

Holocene sediments of the Rhine-Meuse-Scheldt estuaries as aids to interpret tidal and fluvial-tidal deposits in outcrop and core

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Introduction

Despite enormous technological and statistical advances in the last decade, the building of geologically-based 3D reservoir models will always be demanding. Moreover, it is imperative that uncertainty is handled appropriately, especially as remaining resources are increasingly found in smaller and/or more complicated reservoirs and undrained compartments. One way of reducing information loss is to incorporate complementary data into the interpretation of subsurface core data sets. To achieve this, geologists must continue to study modern and ancient analogues and archive their findings in a systematized 'library' (conceptual, qualitative & quantitative). Such a library should capture the natural variability of environments and facies, and include methodologies and guidelines for estimating and reducing subsurface uncertainty. This collective understanding and information can also be used for training purposes.

A library of observations and interpretations of modern and ancient outcrop analogues can help to reduce subsurface geological uncertainty and, more generally, aids the development of conceptual depositional models, (sequence) stratigraphic correlation methods, and the construction of quantitative subsurface 3D models suitable for reservoir simulation. As such, it can play a vital role in the reservoir characterization work flow. Such a library will also be a means to mitigate the risks of the overuse of simple structures to try and interpret an entire environment.

Aim

The primary aim of this project is to establish a way of seamlessly transferring information from modern depositional systems through outcrops of analogous ancient depositional systems to analogous ancient subsurface systems revealed, for example, in core or borehole image logs.

This study addresses three issues in particular:

1. the often inadequately addressed links between sedimentary structures and the depositional processes that generated them, and the environmental conditions in which they were deposited;
2. the focus of many studies on the characteristics of vertical sedimentary successions rather than the diagnostics of (assemblages of) sedimentary structures;
3. the uncertainty attached to the application of modern and ancient analogues to hydrocarbon-related core studies.

A number of modern and ancient outcrop as well as subsurface examples are given of characteristic sedimentary structures. The examples come from inshore tidal environments and tidally-influenced river channels subject to micro- to mesotidal conditions and are comparable to known Pliocene to Modern

examples taken from the Rhine-Meuse-Scheldt coastal plain (The Netherlands) as reported by Martinius and Van den Berg (2011).

Examples

In the second half of the last century a number of pits were excavated in the estuaries of the southwestern Netherlands for the construction of large engineering works. These temporary pits opened up a unique opportunity to study subtidal deposits in considerable detail and link them to their well-know hydrographic background. The deposits of the Rhine-Meuse-Scheldt system are analyzed from the temporary construction pits together with a large open cast mine in Germany (Hambach). The exposures revealed a variety of exceptionally well-preserved fluvial, tidal and transitional fluvial-tidal sediments whose information content was captured using drawn diagrams and sections, high quality lacquer peals (Fig. 1) and photographic images. Their interpretation was facilitated by the detailed environmental records of the Holocene deposits, which has been reconstructed from historical and recent hydrographic maps and measurements of river flow and tides (some of the records go back several centuries).

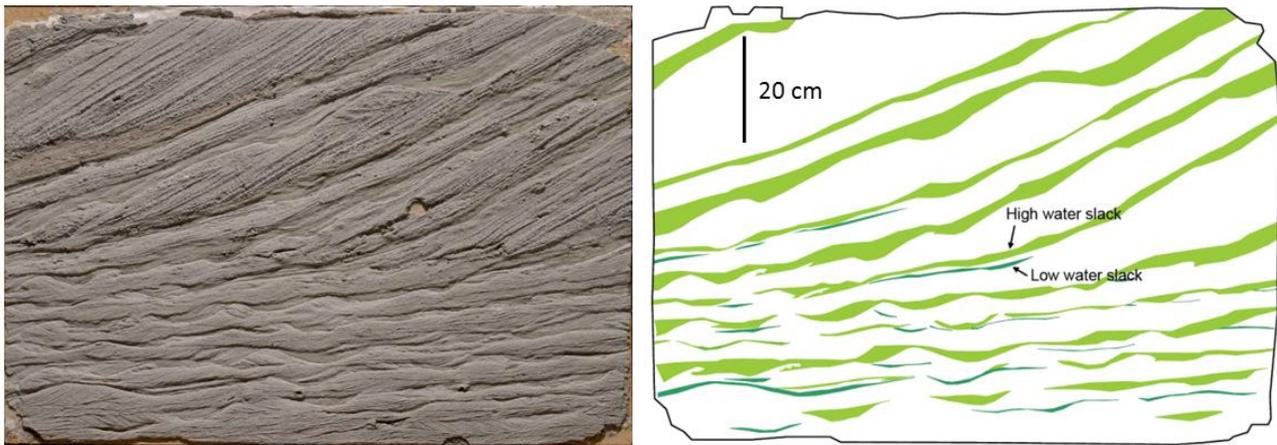


Figure 1: Dune deposits in a fluvial-tidal transition zone channel (Hambach quarry) showing the influence of up- and down-river shifts of the turbidity maximum. During flood tides, the turbidity maximum travels up-river, leaving a thick drape at high tide. During ebb tides the turbidity maximum shifts to a reach further downstream and suspended mud concentrations at low water slacks are relatively minor. The upper mud drape of a double-mud couplet is therefore much thicker.

