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Initiation of Salt Minibasins under Uneven Sedimentation

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Can uneven sedimentation explain the enigmatic early initiation of salt minibasins at rifted continental margins when the sediment fill is less dense than the underlying salt? Using isostatic balancing arguments for compacting sediments, we first demonstrate that minibasin-scale thickness variations in a weak sedimentary overburden can cause pressure differences large enough to initiate salt minibasins. These contribute toward the minibasin attaining the Rayleigh-Taylor threshold, the point at which sediments sink into an underlying salt layer. Secondly, using two-dimensional plane-strain finite element models, we show that uneven sediment loading on a viscous salt channel can initiate salt minibasins even when sediments have finite strength, as is likely in natural systems. Uneven sedimentation is idealized in the models as uniform aggradation of compacting sediment with a superimposed smooth sinusoidal topographic perturbation, wavelength λ, maximum height h_l.

Our main goal is to estimate the minimum duration that uneven sedimentation must persist, t_P, when followed by uniform aggradation, such that the strength of the sediments is overcome and a successful minibasin develops. We investigate models with widths, W, equal to λ (confined salt models), and greater than λ (unconfined salt models). Our results suggest that for models that develop successful minibasins there is an optimal value of λ, λ_{OPT}, for which t_{RT}, the time to attain the theoretical Rayleigh-Taylor threshold based on isostasy arguments, and t_P are the smallest. This wavelength selection exists when the sediments have moderate (e.g., shale) to high (e.g., carbonates) density but is not prominent for low density sediments. For confined salt models at λ_{OPT}, t_P varies from 8.0 - 2.25 Ma for low to high density sediments, respectively, when h_l ranges from 40 to 80 m. In unconfined models, where salt can be expelled over larger distances than λ, t_P is reduced and ranges from 7 - 1.5 Ma. For a given sediment density and compaction model, there is a lower limit of λ below which uneven sedimentation alone does not initiate minibasins. However, successful minibasins develop over a wider range of λ in unconfined models and when $W \gg \lambda$, uneven sedimentation in one location can indirectly lead to the development of outboard basins.

Uneven sediment may alternatively be deposited on a uniformly thick, compacting pre-kinematic sediment layer. Under these circumstances t_P is further reduced to 9.0 - 0.5 Ma depending on the density of the sediments. Weak in-plane contraction can further reduce t_P to 3.5 - 0.375 Ma even for low density sediments. Our results indicate that under optimal conditions a period of uneven sedimentation of this type in an otherwise uniformly aggrading sequence need only have a topographic amplitude of 40 - 80 m and persist from 0.05 to 2 Ma in order to seed the development of a successful minibasin. Our idealized uneven sedimentation model can be interpreted as a proxy for channel-levee systems, deposition of turbidite lobe complexes, and/or lateral density variations within the sediments that cause equivalent sediment loading and which occur both in the down-dip and along-strike directions of a rifted margin.