Bed-scale clay distribution in deep-water sandstones- results from XRF profiling of Ross cores, western Ireland

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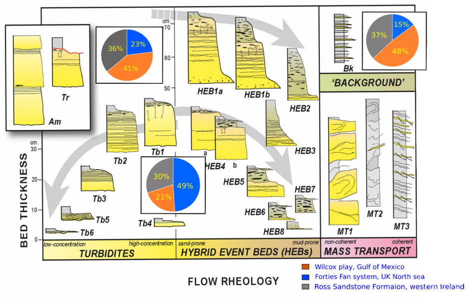
Introduction

Sediment gravity flow deposits form important hydrocarbon reservoirs in many basins worldwide, including potentially the Irish offshore. The fundamental building blocks of deep-water successions are individual beds deposited from single flow events. Emerging evidence suggests that clay can modulate turbulence in these event flows by forcing the deposition of sand and clay together as the flow decelerates, resulting in hybrid event beds (sensu Haughton et al., 2009). Variable clay distribution has important implications for bed-level heterogeneity and reservoir quality, including those in the distal Forties Fan in the North Sea and outboard Wilcox in the Gulf of Mexico. However, determining the details of continuous clay distribution and relating this to original flow processes poses significant challenges.

The present study shows how multi-element compositional profiling has helped to characterise the textural profiles of hybrid event beds (HEBs) in the Pennsylvanian Ross Sandstone Formation, western Ireland, an important deep-water reservoir analogue.

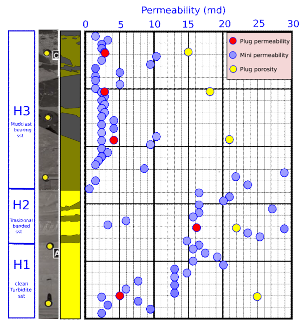
Bed type variability in gravity flow deposits



Key bed types in deep-water sandstones

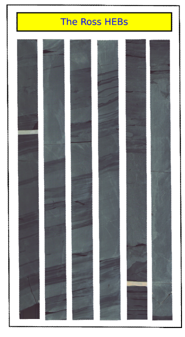
The pie charts shows the distribution of event beds in both outcrop (the Ross, after Pierce , 2015 and Obradors Latre, 2016) and subsurface examples from Wilcox sandstone, Gulf of Mexico (Kane & Ponten, 2012) and Forties Fan system, UK Central North Sea (Haughton et al., 2009).

Vertical permeability structure in HEBs



Permeability variation in subsurface HEBs (Southern et al., 2016). Permeability varies three orders of magnitude in the same event bed owing to difference in clay contents. Porosity is relatively stable even in linked debrite part because of clay's Microporosity.

HEBs under study

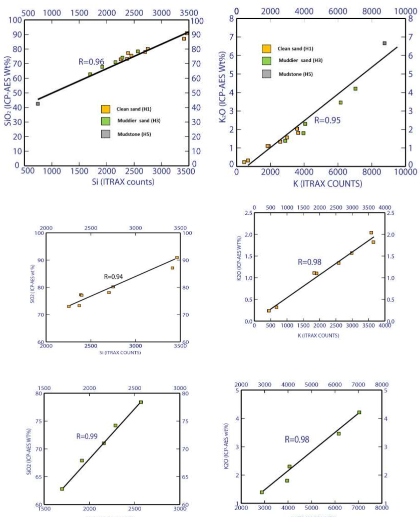


Behind-outcrop cores from Ross Sandstone Formation showing different types of Hybrid event beds (HEBs). All cores are meter long.

Compositional profiling of the Ross cores

15 m of scanned Ross core
50 different beds

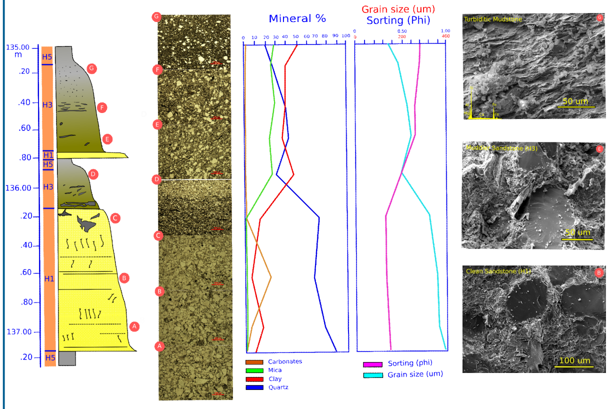
Element	R^2 cumulative	R2 Clean sand (H1)	R^2 Muddier sand (H3)
Ca	0.98	0.99	0.98
Fe	0.96	0.97	0.85
Al	0.47	0.55	0.01
Ti	0.97	0.99	0.87
Mn	0.80	0.83	0.15
Zr	0.63	0.69	0.2
Rb	0.97	0.92	0.99



ITRAX core scanner set-up for rapid (1 m core takes 8-12 hours), non destructive XRF mapping (200 um spacing) of the Ross Cores. The cross plots show calibration of ITRAX counts against whole rock ICP-AES analysis on representative core plugs from the same HEBs from basal clean turbidite sandstones (H1), linked debrites (H3) and mudstones (H5) for the same beds. The R-square values for some other elements of interest are given in the section table.

