



Deep-sea sediments, edited by H. Hüneke & T. Mulder, 2011.

Developments in Sedimentology 63. Elsevier, Amsterdam. Hardbound, 849 pages. Price US\$ 195.00. ISBN 978-0-444-53000-4.

This thick (849 pages), thematic volume, with a broad title is refreshing. It is composed of 12 chapters:

- (1) Progress in deep-sea sedimentology, by Thierry Mulder, Heiko Hüneke & A.J. (Tom) van Loon, covering 24 pages (3%);
- (2) Gravity processes and deposits on continental slope, rise and abyssal plains, by Thierry Mulder, covering 124 pages (15%);
- (3) Contour currents and contourite drifts, by Jean-Claude Faugères & Thierry Mulder, covering 66 pages (8%);
- (4) Pelagic sedimentation in modern and ancient oceans, by Heiko Hüneke & Rüdiger Henrich, covering 137 pages (17%);
- (5) Hemipelagic advection and periplatform sedimentation, by Rüdiger Henrich & Heiko Hüneke, covering 44 pages (5%);
- (6) Benthic deep-sea carbonates: reefs and seeps, by A.J. Wheeler & A. Stadnitskaia, covering 59 pages (7%);
- (7) Volcaniclastic processes and deposits in the deep-sea, by Steven N. Carey & Jean-Luc Schneider, covering 59 pages (7%);
- (8) Deep-sea ichnology: the relationships between depositional environment and endobenthic organisms, by A. Uchman & A. Wetzel, covering 40 pages (5%);
- (9) Early diagenesis of deep-sea sediments, by Reinhard Hesse & Ulrike Schacht, covering 157 pages (19%);
- (10) Industrial application of deep-sea sediments, by Patrice Imbert, covering 50 pages (6%);
- (11) Mesozoic pelagic sediments: archives for ocean and climate history during greenhouse conditions, by Helmut Weissert, covering 28 pages (3%); and
- (12) Climate records of deep-sea sediments: towards the ice house, by Torsten Bickert & Rüdiger Henrich, covering 31 pages (4%).

From the above summary, two points are obvious. Although the book covers a broad spectrum of topics, its emphasis is on muddy sediments with 4 chapters (4, 5, 9, and 11) dedicated to this topic and there is a great disparity in the allocation of pages between chapters. For example, Chapter 9 occupies 157 pages, whereas Chapter 11 occupies only 28 pages. But the editors did not provide any explanation as to what criteria they have used for allowing such disproportionate lengths between chapters. In addition, several chapters do not have an Acknowledgements section. This is unfortunate because such a section provides important information to the reader on who are the reviewers of the manuscript. Even if the reviewers wish to remain anonymous, this section yields information on the number of reviewers. Otherwise, the absence of acknowledgements may be construed as a lack of any peer review in edited volumes.

In Chapter 1, Mulder, Hüneke and Van Loon describe, among other topics, the meaning of the term 'deep-sea sediments'. They omit, however, the most important information from

the discussion, viz. the details of criteria for recognizing deep-sea sediments in the ancient stratigraphic record. For example, what are the criteria that one might consider in establishing the deep-water origin of Cambrian sandstone vs. Pliocene sand? This is important because controversies still abound regarding the interpretation of ancient sandstone as 'deep-water' in origin (e.g., Mulder et al., 2009, 2010; Higgs, 2010).

In Chapter 2, Mulder sets the stage for the entire book with his perspectives on deep-sea processes. His focus on the 'Bouma sequence' (Bouma, 1962), the 'Lowe sequence' (Lowe, 1982), and the Mutti (1992) facies scheme clearly establishes the conceptual foundation of the book that sandy and gravelly turbidity currents are the primary processes for transporting and depositing sand and gravel in the deep-sea. However, there is one major chronic problem with this basic tenet. To date, no one has ever documented gravelly or sandy turbidity currents in modern oceans using vertical sediment-concentration profiles and grain-size measurements. Nor has anyone ever replicated *turbulent* turbidity currents that could carry coarse sand and gravel *in suspension* in laboratory flume experiments. In the absence of empirical data on sandy and gravelly turbidity currents, genetic turbidite facies models are irrelevant for interpreting real-world sandy and gravelly deposits. Although simple turbidite models were necessary during the early days in the 1960s and 1970s when we were grappling with understanding the complex deep-water environments, these models are obsolete today.

