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Numerical modelling of collapsing volcanic edifices

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The flanks of Oceanic Volcanic Edifice's (OVEs) can occasionally become unstable. If that occurs, they can deform in two different modes: either slowly along localization failure zones (slumps) or catastrophically as debris avalanches. Yet the physics of this process is incompletely understood, and the role of factors such as the OVE's strength (viscosity, cohesion, friction angle), dimensions, geometry, and existence of weak layers remain to be addressed.

Here we perform numerical simulations to study the interplay between viscous and plastic deformation on the gravitational collapse of an OVE (diffuse deformation vs. localization of failure along discrete structures). We focus on the contribution of the edifice's strength parameters for the mode of deformation, as well as on the type of basement.

Tests were performed for a large OVE (7.5 km high, 200 km long) and either purely viscous (overall volcano edifice viscosities between 1019-1023 Pa.s), or viscoplastic rheology (within a range of cohesion and friction angle values). Results show that (a) for a strong basement (no slip basal boundary condition), the deformation pattern suggests wide/diffuse "listric" deformation within the volcanic edifice, without the development of discrete plastic failure zones; (b) for a weak basement (free slip basal boundary condition), rapid collapse of the edifice through the propagation of plastic failure structures within the edifice occurs.

Tests for a smaller OVE (4.5 km by 30 km) show that failure localization along large-scale listric structures occurs more readily for different combinations of cohesion and friction angles. In these tests, high cohesion values combined with small friction angles lead to focusing of deformation along a narrower band. Tests with a weak layer underlying part of the volcanic edifice base show deformation focused along discrete structures mainly dipping towards the distal sector of the volcano. These tests for a small OVE constitute a promising basis for the study of a currently active slump in the SE flank of Pico Island (Azores, Portugal).

We will also address the effect of lithospheric flexure, and discuss initial 3D modelling results.