The role of physical oceanographic processes in contourite sedimentation and how we can work together

Anna Wåhlin[1]

1   Department of Earth Sciences, University of Gothenburg, PO Box 460, SE-405 30 Göteborg, Sweden. Anna.wahlin@gu.se

Abstract: An overview of the dynamics of geostrophic dense currents flowing along the continental slope is given. The effect of Earth's rotation, bottom friction and additional small-scale topography, for example submarine canyons, on the dense water is considered. As a first-order approximation the water moves forward along the depth contours and parallel to the coast. Bottom friction induces a stress which gives rise to the Ekman spiral and a downhill Ekman transport in the benthic boundary layer. The boundary layer dynamics have consequences for the erosion and deposition of sediment and will be described in detail. The transport in the boundary layer also gives rise to a secondary circulation inside the main current, which influences the cross-current transport of suspended sediment. Topographic corrugations such as canyons, ridges and corrugations cross-cutting the path of a dense plume may effectively steer all or part of the dense plume downslope, and an overview of such flows will be given. Typical lateral variations of flow speed will be described and discussed. Depending on the scales of the flow these differences can have consequences for the formation of contourites, which will be discussed. Some examples of how successful multidisciplinary studies involving marine geology, benthic biology and physical oceanography will be presented.

Key words: Physical oceanography, contourites, sedimentary processes

LARGE-SCALE TOPOGRAPHY

The focus of this abstract is on the dynamics of a dense current flowing along a sloping topography, and the consequences of these dynamics on the sedimentation and erosion of bottom contourites. The deep waters of the oceans are formed primarily in marginal seas or shallow shelf regions where the water is made cold and dense by cooling and/or ice formation, or highly saline upon strong evaporation (e.g. Ambar and Howe, 1979; Dickson and Browne, 1994). The relatively dense water thus formed flows into the ocean via narrow or shallow straits. When the water is no longer constricted by the topography, it reshapes into a wider structure that adjusts to the forces of gravity, rotation, and bottom friction.

The Earth's rotation tends to steer bottom currents to the right (in the Northern Hemisphere) to flow parallel to large-scale bathymetry (e.g. along the continental margins). Bottom friction in combination with rotation acts to form a thin bottom boundary layer (the Ekman layer) in which fluid is drained to the left of the main current velocity, i.e. downhill for the largest part of the flow (Fig. 1). At the lateral boundaries, the edges of the dense water mass adjusts in order to make the dense interface horizontal where possible (Wåhlin and Walin, 2001; Price and Baringer, 1994). This is possible e.g. at the upper edge (Fig. 1), or if the flow has carved out a channel so that there is a ridge at the lower side against which it can lean. When the interface is horizontal the velocities are very small, and the Ekman transport reduced so that this is a stable state. This process will tend to increase the deposition upslope of a major bottom current, or in the vicinity of an along-slope directed ridge.
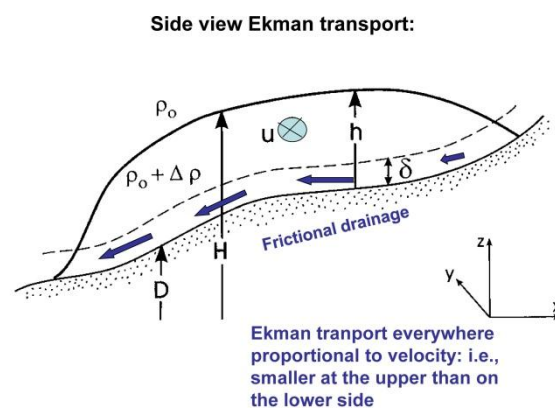

Side view Ekman transport:

FIGURE 1: Side view of a dense water mass flowing along a sloping topography.

SMALL-SCALE TOPOGRAPHY

Small-scale topographic features such as ridges and canyons can redirect the flow so that it flows antiparallel to the large-scale bathymetry (Figure 2). Examples of this is found in e.g. Darelius and Wåhlin; Allen and deMadron, 2009; Cossu et al, 2010. When this happens the velocity is generally smaller on the right hand side (looking downstream) of the canyon or ridge (in the Northern Hemisphere). Large-scale turbidity currents in submarine channels often show a significant asymmetry in the heights of their levee banks. In the Northern Hemisphere, there are many observations of the right-hand channel levee being noticeably higher than the left-hand levee, a phenomenon that is usually attributed to the effect of Coriolis forces upon turbidity currents (Cossu et al, 2010). It is a good example that shows how the physical

oceanographic dynamics inherent in the flow creates horizontally varying flow speeds that are persistent enough to affect the sedimentation during long time scales (i.e. contourites).
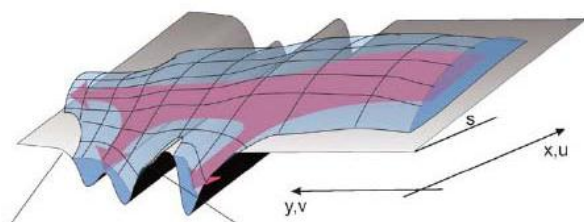

FIGURE 2. Sketch of a current flowing in corrugated topography with portions of it steered down inside the canyons

An example of how we can work together is to select sites for geophysical surveys that are known to harbour persistent physical oceanographic processes, and also the opposite to let the geophysical observations be the guide for where to perform intense physical oceanographic process studies.

REFERENCES

Allen, S., Durrieu deMadron, X., 2009. A review of the role of submarine canyons in deep ocean exchange with the shelf. Ocean Science 6, 1–38.

Ambar, I., Howe, M.R., 1979. Observations of the Mediterranean Outflow II: the deep circulation in the Gulf of Cadiz. Deep Sea Research Part I: Oceanographic Research Papers, 26, 555–568.

Cossu, R.,Wells,M.,Wåhlin, A., 2010. Influence of the Coriolis force on the flow structure of turbidity currents in submarine channel systems. Journal of Geophysical Research Oceans 115 (11), C11016.

Darelius, E., Wåhlin, A., 2007. Downward flow of dense water leaning on a submarine ridge. Deep Sea Research Part I: Oceanographic Research Papers 54, 1173–1188.

Dickson, R., Browne, D., 1994. The production of North Atlantic Deep Water: sources, rates, and pathways. Journal of Geophysical Research 99 (C6), 12319–12341.

Wåhlin, A., Walin, G., 2001. Downward migration of dense bottom currents. Environmental Fluid Mechanics 1, 257–279.

Price, J.F., Baringer, M.O., 1994. Outflows and deep water production by marginal seas. Progress in Oceanography 33, 161–200.