

time in contourite depositional systems. Although their study has been one of the most active lines in marine geoscience research over the last decades, necessitating an interdisciplinary approach that encompasses sedimentology, oceanography, stratigraphy, bio-geochemistry, geophysics, palaeoceanography and palaeoclimatology, the visualising and understanding of their driving processes is largely dependent of (and restricted to) the improvement of deep-water geophysics, coring and drilling facilities and oceanographic monitoring tools (Faugères et al., 1999; Rebesco, 2005; Hernández-Molina et al., 2011).

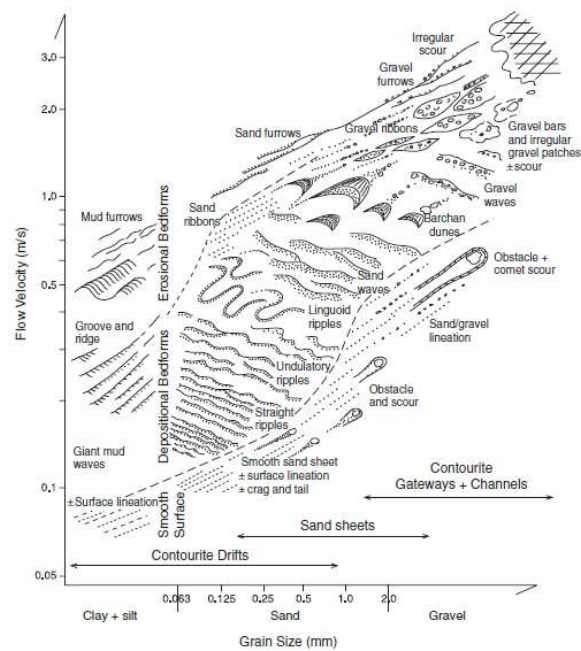


Figure 1. Bedform-velocity matrix for deep-water bottom current systems, showing mean grain size of sediment versus flow velocity at or near seafloor with schematic representation of bedforms present under specific velocity-grain-size conditions (Stow et al., 2008).

However, they only indicate the present day current direction and strength, whereas during the depositional history of the entire sediment body both direction as intensity may have changed significantly. On a larger scale, 3D seismic geomorphology may assist in better visualizing palaeotopographic features, whereas only through coring and drilling the fine-scale bottom current intensity changes may be deciphered. Unfortunately, the contourite sedimentary record only sporadically leaves behind traces of the wealth of present-day bedforms.

3. RELEVANCE & CHALLENGES

Contourite processes cover a specific part of all bottom currents, actively distinguished from the better studied downslope processes, forming turbidite deposits, organised in deep-sea fans. It largely the economic interest of the latter that pushed research to bottom-parallel currents into the shade. Ironically, it is a renewed economic interest (Viana et al., 2007) that has put the spotlight on these deposits. Besides this, the relevance of contourite studies to science and society is manifold, despite their presence is little known and even less understood.

3.1 Palaeoceanography & global change

In the first place, both deep and shallow water circulation is driven by climate. Hence, continuous contouritic deposits, accumulated under enhanced sedimentation rates, are excellent recorders of past climate change (either local or global) and assist better understanding the modulating role of the deep ocean in our climate's system (Rebesco, 2005). However, deconvolving the different signatures (bottom current intensity, bottom water temperatures & salinities, source fingerprinting,...) from these records is not straightforward. A multidisciplinary approach is required for better relating ocean circulation and bottom currents to their deposits and therefore for determining how best to read the palaeoceanographic or palaeoclimate signatures from contourite deposits.

3.2 Geohazards

Contourite deposits are observed all over the Earth's continental margin, predominantly as vast

sheets of fine-grained material (Rebesco & Camerlenghi, 2008). The combination of these oceanographic regimes in great detail. However, in deposits, together with oversteepened slopes, (isostatic) seismicity, oversedimentation, free gas and overpressure may lead to geo-hazards especially in polar continental margins. They lie a

the origin of major slope instabilities, leading to catastrophic slope collapse and consequent damage to subsea installations and cables. Slope collapse can lead directly to major tsunami events and likely devastation to coastal regions (cfr. Storegga Slide (Bryn et al., 2005)), whereas high velocity bottom currents can erode subsea structures undercut seafloor pipes and chafe submarine cables (Rebesco, 2005).

3.3 Earth resources

Similar to turbidite systems, also contourites may generate well-sorted deep-water sands (Stow et al., 2009). They occur in nearly any complex environment where sandy contourites are a new reservoir play for subsurface oil and gas; muddy contourites may act as potential source rocks, reservoir seals or unconventional reservoirs. Moreover, the role of deep-water circulation on the growth and distribution of ferromanganese nodules is still under debate.

