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Fluid-Solid Interaction and Multiscale Dynamic Processes: Experimental Approach

Alejandra Arciniega-Ceballos (1), Laura Spina (2), Gerardo M Mendo-Pérez (1), Enrique Guzmán-Vázquez (3), Bettina Scheu (2), Francisco J Sánchez-Sesma (3), and Donald B Dingwell (2)

(1) Institute of Geophysics, UNAM, GEOPHYSICS, VOLCANOLOGY, Mexico (maac@geofisica.unam.mx), (2) Ludwig-Maximilians-Universität München, Germany, (3) Institute of Engineering, UNAM, Coyoacan, Mexico

The speed and the style of a pressure drop in fluid-filled conduits determines the dynamics of multiscale processes and the elastic interaction between the fluid and the confining solid. To observe this dynamics we performed experiments using fluid-filled transparent tubes (15-50 cm long, 2-4 cm diameter and 0.3-1 cm thickness) instrumented with high-dynamic piezoelectric sensors and filmed the evolution of these processes with a high speed camera. We analyzed the response of Newtonian fluids to slow and sudden pressure drops from 3 bar-10 MPa to ambient pressure. We used fluids with viscosities of mafic to intermediate silicate melts of 1 to 1000 Pa s and water. The processes observed are fluid mass expansion, fluid flow, jets, bubbles nucleation, growth, coalescence and collapse, degassing, foam building at the surface and vertical wagging. All these processes (in fine and coarse scales) are triggered by the pressure drop and are sequentially coupled in time while interacting with the solid. During slow decompression, the multiscale processes are recognized occurring within specific pressure intervals, and exhibit a localized distribution along the conduit. In this, degassing predominates near the surface and may present piston-like oscillations. In contrast, during sudden decompression the fluid-flow reaches higher velocities, the dynamics is dominated by a sequence of gas-packet pulses driving jets of the gas-fluid mixture. The evolution of this multiscale phenomenon generates complex non-stationary microseismic signals recorded along the conduit. We discuss distinctive characteristics of these signals depending on the decompression style and compare them with synthetics. These synthetics are obtained numerically under an averaging modeling scheme, that accounted for the stress-strain of the cyclic dynamic interaction between the fluid and the solid wall, assuming an incompressible and viscous fluid that flows while the elastic solid responds oscillating. Analysis of time series, both experimental and synthetics, synchronized with high-speed imaging enables the explanation and interpretation of distinct phases of the dynamics of these fluids and the extraction of time and frequency characteristics of the individual processes. We observed that the effects of both, pressure drop triggering function and viscosity, control the characteristics of the micro-signals in time and frequency. This suggests the great potential that experimental and numerical approaches provide to untangle from field volcanic seismograms the multiscale processes of the stress field, driving forces and fluid-rock interaction that determine the volcanic conduit dynamics.