Contourites in the deepwater sequence stratigraphic framework

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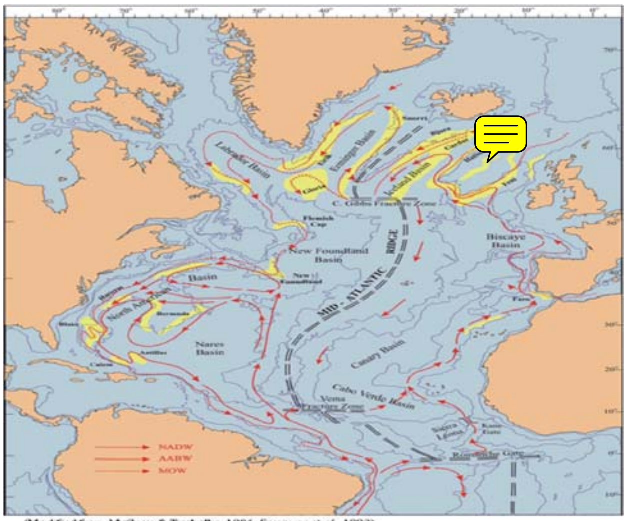
Abstract: *The present contribution represents an important first attempt to place contourite depositional systems firmly within a sequence stratigraphic framework. The model presented builds on earlier work by Diez et al (2008) and is based on many examples of contourite systems from around the world, which collectively show the complexity of controls on deposition and erosion by bottom currents. However, within this complexity we recognise the role of sea-level in the evolution of contourite systems as follows: LST – Muddy Sheeted Drifts intercalated with basin floor and slope fans; TST to HST – principle development (progradation and aggradation) of Mounded Elongate Drifts; HST – development of widespread Erosive Surfaces and Sandy Sheeted Drifts. Other controlling factors can significantly modify the distribution and development of contourite elements linked to sea-level variation.*

Key words: *Sequence stratigraphy, margin sedimentation, contourites, bottom-current controls.*

INTRODUCTION

One of the current dominant paradigms for the description and interpretation of continental margin sedimentary systems is sequence stratigraphy, as developed from the seminal work of Peter Vail and others in the later 1970s. However, despite much progress and refinement of the sequence stratigraphic models over the past three decades and despite ever-growing interest in deepwater sedimentation for hydrocarbon exploration, there is still almost no mention in these models of contourites and bottom currents. Furthermore it is now clearly recognised that contourite depositional systems are a hugely important component of deepwater systems, everywhere from the upper slope to abyssal plains (e.g. Stow *et al.* 2002; Viana & Rebesco 2007; Rebesco & Camerlenghi 2008) (Fig. 1).



(Modified from McCave & Tucholke, 1986; Faugeres *et al.*, 1993).

FIGURE 1. Principal contourite depositional systems (yellow) associated with deepwater circulation (arrows) around the North Atlantic continental margins (modified from Faugeres et al 1993).

The present contribution represents an attempt towards rectifying such an imbalance by placing contourite depositional systems within a sequence stratigraphic framework. We build on earlier work by Faugeres *et al.* (1993, 1999) and Diez *et al.* (2008).

SEQUENCE STRATIGRAPHIC MODEL FOR DEEPWATER SEDIMENTARY SYSTEMS

Both downslope and alongslope (contourite) depositional systems are significantly and variously affected by sea-level variation. The larger and more established of both system types are known to evolve through many different sea-level cycles and to become more or less active through the different sea-level systems tracts. In general, downslope systems are more active during lowstand systems tracts (LST) and contourite depositional systems are more active through transgressive (TST) and highstand systems tracts (HST). We elaborate briefly below, focussing entirely on deepwater elements (Fig. 2).

LST: This system tract is dominated by *downslope processes*. It is characterised by a base-level drop leading to canyon incision across the shelf edge, channel erosion and bypass across the slope apron, and preferred accumulation of turbidite and related facies in base-of-slope fans. Submarine sliding, channel initiation and widespread occurrence of mass transport complexes are typical of open slope aprons. Large muddy fans become especially active across the slope (slope fans), leading to thick sandy turbidite fill and widespread levee-interchannel accumulation of thin-bedded turbidites. There is a relative inactivity of *alongslope processes*, characterised by the intercalation of muddy sheeted drifts with these various downslope elements. Along some margins this is due to a masking of contourite sedimentation by very active downslope processes, in some cases filling contourite channels and other erosive elements, and on other margins it reflects a true decrease in bottom current activity.

TST: This system tract is transitional in nature. Downslope systems, especially the larger muddy slope fans continue to be active and their channels to backfill. However, this is the time for renewed activation of contourite deposition in large elongate mounded drifts along open slope aprons. Mounded drifts show active aggradation and progradation. Other drift activity may begin to fill erosive scars left by submarine slide events, or spread into downslope channel systems. Alongslope reworking of downslope systems becomes important, both as bottom currents increase in strength and downslope processes decrease in significance.

