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Analogue modelling of salt diapirism induced by differential loading

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In salt tectonics, two general concepts exist to explain salt diapirism. First, the theory of active piercement by Trusheim (1960) states that salt rises up and pierces its overburden autonomously by buoyancy forces. Second, the theory of reactive piercement by Vendeville and Jackson (1992) considers a tectonic stress field responsible for initiation of salt uplift and has been tested in many analogue experiments. In this study, we investigated the hypothesis in which salt diapir formation is activated by sedimentary processes alone, i.e. without a tectonic trigger. Our models consisted of a viscous silicone layer simulating rock salt overlain by layers of sand that mimic brittle behaviour in natural overburden sediments. The experiments were monitored with a high-resolution strain analysis tool based on digital image correlation (particle image velocimetry, PIV). Deformation in the silicone was initiated by a lateral variation in the thickness or density of the overburden, which established a differential loading on the silicone layer. Subsequent sedimentation in certain time intervals forced the silicone to rise up and break through the initial sand layer by buoyancy forces.

The model results support the hypothesis of active piercement of diapirs. Uplift of the silicone and creation of a pillow structure with a significant elevation can be achieved if the overburden does not exceed a critical thickness and if the load gradient in the overburden reaches a minimum value. Then, ongoing sedimentation in adjacent areas increases the lateral load gradient until the buoyancy force in the silicone is high enough to overcome the shear strength of the sand. Synkinematic sedimentation produces some typical strata geometries in the sand layer that can also be observed in nature, e.g. drag folds bordering the diapirs and layer thickening in the peripherical rim synclines. The creation of one diapir and its peripherical sinks induces a lateral migration of the deformation to the adjoining areas. This leads to further generation of diapirs in a purely "halokinetic" way. The potential to form these "secondary diapirs" (Parker and McDowell, 1955) basically depends on the thickness of the silicone layer and on the sedimentation rate. The deformation paths and the strains in the experiments can be well observed with the PIV, which offers a new application in the analogue modelling of salt diapirism.

Our experiments contribute new insights in the discussion of diapir formation. They show that sedimentary processes can initiate diapirism without any tectonic influence if the salt movement starts early after its deposition. Additionally, the model results provide a validation of the theory of "salt-stock families" in the Northwest German Basin (Sannemann, 1965) in the light of new analogue modelling techniques.

References

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