# EXAMPLES OF EARTHQUAKES AS A SOURCE OF VOLCANIC TREMOR HOW COMMON ARE EARTHQUAKES **AND TREMOR WITH SIMILAR SPECTRA?**

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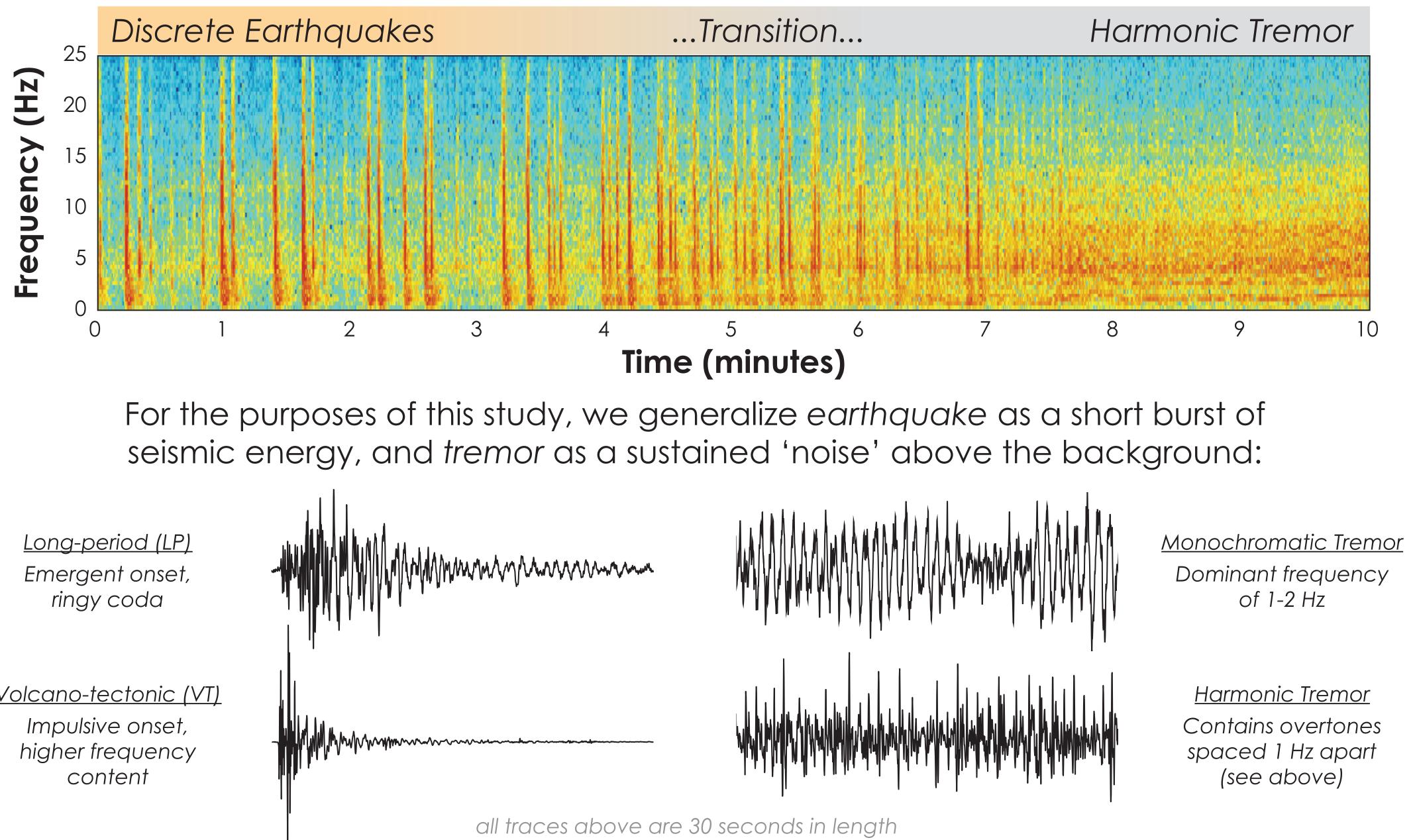
#### ABSTRACT

It has been proposed that shallow, frequently-repeating long-period earthquakes (LPs) are the underlying source of volcanic tremor. We demonstrate for several andesitic and dacitic volcanoes that repeating earthquakes and tremor do share a common source. This hypothesis is based on similar spectral content and the observations of earthquakes merging into or out of tremor, as inter-event times gradually change. Additionally, we construct synthetic tremor from repeating earthquake waveforms as a proof of principle.

