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Mechanical Controls on Halokinesis in Layered Evaporite Sequences: Insights from 2D Geomechanical Forward Models

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Mechanical stratification in LES (Layered Evaporate Sequences) can have a distinct impact on structural and depositional styles in rifted margin salt tectonics. The bulk mechanical response of an LES under geological loading is dependent, among other factors, on the relative proportions of salt and sediment, salt mobility and sedimentation rate.

To assess the interactions among the aforementioned factors in a physically consistent manner, we present 2D, large-strain finite element models of an LES salt minibasin and diapirs. Loading from the deposition of alternating salt and sediment layers (i.e. LES), gravity and a prescribed geothermal gradient provide the driving force for halokinesis in the models. To accurately capture the mechanical impact of stratification within the modeled LES, salt is assigned a temperature-dependent visco-plastic rheology, whereas the sediments are assigned a non-associative cap-plasticity model that supports both compaction and shear localization. Perturbations in the initial salt-sediment interface are used to initiate the salt diapirs.

Model results suggest that active diapirism in the basal halite layer initiates when the pressure at the base of the incipient salt diapir exceeds that beneath the minibasin. Vertical growth of the diapir is also accompanied by its lateral expansion at higher structural levels where it preferentially intrudes the adjacent pre- and syn-kinematic salt layers. This pressure pumping of deeper salt into shallow salt layers, can result in rapid thickness changes between successive sediment layers within the LES. Caution needs to be exercised as such thickness changes observed in seismic images may not be entirely due to the shifting of depocenters but also due to the lateral pumping of salt within the LES. The presence of salt layers at multiple structural levels decouples the deformation between successive clastic layers resulting in disharmomic folding with contrasting strain histories in the sedimentary stringers. A significant proportion of the bulk deviatoric strain is preferentially partitioned into the salt layers. Effective plastic shear strains within the sediment stringers generally remain low in the minibasin but can be significantly higher with attendant intense folding near the diapirs. In non-LES systems, the shape of a salt diapir is often used as indicator of relative rates of salt supply and sedimentation over geological time. However our models suggest that this rule-of-thumb may not apply in LES where the shape of the salt diapir is a function of the mechanical properties of the salt layers at various structural levels in addition to the relative rates of salt supply and sedimentation. Imaging challenges in LES may preclude placing strong constraints on structural timing based on interpretation of interfaces between the stringers and the salt diapir. In such situations, geomechanical forward modeling can be a useful tool in placing physics-based quantitative constraints on the timing of LES structures.