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Study of the Formation Mechanism of Inverse Grading in Turbidity Deposits

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Abstract
The knowledge about the physical processes involved in the transportation and deposition of marine turbidity sequences is the key for the creation of reliable predictive models, which minimise exploration uncertainty.

Physical simulation of density currents has been used to study the formation mechanism of turbidite around the world. Normally graded beds caused by density currents are described by Kuenen (1951), however Kneller (1995) suggests that rarity of normally graded beds in the rock record means that deposits of true turbidity currents are rare in nature. Usually natural records show massive layers with inverse grading.

The present study employed the simulation of density currents in sequence, i.e., the succession of density currents before the sediment load of the first one is completely settled down, in order to evaluate its depositional patterns. The results show that mainly coursing-upward sequences are formed, what is confirmed by sampling analysis and visual inspection. The formation of such deposits may be associated to an inertial component of centripetal forces which may displaced coarser material to external portions of currents vortex. This behaviour is currently being studied through the application of portable ultrasound scanner (Brito et al., 2002) in the visualisation of internal structures.

Introduction
The occurrence of massive and/or inverse graded beds in deposits associated with turbidity sequences is largely documented by researchers around the world. Some authors though interpret these sedimentary structures as the depositional result of sandy debris flows (Lowe, 1982) or hyperconcentrated flows (Shanmungan, 1997). Simulations of non-conservative density currents in bidimensional channel show that such structures are not exclusively associated with the mixture concentration, but can also be associated to other factors, as initial grain size range and/or deposition period of the first current.

Methodology
The simulations which are presented in this study were developed at the Density Currents Research Center (NECOD) at UFRGS in a small scale bidimensional channel (300 x 12.5 x 20cm) as showed in Figure 1. The experiments consisted in the injection of two consecutive currents, i.e., the second current was ignited before the first one was completely settled down. The main objectives of this study were: 1) to evaluate depositional patterns registered in the sedimentary package and 2) to evaluate the current development in order to correlate its parameters with its respective sedimentary structures.

To analyse the currents digital camera and ultrasound scanner imaging were used (figure 2). To evaluate the deposits both visual inspection and image interpretation from photographic images were performed. The deposits were sampled in 10cm intervals and divided in two horizons (top and base). Finally a grain size analysis was conducted in order to allow data interpretation.

Experiment Parameters
The parameters for the six experiments carried out, two in the first stage and four in the second stage, are listed in the table 1

Table 1 – Characteristics of simulations

Experiment	Coal Type	Grain Size Distribution	ρ (current)
1A	207 (ρ = 1365)	0.297 - 0.053mm	1022
2A	207 (ρ = 1365)	0.297 - 0.053mm	1022
1B	205 (ρ = 1190)	0.297 - 0.053mm	1022
2B	207 (ρ = 1365)	0.297-0.177mm and 0.088-0.053mm	1022
3B	205 (ρ = 1190)	0.297-0.177mm and 0.088-0.053mm	1030
4B	205 (ρ = 1190)	0.297-0.177mm and 0.088-0.053mm	1022

Results
The grain size analysis showed normal graded deposits, as well as massive deposits and with inverse grading. The determination of this structures was made according the concentration of each granular fraction and its position in the sedimentary deposit.

The massive deposits were located in several intervals along the channel. The presence of this structure may be associated to the fact that sediment of the deposit formed by the first current experiences a remobilization caused by the second current, creating grain disorganisation. Thus the resulting deposit will not present particle internal arrangement. Inverse graded beds were observed only in the experiments which used extended grain size ranges (experiments 1A, 2A and 1B), occurring in the proximal (figure 3) and intermediate (120-160cm) portions of the channel.

The formation of such deposits may be associated to an inertial component of centripetal forces which may displaced coarser material to external portions of currents vortex. In the other hand, Kneller (1995) explain the occurrence of these structures (massive and inverse grading deposits) are associated with the velocity and acceleration variations. This behaviour is being studied with an ultrasound scanner (figure 4).

Conclusions
According the conducted experiments of consecutive currents it was observed:
1. The interaction of the second current with the sedimentary deposit should be the main factor in the formation of massive deposits, as long as it is capable to remobilize the deposition caused by the first current and creating grain disorganisation.
2. The presence of inverse graded beds may not be directly associated with the mechanical interaction of the second current with the first one, but with the initial grain size of the mixture, or with the current deposition period, or with both.

References
BRITO et al. 2002. Emprego de Equipamento de Visualização (Ecógrafo Médico) para o Estudo de Correntes de Densidade Não Conservativas. Revista Técnica de Energia Petróleo e Gás, Rio de Janeiro, vol. 1,n.2 (jul./ago./set./2002), p. 54-58.

KNELLER, B. 1995. Beyond the turbidite paradigm: physical models for deposition of turbidites and their implications for reservoir prediction. In: Characterization of deep marine clastic systems. London: The Geological Society Special Publication, p. 31-49. (Geological Society Special Publication, n. 94).

KUENEN, P. H. 1951. Properties of turbidity currents of high density. Tulsa: Society of Economic Palaeontologists and Mineralogists, p. 1-14. (Special Publication. n. 2).

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, Tulsa, v.52, n.1, p. 279-297.

SHANMUGAM, G. 1997. The Bouma sequence and the turbidite mind set. Earth Science Reviews, Amsterdam, v.42. p.201-229.