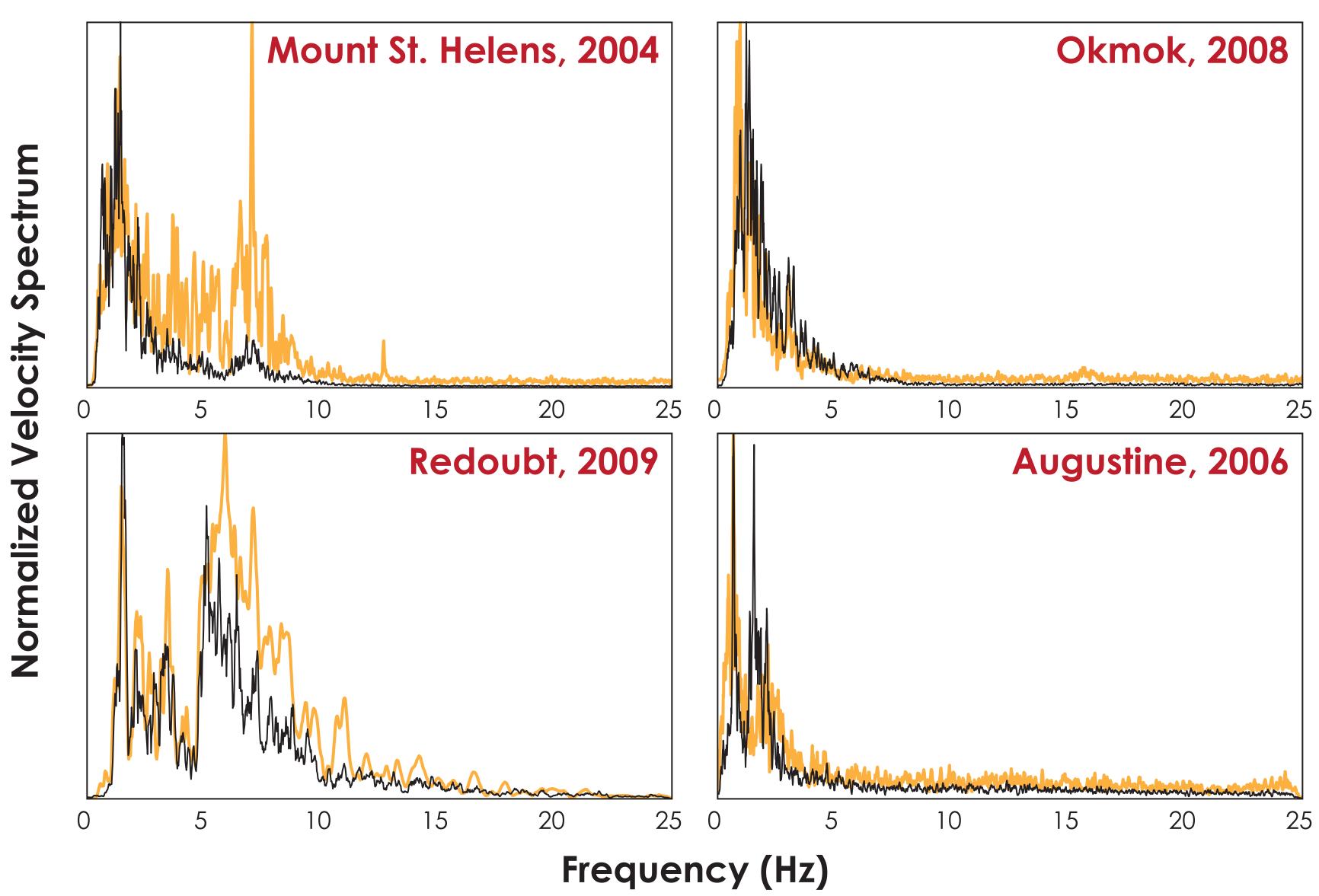
Fluids such as gases, hydrothermal water, or sub-solidus magma are commonly inferred to be the causes of both LPs and volcanic tremor, especially harmonic tremor. However, we find the properties of both tremor and related earthquakes sometimes inconsistent with expected observations for a fluid source when evaluated in detail. Specifically, we find on Redoubt Volcano, Alaska, that repeating earthquakes, which eventually blend seamlessly into harmonic tremor, had impulsive first P-wave motions and strong S-waves that are most compatible with brittle failure. We suggest that a possible source could be frictional processes at or near the conduit, related to the movement and fracture of highly viscous magma during extrusion. This possibility is more consistent with our observations on Redoubt, and we explore its applicability more broadly to other, similar eruptions.

