

# **PS Complementary Results on Experiment-Derived Classification of Submarine Sediment Gravity Flows\***

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## **Abstract**

A sequence of ten fully-equipped experiments of continuous flows of sediment gravity flows (SGF) was conducted in a long-glass flume ( $15 \times 0.4 \times 0.6$  m) in order to identify variations in their depositional and hydrodynamic behavior in function of increments in sediment concentration and/or clay content. Mineral Coal (D50 =  $55\mu\text{m}$ , density =  $1,190 \text{ kg/m}^3$ ) Kaolin (D50 =  $6 \mu\text{m}$ , density =  $2,600 \text{ kg/m}^3$ ) mixtures were prepared to constitute distinct SGF with volumetric concentrations ranging from 2 and 40% and clay contents of 5, 12.5, and 50%. The mixture volumes were 200 and 400 liters, and the discharge varied from 50 to 60 l/min. Images of all simulated SGF were obtained using two video cameras and two medical ultrasound scanner. Velocity and concentration data were also collected using, respectively, 24 UVP probes and 6 UHCM probes. Results showed that significant changes occurred in the dynamics of flow as well as in the deposits generated as concentration/clay content increases. Low concentration flows ( $C_v < 7.5\%$ ) were thicker; lower velocity, and turbulence keep sediments in suspension. In line, more concentrated flows ( $C_v > 10\%$ ), a bipartite flow stratification was observed. In the top layer, the predominant sediment-support mechanism was turbulence. However, in the basal layer, mass transport became predominant ( $C_v > 20\%$ ). When the clay content was greater than 12.5%, the formation of a mixed layer was fully inhibited. The Sediment-support mechanism also drives the depositional process: the sediment transported by turbulent flows was deposited grain by grain as flow decelerates, whereas the mass transported sediment was deposited just after an abrupt stop (injection stop), characterizing to a frictional (no clay) and/or cohesive freezing (with clay). The slicing analysis of the non-cohesive flow deposits showed that the amount of material deposited (thickness) and the grain size decreasing along the channel. In addition, increase in concentration provided greater flows competence, which can be identified by the larger sediment size in the most distal part of the channel. The increase in clay content, in turn, reduced the flow capacity of transport causing the formation of thicker deposits. Rheological aspects of these distinct flows can also explained the differences between SGF simulated. Finally, those new results can complement/better conception previous experiment-derived classification models for submarine sediment gravity flows.