3.4 Ecosystems & environmental change

Over the past decade it has become clear that most of the deep-water ecosystems (cold-water corals) are highly influenced by the presence of deep water circulation (Hernández-Molina et al., 2011). These deep-water bottom currents are essential for the construction and maintenance of entire deep water habitats, some of which are still little known to science and some of which provide ideal nurseries for several fish species. A better understanding of the role of bottom currents in the continued "health status" of such ecosystems will help our appreciation of the impact of climate change (long term) or oil spills (short term).

3.5 Oceanographic processes

Although the contourite paradigm has existed for over 40 years, there still seems to be a missing dialogue between physical oceanography and sedimentary observations. Nevertheless, contourite

3.6 Challenges

Despite the increasing relevance of contourite studies, many challenges lie ahead (Hernández-Molina et al, 2012). There still is no uniform and unequivocal classification, since the coupling between geological and hydrographic processes is rather vaguely defined due to the lack of good "in-situ" observations. However, there is further good potential for achieving a fundamental breakthrough in our understanding of ocean circulation and how the associated physical processes relate directly to sedimentary processes and their products (e.g. contourites). This area at the boundary between the often disparate disciplines of physical oceanography and sedimentology has been relatively neglected. Associated to this, more unambiguous diagnostic criteria, based upon a better integration of geophysical, sedimentological and geochemical observations may assist in better recognizing land sections, which are poorly documented and fully underrepresented.

Contourites have previously passed beneath the radar when it comes to the assessment of potential economic resources along continental margins and in deeper basin settings. However, as a principal constituent of deep-water sedimentary systems, they must constitute an essential element in the exploration of progressively deeper waters by the hydrocarbon industry. During IODP Expedition 339, for the first time, several 100 m of sandy contourites with reservoir quality were drilled (IODP Expedition Scientists, 2012).

Furthermore, palaeoceanographers are developing more advanced geochemical proxies to better reconstruct the physical and (biogeo)chemical properties of the water-masses. The most challenging task, however, is to identify, document and understand shallow-water contourites, observed in shallow seas and lakes. In terms of geometry, a lot of similarities are observed with respect to their deep-sea counterparts, but since they are predominantly dependant of (near-) surface wind-driven currents, the responsible processes and the palaeoceanographic potential are

poorly known. Ultimately, no real definition has been defined where the “upper” boundary of the contourite occurrence is located, and where this (almost literally) flows over to sandbank and dune dynamics.

4. CONCLUSIONS

It is not by chance that this paper is presented during the “Marine and River Dune Dynamics” conference. The previously stated challenges have recently lead to the initiation of both the IGCP project n° 619, entitled “Contourites: geological record of ocean-driven paleoclimate, accomplice of submarine landslides and reservoir of marine geo-resources” and INQUA project n° 1204 “The Quaternary Contourite Log-book: a deep-water record(er) of variability in palaeoclimate, palaeoceanography and deep-water ecosystems”. Both projects, which basically represent research networks, are grouped under the website <http://www.contourites.org>, aspire to bring together scientists from over the entire marine (geo)science community in order to try to bridge the knowledge gaps. The association of bedforms and their responsible oceanographic processes is key to both the contourite as shallow water community. In contrast to shallow marine and river systems, good and frequent “in-situ” observations are scarce, due to the demanding logistic challenges of deep-water research. Nevertheless, both communities can significantly contribute to each other. Therefore, the major aim of this paper is to aspire and promote an open dialogue between the deep and shallow water sediment dynamic communities.

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Water has become one of the foremost modern-day challenges in this early part of the third millennium. This is because one of the targets of the Millennium Development Goals is to halve the proportion of the population without sustainable access to safe drinking water between 2000 and 2015 and subsequently achieve universal coverage. Another reason is that the era of free drinking water in unlimited quantity is over. During recent decades, a combination of human demographics and human activity has in many global regions transformed water from an abundant element to a scarce resource. This study reviews our current knowledge of the main physical processes affecting the dynamics and properties of dense water overflows and cascades in the ocean. Dense water formed by cooling, evaporation or sea-ice formation in the surface layer of the ocean descends into a deep ocean basin over sloping topography as an overflow or cascade. Large-scale overflows provide substantial contributions to globally important water masses that ventilate the abyssal ocean and force the global meridional overturning circulation. Our understanding of dense water overflows is far from comprehensive due to a lack of data on dense-water bottom currents in the Southern Adriatic Sea in spring 2012. *Marine Geology*, Vol. 375, Issue. , p. 134. CrossRef. Google Scholar. Zhang, Wenyan Hanebuth, Till J.J. and StÅrber, Uwe 2016. Short-term sediment dynamics on a meso-scale contourite drift (off NW Iberia): Impacts of multi-scale oceanographic processes deduced from the analysis of mooring data and numerical modelling. *Marine Geology*, Vol. 378, Issue. , p. 81. CrossRef. Oceanographic processes and morphosedimentary products along the Iberian margins: A new multidisciplinary approach. *Marine Geology*, Vol. 378, Issue. , p. 127. CrossRef.