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A quantitative knowledge base of continental depositional systems: new approaches to fluvial facies models and sequence stratigraphy

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Fluvial facies models and sequence stratigraphic models play a central role both in driving interpretations of continental strata, in terms of depositional context and associated controlling factors, and in guiding predictions of subsurface sedimentary heterogeneity. However, traditional facies models are fundamentally qualitative and unable to capture the complexity and variability that is inherent in the types of depositional systems they aim to represent. Sequence stratigraphic models for continental successions are strongly influenced by concepts originating from the study of shallow-marine strata, are monodimensional in the sense that – although the importance of a range of allogenic controls and autogenic dynamics is widely recognised – they tend to categorise stratigraphic architecture based on single selected parameters (e.g., accommodation, relative sea level), and partly overlook the time-scale dependence of architectural characteristics.

A database-driven approach brings together results of facies analysis, architectural-element analysis and geomorphological studies from many investigations, coded to a common standard to ensure that meaningful comparisons, or syntheses of datasets, can be achieved. This database serves to provide a wide-ranging catalogue of sedimentological data (e.g., deposit types, geometries, spatial relationships) relating to sedimentary and geomorphic units at multiple scales, and of attributes that describe the depositional systems in which such units are contained. The database can be interrogated through queries of geological significance, and the resulting output can be blended to construct novel quantitative facies models, or analysed and applied to test the importance of factors that control sedimentation. To showcase this database-informed quantitative approach to facies modelling, a number of examples are illustrated for depositional-system types that are commonly considered in the categorisation of traditional facies models (e.g., braided rivers, fluvial fans, dryland systems). Examples show how the significance of facies models as templates for interpretations and syntheses of current knowledge is leveraged, for example by the ability to tailor the models to the scales of observation of interest, or to discriminate the relative contribution of data from ancient and modern systems. Furthermore, the value of quantitative facies models as composite analogues to fluvial hydrocarbon reservoirs or aquifers is demonstrated through application to typical subsurface workflows.

Through the compound analysis of many depositional systems, the database approach finds application in comparative studies aiming to assess the sensitivity of fluvial sedimentary architecture to controls, or the value of depositional-system parameters as predictors of sedimentary architecture. The commonly held view that channel-deposit density should generally be inversely proportional to floodplain aggradation rates is challenged by a quantitative comparison of literature case studies of fluvial sedimentary successions. The analysis indicates that channel-body density, geometry, and stacking pattern are not reliable diagnostic indicators of rates of accommodation creation. This questions the sensibility and predictive value of establishing accommodation-based ‘systems tracts’ and ‘settings’ in

application to fluvial successions. Further, it is shown how meta-analyses of fluvial systems recording changes in depositional-system boundary conditions that are well-constrained in both magnitude and timing help reveal the emergence of depositional patterns and tentatively quantify relationships between products and controls.

Overall, the selected examples demonstrate the value of the database-driven approach as a tool that enables the improvement of fluvial facies models and represents a basis for the development of more comprehensive sequence stratigraphic models. This value would be enhanced by a collaborative effort to the compilation of a global knowledge base of fluvial sedimentology.