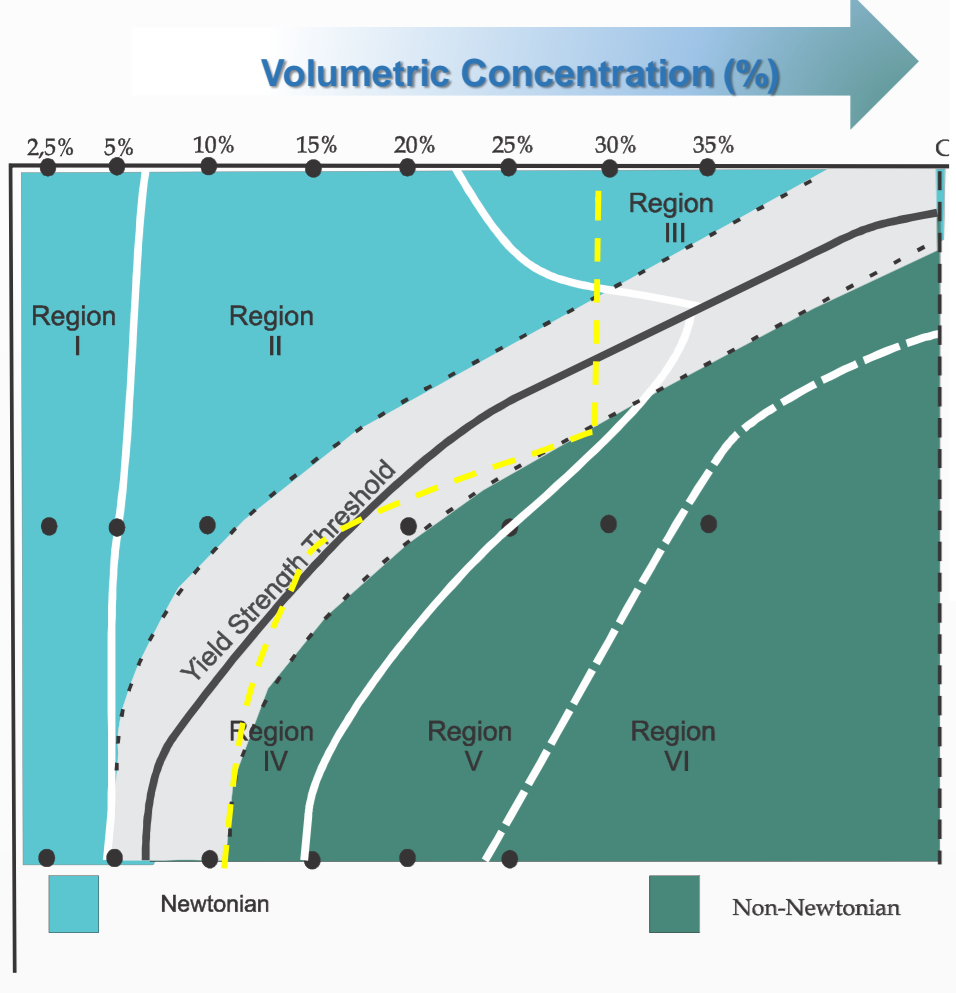
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