### ARE EARTHQUAKES AN "IMPULSE RESPONSE" OF **CONTINUOUS VOLCANIC TREMOR?**

Earthquakes and tremor are prolific during nearly all volcanic eruptions. Determining what produces them and why may aid in our understanding of volcanic behaviors. We have observed that earthquakes merged into/out of tremor on several volcanoes, and infer that the two signals likely share a common source.

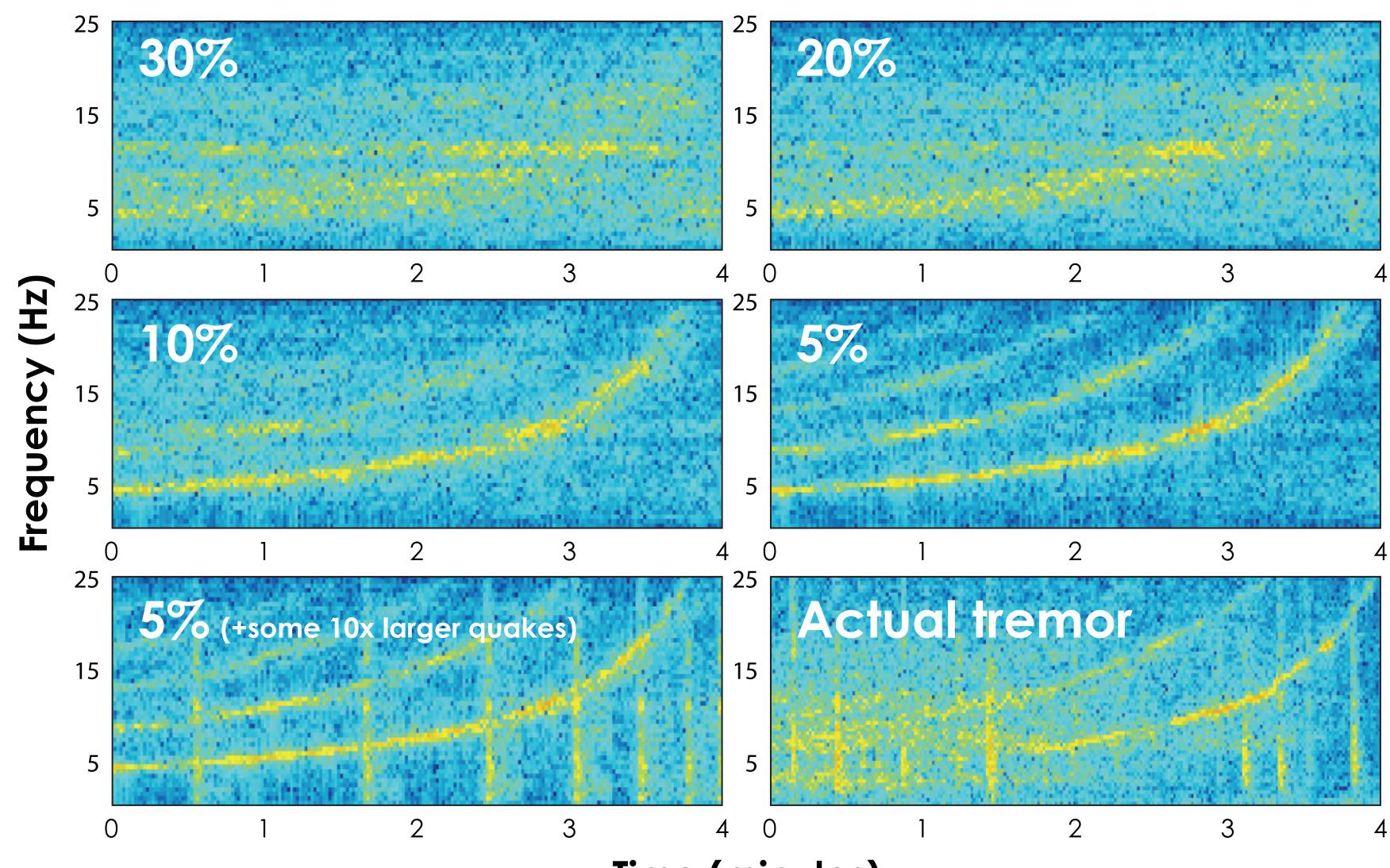


If tremor is a sum of many earthquakes too frequent to resolve, they should share similar spectra. We demonstrate this for four different volcanoes:



