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Late Cretaceous Turbidite Reservoirs Along the Equatorial West African Margin: An Industry Perspective on Source-to-Sink Relationships

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The source-to-sink mindset provides an important framework for the exploration geologist. It enables an integrated understanding of hinterland and basin, and can lead to subsurface risk mitigation, particularly with respect to predicting reservoir location and quality. Despite the numerous benefits associated with source-to-sink analysis, such studies are time-consuming to generate, encompassing a large array of disciplines and data, and are not routinely performed within the hydrocarbon industry. The discovery of several significant hydrocarbon fields along the equatorial West African margin has been followed by a series of expensive failures throughout the last decade associated with reservoir quality/presence. This paper discusses a case study focused on the equatorial West African margin, demonstrating how three well-known but effective approaches can be integrated to reconstruct source-to-sink relationships in an ancient sedimentary system, helping de-risk exploration efforts.

The first step is to characterize the hinterland. To do this, detailed information was collected for two separate but interlinked datasets—mineral deposits and hard rock geochronology. Combined, these two datasets allow an understanding of the timing and nature of an areas tectonic evolution to be easily developed. The data can be used alongside stratigraphic data and geodynamic information from a plate tectonic model to reconstruct topography and bathymetry of the earth at different episodes of geological time. Paleo digital elevation models (PDEMs) give a first-order approximation of hinterland topography and therefore allow possible sediment source areas to be identified and potential sediment transport pathways to be visualized by means of the digital reconstruction of paleo-drainage networks and their attendant watersheds.

This integrated global dataset of hinterland geochronology provides useful “source” information complemented by “sink” information contained within a detrital geochronology database. By combining these two datasets and matching the age populations, sediment provenance can be deduced and source-to-sink relationships can be unraveled. Sedimentary provenance analysis from detrital/hinterland geochronology, and the application of flow routing algorithms to PDEMs, allow for the physical limits of paleo-drainage basins to be reconstructed. Assessment of the nature and composition of the hinterland within individual paleo-drainage basins provides a useful means of predicting the quality of sediment in associated point-sourced depocentres along the margin. For example, the erosion of hinterlands with markedly different compositions can have dramatic effects on the quality of sediment delivered to the surrounding basins.

Sediment transport pathways provided by PDEMs and detrital zircon geochronology provide a paleo-drainage network that can be further developed by exploiting power-law scaling relationships observed between source-to-sink systems (Somme et al. 2009). These relationships, and more general predictive models (e.g., Syvitski and Milliman 2007), allow for semiquantitative approximation of morphological and sedimentological parameters in both the source and sink domain and provide a useful means of verifying inferred drainage patterns. In frontier areas where subsurface constraint is sparse, an appreciation of sink characteristics, such as fan size and sediment flux are extremely valuable as a first-pass basin screening tool.