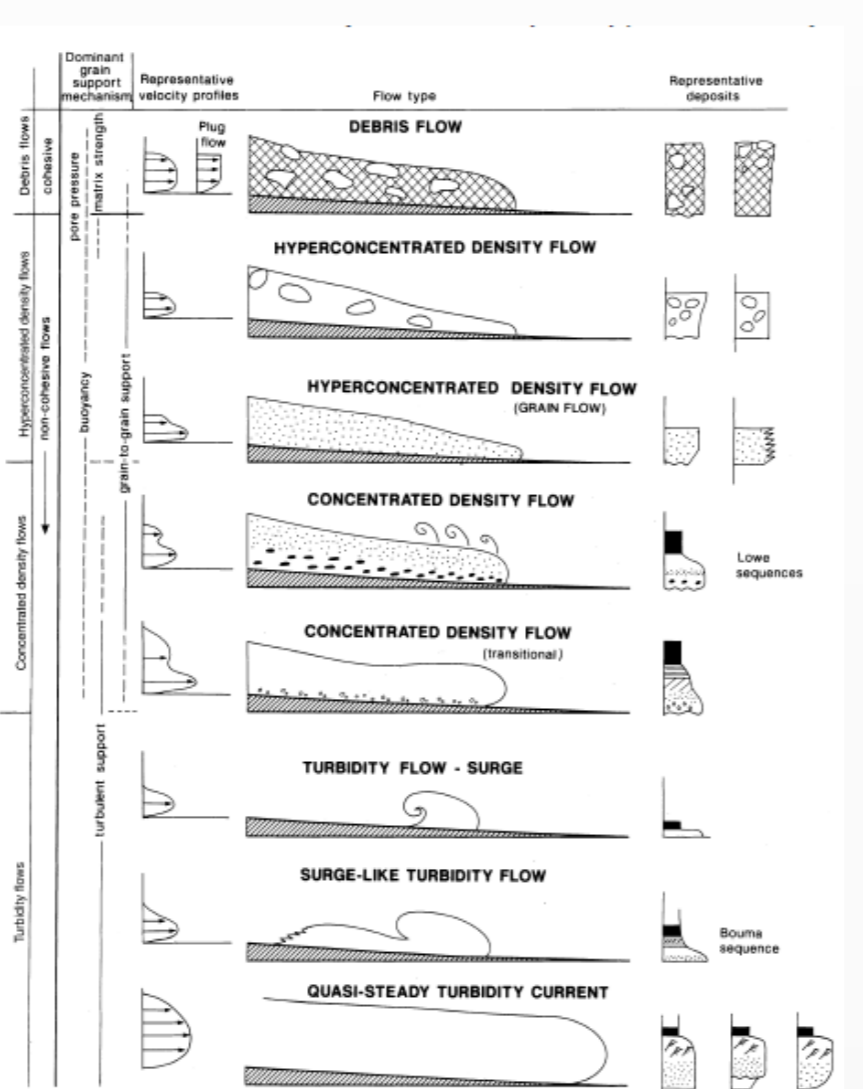
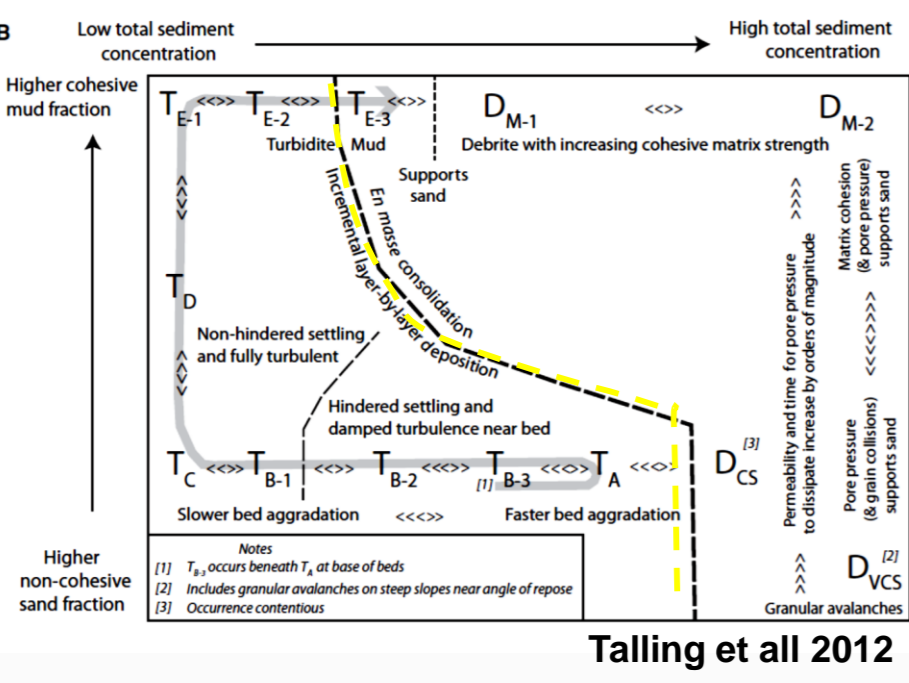
INTRODUCTION & BACKGROUND

