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Modelling the chemical composition transients in volcanic soil gases to evaluate the source depth of the gas reservoir

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Continuous and high frequency monitoring of the chemical composition changes of the gas emissions aimed to the volcanic activity surveillance, requires the investigation of the transport dynamics in a multiphase system. In order to study the relationships among the chemical composition of the gas emissions, the sub-surface gas flux regime, the features of the porous medium and the depth of the gas reservoir, we have designed several laboratory experiments and developed the theoretical model needed to understand both the results as well as the data collected in the field measurements. In our model, we describe the gas transport through a porous medium as the result of both diffusive and advective processes, stressing the mass transfer features during a transient state induced through the disturbance of the flux variables of the system. A cylindrical container filled with volcanic ashes of known size and shape of the grains has been used in laboratory as gas flux simulator. At the uppermost base, it was provided with both the H_2 and CO_2 detectors. The chemical gas disturbance was induced at the lower base of the cylinder through a gas flux ranging from 10^{-3} to 10^{-1} $cm^3 s^{-1} cm^{-2}$ of H_2 and CO_2 in N_2 matrix. This interval well includes the experimental values measured in the field. The temperature and pressure conditions were also controlled. Our results show that the first arrival times of the chemical gas disturbance depend on the height of the cylinder, the advective flux velocity and the diffusive features of each gas species. We also observe that the CO_2 concentration disturbance regularly arrives later than the H_2 one and the time delay between them increases as the advective flux velocity decreases. We believe that the different diffusive features of the H_2 and CO_2 molecules can explain such a sort of chromatographic effect. Although the advective flux is the more efficient transport process, the diffusive one operates towards the separation of the mixture in its own components. Since the arrival time of the concentration disturbance of each gas species depends also from the distance of the source, the measurements of both their time delays and the advective gas flux velocity allow the evaluation of the depth of the gas reservoir. The high frequency monitoring data acquired at Stromboli volcano have shown good agreement with laboratory results since the main changes of H_2 concentration precede the CO_2 ones systematically up to a few tens of hours.