In strong contrast to the elusive sandy turbidity currents in modern oceans (Shanmugam, 2006), sandy mass-transport processes have been documented by direct observations and underwater photographs in modern submarine canyons (Dill, 1964, 1966; Shepard & Dill, 1966; Shepard et al., 1969), on submarine-fan lobes (Gardner et al., 1996), and on the open continental rise (USGS, 1994). Although in the book's Preface, Hüneke & Mulder claim that "*We have endeavoured to produce a well-balanced book without important omissions*", Mulder has decided to ignore empirical observations that have been made during the past fifty years.

In promoting turbidite-facies models, Mulder has re-used (his Fig. 2.11) one of my published illustrations (fig. 23 in Shanmugam, 2000) that shows 16 divisions in an ideal turbidite bed. Ironically, I have constructed this figure to illustrate the absurdity of turbidite-facies models with 16 divisions in a single ideal turbidite bed! Mulder, however, did not reveal to the reader my true intention behind publishing the figure. By his non-action, Mulder erroneously implies that my figure advocates Mulder's flawed philosophy. From a fluid dynamics point of view, it is impossible to explain the depositional origin of 16 divisions that contain both traction and suspension units from a turbulent suspension (i.e., turbidity current). Plus, the ideal turbidite bed with 16 divisions has never been documented in the stratigraphic record, nor has it been replicated in flume experiments.

Finally, Mulder discusses the importance of sequence stratigraphy in deep-sea turbidite systems, without acknowledging recent developments in the field. For example, systematic studies of seismic-core calibration in the North Sea and the Norwegian Sea have shown that sequence-stratigraphic concepts are obsolete for deep-sea systems (Shanmugam et al., 1995; Shanmugam, 2007). By failing to acknowledge observations made by others that do not conform to his views, Mulder presents a distorted view of deep-sea sedimentation.

Chapter 3, on contourites, also suffers from major omissions and distortions. Examples are:

1. In introducing the topic, Faugères & Mulder include two figures, one showing ocean surface currents (Fig. 3.1) and the other one thermohaline circulation (Fig. 3.3). The captions of these two figures do not give any credit to original data sources. What are the original sources of data used in constructing these two figures?
2. Faugères & Mulder discuss 'Geostrophic thermohaline circulation' in Section 2.2. What is striking is that the entire section does not include a single reference to earlier contributions by pioneering researchers on this topic. Are Faugères and Mulder the original authors of the concept of the thermohaline circulation? Broecker (1991), for example, was the first one who presented a unifying concept of the global oceanic 'conveyor belt' by linking the wind-driven surface circulation with the thermohaline-driven deep circulation regimes. But no credit was given to Broecker (1991) in this chapter.
3. Without any justification, Faugères and Mulder have selected thermohaline-driven contour currents as the sole example of bottom currents, although there are four types of bottom currents: (1) thermohaline-driven currents (2) wind-driven currents, (3) tide-driven currents, and (4) internal-tide-driven currents (Shanmugam, 2008a). If Faugères and Mulder disagree with four types of bottom currents, the normal course of action for advancing science is to provide data that dispute my claim and justify their selection of contour currents as the only candidate for bottom currents.
4. There is a considerable body of data and literature on deep-marine tidal bottom currents and their deposits (Klein, 1975; Shepard et al., 1979; Shanmugam, 2003). Faugères and Mulder have totally ignored also this topic, without any justification. From an economic viewpoint, deep-water tidalites have been documented to be part of petroleum-producing reservoirs in the Krishna-Godavari Basin, Bay of Bengal (Shanmugam et al., 2009).
5. Faugères and Mulder have used (Fig. 3. 18) the contourite facies model originally published by Faugères et al. (1984). This model has undergone major revisions recently by Stow & Faugères (2008: their fig. 13.9). In this revised model, five internal divisions (C1 through C5) occur, analogous to the Bouma turbidite model, but Faugères and Mulder have neglected to include the most recent version of the contourite model, without any explanation.
6. Both the original and the revised contourite facies model are fundamentally flawed. The three diagnostic criteria of contourites, according to Faugères and Mulder (p. 178-179), are: (a) abundant bioturbation, (b) bad preservation of primary structures, and (c) coarsening-up and fining-up grain size trends. First, bioturbation is common in all parts of turbidites (Nilsen & Abbott, 1979) and not unique to contourites. Second, the logic of using lack of sedimentary structures for interpreting processes goes against the founding principle of process sedimentology, in which primary sedimentary structures are the sole foundation for interpreting depositional mechanics (Sanders, 1963). Third, coarsening-upward and fining-upward grain-size trends are not unique to contourites because they are also common in hyperpycnites (see Fig. 2.12C). More importantly, none of the three criteria reveals anything unique about contour-following bottom currents in order to qualify the deposit as contourites.

