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Axi-asymmetric development of buoyant diapirs in analogue and numerical experiments: the role of source-layer tilts

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Diapiric structure owing to gravity instabilities, triggered by density inversion in the rock sequences, is a unique geodynamic manifestation. High-density layers that rest upon low-density layers tend to sink, forcing the latter to squeeze up in the form of domal shapes, called buoyant diapirs. Using two-layer viscous model experiments, we investigated the effects of source-layer tilt (β) in controlling the ascent behaviour of buoyant diapirs initiated by a Rayleigh-Taylor instability. Results from our laboratory experiments, performed with a buoyant viscous layer (PDMS; density: 965.0 kg/m^3) underlying a denser fluid (water; density: 998.2 kg/m^3) suggest that the diapir shape is highly sensitive to β. The results suggest that diapirs growing from a tilted source layer ascend with contrasting lateral spreading rates in the up and down slope directions, resulting in axi-asymmetric geometry. Conversely, diapirs initiated from a horizontal source layer always maintain axi- symmetric shape as they grow. Interestingly, diapir heads retain a circular outline on the horizontal top surface irrespective of their degree of symmetry. However, for the axi-asymmetric cases, the upwelling axis is shifted more in the up-slope direction, i.e. away from the centre of this circular geometry. We show a spectrum of the axi-symmetric to -asymmetric geometrical transitions as a function of the source-layer tilt (β). For large β ($> 4^o$), the diapirs become unstable, and their stems undergo a continuous drift in the upslope direction during their vertical growth. Whilst, several studies have shown the development of axi-asymmetric diapirs, the underlain flow kinematics in the viscous layers as a function of source layer tilt leading to such shape transition remains unclear. With this objective we ran computational fluid dynamic (CFD) simulations, by employing the volume of fluid (VOF) method, to investigate the role of underlying dynamics for axi-asymmetric diapiric growth. This study shows for the first time that $\beta>$ 0^oconditions develop stronger flow vortices on the down-slope side of an ascending diapir, leading to a pressure difference between the up- and down-slope flanks, which in turn drives the diapir head to spread at a faster rate in the tilt direction. We also provide an estimate of the ratio of spreading rates in the up- and down-slope directions as a function of β.