Statistical Shape Characterization of Fluvial Sand Bodies and Implications for Reservoir Models

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Abstract

The three-dimensional geometry of fluvial channel sand bodies has received considerably less attention than their internal sedimentology, despite the importance of sandstone body geometry for subsurface reservoir modelling. The aspect ratio (width/thickness, W:T) of fluvial channels is widely used to characterize their geometry. However, these approaches do not provide a full characterization of fluvial sand body shape, since one W:T ratio can correspond to many different channel geometries. The resultant over- or under-estimation of the cross-sectional area of a sand body can have significant implications for reservoir models and hydrocarbon volume predictions. There is thus a clear need for the generation of versatile, quantitative, and statistically robust models for sand body shape. The main aim of this research is to develop a new statistically-based approach that will provide quantitative data, derived from outcrop analogues, to fully constrain stochastic fluvial reservoir models. Here, we describe the construction of a new sand body shape database and conduct a preliminary qualitative analysis in order to understand measurement and other uncertainties, and to explore the catalogue of shape configurations. Data of sand body shape was acquired from the excellent exposure of fluvial sediments in the Central Iberian Basin, Spain using a real-time kinematic GPS and photogrammetric methods. The collected polylines do not reflect the true cross-sectional shapes, as the recorded data is dependent on the orientation of the exposed outcrop surface as well as the shape. To correct for this parameter, the three-dimensional polylines are projected into a plane perpendicular to the palaeocurrent direction; this leads to a two-dimensional representation of the cross-sectional sand body shape. Three main shape classes were identified in the dataset: elongate,

sheet-like sand bodies, ribbon-shaped sand bodies and amalgamated complexes. The three main classes identified above rely on a basic classification of shape using simple geometric features and the presence of internal stacking. As a result, shapes can be part of more than one class, thereby conflicting with the width vs thickness classification into ribbons or sheets. The resulting dataset possesses exceptional potential as the foundation for future statistical shape analysis enabling forecasting of geometries and shapes that can be built into existing reservoir models, e.g. for the Triassic Skagerrak Formation, North Sea. By combining Bayesian methods and statistical shape modelling with machine learning methods such as deep learning, quantitative sand body shape analysis will be performed using the dataset, resulting in methods for, e.g. classification of sand body shapes into existing or new classes, regression of geological properties of interest on shape, and shape clustering to discover important new shape features.