The dynamics of buoyancy driven fragmentation in a deep subaqueous volcanic eruption, observations of the 2009 eruption of West Mata

*Arran Peter Murch[1], Ryan A. Portner[2], Kenneth H. Rubin[3], David A. Clague[4]

1. Department of Geology and Paleontology, National Museum of Nature and Science, Tsukuba, Japan , 2. Geology Department, San Jose State University, USA, 3. SOEST, University of Hawaii at Manoa, USA, 4. Monterey Bay Aquarium Research, Moss Landing, USA

All subaqueous eruptions interact with ambient water. Interaction occurs both through rapid heat transfer on direct contact between magma and water, and as a result of water's differing physical properties compared with air. The potential implications of these interactions are understood i.e. reduced degree of volatile exsolution due hydrostatic pressure, explosive boiling of water, rapid quenching of magma, etc. However due to the difficulty of studying such eruptions *in situ* the exact nature of the interaction processes, from effusive to pyroclastic, during deep subaqueous eruptions (>500 m below sea level (mbsl)) remain enigmatic.

In May 2009 a submarine eruption at West Mata volcano, located in the Northeast Lau Basin, was directly observed and sampled using remotely operated vehicle Jason2. The eruption occurred from vents Hades (1200 mbsl) and Prometheus (1175 mbsl). Pyroclastic activity occurred at both vents, but this study will focus on activity at Hades, which exhibited the discontinuous release of 0.6-2 m diameter volatile-filled magma-skinned bubbles that fragmented and quenched in the water column. In addition, pillow lava flows up to 350-500 m long were erupted from Hades vent. The 2009 West Mata eruption is one of only two deep submarine eruptions for which both syn-eruptive visual observations and seafloor samples have been collected. The wealth of syn-eruptive data for the 2009 West Mata eruption provides the ideal opportunity to develop an eruption model of small scale mafic pyroclastic deep submarine volcanism.

Here we present inferences on an eruptive style termed bubble blowing, defined by the irregular eruption of distinct volatile bubbles that ductily inflate the overlying magma and quench within 1 s. We combine detailed observations from frame by frame examination of eruption video with heat loss and volatile expansion modelling to give an integrated view on a range of eruption processes such as magma fragmentation and magma-water interaction processes at various stages during the eruption.

Bubble blowing eruptions can be broadly split into four stages based on changes in volatile and magma behavior. Those stages are 1. Buoyant ascent of a volatile bubble through the magma column causing inflation and deformation of the magma's surface into a magma-skinned volatile-filled bubble, 2. Ductile fragmentation and retraction of the magma-skin bringing the volatile bubble into direct contact with ambient water, 3. Rapid contraction of the volatiles due to cooling/condensation leading to implosion of the bubble, and 4. Formation of a turbulent plume of heated water and entrained particles.

The influence of the ambient water column plays a key role at all stages during bubble blowing eruptions. Volatile expansion, a key process in driving subaerial explosive volcanism, is highly restricted at pressures higher than that equivalent to water depths of ~ 100 m. At the depth of West Mata vents volatile expansion is negligible. Volcanism and fragmentation are therefore driven not by rapid volatile expansion, but by the buoyancy of the volatile bubble. The driving eruption force however switches to implosion following rapid cooling of the volatiles on contact with the ambient water. Therefore, we suggest bubble

blowing is a buoyancy implosive eruption style.

Extensive evidence of ductile fragmentation in the products of bubble blowing eruptions and heat loss modeling also show that magma can behave in a ductile fashion on eruption timescales despite direct contact with the ambient water.

Observations of bubble blowing activity question several fundamental concepts in subaqueous volcanology including what we mean by “explosive” fragmentation, whether there is a single transition between deep and shallow eruptions, and the effect of quenching of eruption processes. However, detailed observations can also more widely inform discussion of magma fragmentation and magma-water interaction processes in all environments.

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