CONTOURITES: from large drifts to facies models

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Abstract: *This paper is dedicated to some questionable aspects of contourite deposits. It shows the large variability of the contourite drifts and facies especially when contour currents interact with other sedimentary processes, and points out the difficulty to identify contourite deposits in mixed turbiditic-contouritic systems. The demonstration is supported by numerous examples.*

Key words: *drift, mixed turbiditic-contouritic systems, seismic units, contourite facies*

INTRODUCTION

Despite the increasingly interest for the contourite deposits during last decades, these sediments still remain not very well understood complex deposits and their characteristics are not easily recognized and decoded in the deep-sea deposits. As they are still surrounded by controversy, we focus this paper on some questionable aspects in order to stimulate further research.

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The overall drift morphology and deposit geometry is controlled by several interrelated factors : -(1) the bathymetric and morphological/tectonic background; -(2) the current velocity and variability; -(3) the amount and type of sediment available; -(4) the length of time over which the bottom current processes have operated. According to these factors a few major types of contourite drifts have been defined (Mc Cave and Tucholke, 1985, Faugères *et al.*, 1999). Such an attempt to classify the contourite drift may have been useful to understand the contourite deposits. However, drift type classifications are never exclusive as in fact we observe a large variability of the drift overall morphology and geometry. Very often gradation and overlap between all types are the norm as shown by many examples and in some way, each new studied example escapes, at least partly, from the rules established previously. Therefore we should refrain from dealing with inflation in drift types as these make for greater complexity in terminology and add little by way of fundamentally different genetic systems.

The drift large variability may also result from the other deep-sea processes of deposition that may participate in drift construction and interact with the contour currents in the sediment deposition giving birth to what has been called «mixed drift» or «modified drift» (Stow *et al.*, 2002). In this case, it remains an up-to-date challenge to discriminate contourite deposits from other deep-sea deposits, especially to discriminate contourite systems vs turbidite systems as morphological convergences may occur between both systems. This challenge is still more difficult when dealing with «mixed turbidite-contourite systems «(M.T.C.S.).

M.T.C.S. that result from the interaction of contour currents and turbidity currents are very common in the deep-sea (Mulder *et al.*, 2009). Their sediment patterns are controlled by several factors: the relative energy of both currents (the major factor), but also the bathymetry and morphological location of the system, the amount and type of the available sediment supply, the time-scale over which the interacting processes have operated and the frequency of current energy variations. According to these factors, the process interaction and sedimentary record (deposit inter-fingering, geometry and facies) may largely vary and a large variety of scenario can be observed.

In case of M.T.C.S. deposited by along slope Contour Currents («C.C.») crossing down slope Turbidity Currents («T.C.»), various scenario of process interaction are observed according to the current energy: from T.C. of very high energy that masks totally the action of the C.C. to T.C. of moderate energy and C.C. of moderate to high energy with the process interaction recorded at the scale of the sediment body overall morphology, seismic units and deposit facies.

The process interaction may be recorded at the scale of the sediment body overall morphology in case of turbiditic channel-levee or lobe system reworked by C.C. or when overlapping-imbrication of contouritic and turbiditic sedimentary bodies occurs, due to the evolution of the sedimentary relief during the system deposition.

The record of process interaction at the scale of the seismic units is more difficult to interpret. It may be illustrated by sediment body built by alternating contouritic and turbiditic deposits that are not easy to discriminate without drilling control. Such discrimination is still more difficult in the case of mixed contouritic-turbiditic channel infill evolution.

In less frequent case of M.T.C.S**.** due to down-welling bottom currents, as in the Gulf of Cadiz continental slope, gravity processes are forced by contour current processes (Habgood *et al.*, 2003 and Hanquiez *et al.* 2009). In that case, a down-slope contouritic channel-lobe system is built on the upper continental slope that mimics a turbiditic channel-lobe system. Down-slope, the lobe contouritic deposits are re-worked by gravity processes and form a turbiditic channel-lobe system. Deposit facies are very similar in both systems, however some deposit features may allow to discriminate the deposit processes.

Contourite facies may help to identify drift deposits. However, besides some typical contourite facies and sequences as described from the Gulf of Cadiz drifts, it is often not easy to distinguish between these deposits and other deep-sea sediments.

It seems sometimes that deep-sea sediments from modern oceans are called «contourites» only because the authors know that contour currents are flowing across the studied area, otherwise they could have been called turbidite, pelagite, hemipelagite, red clay, manganiferous clay. In addition, as for the deposit geometry, contourite recognition is still more difficult when interacting processes control the deposition as illustrated by what is called «contour current reworked-turbidites» described in modern sediments as well as in field rocks.

However, in case of fossil sedimentary series, contourite identification is the hardest, because field-based descriptions of contourites and sediment drifts are scarce compared to the modern ones and are not always reliable due to the diagenetic processes that often mask the original diagnostic features. Consequently, in the past, fossil fine-grained turbidites may have been interpreted as contourite or reworked-turbidites because they show wavy bedding or HCS-like structures. Nowadays, reliable examples of fossil contourite could be bioturbated fine-grained sandstones or clayey-silty laminated rocks without any feature of turbidite sequence but containing reworked micro-fauna that can only have been transported by bottom currents as described from the Paleogene Ultrahelvetic Prealps (Kindler *et al.*, 1995).

FINAL CONSIDERATIONS

To conclude, drifts and contourites show a very large variability compared to the other deep-sea deposits. Reliable diagnostic paramaters are rare and may be used only in specific context. Most of the time, their recognition needs to use a multi-scale and multi-parameter approach, from the large scale basin physiography, hydrology, and drift geometry to the sediment particle scale (grain-size, nature, composition, geochemistry…).

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