V22B-01 Stepping back to the source: The expression of eruption column collapse through submarine terraces (Invited)

Tuesday, 10 December 2024

10:20 - 10:30

204 A-C (Convention Center)

Abstract

Explosive eruption jets rising through relatively shallow water layers form eruption columns that can deliver volcanic ash, gases, and entrained water to the atmosphere and ocean in-sequence or simultaneously, depending on eruption source parameters (Gilchrist et al. 2023). Despite the mesospheric eruption column height of the January 15, 2022 eruption of Hunga Tonga-Hunga Ha'apai (HTHH), the majority of erupted material was delivered to the surrounding seafloor via submarine pyroclastic density currents (PDCs). Deposits of HTHH show evidence of axisymmetric terraced deposits, which we show are linked to the mass eruption rate and dynamics of column collapse. We use scaled analog experiments on multiphase sand-water fountains injected into water layers of varying depth to model the collapse dynamics of shallow water eruption columns and to link fountain source conditions to deposit topography. The source strength of multiphase fountains predicts whether they collapse periodically or continuously via sedimentation waves with varying frequency and momentum. In turn, the frequency and momentum of sedimentation waves impacting the tank base determines whether ground-hugging gravity currents flowing out of the sedimentation wave impact zone are initially erosive or depositional. On the basis of experiments, we propose that syn-eruptive shallow submarine caldera deposits that show evidence of

terracing and proximal scouring are linked to relatively strong eruption jets in the regime where the jet is in partial collapse or total collapse. In these regimes, the eruption jet collapses periodically as sedimentation waves that erode the deposit in the impact zone and transition into submarine PDCs that deposit the sedimentation wave mixture into regularly spaced terraces thereafter (Fig. 1, black boxes). In contrast, we expect weak eruption jets to occur in the total collapse regime where sedimentation waves descend in rapid succession and effectively supply submarine PDCs continuously which, in turn, build deposits lacking terraces (Fig. 1, blue box). For common values of caldera eruption source parameters, we link submarine PDC deposit morphology to eruption jet strength and plausible mass eruption rates.

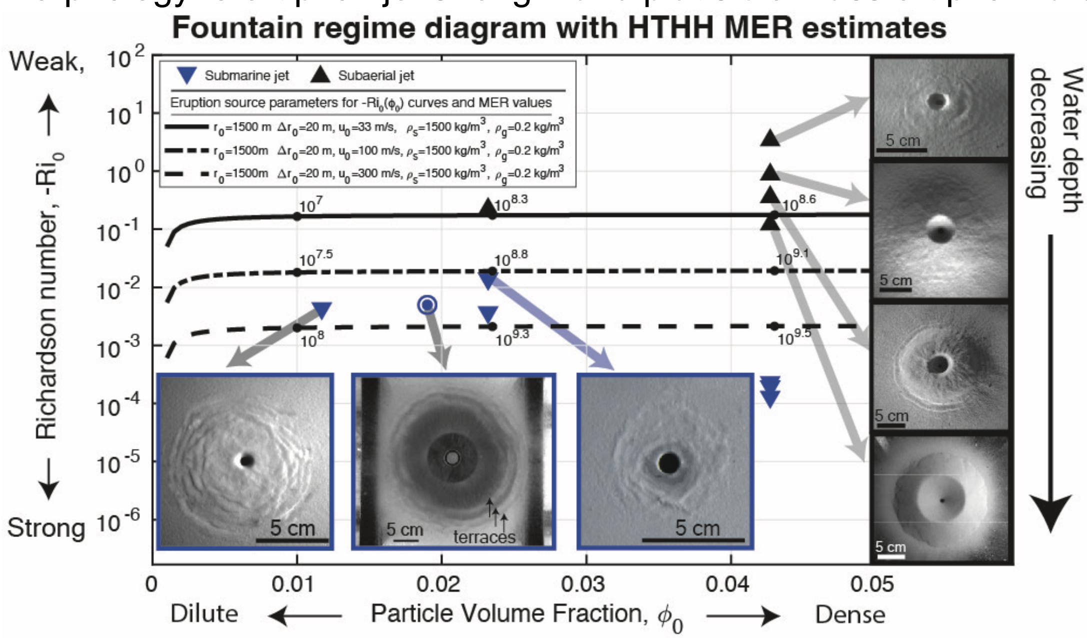

Figure 1: Regime diagram for multiphase fountains and inset images of associated deposit architectures. Multiphase fountain experiments plotted for source Richardson number ($-Ri_0$) and particle volume fraction (ϕ_0) values taken at the submarine tank nozzle and modelled at the water surface where fountains breach into the overlying air layer. Curves show source Richardson number with dot markers showing mass eruption rate (MER) for plausible Hunga Tonga-Hunga Ha'apai caldera eruption source parameters that are held constant and vary with source particle volume fraction. The circle-dot marker is for an experiment through an annular nozzle modeling a caldera ring-fissure vent geometry whereas all other markers are for experiments with cylindrical nozzles.

Plain-language Summary

The January 15, 2022 eruption of Hunga Tonga-Hunga Ha'apai volcano in Pacific ocean sent volcanic ash, rocks, gases, and vaporized seawater to unexpected heights in the stratosphere. However, the majority of the erupted material was deposited on the seafloor

surrounding the volcano by submarine hot rock avalanches that devastated all life and infrastructure in its path. The deposit shows regularly-spaced rings, or terraces, of deposited material that is observed at similar volcanic settings elsewhere on Earth. Here we use laboratory experiments simulating this type of eruption to show that the terraces are built by submarine hot rock avalanches which, in turn, originate from erupted material collapsing above the volcano. By linking submarine volcanic terraces to the volcano, we are able to estimate the eruptive conditions reconstruct the hazards of ancient submarine volcanic eruptions, and improve predictions of hazards for future eruptions.

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