A sequence of ten fully-equipped experiments of continuous flows of sediment gravity flows (SGF) was conducted in a long-glass flume (15 x 0.4 x 0.6 m) in order to identify variations in their depositional and hydrodynamic behavior in function of increments in sediment concentration and/or clay content. Mineral Coal (D50 = 55 μm, s.g. = 1,19 ) and Kaolin (D50 = 6 μm, s.g. = 2,6) mixtures were prepared to constitute distinct SGF with volumetric concentrations ranging from 2 and 40% and clay contents of 5, 12.5 and 50%. The mixture volumes were 200 and 400 liters, and the discharge varied from 50 to 60 l/min. Images of all simulated SGF were obtained using two video cameras and two medical ultrasound scanner. Velocity and concentration data were also collected using, respectively, 24 UVP probes and 6 UHCM probes.

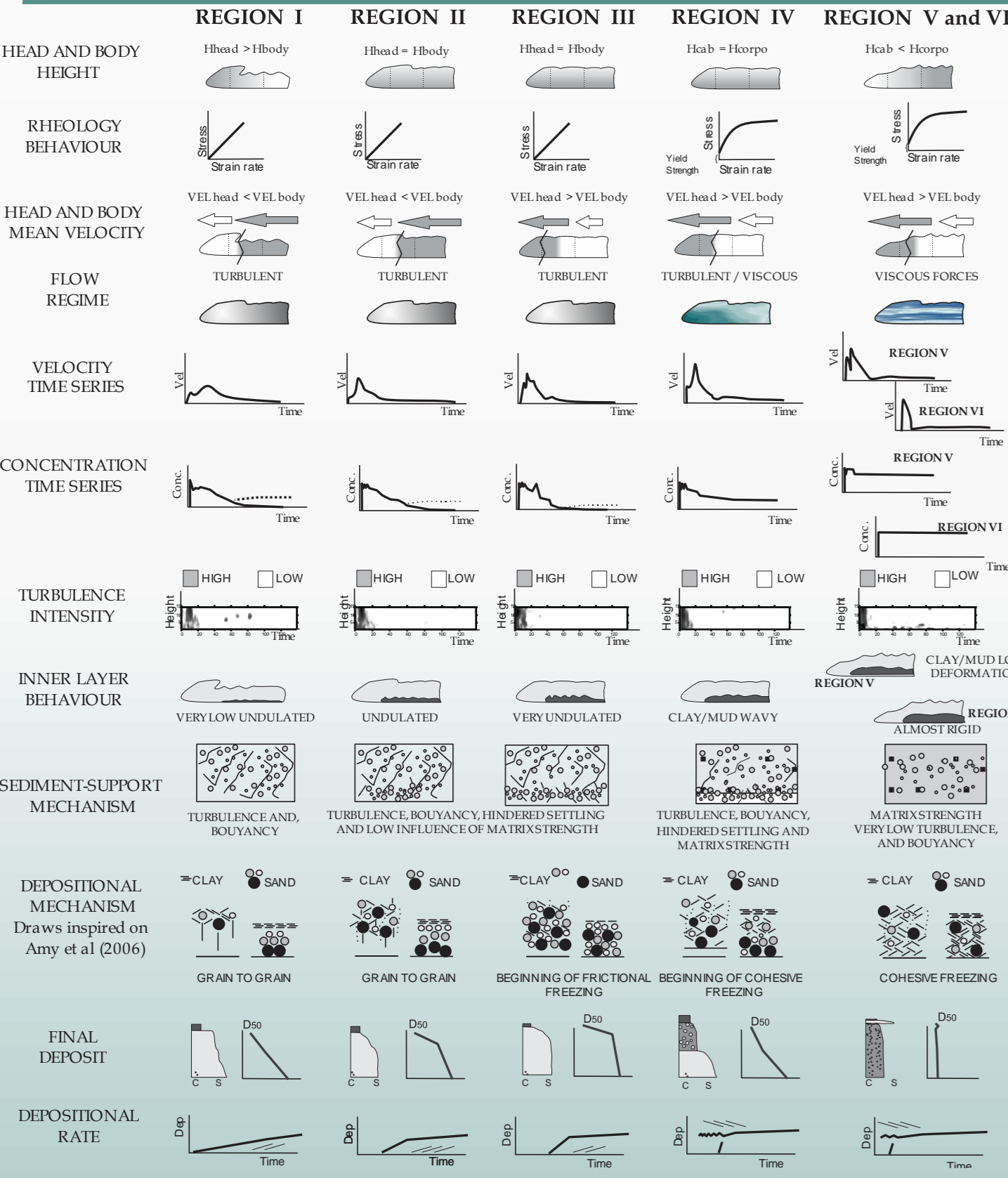
EXPERIMENTAL-DERIVED CLASSIFICATION - MANICA (2009)



