A Seismo-Acoustic Investigation of a Localized Crater Terrace Collapse at Stromboli Volcano

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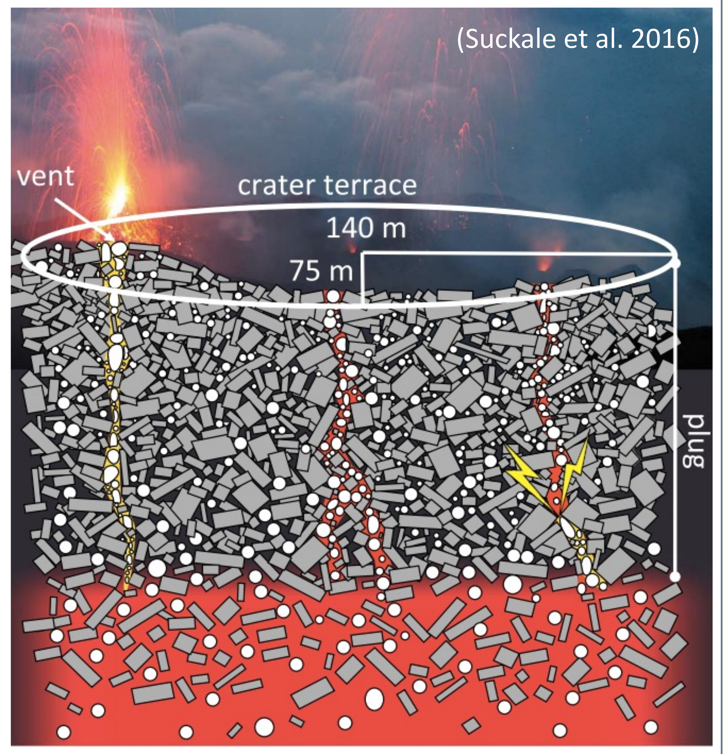
INTRODUCTION/OBJECTIVES

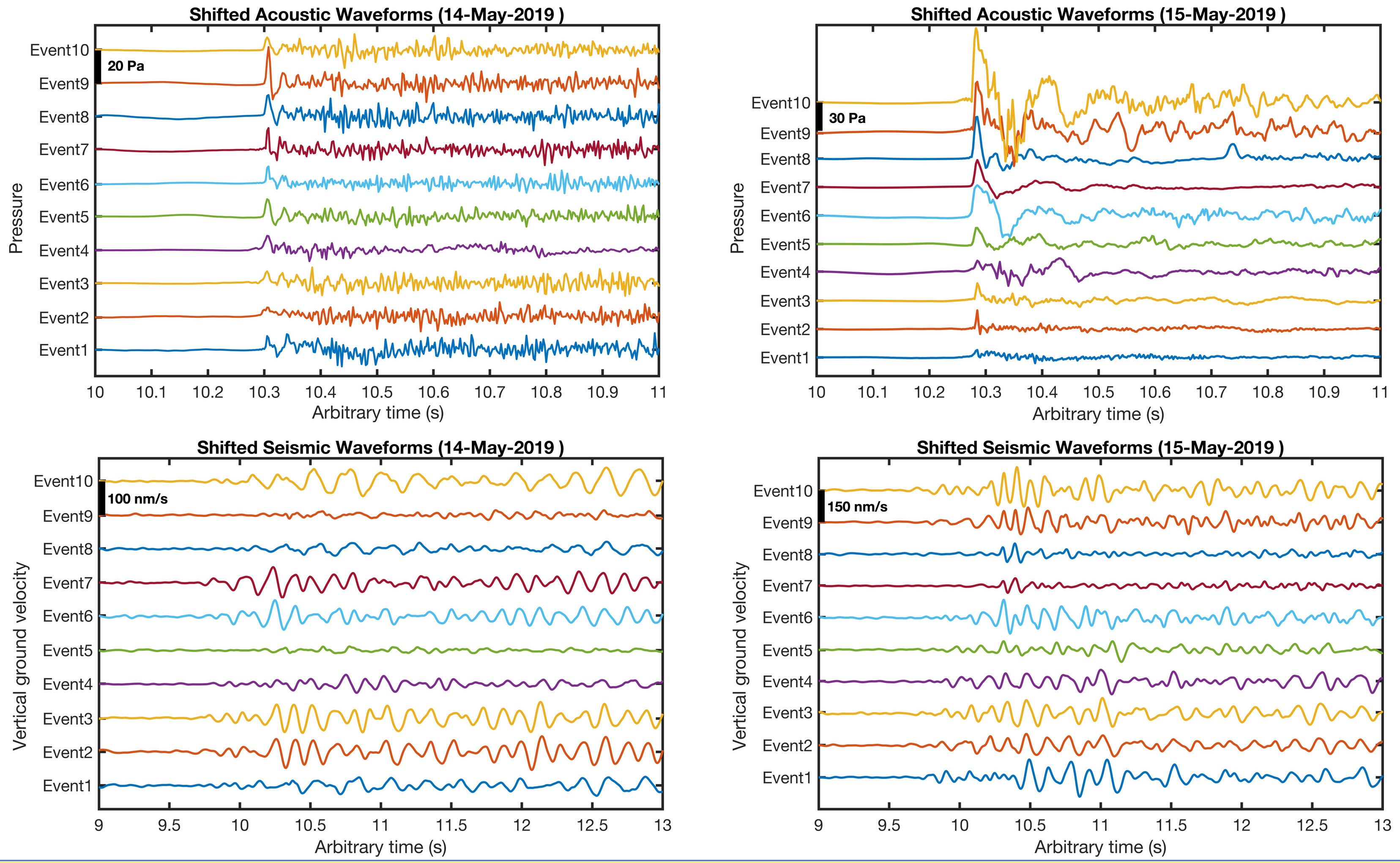
Stromboli volcano is an active island stratovolcano with a complex plumbing system and recurring paroxysms. It is known for its consistent Strombolian eruption style, multiple active vents (fig right), and regular vent evolutions[3] to its crater terrace. This study focuses on a single localized collapse of the crater terrace (15 May 2019) where the S1 vent changed from a spatter cone to a pit crater. This collapse resulted in a change in eruption style at this vent from jetting to Strombolian. We investigate the seismo-acoustic arrival times and energy ratios between our co-located acoustic and seismic signals before and after the collapse to identify changes associated with eruptive signal and source location.



