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A new quantitative approach in modelling regional tectonic processes and syn-depositional systems in coupled analogue-numerical models

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Tectonically active settings such as rift basins are complex, dynamic environments, with the interplay between sedimentation and tectonics exerting a controlling influence on architectural development. Scaled 3D analogue experiments constrained by geological data, with high-resolution digital 3D deformation monitoring, are able to simulate fault localisation, linkage and displacement and resulting tectonic basin subsidence, including 1st order syn-kinematic sedimentation, with high spatial and temporal resolution. However, to date, deposition of syn-kinematic sediments onto analogue models has been done manually by depositing incremental homogeneous sand layers on top of the evolving experiment surface to simulate tectonic loading. As a result, syn-kinematic sedimentation in analogue experiments currently cannot simulate more complex stratal architectures or include depositional parameters like sea level and climate. Conversely, numerical stratigraphic modellers are able to produce these more complex stratal geometries and their controlling parameters but currently lack the ability to simulate the complex tectonic subsidence of basins realistically, or in sufficient resolution.

This work presents a new approach by combining numerical stratigraphic forward modelling and analogue experiment methods. We apply cellular carbonate stratigraphic forward modelling software (CarboCAT) to determine volumes and distributions of sediments to be repeatedly deposited onto the surface of an evolving sandbox experiment. When the derived sedimentation patterns are applied to the analogue model it should tectonically respond in a more in-depth manner than current methods are able to achieve.

The workflow uses Digital Image Correlation (DIC) to derive the surface topography and subsidence field of the analogue experiment to act as a scaled input for the numerical modeller, which is run with suitable production parameters (production rate, surface light intensity, extinction coefficient etc.) for the desired time increment, producing the sedimentation volumes and distribution. We developed and tested a sieving device to deposit this incremental sediment volume onto the experiment surface. A cellular array of tubes allows the deposition of calculated material volumes onto the corresponding surface location. This apparatus is capable of repeatedly depositing heterogeneous sandpacks with locally controlled volumes and homogeneous mechanical properties. The integrated workflow has been tested in a series of static experiments with varying initial parameters for both the analogue and numerical modelling techniques. Model evolution is purely deterministic, producing diverse final architectures solely as a result of initial parameters and feedback between the analogue and numerical modelling.

This approach is to be further developed, including semi-automatic deposition of syn-kinematic sand layers, to be applied to kinematic experiments at a regional scale, investigating rift basins and continental margins.