at this volcano are of particular importance to mitigate disasters associated with eruptions for the surrounding communities. The seismic activity of Purace is characterized by long period (LP) events and tremor (TR) associated with volumetric change processes; volcano-tectonic (VT) events generated with fractures in the volcanic edifice; hybrid (HB) events showing both LP and VT signatures. The main objective of this study is to understand the mechanisms that control the origin and the behavior of "tornillo" type LP (TLP) events. They have been identified as precursors of volcanic eruptions at various volcanoes, and it is therefore important to study their behavior and relation to field observations such as structural geology, temperature and geochemistry of the magma and hydrothermal systems. We first established a 1-D velocity model in order to locate seismic events (LP, TLP, TR, HB, and VT) that occurred between 2000 and 2018. We then performed a spectral analysis with the Sompi method and determined the frequencies (f) and quality factors (Q) for the TLP events in 2009-2013. Our results showed a systematic change in f between 3 and 7.5 Hz and scatter in Q values ranging between 10 and 400. Assuming the crack model as the source of the TLP events, we estimated that the crack vibrates with a fundamental odd longitudinal mode with the crack stiffness of 2.41 and the crack width to length ratio of 0.74. Based on the location of the events, we assumed that each TLP event occurred in a dendritic fracture zone around 1 km below the summit crater. The location and high Q values suggest a crack filled with gas and mist particles. We examined a possible relationship among the temporal evolution in L and f, field observation data (measurements of temperature and chemical concentration of cations/anions from hot springs around the volcano, and precipitation) and the number of VT and TLP events. We found a strong correlation in the occurrences of VT and TLP events, in which VT events tended to occur before TLP events. We also found that the TLP frequency f varied inversely with crack length L and increased with increasing precipitation, anions (Cl-), cations (SO4), and temperature in the hot springs. This finding indicates that physical/chemical changes in the hydrothermal system were correlated with the changes in the crack resonance length and frequency. Our results suggest that the TLP events were generated in the hydrothermal system highly connected with a heat source of magma beneath the volcano, which caused stress changes in the volcano edifice and generated the VT events before the TLP events.