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A process-based method to predict 3D sedimentary architecture conditioned to real-world data: alluvial architecture in the Rhine-Meuse delta

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Current methods for interpretation and interpolation of sedimentological records often rely on qualitative process knowledge. This has the disadvantage that results are often subjective and open for multiple interpretations. An alternative approach is to use process-based models simulating processes that were active to produce the observed deposit. Because process-based models formalize process knowledge in mathematical equations, this approach has the advantage of being more objective. Thus far, the use of process-based models to create 3-D models of sedimentological architecture is limited, because it is considered impossible to condition the models to observations.

Here we present results that show that conditioning of process-based models to real-world data is possible, using the fluvial system as an example. We use a new quantitative, 3-D, process-based, fluvial sequence stratigraphy model to simulate the distribution of channel-belt deposits (sand bodies) and overbank deposits (mud, thin sands and peat) in the Rhine-Meuse delta. The model is conditioned such that simulated alluvial stratigraphy fits real-world data from boreholes within specified tolerance limits.

The model simulates an aggrading floodplain with avulsing channel belts of variable width and thickness. Floodplain aggradation increases or decreases in downstream direction. Overbank aggradation decreases away from channel belts. The model uses a small number of inputs and parameters that are defined as stochastic variables with a prior distribution that is uniform.

Fitting the model to a set of borehole data is done by automatically adjusting parameters and inputs until model outputs are found that condition to the observed stratigraphy. This is done using a genetic algorithm. We use borehole data from a well-studied area in the Rhine-Meuse delta, the Netherlands. The approach is evaluated by using different scenarios of borehole data. Goodness of fit is calculated by comparing the simulated alluvial stratigraphy with deposits that were not used initially for conditioning. It is shown that the prediction uncertainty decreases with an increase in the number of boreholes used for conditioning. Also, uncertainty decreases away from boreholes.

To our knowledge this is the first time that a 3-D, process-based model of fluvial sequence stratigraphy has been fitted directly to a real-world data set. The approach is capable to identify the most important controls on alluvial architecture. This research is also an essential step towards construction of a process-based model and user-friendly software that can be used for inverse modelling and predicting the character of both fluvial hydrocarbon reservoirs and aquifers.