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Lithospheric flexure and sedimentary basin evolution: depositional cycles in the steer's head model

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Backstripping studies of biostratigraphic data from deep wells show that sediment loading is one of the main factors controlling the subsidence and uplift history of sedimentary basins. Previous studies based on single layer models of elastic and viscoelastic plates overlying an inviscid fluid have shown that sediment loading, together with a tectonic subsidence that decreases exponentially with time, can explain the large-scale 'architecture' of rift-type basins and, in some cases, details of their internal stratigraphy such as onlap and offlap patterns. One problem with these so-called 'steer's head' models is that they were based on a simple rheological model in which the long-term strength of the lithosphere increased with thermal age. Recent oceanic flexure studies, however, reveal that the long-term strength of the lithosphere depends not only on thermal age, but also load age. We have used the thermal structure based on plate cooling models, together with recent experimentally-derived flow laws, to compute the viscosity structure of the lithosphere and a new analytical model to compute the flexure of a multilayer viscoelastic plate by a trapezoid-shaped sediment load at different times since basin initiation. The combination of basin subsidence and viscoelastic flexural response results in the fluctuation of the depositional surface with time.

If we define the nondimensional number Dw= $\tau m/\tau t$, where τm is the Maxwell time constant and τt is the thermal time constant, we find that for Dw«1 the flexure approximates that of an elastic plate and is dominated by "onlapping" stratigraphy which evolves through the sedimentary facies with a progressive deepening of the depositional surface. For Dw»1 the flexure approximates that of a viscoelastic plate and is dominated by "offlapping" stratigraphy, with the basin edges evolving through shallow marine facies; though erosion late in the basin formation prevents much of this from being recorded in the stratigraphy.

Interestingly Dw$\sim$1 produces a basin in which onlap dominates its early evolution while offlap dominates its later evolution with an unconformity separating the two different stratal patterns. This case lends a level of complexity to the behaviour of the depositional surface, which can exhibit both shallowing and deepening in cycles. Therefore, when consideration is given to the fact that the long-term strength of the lithosphere depends on both thermal and load age we are able to produce stratal geometries that not only closely resemble stratigraphic observations, but do not require either long-term sea-level or sediment flux changes in order to explain them.