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Mechanisms of saucer-shaped sill emplacement and associated doming: insights from experimental modelling

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Horizontal sheet-like magmatic intrusions such as sills have emplaced within various sedimentary basins associated with large igneous provinces (i.e. in the Karoo basin, South Africa; the Norwegian and North Sea; the Tunguska basin, Siberia). In these basins, most of the intrusions developed a saucer morphology. These particular intrusions have a strong impact on petroleum systems by (1) enhancing organic matter maturation and (2) lifting up the overburden to form dome-shape structural traps. Therefore, the processes controlling saucer-shaped sills emplacement and the resulting deformation are fundamental for understanding sedimentary basin evolution. Interactions between sill emplacement and its overburden deformation are also important for volcanic hazard. In this work, we propose to constraint such mechanisms by performing experimental modelling.

Our experiments were scaled down to simulate basin-scale processes. The model rock and magma were fine-grained silica flour and molten vegetable oil, respectively. The oil was injected at constant flow-rate within the silica flour. The oil pressure and the topography of the model surface were constantly monitored. The oil pressure dropped with time and followed a hyperbolic trend, which indicated that the oil emplaced by hydraulic fracturing. The oil initially propagated horizontally into the silica powder to form an inner sill. Synchronously a smooth dome structure formed at the surface of the model. Subsequently, the oil propagated upwards to form inclined sheets; the dome almost stopped widening but kept lifting up, and its rims became sharper and steeper. As outward propagation of the oil proceeded, the sheets gradually flattened

close to the surface and developed into an outer sill; the dome slightly widened and lifted up. The experiment stopped when the oil finally erupted at the surface at the edge of the dome. Then, the oil solidified, and the intrusion was unburied. The final shape of the intrusion was saucer-like, similar to sill complexes observed in nature.

Our experiments showed that the emplacement of the oil controlled the evolution and the shape of the dome. In contrast, the deforming upper free surface and overburden generated stresses that most likely influenced oil propagation. Our results support the working hypothesis where the emplacement of sills, and especially saucer-shaped sills, results from a complex mechanical interplay between over-pressured magma and deforming host.