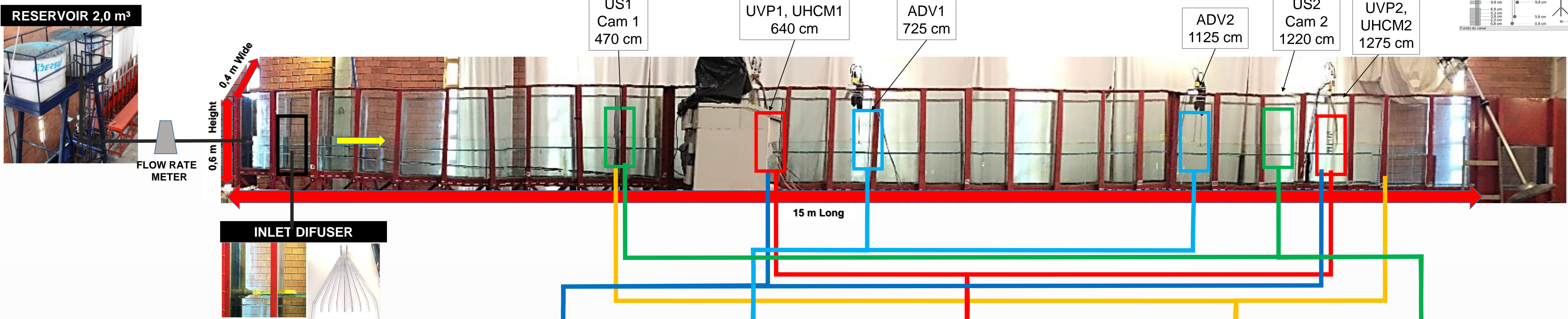
EXAMPLES OF SGF CLASSIFICATION



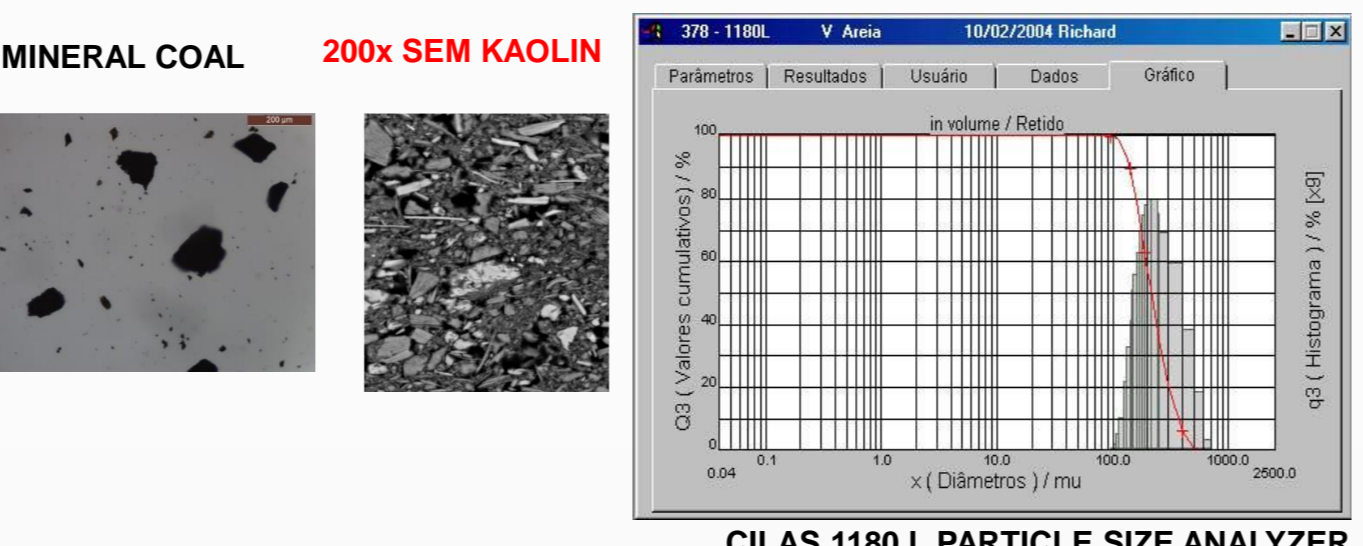
SEDIMENT GRAVITY FLOWS PROPERTIES (MANICA 2009)



FACILITES & EXPERIMENTAL SETUP



SEDIMENTS CARACTERIZATION



Sediment	KAOLIN	COAL
Symbol	K	C
Cohesive	YES	No
Density [kg.m <sup>-3</sup> ]	2600	1190
D <sub>10</sub> [μm]	1.09	2.72
D <sub>50</sub> [μm]	6.55	41.4
D <sub>90</sub> [μm]	29.35	105.74
D <sub>m</sub> [μm]	12.33	49.95

COMPLEMENTARY EXPERIMENTS OF SEDIMENT GRAVITY FLOWS

Continuous Flows experiments

Long Flume (> 15 m)