The Rhine-Meuse-Scheldt system was used as a standard of reference and a comparator for worldwide ancient outcrop analogues believed to cover a similar range of natural variability. The information obtained from the recent exposures and, to some extent, the outcrop analogues was finally applied to the interpretation of subsurface core data from the Norwegian Continental Shelf to illustrate a variety of analogous and comparable tidal facies and sedimentary structures encountered in prospective Late Triassic to Jurassic sedimentary systems (Fig. 2).

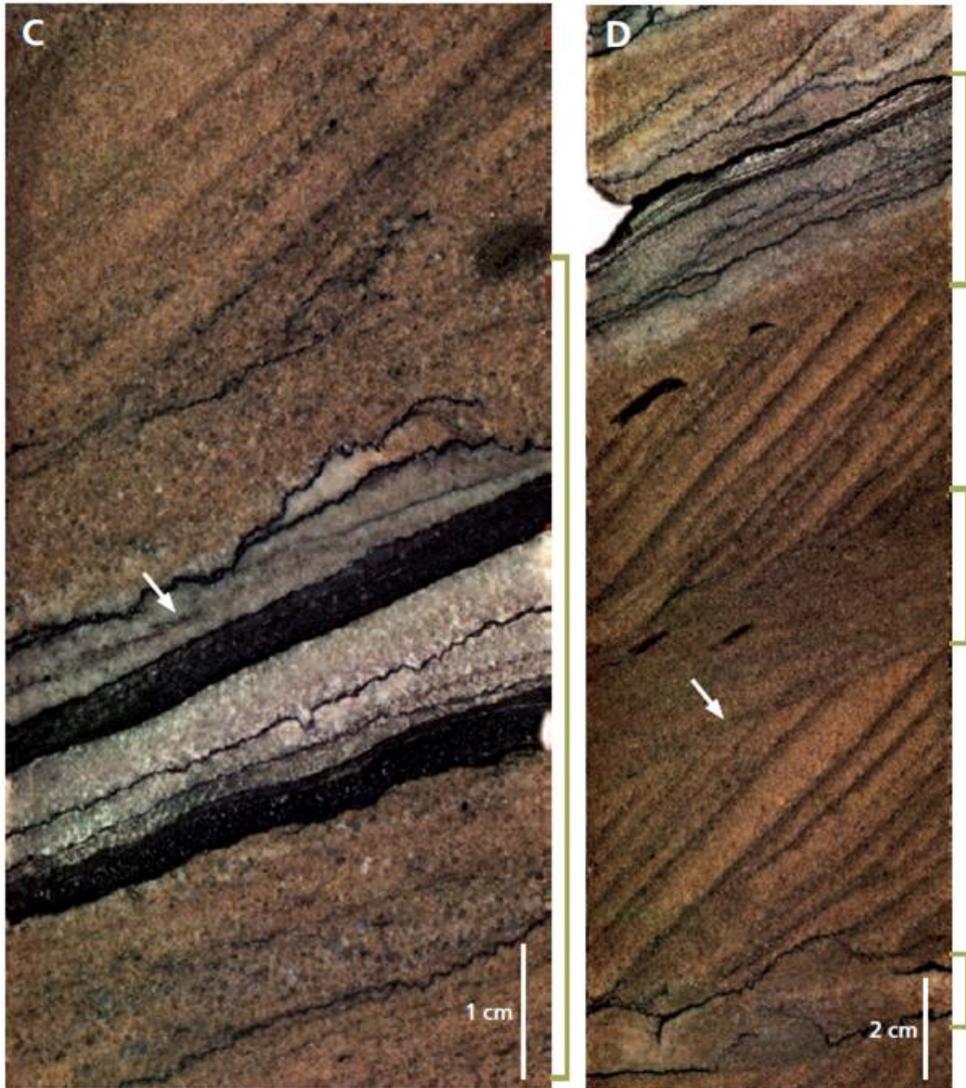


Figure 2: Two details (C and D) of an erosional distributary channel fill complex of a bay-head delta in the Tubåen Fm (Early Jurassic, Hammerfest Basin, Barents Sea, northern Norway), underlain and overlain by in-situ rooted coal horizons. The fill consists of stacked units of tabular and cross-stratified, moderately- to poorly-sorted, coarse-grained sandstone. Individual beds vary in thickness from 0.2 to 0.6 m and fine upwards. Up to 3 cm thick fluid mud layers occur but they are rare. Thick, fine-grained bottomsets (brackets) are characterized by the somewhat disorganized superimposition of small backflow ripples (arrows) and possibly co-flow ripples.