DATA AND METHODS

Data from the terrace of Stromboli was collected May 11-15, 2019, with two 3-channel infrasound arrays (*InfraBSUs*) and six co-located vertical geophones about 200-250 m from the S1 vent. Sensor data and GPS locations were logged via the Omnirecs DATA-CUBE. Acoustic and seismic data were both sampled at 400 Hz.

Acoustic signals are high-passed above 1 Hz and seismic signals are low-passed below 4 Hz. Using time lags and high correlation values across the arrays, ten events for each eruption style (jetting spatter cone, 14 May; Strombolian pit crater, 15 May) are selected. All acoustic events are shifted to align their initial pressure onsets. Each seismic event is then shifted by the same amount as its acoustic counterpart (figs below). We compare the cumulative event arrival times across the co-located sensors as well as changes to these co-located sensors' volcano acoustic seismic ratio (VASR) from before to after the collapse.

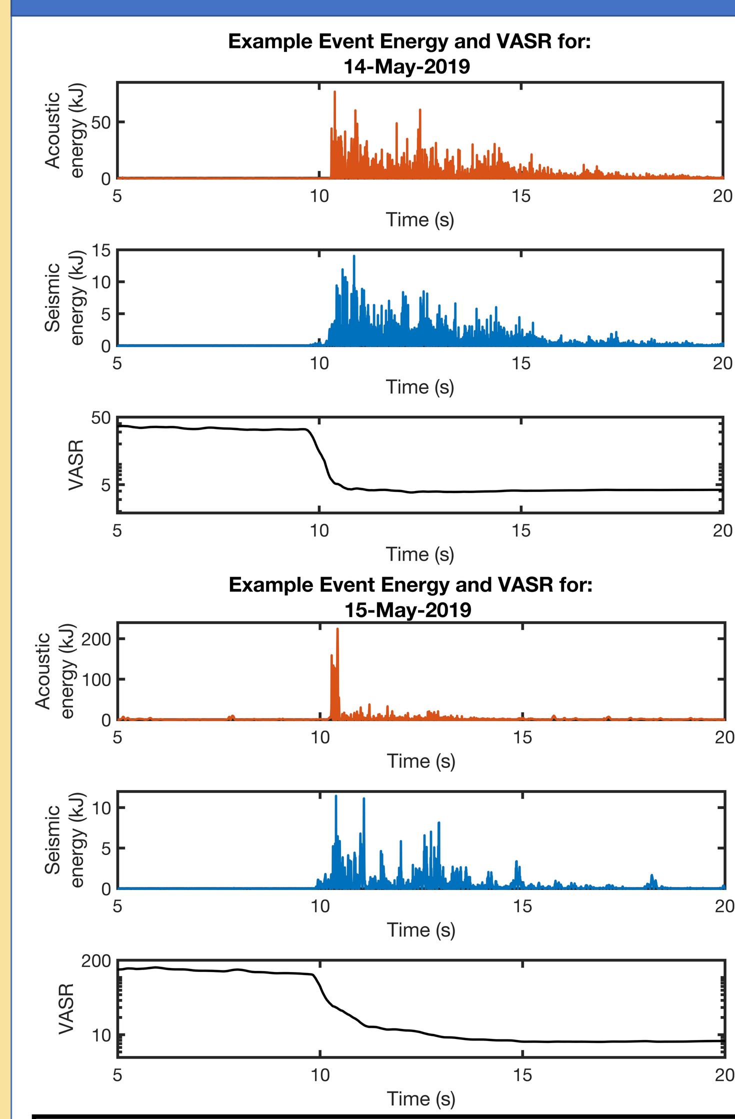