HST: This system tract is characterised by the continued pronounced activity of contourite depositional systems at all scales and along many parts of the continental margin, coupled with relative inactivity of downslope systems. Mounded elongate drifts continue to grow. Where currents are stronger so the contourites become sandier in nature and, in some cases, widespread erosive/non-depositional surfaces are developed. Contourite erosional elements are significant. This is also the period when sandy sheeted drifts are most likely to form, in upper slope and middle slope settings in particular, and as the fill of contourite channels.

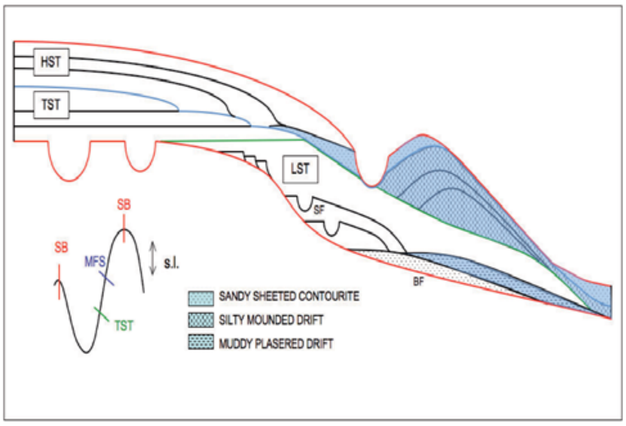


Figure 2: A new model showing the sequence stratigraphic framework for downslope and alongslope (contourite) deepwater depositional systems. HST = Hightstand systems tract; TST = Transgressive systems tract; LST = Lowstand systems tract, SF = slope fan; BF = basinfloor fan; SB = Sequence boundary; s.l. = sea level

OTHER CONTROLS AND CYCLES

The model presented above clearly emphasises sea-level control and the placement of contourite elements in the sequence stratigraphic framework. However, it is well known that other controlling factors may be equally or still more significant along any one margin (e.g. Faugeres *et al.*, 1993, 1999; Hernandez-Molina *et al.*, 2008; Diez *et al.*, 2008). These controls include: sediment supply, basin and slope morphology, synsedimentary tectonic activity and climate. All of these may independently act to influence the intensity and/or distribution of principle bottom current pathways along a continental margin.

Within many contourite depositional systems (both mounded and sheeted drifts) a distinctive seismic cyclicity has been identified (e.g. Stow *et al.* 2002; Llave *et al.* 2007) involving: a transparent zone at the base, passing upwards through parallel reflectors of moderate to high amplitude, to a marked high amplitude upper surface that is locally or more widely erosive in nature. These seismic cycles have been related to cyclic changes in contourite grain size (upward coarsening cycles) driven by long-term variations in bottom-current intensity. Although the underlying controls on this cyclicity are not fully understood, we note here that their scale and duration is comparable with that of parasequences in sequence stratigraphic models.

Further work in progress on contourites and sequence stratigraphy aims: (1) to deconvolve the patterns driven from the northern high latitude, southern high-latitude, and Mediterranean low-latitude bottom-water kitchens; and (2) to further explore the development and extent of sandy contourite systems.

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REFERENCES

Diez, R., Stow, D.A.V., Hernandez-Molina, J. 2008. Sequence stratigraphy of contourite drift deposits in North Atlantic basins.

Faugeres, J.C. and Stow, D.A-V. 1993. Bottom-current-controlled sedimentation: a synthesis of the contourite problem 1993. Sed. Geol. 82, 287-297.

Faugères, J.C., Stow, D.A.V., Imbert, P., Viana, A., 1999. Seismic features diagnostic of contourite drifts. *Marine Geology*, 162: 1-38.

Hernández-Molina, F.J., Llave, E.; Stow, D.A.V., 2008. Continental slope contourites. In: M Rebesco, A Camerlenghi (editors), *Contourites*, Developments in Sedimentology Series, Elsevier, 60, 379-400.

Llave, E.; Hernández-Molina, F. J., Somoza, L., Stow, DAV and Díaz del Río, V., 2007. Quaternary evolution of the Contourite Depositional System in the Gulf of Cadiz, *Geol. Soc. London Special Publication*, 276, 49-80.

Rebesco, M., Camerlenghi, A. (editors) 2008. *Contourites*, Developments in Sedimentology Series, Elsevier, 60, 189-202.

Stow, D.A.V., Pudsey, C.J., Howe, J.A., Faugeres, J.C., Viana, A (editors) 2002. Atlas of deep-water contourite systems: modern drifts and ancient series, seismic and sedimentary characteristics. *Geol. Soc. London. Memoir*, 22, 464pp.

Viana, A.R., Rebesco, M. (editors) 2007. Economic and paleoceanographic significance of contourite deposits. *Geol. Soc. London Special Publication*, 276