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Lateral collapse of Oceanic Volcanic Edifices: numerical modelling

Ana Costa (1), Fernando Marques (2), Boris Kaus (1), and Anthony Hildenbrand (3)

(1) Johannes Gutenberg University Mainz, Mainz, Germany (anacosta@uni-mainz.de), (2) Geology Department, University of Lisbon, Lisbon, Portugal, (3) Univ Paris-Sud, Laboratoire IDES, UMR8148, 91405 Orsay, F-91405, France

Oceanic Volcanic Edifices (OVEs) can become gravitationally unstable during their evolution. Evidence has been found worldwide that large-scale destabilization events can either occur slowly and form slumps, or occur in a catastrophic manner as debris avalanches. Slumps can be long-lasting structures, at the time scale of the geological evolution of the volcanic edifice itself. Yet, the physics of gravitational deformation in OVEs is incompletely understood, in particular with respect to the role played by factors such as the OVE's strength (viscosity, cohesion, friction angle), dimensions, geometry, and occurrence of weak layers.

Our work was previously focused on the effects of two end-members on the long-term gravitational deformation of a large-scale OVE (7.5 km high, 200 km long): an extremely strong basement (no slip basal boundary condition) or a very weak basement (basal free slip boundary condition). Despite the valuable insight obtained from such tests, the results obtained for the basal free slip boundary condition show that such case is too unrealistic, as it results in an extremely fast flattening of the volcanic edifice.

Here, we report on 2D high-resolution numerical models that take visco-elasto-plastic rheologies into account to study how a small OVE (4.5 km high, 30 km long), deforms over a period of time up to 10 Ma, in which we consider a strong basement (no slip basal boundary condition). We test the effects of different rheologies: purely viscous (overall volcano edifice viscosities between 10ˆ20 - 10ˆ23 Pa s), visco-plastic (within a range of cohesion and friction angle values), visco-elasto-plastic, and visco-elasto-plastic with strain weakening on the evolving dynamics of the system.

We observe for which conditions we obtain localization of failure, deeply rooted in the volcanic edifice and long-lasting. Model results and derived strength parameters are compared with the structure of an active slump in the SE flank of the Pico Island (Azores, Portugal).