# THE EFFECT OF REGULARITY IN TIMING

Earthquakes can form harmonic tremor if they occur regularly in time. We explore how much this regularity can vary and still produce visible overtones by creating synthetic tremor out of many earthquake copies:



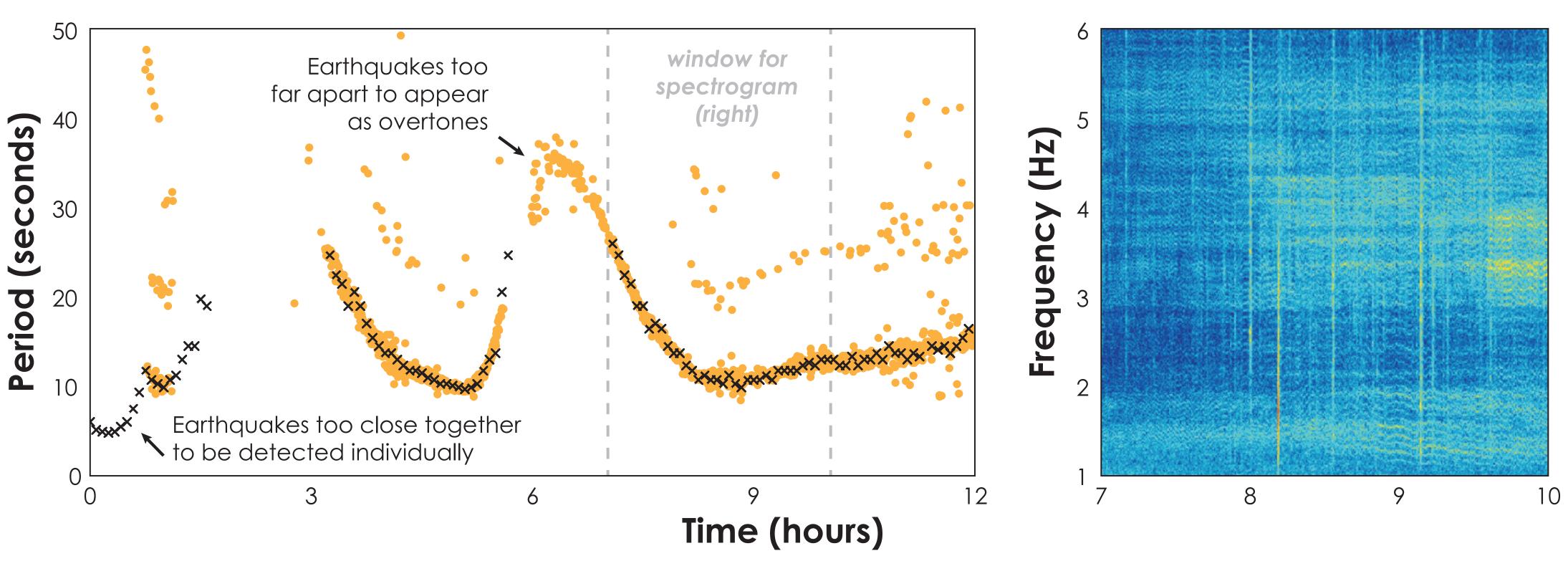
erage period between each earthquake decays as a linear function of time. Percentages represent how much the period between each copy varies from the average. Tremor and source earthquake from Redoubt, 2009.

Spectra of 15 second long window of one repeating earthquake (yellow) and 5 minute long window of tremor (black). These were temporally separated by 1 to 6 hours.

