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Numerical modelling of mud volcanoes: how do mud chambers control surface fluid emissions?

Davide Oppo and Mehrdad Manzari
University of Aberdeen, School of Geosciences, United Kingdom (davide.oppo@abdn.ac.uk)

Mud volcanoes are dynamic components of the Earth's surface whose role as natural hazards has become particularly evident in recent years. A clear understanding of the processes governing fluid emission from mud volcanoes is fundamental to evaluate their impact on nearby human communities and natural ecosystems, and to properly consider their role in geological and socioeconomic models at a regional scale. Despite extensive work, the processes triggering and controlling mud eruptions are still not completely understood. Numerical modelling is a relatively novel approach to the study of mud volcano systems and a comprehensive and accurate physical model has not been developed yet. Due to mud volcanoes complexity, we must focus on building reliable numerical models of their single components, which can be later integrated in a comprehensive model.
Starting from earlier works, we developed a numerical model to quantify the time-dependent response of mud volcanoes to various pressure perturbations. We investigated the role of mud volcano chambers, located at an intermediate depth between the deep fluid source and the surface, in regulating the fluid emission on the surface. The effect of mud chambers on the activity of mud volcanoes has never been studied in detail as they are considered marginally in literature. However, these rock volumes with increased fluid content have been documented in several mud volcanoes worldwide and, when present, might be a critical component of the system. We present the preliminary results of a numerical model of mud chambers that has been benchmarked with subsurface data acquired on mud volcanoes in Trinidad and Tobago. We observed that the mud chambers act dynamically as a buffering zone within the mud volcano plumbing system, significantly affecting the frequency and intensity of eruptions via volumetric expansion and contraction resulting from pressure changes at depth. We simulated an asymmetric sinusoidal pressure pulse from the fluid parent zone and observed that is not straightforwardly associated with an increased fluid emission on the surface. Instead, the system experiences an initial pressure drop both within the shallow mud volcano system and the underneath chamber as this latter expands and accommodates the input of the new fluids from depth. It is only after some time that the pressure pulse reaches the surface with values above the background condition. The pressure and emission intensity curves are thus not reflecting the initial sinusoidal input but have a more irregular shape that reflects oscillations below and above the original mud volcano background activity.
These preliminary results demonstrated that intermediate mud chambers have a role in governing the pressure and fluid dynamics in the mud volcanoes subsurface. More advanced simulations and results will be significant to the general understanding of the mud volcanism phenomenon, and to practical applications such as risk assessment within socio-economic and industrial frameworks.