Along- and down-slope process interactions in proximal channel-levee systems: Implications for hydrocarbon exploration

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Abstract: *There is an increasing catalogue of turbidites hosting atypical characteristics across proximal channel-levee systems. While some of these may be attributed to system instabilities, these proximal deposits host characteristics more associated with contourites than turbidites, identifying a potential for a new 'mixed-levee zone' to become incorporated into turbidity models. Integrating pre-existing mixed-drift theories with a large literature review and newly acquired 3D seismic data, we have began to identify key characteristics promoting the interplay of along- and down-slope processes along proximal turbidity system, suggesting a 'mixed-levee' system should be used in proximal settings. Deposit confinement has been recognised due to the morphological constraints of turbidites and contourite drifts, though synchronous (simultaneous) and interpolated (in between) process-interactions offers the most significant potential for deposit alteration. Interpolated interactions are fairly long-lived, with the potential to rework sediments across submarine fans, though will offer only subtle differences in reservoir geometries and qualities and have little effect proximally. Synchronous interactions are periodic, following the frequency of turbidity events, bottom-currents have the potential to strip fine-grained overspill in proximal zones, leaving reduced flow quantities, but better sorting. The extent of this flow-stripping in mixed-levee systems has the potential to significantly enhance flow quality, and has been proven to provide economic quantities of 'clean' channel-fill deposits.*

Key words: *mixed-drift, reworked deposits, reservoir quality, 'cleaned' turbidite, channel-levee*

INTRODUCTION

The recent quest for hydrocarbons has seen exploration efforts target more distal settings on continental margins. While this has lead to a significant increase in our understanding of turbidity deposits, contourite and mixed-drift deposits have only recently seen resurgence in research.

Following the discovery of the 100 tcf gas field in the Mamba complex, Mozambique, there has been a recent resurgence in the demand for characterising mixed-system plays. While Faugères et al (1999) and Mulder et al. (2008) offer insights into process-interaction, it is becoming more apparent that these interactions are more common and significant than previously thought. Despite this, bottom currents are often overlooked in hydrocarbon exploration.

Mixed-drift plays have been speculated across the North Sea and Gulf of Mexico, (Shanmugam. 2012), though the absence of diagnostic criteria means these claims still remain speculative. With the aid of 3D seismics, new defining characteristics have been recognised across several frontier exploration programmes across the South Atlantic Margin and offshore east Africa. Based on atypical deposit morphologies and seismic stacking patterns, it is now possible to begin to characterise the nature of interaction between

METHODOLOGY

Integrating a large literature summary with newly acquired 3D seismic surveys, we have begun to characterise possible zones of interaction between turbidity and contourite processes in the late Cretaceous. Recognising anomalies due to system-based inefficiencies, it is possible to differentiate geometric and sedimentological anomalies due to process interaction, from those internal variances within the down- and along-slope redistributary system.

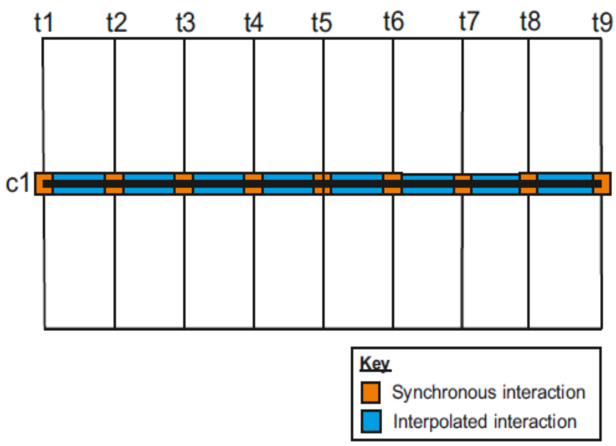

FIGURE 1. Schematic diagram showing the interaction of a contour current (c1) with turbidity events (t1 – t9). The dominance of synchronous styles of interaction occurs as a function of turbidity event frequency.