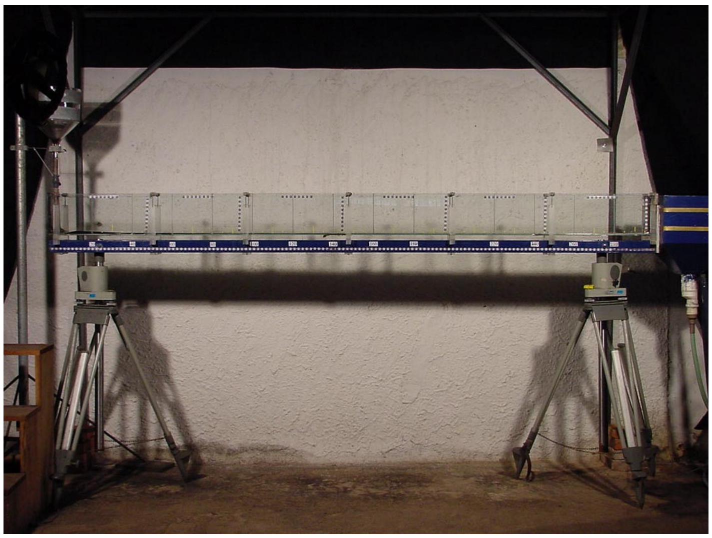

Fig. 1: Bidimensional channel

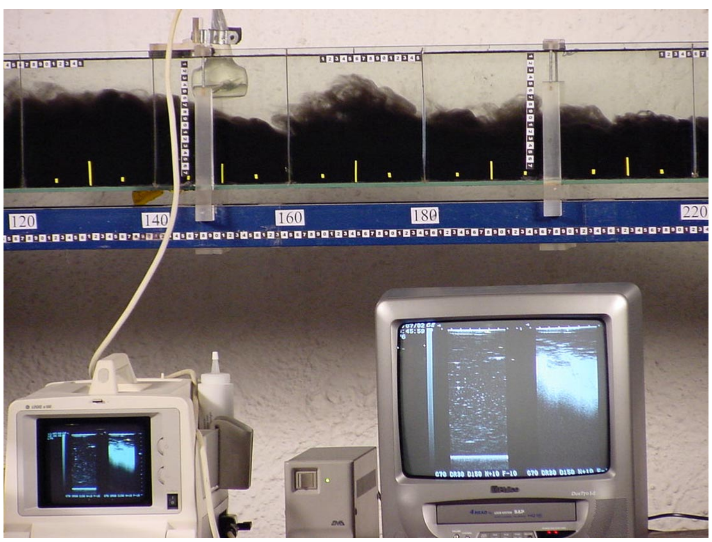

Fig. 2: Ultrasound scanner imaging acquisition

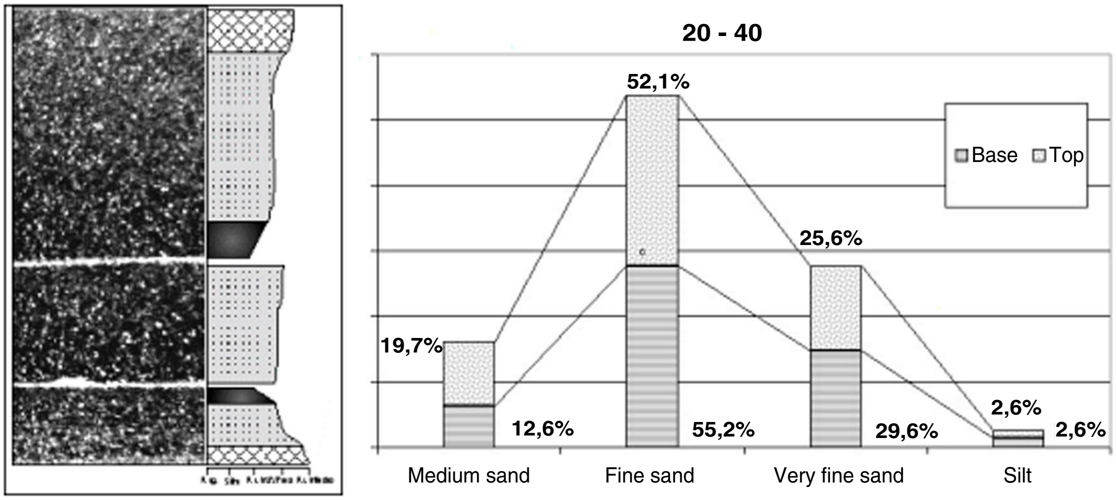

Fig. 3: Inverse graded in the proximal regions (20-40cm) of the channel.

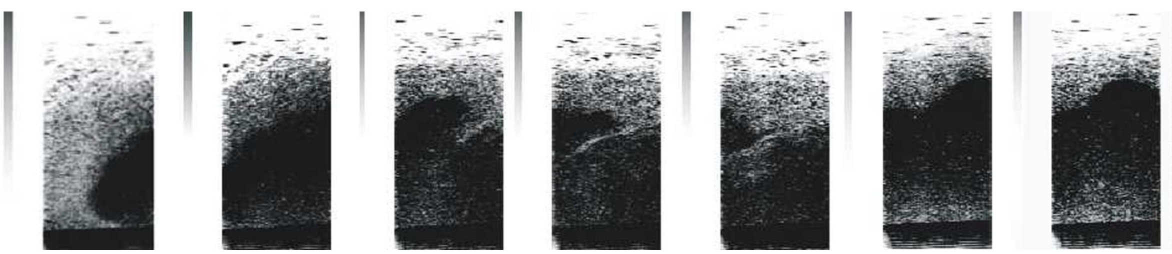

Fig. 4: Ultrasound pictures showing some stages of vortex shedding