7. Another deliberate omission from this chapter is the discussion of the importance of traction structures in bottom-current deposits. The significance of traction structures in such deposits have been the focus of discussion since the 1960s (Hsu, 1964; Hollister, 1967; Natland, 1967; Klein, 1975; Shanmugam et al., 1993a,b, 2008a; Martini-Chivelet et al., 2008).

The chapters on pelagic, hemipelagic, benthic carbonate, and volcanoclastic sediments provide good reviews of individual topics. In particular, Figure 4.34 on the origins of chert rhythms has brought back good memories of the lively debate between Earl McBride and Robert Folk in the 1970s.

In their review of deep-sea ichnology in Chapter 8, Uchman & Wetzel realize that shallow-marine trace fossils (e.g., *Ophiomorpha*) can occur in deep-marine environments, and that trace fossils therefore may not be a reliable depth indicator. This information has been known for the past 30 years (e.g., Nilsen & Abbott, 1979). In Figures 8.9 and 8.10, the authors associate types of trace fossils to individual divisions of the 'Bouma sequence', but the hydrodynamic validity of the 'Bouma sequence' is itself in doubt (Hsu, 1964; Sanders, 1965; Van der Linde, 1969; Shanmugam, 1997, 2000).

In Chapter 9, Hesse & Schacht provide an exhaustive and excellent treatment of early diagenesis of deep-sea sediments. The authors focus on muddy sediments with a special section dedicated to highly reactive volcanogenic sediments. As one might expect, the chapter is heavily chemistry-oriented.

Chapter 10 is the only contribution from the petroleum industry. As a petroleum geologist for over 30 years, I was keen to read this contribution, and I came to the following conclusions.

(1) The author presents a comprehensive account of the various elements of petroleum exploration and production.

(2) Case studies of reservoir sedimentology (Fig. 10.3) are based on unpublished material. The author does not disclose the geographical location of study area, the age of the reservoir, the reservoir's name, the depth of burial, the vertical and horizontal scale, the type of seismic data, etc. Such fictional examples are a waste of printed space.

Weissert, in Chapter 11, details the close interaction between marine- and land-based geologists since the late 19th century, and discusses the value of integrating sedimentological, micropaleontological and geochemical data with an 'earth-system concept' for the understanding of the evolution of oceans, life and climate through time. This is a good historical account of research.

Finally, in Chapter 12, Bickert & Henrich objectively deal with both sides of the controversy surrounding the onset of northern-hemisphere glaciation; they conclude the chapter with the statement "*Whatever the correct answer may be, this controversy clearly depicts that we are far away from understanding the dynamics and processes of the Earth's climate change.*" As a rock-based sedimentologist, I am not sure as to how this controversy fits into the theme of the 'deep-sea sediments' volume.