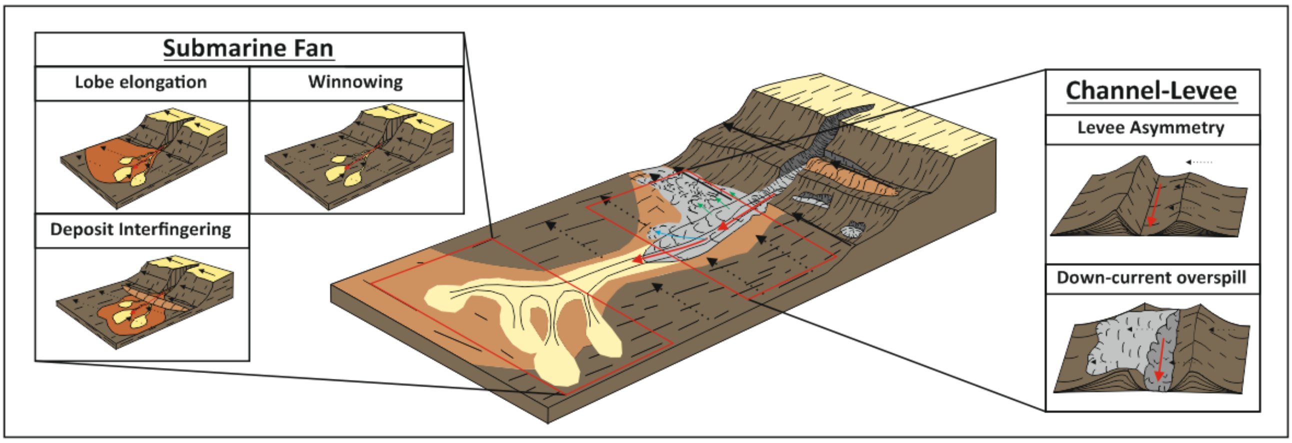

FIGURE 2. Conceptual diagram showing the various zones of process interaction across a turbidity system and examples of how geometries and sediments are affected. Red arrows = turbidity currents; black = along-slope currents; blue arrow = turbidity overspill; green arrow = along-slope induced overspill.

DISCUSSION

Building on the foundations laid by Mulder et al. (2008), we now propose a three stage model for turbidity systems: mixed-levee system; channel-levee system; and distal fan. The nature of interaction changes significant within these zones, though three typical styles of interaction have been recognised:

- **Morphological interactions**
- **Process interactions**
    - Synchronous
    - Interpolated

Morphological interactions focus on the positioning of the overall system. Typically, drifts form down-current from turbidity systems, with often large drifts forming perpendicular to the slope. Submarine channel orientation may also be loosely confined into troughs between slope-perpendicular drifts.

Process interactions aims to understand the resulting effects due to the synchronous (same time) and interpolated (between event) interactions.

Synchronous events are typically short-lived, due to the episodic nature of turbidites. They have the potential to trigger preferential deposition on one levee and remove fine-grained overspill, 'clean' channel fill deposits in proximal zones. In distal channel-levee systems, these are commonly not recognised.

Interpolated events are much more long-lived, occurring between two major turbidity events. While these may not affect the initial deposition of units, these may winnow or erode fine-grained sediments away from deposits, enhancing the net-to-gross sand ratio.

The dominance of synchronous events occurs based on the frequency and magnitude of the turbidity event. As a near-permanent entity, bottom currents will continuously rework the deposits. While these may introduce external sediments into the system, the quality is ultimately controlled by the turbidity system.

CONCLUSIONS

The frequency and magnitude of the turbidity system ultimately dictates the reservoir quality of a mixed-drift system. While morphological interactions may loosely control the geometries of deposits, process interaction offers the most substantial implications for deposit enhancement.

Synchronous events offer the most potential for reservoir enhancement, with the removal of fine-grained overspill in channel-levee systems, which will 'clean' channel-fill sediments and the subsequent flow. While interpolated interactions may subtly affect reservoir geometries, the quality of reworking is still ultimately dictated by the material in the turbidity systems.

These interactions are mainly recognised in proximal settings and change distally into typical channel-levee systems. From this, we propose a 'mixed-levee system' zone should be applied to proximal turbidites, where they host both turbidite and contourite characteristics.

ACKNOWLEDGEMENTS

I thank BG Group for access to their collection of 3D seismic data and Phil Thompson and Gianluca Badalini for their cooperation and discussions.

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