Multi equipped experiments

Spatial data analysis – 2 sets (proximal and distal)

Rheology of the mixtures used (coal and kaolin from Castro 2016)

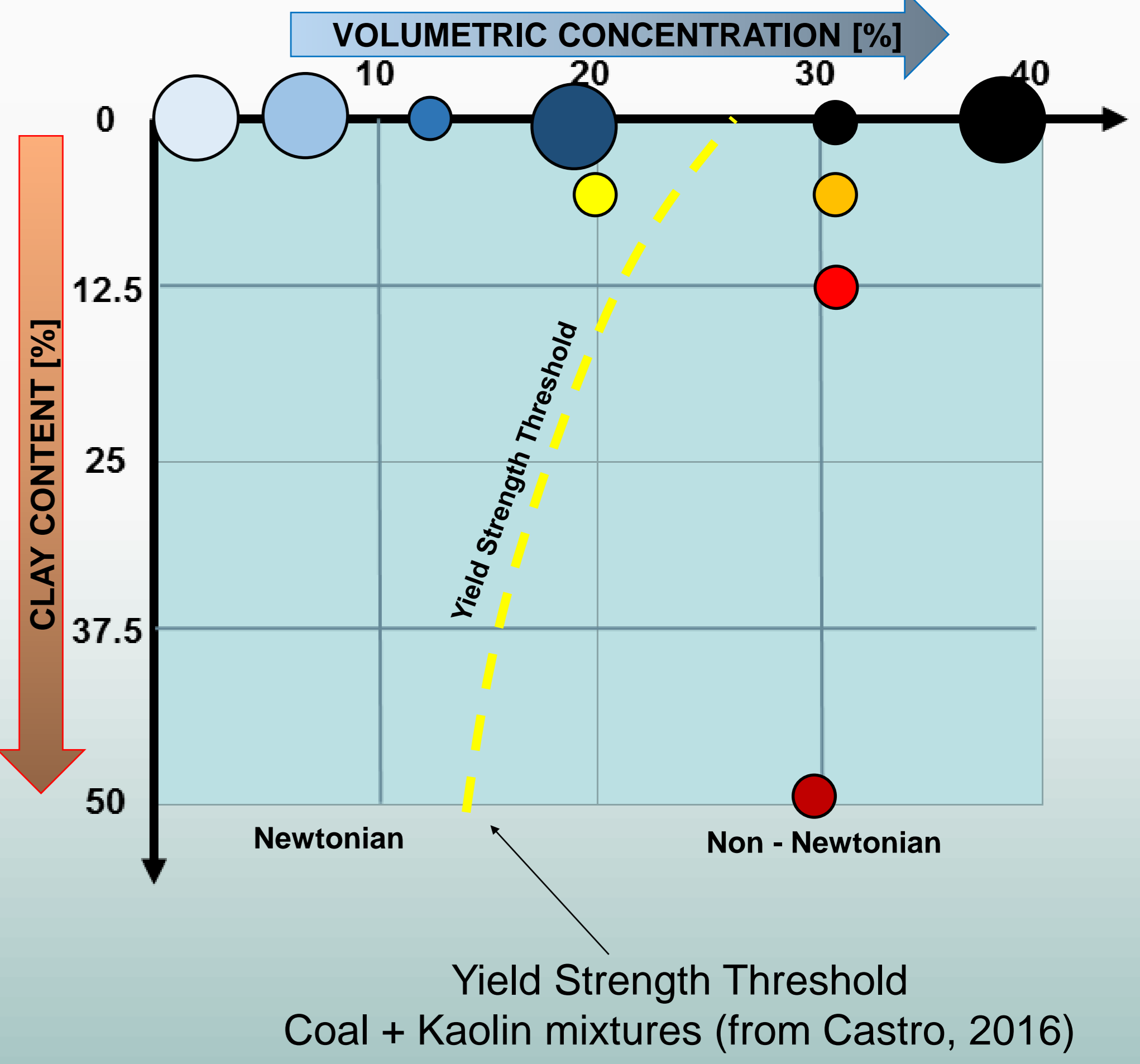
Inner visualization of the – (medical ultrasound)

