

## **A fluctuating lava lake at Villarrica volcano, Chile, inferred from repetitive long-period seismic and infrasonic arrivals in conjunction with persistent infrasonic tremor**

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Villarrica volcano, which has exhibited nearly continuous open-vent status since the last major eruption in 1985, hosts a persistent lava lake in its summit crater. Minor strombolian style eruptions produce occasional spatter from large bubble bursting events, while persistent outgassing has been shown to produce continuous shallow seismic and acoustic tremor. During three campaigns from 2010 to 2012, we deployed seismometers and infrasound microphones around Villarrica, on the flanks, and within the crater itself to further study the characteristic seismicity and link it to magmatic processes. We noticed an LP event in 2011 with our linear array configuration, and linked it to a strombolian eruption. We then identified hundreds of thousands of smaller amplitude, but nearly identical events using a time domain matched filter technique. We returned in 2012 to better instrument this event type azimuthally, and performed a full-waveform inversion to understand the source mechanism of this repetitive event. The source inversion revealed a shallow east-directed single force, approximately located near the top of the lava lake, and can be explained by restoring forces within the lava lake as a result of mass escape during outgassing. Based upon the infrasonic and seismic travel times of the station located within the crater, we concluded that the infrasonic and seismic sources were nearly collocated.

Using the repetitive LP event observed in 2011 and 2012, we applied knowledge of this event to our longest running deployment in 2010. Using a collocated infrasonic array and a long-running seismic station, we calculated the seismic-acoustic time delay, calculated event energies, calculated the volcano acoustic-seismic ratio (VASR), and analyzed the peak infrasonic tremor frequency with time. These seismic and infrasonic attributes pointed to a fluctuating lava lake level, consistent with at least two injections of juvenile volatile rich magma. We also propose a new model for the source of infrasonic tremor consistent with our observations in 2010, using the combination of the shaft and crater as a stable resonator.