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Use of 3D integrated stratigraphic and structural model

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The study of the relationship between tectonics and sedimentation can be a key to decipher stratigraphic records in synkinematic series, such as in foreland basins (e.g. Canadian Foothills), or in deltaic series affected by growth faulting (e.g. offshore West Africa) or salt tectonics (e.g. Gulf of Mexico, Brazilian margin). Thanks to recent developments in numerical modelling, this relationship can now be simulated and quantified using coupled stratigraphic and structural modelling. This paper is focused on this new technology, and in particular on a simple 3D stratigraphic and structural model (Dionisos), its principles and an application on the Gulf of Mexico.

Classical stratigraphic models take into account only vertical basin deformation. Their use is thus restricted to relatively quiet basin, and in particular they cannot be applied on complex tectonic settings, with thrusts, growth faults, or shale/salt diapirsms. On the contrary, forward and backward structural models are able to deal with such complex systems, but they usually work in 2D and represent only large-scale basin deformation, without any detailed description of the stratigraphy of the sedimentary layers. They usually deforme, break and move homogeneous sedimentary layers.

In this paper, we propose to investigate the interaction between stratigraphic and structural processes using a forward model which take into account a "simple complex" deformation. Geological processes are simulated through time in a sequence of time step, from the past up to the present. At each time step, three main processes are taken into account : basin deformation, sediment supply and transport.

(1) we will assume that a 3D detachment surface, which represents in the same time a growth fault, a detachment surface sensu stricto and an inverse fault, splits the sedimentary basin in two vertical parts. The full basin is firstly deformed by vertical subsidence, eustasy, compaction and flexure. Then, above the detachment surface, sediment are moved in 2D in agreement with a displacement vector field defined by the user, and

using a vertical shear deformational mode, to mimic the 3D structural deformation.

(2) The supply of sediment may be aclastic inflow coming into the basin from the erosion of adjacent drainage areas, or an in situ carbonated production.

(3) The transport of sediment is finally simulated using two main laws : a slope-based water-driven equation to mimic long-term and short-term sediment transport controlled by fluvial discharge and gravity processes, and the Komar and Inman equation to simulate the nearshore drift.

Also this methodology is quite simple, it allows to test rapidly the link between stratigraphic and structural model. To really model the structural and stratigraphic evolution of sedimentary systems in three dimensions, it is clear that one would need to develop a fully integrated model, but this simple link already provides interesting outputs which will be illustrated with an application on the Gulf of Mexico, where very nice growth faults and inverse faults anchored on salt diapirs interact with sedimentary processes. This simple model allows us to study in detail both the slumps along the faults, progressive onlap, downlap and sequence boundaries closed to the inverse faults, ...

In fine, this coupled stratigraphic and structural approach has great potential both (1) for teaching and academic studies to better understand the interaction between these different complex geological processes, and (2) for petroleum exploration to better characterize geometry and property of sedimentary layers.