Results and Conclusions

Case studies provide sedimentologists and reservoir geologists with criteria, models and a library of examples which can be used to understand better the spatial distribution and character of reservoir heterogeneities. Differences in physical processes in the inshore tidal area and the fluvial-tidal transition zone result in various assemblages of sedimentary structures that provide diagnostic features for a number of subenvironments. The characteristics of inshore estuarine sedimentary structures depend strongly on whether an inshore tidal basin is filled or unfilled, and what types of transformation have occurred between them. Although a complete view of these assemblages demands excellent outcrop conditions, core exposure may contain enough indications to enable their recognition. For

instance, only part of the diagnostic features of the large assemblage that characterizes inshore subtidal cross-bedding can be recognized with certainty in cores (Fig. 3). One of the most striking and possibly disconcerting revelations to emerge from the work that led to the atlas is that only a small proportion of information on modern systems and ancient outcrop analogues is useful for interpreting subsurface core data. The reason for this is that the recognition of many criteria requires a much larger surface area than that afforded by cores whose average diameters are about 10-12 cm.

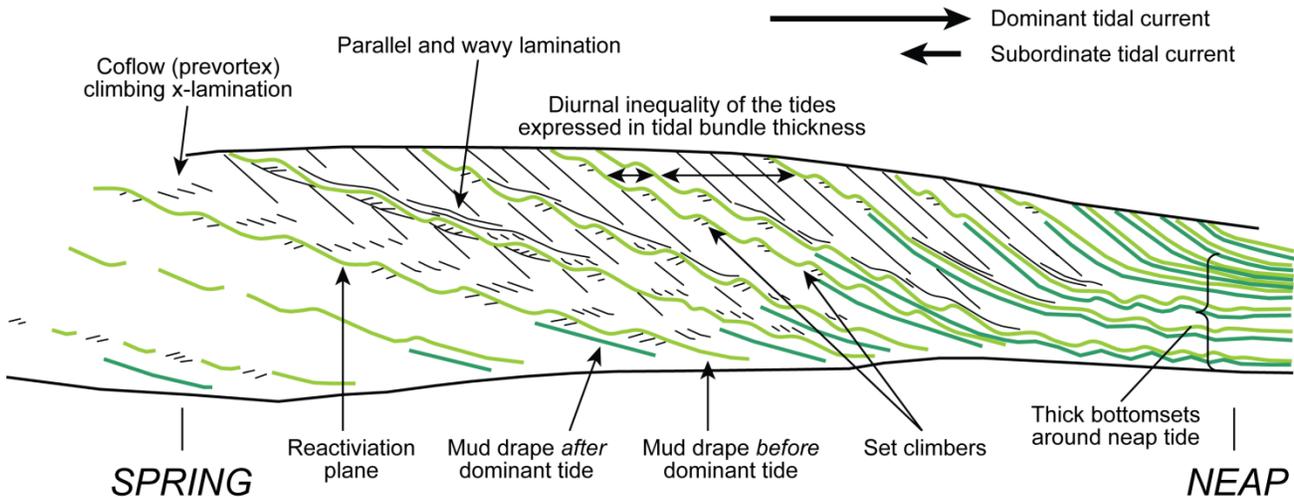


Figure 3. Neap-spring cyclicality in inshore tidal cross-bedding showing the entire spectrum of tidal bundle structure variation from type A at neap tides to type E at spring tides (as suggested by Roep, 1991). It must be stressed that the simultaneous existence all of these features in a single cross-bedded set is not supported by field evidence and is also unlikely from a hydraulic point of view: a switch from an absence of erosive pause planes at neap tides to highly erosive reactivation surfaces at spring tides requires unrealistic neap-spring variations in flow strength and tidal asymmetry. Length scale of picture: 3-10 m.

Acknowledgements

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References

- Martinius, A.W. and Van den Berg, J.H., 2011, Atlas of sedimentary structures in estuarine and tidally-influenced river deposits of the Rhine-Meuse-Scheldt system: Their application to the interpretation of analogous outcrop and subsurface depositional systems. European Association of Geoscientists and Engineers (EAGE), Houten, The Netherlands, 298 p. ISBN: 978-90-73834-11-8.
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