THE COLLAPSE

14-May 2019: jetting spatter cone

15-May 2019: Strombolian pit crater

SEISMO-ACOUSTIC ENERGY RATIO



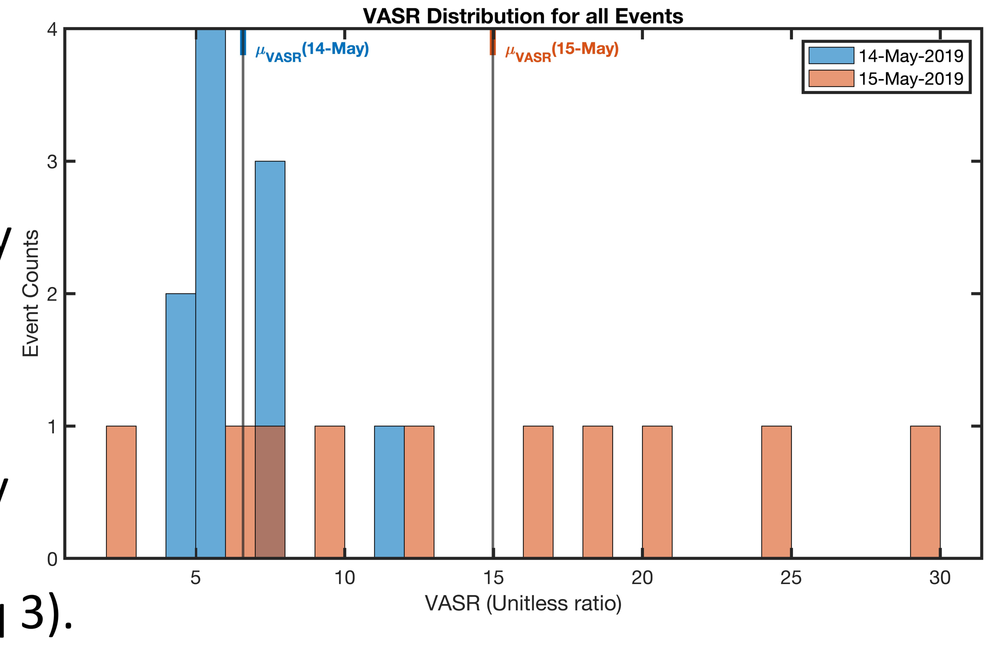
In order to properly characterize the acoustic and seismic energy of discrete eruptive events, we integrate over a time window spanning 5 seconds prior to the event onset to a time where the acoustic and seismic signals reach background levels. Using formulas along with standard density and propagation speed values detailed by Johnson & Aster[1] (Eq 1 & 2), we calculate an approximate energy release (kJ) for each individual event. These summed energies are then divided by their co-located counterpart to produce VASM values (Eq 3, fig left). In general, there is more acoustic energy and a similar amount of seismic energy post-collapse.

$$E_{acoustic} \propto \frac{2\pi r^2}{\rho_{atmos} c_{atmos}} \int \Delta P(t)^2 dt \qquad (1)$$

$$E_{seismic} \propto 2\pi r^2 \rho_{Earth} c_{Earth} \int V(t)^2 dt \qquad (2)$$

