# Avalanches of sediment form deep-marine depositions

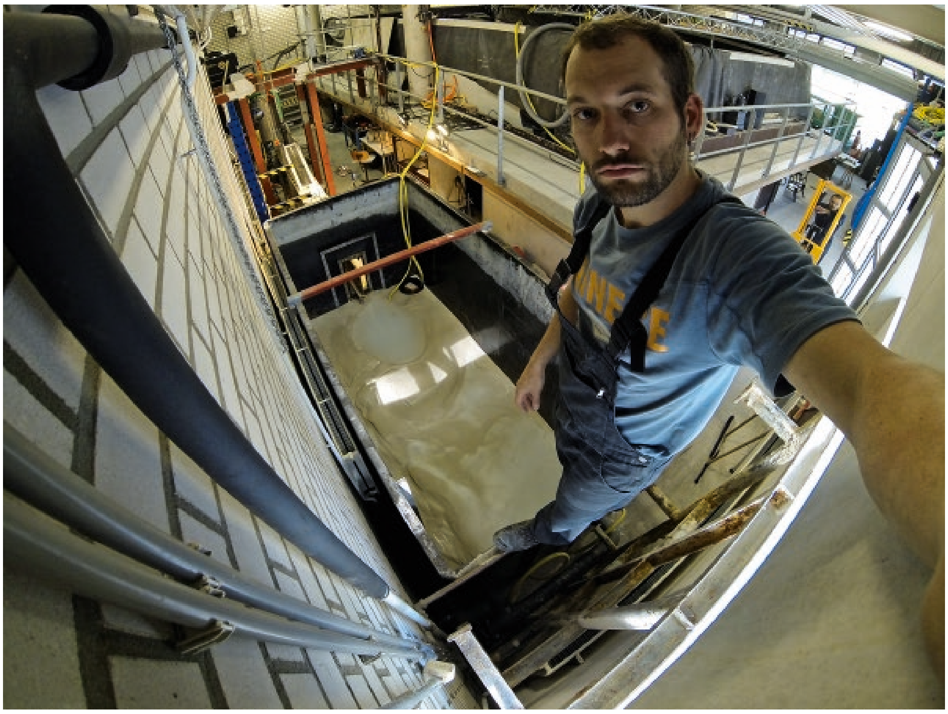
**The deep ocean is the largest sedimentary system basin on the planet. It serves as the primary storage point for all terrestrially weathered sediment that makes it beyond the near-shore environment. These deep-marine offshore deposits have become a focus of attention in exploration due to the progressive depletion of conventional onshore reservoirs. Florian Pohl's performs experiments in the Eurotank of Utrecht University linking the sedimentological characteristics of turbidity currents to the topography of the ocean floor.**

The principle transport agent in deep ocean environments are turbidity currents, avalanches of sediment and water that travel down the continental slope, continue for 1000s of kilometres over the ocean floor, and build up lobe shaped sandy deposits (submarine fans) that form massive oil and natural gas reservoirs.

For the exploration and production of oil and gas from these reservoirs the understanding of the sand distribution is essential, because it results in variations in permeability and porosity. The sand distribution is controlled by the flow dynamics of the turbidity currents. Therefore, oil companies design numerical models of turbidity currents from the past to predict the sand distribution of the deposits and hence, reservoir architecture and quality.

## Hostile and dark

Turbidity currents are very destructive and can destroy pipelines and communication cables that carry approximately 95% of trans-oceanic data traffic, including the internet and the global financial markets. Despite their significance, the surface of the moon is better known than the surface of the deep oceans, which represents a poorly accessible, hostile and dark environment to research efforts. Due to difficulties in predicting the timing of individual flow events, their destructive behaviour, and the fact that installing monitoring equipment in a deep-marine environment remains difficult and expensive, there is only a limited number of studies of natural turbidity currents on the ocean-floor. Consequently, very little is known about the processes in real world turbidity currents that shape deposits. With our research, we aim to improve the understanding of the flow dynamics in these currents and the associated deposits. This will improve the accuracy of numerical models, as well as risk assessment of hazards caused by turbidity currents.