In summary, Chapters 4, 5, 6, 7, 9, 10, 11, and 12 present conventional state-of-the-art review articles that provide a comprehensive source of detailed information, which is Elsevier's objective for publishing the *Developments in Sedimentology* book series. Chapters 2 and 3

present a narrow and incomplete view of the deep-sea with an unrealistic emphasis on turbidity currents, hyperpycnal flows, and contour currents. Chapter 8 offers information that is of no relevance in advancing our understanding of deep-sea sediments. Despite the ambitious goal set by the editors, the volume falls short due to omissions of the following critical topics:

- sandy mass-transport deposits (Meckel, 2009; Shanmugam, 2006, 2010, 2012);
- deep-marine tidal currents and their deposits (Klein, 1975; Shepard et al., 1979; Shanmugam, 2003; Shanmugam et al., 2009);
- deep-marine internal tides and their deposits (Gao et al., 1998; Garrett & Kunze, 2007; Shanmugam, 2012);
- the influence of tsunamis and tropical cyclones on deep-sea sediments (Shanmugam, 2008b);
- diagenesis and reservoir quality of deep-marine sandstones (Mansurbeg et al., 2008).

Comments on related matters are:

- (1) figures are reduced to such extremes that, in some cases, lettering is illegible (e.g., Fig. 6.19, left);
- (2) in Figure 2.36, two photographs are labeled A and B, but there are no corresponding captions for A and B;
- (3) I find it awkward to stop reading the print version of the book and go to the computer for the color version of a figure, and the current print-CD format is not reader-friendly when it comes to color figures; hopefully this problem will disappear when we move into a totally digital book format;
- (4) I like the idea of each chapter having its own set of references: this self-contained package is useful when the authors distribute reprints (PDFs) of their contribution to colleagues.

Acknowledgements

I thank A.J. (Tom) van Loon for giving me the opportunity to review this book and for providing valuable information on the peer-review process of the volume. I also thank the editors of the Sedimentary Record for their helpful comments. As always, I am grateful to Jean Shanmugam for her general comments.

References

- Bouma, A.H., 1962, *Sedimentology of Some Flysch Deposits: A Graphic Approach to Facies Interpretation*: Amsterdam, Elsevier, 168 p.
- Broecker, W.S., 1991. The great ocean conveyor. *Oceanography* 4, 79-89.
- Dill, R.F., 1964. Contemporary submarine erosion in Scripps Submarine Canyon. Unpublished Ph.D. thesis, University of California, Scripps Institution of Oceanography, San Diego, 269 pp.
- Dill, R.F., 1966. Sand flows and sand falls. In: R.W. Fairbridge (Ed): *Encyclopedia of oceanography*. Reinhold Publishing Co., New York, 763-765.
- Faugères, J.-C., Gonthier, E., Stow, D.A.V., 1984. Contourite drift moulded by deep Mediterranean outflow. *Geology* 12, 296–300.