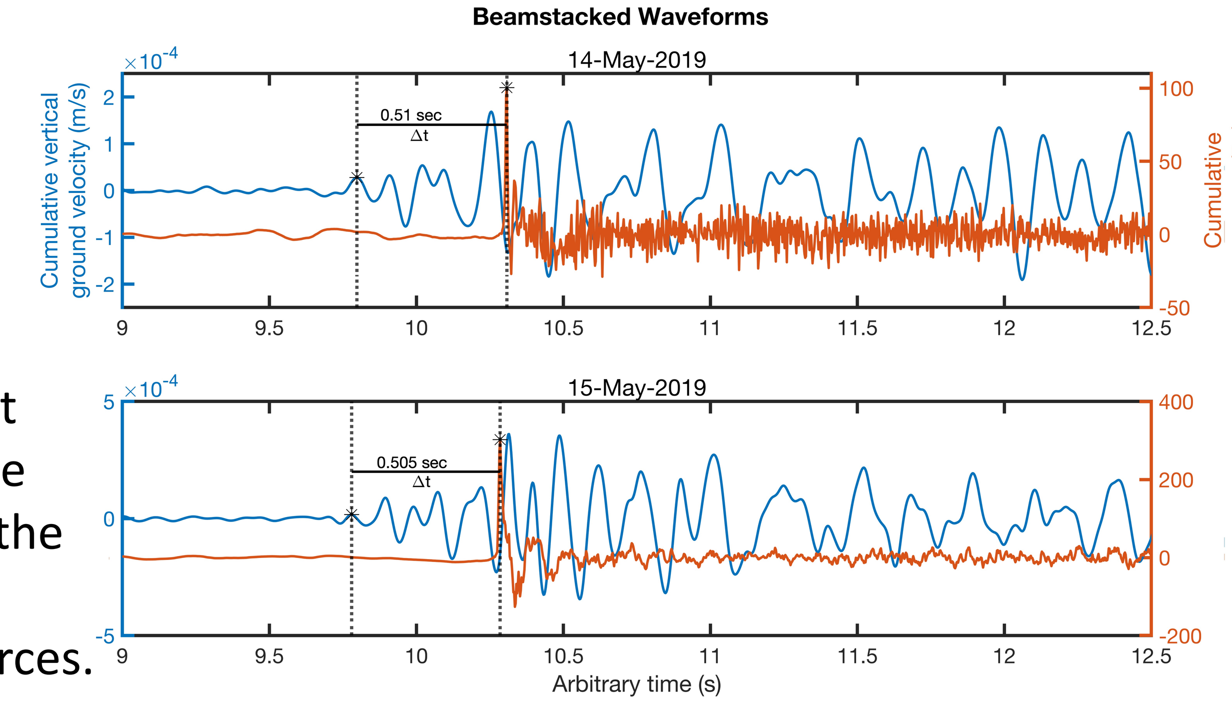
$$VASR = \frac{E_{acoustic}}{E_{seismic}} \qquad (3)$$

We find lower VASR values before the localized collapse (fig right). Since the spatter cone's vent is narrower[2] and there's more acoustic energy after the collapse, it is reasonable to assume that the spatter cone vent released more elastic energy (seismic) into the earth resulting in a lower VASR (Eq 3).



SEISMO-ACOUSTIC TIMING

To investigate the timing information across the seismic and acoustic signals, we beamstack, or sum, all events of the same type. As seen in the plot below (fig below), the timing information from the S1 vent between the co-located geophone and *InfraBSUs* cumulative signals does not seem to change much after the May 15th collapse. Prior to the collapse, the acoustic signal reached the sensor ~204 samples (~0.51 seconds) after the initial onset of the seismic signal. Post-collapse, the acoustic signal reached the sensor ~202 samples (~0.505 seconds) after the initial onset of the seismic signal. This result shows an insignificant change in the arrival times of ~2 samples (~0.005 seconds). Thus, we assume the source for the S1 vent is non-changing throughout this period. This also leads to the reasonable assumption that there is no significant change to the locations of the seismic and acoustic sources.



CONCLUSIONS

This study investigates a single localized collapse of the crater terrace of Stromboli volcano, which resulted in a change of eruption style from jetting to Strombolian. The moments before and after this collapse were recorded with co-located acoustic and seismic sensors. We found that there was no significant change in the seismo-acoustic timing from before to after the collapse, indicating that the overall source as well as the source location for both signals is non-changing. In addition, we found that the VASR increased from before to after the collapse indicating that more elastic energy was released into the earth (as seismic waves) before the collapse. This study only includes a total of 20 events from this expedition. More research as well as more events are needed to produce a robust outcome from this dataset.

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