#### Time (minutes)

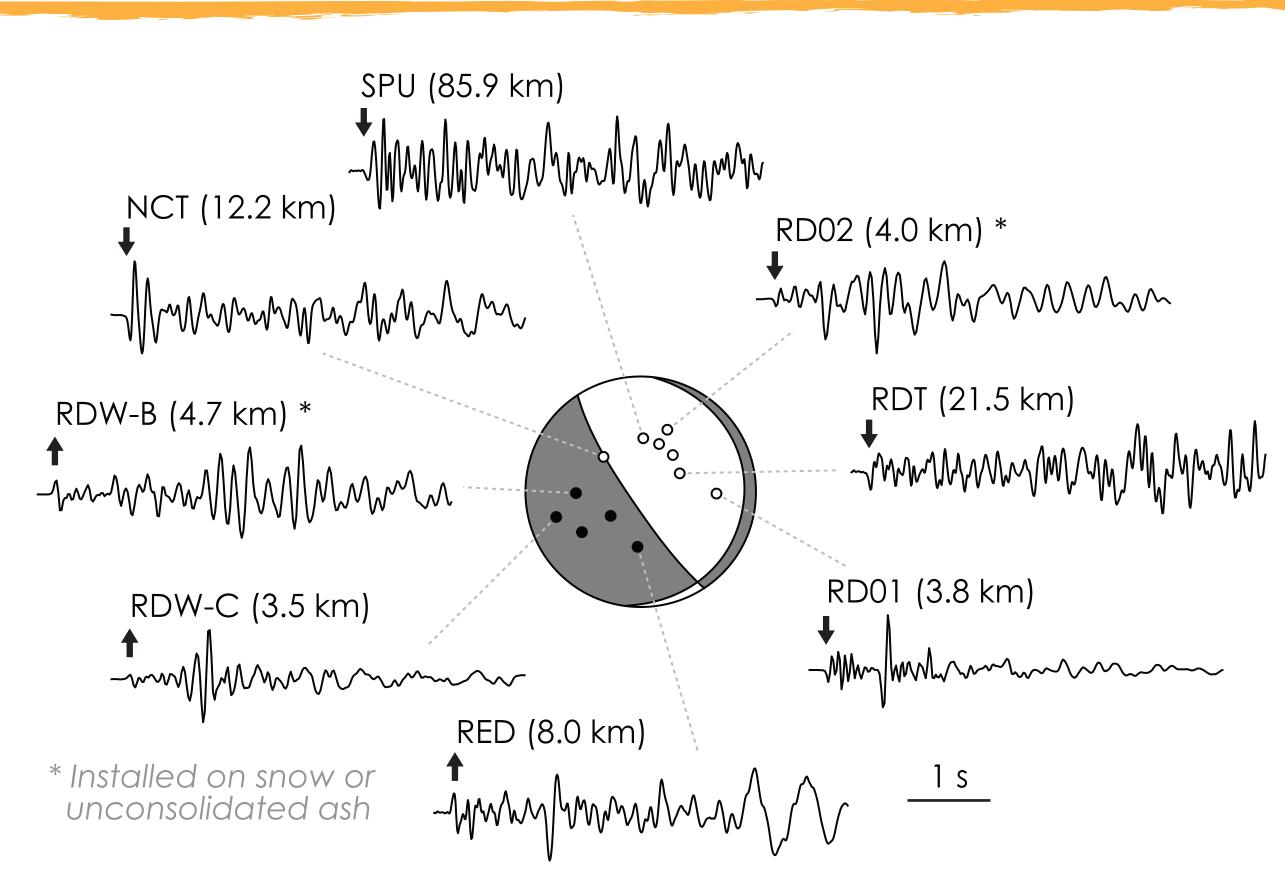
### V33B-2634 **ARE EARTHQUAKES REGULARLY** TIMED ENOUGH TO FORM HARMONIC TREMOR?

On Augustine, we found a swarm of repeating earthqakes that occurred with sufficient regularity in timing to produce harmonic overtones if a long enough window was used:



ellow dots represent amount of time between successive earthquake detections using cross-correlation; black x's are the inverse of the spacing between overtones using the spectrogram on the right. Spectrogram was calculated using a 45 second sliding window.

### WHAT IS THE MECHANISM OF THE EARTHQUAKES **AND ASSOCIATED TREMOR?**



## WHAT DOES THIS HAVE TO DO WITH MAGMA **TRANSPORT DURING AN ERUPTION?**

The earthquake swarm on Redoubt was located almost directly beneath the surface vent, suggesting it may have occurred very near the conduit. We propose that the tremor and earthquakes result from repeated stick-slip failure at (or very near) the conduit wall as magma moves upward. This could occur both prior to an explosion and during extrusion.

For an extended discussion of how increasing stressing rates may produce the harmonic tremor as described here, see poster V33B-2635.

On Redoubt, mixed first motions and the character of stacked waveforms on the closest stations indicate a dip-slip or thrust mechanism for the large repeating earthquakes.

We notice that distance from the source and geologic setting of the seismometer can significantly change the appearance and spectral content for both earthquakes and tremor by attenuating higher frequencies.

> We have not yet evaluated the earthquakes for other volcanoes.