- Gao, Z., Eriksson, K.A., He, Y., Luo, S. & Guo, J., 1998. Deep-water traction current deposits - A study of internal tides, internal waves, contour currents and their deposits. Science Press, Beijing, 128 pp.
- Gardner, J.V., Bohannon, R.G., Field, M.E. & Masson, D.G., 1996. The morphology, processes, and evolution of Monterey Fan: A revisit. In: J.V. Gardner, M.E. Field & D.C. Twichell (Eds), *Geology of the United States' sea floor: the view from GLORIA*. Cambridge University Press, New York, 193-220.
- Garrett, C. & Kunze, E., 2007. Internal tide generation in the deep ocean. *Ann. Rev. Fluid Mech.* 39, 57-87.
- Higgs, R., 2010. 'Hummocky cross-stratification-like structures in deep-sea turbidites: Upper Cretaceous Basque basins (Western Pyrenees, France)' by Mulder et al. (2009): *Sedimentology* 56, 997-1015: Discussion. *Sedimentology*. doi: 10.1111/j.1365-3091.2010.01163.x
- Hollister, C.D., 1967. Sediment distribution and deep circulation in the western North Atlantic. Unpublished Ph.D. thesis, Columbia University, New York, 467 pp.
- Hsü, K.J., 1964. Cross-laminated sequence in graded bed sequence. *Journal of Sedimentary Petrology* 34, 379-388.
- Klein, G. de Vries, 1975. Resedimented pelagic carbonate and volcanoclastic sediments and sedimentary structures in Leg 30 DSDP cores from the western equatorial Pacific. *Geology* 3, 39-42.
- Lowe, D.R., 1982. Sediment gravity flows: II. Depositional models with special reference to the deposits of high-density turbidity currents. *Journal of Sedimentary Petrology* 52, 279-297.
- Mansurbeg, H., Morad, S., Salem, A., Marfil, R., El-ghali, M.A.K., Nystuen, J.P., Caja, M.A., Amorosi, A., Garcia, D. & La Iglesia, A., 2008. Diagenesis and reservoir quality evolution of Palaeocene deep-water, marine sandstones, the Shetland-Faroes Basin, British continental shelf. *Marine and Petroleum Geology* 25, 514-543.
- Martin-Chivelet, J., Fregenal-Martí nez, M.A. & Chacón, B., 2008. Traction structures in contourites. In: M. Rebesco & A. Camerlenghi (Eds), *Contourites. Developments in Sedimentology* 60 (Elsevier, Amsterdam) 159-182.
- Meckel III, L.D., 2009. Reservoir characteristics and classification of sand-prone submarine mass-transport deposits. In: Shipp et al. (Eds), *Mass-transport deposits in deepwater settings*. SEPM Special Publication 96, 423-454.
- Mulder T, Razin P, Faugères, J-C., 2009. Hummocky cross-stratification-like structures in deep-sea turbidites: Upper Cretaceous Basque basins (Western Pyrenees, France). *Sedimentology* 56, 997-1015.
- Mulder, T., Philippe, R. Faugères, J.-C. & Gérard, J., 2010. Reply to the Discussion by Roger Higgs on 'Hummocky crossstratification-like structures in deep-sea turbidites: Upper Cretaceous Basque basins (Western Pyrenees, France)' by Mulder et al., *Sedimentology*, 56, 997–1015. *Sedimentology*, doi: 10.1111/j.1365-3091.2010.01162.
- Mutti, E., 1992. Turbidite sandstones. Agip Special publication, 275 pp.
- Natland, M.L., 1967. New classification of water-laid clastic sediments. *AAPG Bulletin* 51, 476.
- Nilsen T.H. & Abbott, P.L., 1979. Introduction. In: T.H. Nilsen & M.A. Arthur (Eds), *Upper Cretaceous deep-sea fan deposits*. Geol. Soc. Amer. Ann. Meeting, San Diego, CA, Fieldtrip 11, 137-166.

