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Journal of Geology & Geophysics

ISSN: 2381-8719

Commentary

Measurement Techniques Used in Geological Flow Studies

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DESCRIPTION

Multiphase flows occur frequently in geological and ecological contexts. Magma is an obvious example of a three-phase suspension because it contains solid particles, gas bubbles, and liquid silicate melts. Another one is where gas bubbles interact with liquid water and the rock matrix, such as in gas hydrates and undersea gas seeps. Even more prevalent are two-phase flows, with solid-liquid, solid-gas, and liquid-gas scenarios all being frequent occurrences. Examples of geological solid-liquid interactions include sediments carried by rivers, water, pollutants, and metallic ore concentrates seeping through porous rock. It takes a complex reactive flow process including chemical reactions and liquid-solid interactions to move melt through a matrix of partially molten rock so that it can collect in reservoirs with high melt fractions and possibly be recovered to the surface. Examples of gas-solid contact include the interaction of dust, manmade particulate matter, or clouds of aerosols like volcanic ash with the atmosphere. The reactive movement of gas through rocks during geological sequestration of CO_2, a possible strategy for decreasing anthropogenic climate change, is influenced by both chemical reactions and fluid mechanics. Gas-liquid interaction is seen in hydrothermal systems such as geysers and undersea gas chimneys.

The behaviour of the system as a whole, as well as the multiphase interactions at the particle or bubble level is studied by geoscientists using analytical and numerical models. For instance, models that represent the dynamics of magma ascending within a conduit, including its deformation, fragmentation, and bubble coalescence, are essential for predicting volcanic eruptions. Others rely on knowledge of lava dynamics at the micro-scale of bubbles and particles and their impact on large-scale processes of channel development, solidification, and inflation to predict the effects of volcanic eruptions on their surroundings. Observations must be used to verify and limit such models. Direct observation and observations of many geological processes are nonetheless difficult or impossible due to their length and time scales, as well as frequently being inaccessible. Therefore, using scaled ("analogue") laboratory experiments using materials and geometries similar to the geological materials and processes is a typical approach in geoscience. In a laboratory flume, sedimentologists frequently research the mechanisms of deposition and erosion. All the many parts of the magmatic system, from the magma reservoir and plumbing system through eruptions and their by-products are studied by volcanologists using analogue experiments.

When conducting analogue experiments, geoscientists pay close attention to how the scale of the experiments compares to the relevant natural occurrences. It is usual practice to accomplish this by taking into account a collection of non-dimensional factors that represent the proportion of forces to length- and timescales in the analogous and natural system. Scientists, for instance, use materials with viscosities and thermal properties that produce behaviour within the same regime (e.g., turbulent versus laminar, solidification dominated versus advection dominated) as the natural system to research the emplacement of lava flows in the lab. Scientists, for instance, use materials with viscosities and thermal properties that produce behaviour within the same regime (e.g., turbulent versus laminar, solidification dominated versus advection dominated) as the natural system to research the emplacement of lava flows in the lab. As analogues for lava and magma, substances including sugar-based syrups, clay slurries, silicone oil, and polyethylene glycol wax have all been used. Scientists select materials that have a similar relative relevance of elastic and plastic behaviour to that of the rocks or tectonic plates in which they are interested in order to research processes like tectonic plate deformation or dyke intrusion, where elasticity plays a role. Geologists have studied analogue systems like salt (NaCl) and water to study reactive flows like magma penetration through the crust and have found that the flow concentrates into channels. Since then, melt extraction models under mid-oceanic ridges and other reactive flows have been developed using these findings. Scaling to the natural system is achieved by choosing the proper length- and timescales by changing slopes, thickness, aspect ratio, and peak discharge rates. Sediment transport in laboratory hydrographs uses materials similar to the natural system (water and rock particles). The goal is to achieve a similar regime ($Ca>1$ or $Ca<1$) in the lab and the natural system being researched. Bubble behaviour is scaled by the capillary number Ca, which indicates the ratio between shear pressures and surface tension forces. By

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Received: 01-Nov-2022; Manuscript No. JGG-22-21105; **Editor assigned:** 03-Nov-2022; PreQC. No. JGG-22-21105 (PQ); **Reviewed:** 17-Nov-2022; QC. No. JGG-22-21105; **Revised:** 24-Nov-2022; Manuscript No. JGG-22-21105 (R); **Published:** 01-Dec-2022, DOI: 10.35248/2381-8719.22.11.1054.

Citation: Zhdanov MS (2022) Measurement Techniques Used in Geological Flow Studies. J Geol Geophys. 11:1054.

reproducing and systematically extending natural systems, analogue experiments have also helped to limit the significance of variables like particle shape and size distribution.