Pore to bed-scale petrographic analysis of HEBs

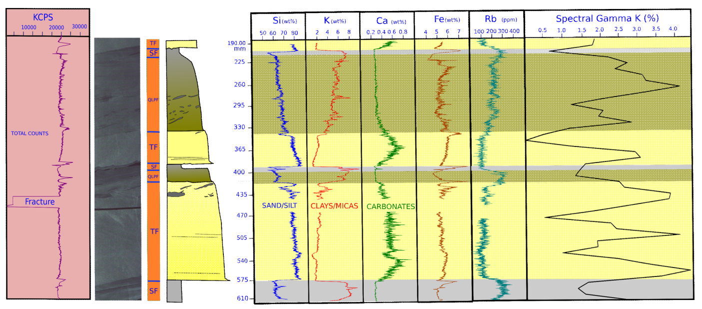
Petrography established that Ross has a simple bimodal mix of quartz rich sand and k-rich clays.

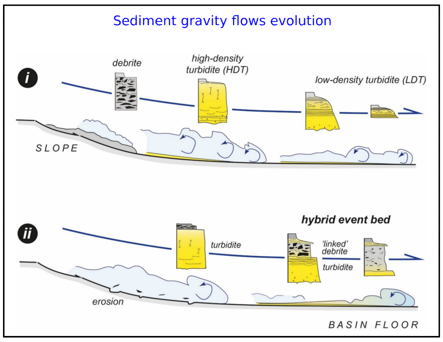


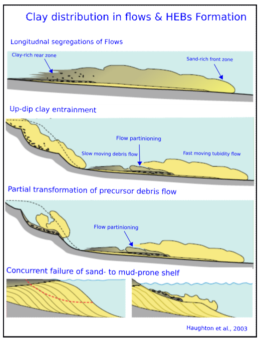
Bed profile and thin-section photographs, from core plugs taken parallel to the bedding, with their corresponding mineral percentages and grain size and sorting data, showing vertical distribution of sandstone textures in the HEBS. The beds are characterised by basal clay poor (1 less than 0% of clay) coarse to medium grained sandstone (H1) in sections A,B & C (sensu Haughton et al., 2009), a chaotic clast bearing muddy sandstone (D, E ,F) with abundant clay (30% of clay) termed as linked debrite (H3) and an upper weakly laminated mudstone cap (sensu Haughton et al., 2009) . SEM images present pore-scale view of H1, H3 and H5 parts of the same event beds. SEM-EDS analysis show that clays are mostly pore filling and K-rich i.e. Illite, chlorite and micas.

ITRAX On Bed-scale clay distribution

Si, K and Ca acting as proxies for sand/silt, clays and/or mica and diagenetic carbonates respectively.

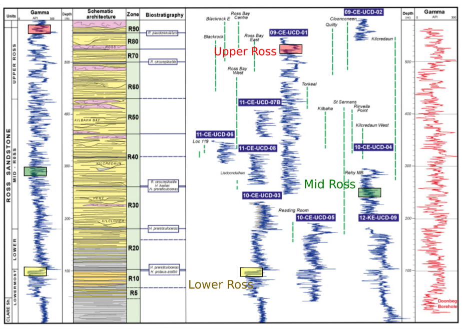


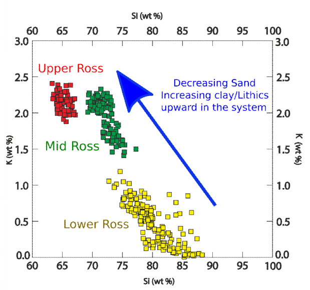




ITRAX compositional trends showing vertical distribution of textures in typical tripartite HEBs. The trends reflect compositional partioning of hybrid flows into sand and clay-rich zones and favourable fractionation of clays and micas into linked debrite part of the flows (Haughton et al., 2003, 2009). In addition, the profiles may also be helpful to understand variable clay distribution in linked debrites, mudclasts profiling and their segregation in particular rheological zone and potential help in constraining the likely source of clay incorporated in the parent flows.

ITRAX integration with spectral gamma





Composite spectral gamma of the entire stratigraphic succession of the Ross. The Lower Ross sands have lowest spectral gamma in all the Ross sands. Preliminary results from integration of spectral gamma with Ross established that Lower Ross sands are the coarsest but least clay/lithic rich as well compared to upper Ross, confirming that the deep-water part of the succession comprises at least two distinct systems.

Conclusions & Future work

1. ITRAX is very useful tool to document continuous compositional trends (sub thin section scale) of important rock forming elements i.e. Si, K, Fe, Ca, Mg, Zr, U, Th, Ni etc in deep-water successions. These elements may potentially act as important textural and/or diagenetic proxies and thus can have important applications in understanding flow processes and reservoir characterization.

2. ITRAX holds some promise for integration with subsurface dataset, particularly wireline (spectral gamma) to resolve sub-gamma resolution heterogeneity in reservoirs. It may also help in developing more accurate electrofacies scheme for deep-water successions.

3. ITRAX data will be integrated with QEMSCAN elemental mapping to quantify the clay content as well as understand pore to bed-level clay distribution that impact reservoir quality of deep-water sands.

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