- Sanders, J.E., 1963. Concepts of fluid mechanics provided by primary sedimentary structures. *Journal of Sedimentary Petrology* 33, 173-179.
- Sanders, J.E., 1965. Primary sedimentary structures formed by turbidity currents and related resedimentation mechanisms. In: G.V. Middleton (Ed.), *Primary sedimentary structures and their hydrodynamic interpretation*. SEPM Special Publication 12, 192-219.
- Shanmugam, G., 1997. The Bouma sequence and the turbidite mind set. *Earth-Science Reviews* 42, 201-229.
- Shanmugam, G., 2000. 50 years of the turbidite paradigm (1950s–1990s): deep-water processes and facies models - a critical perspective. *Marine and Petroleum Geology* 17, 285-342.
- Shanmugam, G., 2003. Deep-marine tidal bottom currents and their reworked sands in modern and ancient submarine canyons. *Marine and Petroleum Geology* 20, 471-491.
- Shanmugam, G., 2006. Deep-water processes and facies models: implications for sandstone Petroleum Reservoirs. Elsevier, Amsterdam, p. 476.
- Shanmugam, G., 2007. The obsolescence of deep-water sequence stratigraphy in petroleum geology. *Indian Journal of Petroleum Geology* 16, 1-45.
- Shanmugam, G., 2008a. Deep-water bottom currents and their deposits. In: M. Rebesco & A. Camerlenghi (Eds), *Contourites. Developments in Sedimentology* 60 (Elsevier, Amsterdam), 59-81.
- Shanmugam, G., 2008b. The constructive functions of tropical cyclones and tsunamis on deep-water sand deposition during sea level highstand: implications for petroleum exploration. *AAPG Bulletin* 92, 443-471.
- Shanmugam, G., 2010. Sandy-mass-transport deposits (SMTD) in deep-water environments: recognition, geometry, and reservoir quality. *American Association of Petroleum Geologists Annual Convention and Exhibition, New Orleans, Abstracts Volume*, 234.
- Shanmugam, G. 2012. New perspectives on deep-water sandstones: origin, recognition, initiation, and reservoir quality. Elsevier, Amsterdam (in production).
- Shanmugam, G., Spalding, T.D. & Rofheart, D.H., 1993a. Process sedimentology and reservoir quality of deep-marine bottom-current reworked sands (sandy contourites): an example from the Gulf of Mexico. *AAPG Bulletin* 77, 1241-1259.
- Shanmugam, G., Spalding, T.D., & Rofheart, D.H., 1993b. Traction structures in deep-marine bottom-current reworked sands in the Pliocene and Pleistocene, Gulf of Mexico. *Geology* 21, 929-932.
- Shanmugam, G., Bloch, R.B., Mitchell, S.M., Beamish, G.W.J., Hodgkinson, R.J., Damuth, J.E., Straume, T., Syvertsen, S.E. & Shields, K.E., 1995. Basin-floor fans in the North Sea: sequence stratigraphic models vs. sedimentary facies. *AAPG Bulletin*, 79, 477–512.
- Shanmugam, G., Shrivastava, S. K., and Das, B., 2009. Sandy debrites and tidalites of Pliocene reservoir sands in upper-slope canyon environments, Offshore Krishna-Godavari Basin (India): implications. *Journal of Sedimentary Research* 79, 736-756.
- Shepard, F.P. & Dill, R.F., 1966. *Submarine canyons and other sea valleys*. Rand McNally & Co., Chicago, 381 pp.
- Shepard, F.P., Dill, R.F. & Von Rad, U., 1969. Physiography and sedimentary processes of La Jolla submarine fan and fan-valley, California. *AAPG Bulletin* 53, 39-420.
- Shepard, F.P., Marshall, N.F., McLoughlin, P.A. & Sullivan, G.G., 1979. *Currents in submarine canyons and other sea valleys*. AAPG Studies in Geology 8, 173 pp.

- Stow, D.A.V. & Faugères, J.-C., 2008. Contourite facies and the facies model. In: M. Rebesco & A. Camerlenghi (Eds.), *Contourites. Developments in Sedimentology* 60 (Elsevier, Amsterdam), 223-256.
- USGS (U.S. Geological Survey), 1994. Geologic features of the sea bottom around a municipal sludge dumpsite near 39°N, 73°W, offshore New Jersey and New York. U.S. Geological Survey Open-file Report 94-152. <http://pubs.usgs.gov/of/1994/of94-152/description.html>. Accessed July 6, 2011
- Van der Lingen, G.J., 1969. The turbidite problem. *New Zealand Journal of Geology and Geophysics* 12, 7–50.

G. Shanmugam
Department of Earth and Environmental Sciences
The University of Texas at Arlington, USA
E-mail: shanshanmugam@aol.com