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The 2011 collapse of Puu Oo pit crater, Hawaii: insights from digital image correlation and Discrete Element Method models

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In March 2011, a spectacular fissure eruption on Kilauea was associated with a major collapse event in the highly-active Puu Oo crater. Time-lapse cameras maintained by the Hawaii Volcano Observatory captured views of the crater in the moments before, during, and after the collapse. The 2011 event hence represents a unique opportunity to characterize the surface deformation related to the onset of a pit crater collapse and to understand what factors influence it. To do so, we used two approaches. First, we analyzed the available series of camera images by means of digital image correlation techniques. This enabled us to gain a semi-quantitative (pixel-unit) description of the surface displacements and the structural development of the collapsing crater floor. Secondly, we ran a series of 'true-scale' numerical pit-crater collapse simulations based on the two-dimensional Distinct Element Method (2D-DEM). This enabled us to gain insights into what geometric and mechanical factors could have controlled the observed surface displacement pattern and structural development. Our analysis of the time-lapse images reveals that the crater floor initially gently sagged, and then rapidly collapsed in association with the appearance of a large ring-like fault scarp. The observed structural development and surface displacement patterns of the March 2011 Puu Oo collapse are best reproduced in DEM models with a relatively shallow magma reservoir that is vertically elongated, and with a crater floor rock mass that is reasonably strong. In combining digital image correlation with DEM modeling, our study highlights the future potential of these relatively new techniques for understanding physical processes at active volcanoes.