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The sagging-spreading transition during volcano growth: an experimental perspective

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A volcano's structure and plumbing system are greatly influenced by its basement. An unresolved question, however, is how basement properties affect a growing volcano. To address this issue, we conducted scaled analogue experiments involving a sand-plaster cone emplaced upon a basement comprising an upper brittle layer and a lower ductile layer. Horizontal deformation, displacement, and velocity fields were quantified by Digital Image Correlation (DIC) analysis of time-lapse images. In a first experiment series, we emplaced the cone instantaneously. We find that cones spread, sag, or display a mixed style, depending on the ratios of ductile (D) or brittle (B) layer thickness to cone height (H). Transitions between these styles were defined in dimensionless B/H vs. D/H space. In a second experiment series, we emplaced the cone in several increments of constant volume, each separated by a period of repose. As the cone grew, its deformation style changed successively from sagging to a mixed style to spreading. This evolution reflects the cone's migration in B/H vs. D/H space through the transitions identified in the instantaneous-emplacement experiments. This structural development during model growth is similar to that determined from field relations at Concepcion volcano, Nicaragua. Moreover, it is broadly consistent with an observation that volcanic rift zones form mainly on edifices that exceed a certain height and volume. Our results thus show how basement-related deformation of volcanoes may profoundly change their architecture during volcano growth.