**Florian Pohl in the Eurotank Laboratory at Utrecht University.**

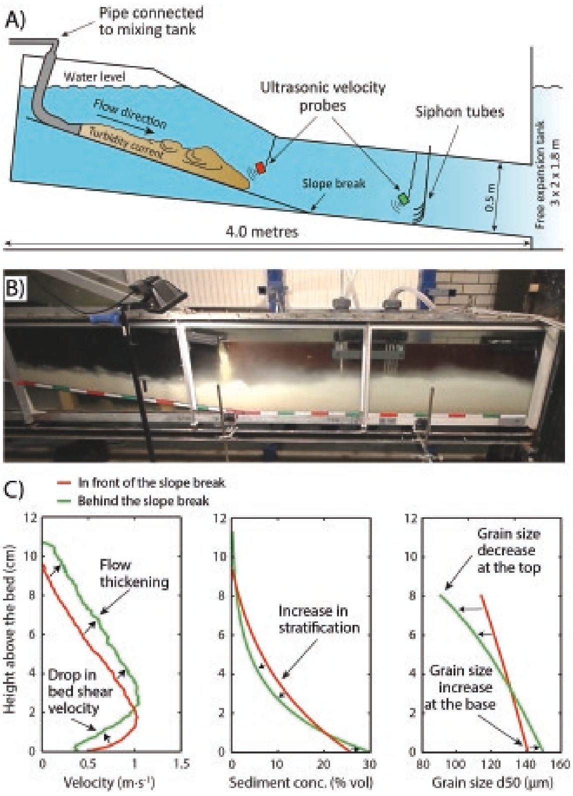
## The deep ocean in the laboratory

In my PhD project, I physically model scaled turbidity currents in a flume tank. This provides insights into the relationships between basin configuration, fluid dynamics and associated depositional styles in a controlled environment. Specifically, I focus on the transition zone between steep channel systems and flat submarine fans. Turbidity currents keep most of their sediment load in suspension on the continental slope and erode into the underlying substrate, thus forming canyons and channels. Upon approaching the more gently dipping abyssal plane, these currents lose their transport capacity and start to deposit their sediment load. The fluid dynamics within these currents and their related depositional patterns at these transitions are contentious and poorly understood.
In the Eurotank laboratory at Utrecht University, we design experiments which resemble the above-mentioned ocean-floor variations. We generate a series of experimental currents over a range of basin geometries to investigate the linkages between the velocity of flows, their density structure and the associated depositional style.

## Counterintuitive depositional patterns

Experimental results show that basin geometry has a strong influence on both the flow dynamics and the depositional pattern of turbidity currents. Currents going through a slope break tend to thicken, which leads to a drop in bed shear stress and initiates sediment deposition. The pattern of these deposits is strongly controlled by the precise geometry of the slope break. The dipping angle upflow of the slope break controls the point where the current begins to deposit sediment, whereas the dipping angle downflow of the slope break controls the thickness of the deposits.

Grain size analysis of the deposits reveals a downstream coarsening trend; this contradicts the classic model which predicts downstream fining between the proximal and distal regions of the deposits. Based on our flow measurements, the downstream coarsening results from rapidly triggered deposition of sediment at the base of the flow, in combination with delayed adjustment of the vertical suspended grain size distribution within the current. Hence, the downstream coarsening reflects the adjustment delay between different mechanisms in the current.




**A) The experimental setup designed for the investigation of the current response to an abrupt change in the dipping angle of the flume tank floor. A mixture of sediment and water is pumped into the flume tank and travels through the experimental setup driven by gravity acting on its excess density. B) A photography of the experimental setup during an experiment. Current velocity was monitored by Ultrasonic Velocity Profilers. These profilers emit an ultrasonic pulse into the flow, which is reflected by the moving sediment particles. The frequency of the reflected pulse is shifted due to the Doppler effect, which is used to calculate the flow velocity of the turbidity current. Vertical sediment concentration and grain size distribution was captured by siphoning on the turbidity current and analysis of the sediment with a laser particle sizer. C) Flow dynamic measurements of the turbidity current in front of and behind the slope break.**

