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Tomographic Image Correction and Feature-Specific Segmentation in Laboratory Simulation of Degassing-Induced Volcanic Eruptions

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The driving force behind magma eruptions in volcanic activities is the gas phase separation, either water or CO_2. In the case of carbonatitic magmas (i.e. magmas consisting mainly of molten carbonates), vapor exsolution may occur as deep as 80 km. This depth, known as the carbonate ledge, demarcates the point above which ascending mantle carbonate melts become unstable and produce gas phases. The extremely large volume expansion during gas separation (degassing) may be the cause of catastrophic carbonatitic magma eruptions, which have roots deep in the mantle. We have developed techniques to simulate the process using synchrotron x-ray diffraction, tomographic imaging, and acoustic emission (AE) detection to study the melt-degassing process at high pressure and temperature. We have been able to correlate AE activities with the degassing reaction when gas bubbles are formed during isothermal decompression.

Imaging using synchrotron micro computed tomography (micro-CT) enables the rapid acquisition of large, highly detailed 3-dimensional (3D) datasets, but the replication of high pressure and temperature conditions leads to artifacts in the final reconstructed images. These errors are mostly due to low signal and uncontrolled motion associated with the mechanical difficulty of keeping uniform movement at high pressures. Here, we present an image processing pipeline that improves the quality of the raw acquired images and enables qualitative and quantitative segmentation-based analysis of potential gaseous bubble formations at varying temperatures and pressures.

With increasing scan size and number at various pressure and temperature conditions, manual image segmentation becomes less feasible and more prohibitive. Moreover, the need to handle the varying differences in contrast levels, textures, and intensities across and within individual scans often prevents the use of classic approaches such as intensity thresholding, watershed expansion, filtering, and edge detection. To segment and analyze all relevant elements across the individual images, we also developed a workflow that combines traditional approaches with a random forest classifier machine learning algorithm. Such methods can save resources and standardize the process across multiple images, allowing downstream quantitative characterization based on attributes such as shape, texture, abundance, or location of the volumes of interest.