## Comparison to outcrops

This research also relies on the study of sedimentary rocks from ancient turbidity current deposits in outcrops. They provide the opportunity to investigate the architecture and its evolution through time, and to validate the experimental result against a real turbidite system. The sites we use are in the Permian of South Africa (Karoo Basin) and the Eocene of Svalbard (Tertiary basin), since these systems have a basin geometry comparable to our experiments and, therefore, provide good analogues to test our laboratory results. Grain size analysis of deposits in the Karoo Basin show a downstream coarsening in the proximal part of the deposits, a result similar to our experimental study. Hence, we think that the experimental turbidity currents from our lab reproduce the processes of natural turbidity currents.

## Implications and outlook

To date, we show that the timing of flow dynamic adjustments to changes in slope angle results in a distinct signal in the deposits, a fact that was previously not recognised. We propose that downstream coarsening can be found in deposits formed due to a rapid change in the ocean-floor topography. This knowledge can be used for interpretations of flow properties and ocean-floor topography from past turbidite systems in the rock record. Furtherrmore, the different timing of flow dynamic processes in turbidity currents is crucial for the development of numerical models, which are used by the petroleum industry for the predictions of location and quality of sand bodies on the ocean floor.

Future work will address the flow transition from a confined channel to an unconfined fan setting. We will use 3D experiments in the Eurotank during the summer of 2017. The results of this work will contribute to our understanding of flow dynamics in the deep ocean, which will help to minimise risks in exploration and production of hydrocarbons, and to evaluate the hazards posed by these currents to infrastructure along the ocean floor.

**Florian Pohl**

Florian Pohl werkt als aio op het Vidi-project 'EuroSEDS: Eurotank Studies of Experimental Deepwater Sedimentology' van dr. Joris Eggenhuisen. Wervelende lawines voeren sediment 1000 km ver door meanderende geulen op de bodem van de oceanen. Deze lawines worden nagemaakt in het laboratorium om erachter te komen hoe dat kan, en om te voorspellen waar in oceanen zand afgezet wordt.

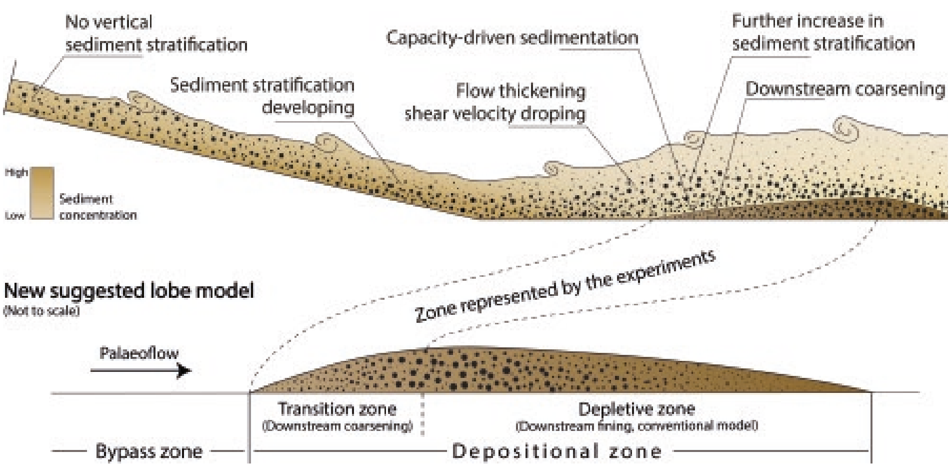



**Illustration of the flow dynamics and the associated deposits of turbidity currents in a slope break setting. Flow direction is from left to right. After the turbidity current enters the flume a vertical sediment stratification develops which increases the grain size and concentration of the sediment at the base of the flow. Downflow of the slope break, thickening of the currents and reduction in shear stress results in deposition. The combination of deposition with the increase in grain size at the flow base results in a downstream coarsening trend in the proximal parts of deposits.**