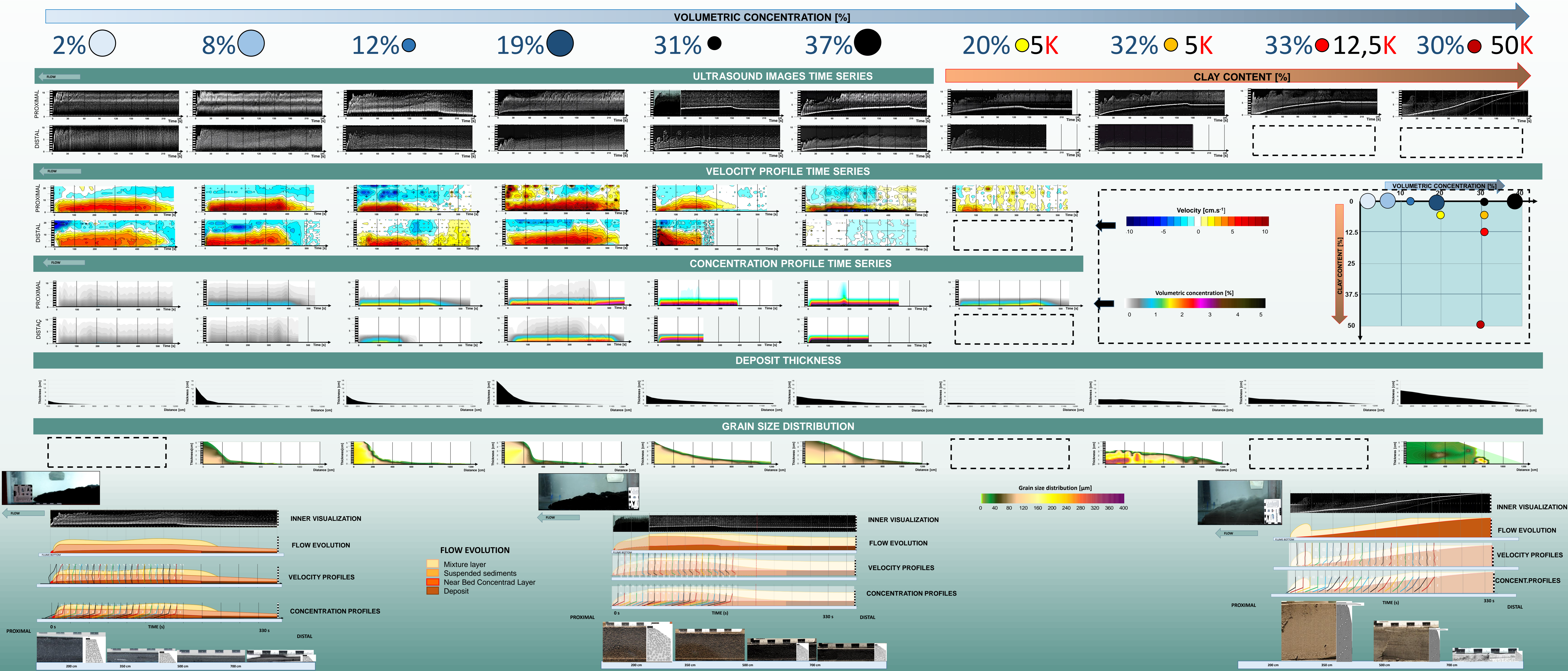
Dip and strike section of the deposit

Process-Based analysis

EXPERIMENTS TABLE

RUN	CV [%]	SEDIMENTS CONTENT	Volume [l]	Q [l/min]
E1	11.9	100% C	200	50
E2	30.6	100% C	200	50
E3	29.29	50% C : 50% K	500	70
E4	33.12	87.5% C : 12.5% K	200	50
E5	31.9	95% C : 5% K	200	50
E6	20	95% C : 5% K	200	50
E7	7.7	100% C	400	60
E8	1.84	100% C	400	50
E9	18.99	100% C	400	50
E10	37	100% C	200	50

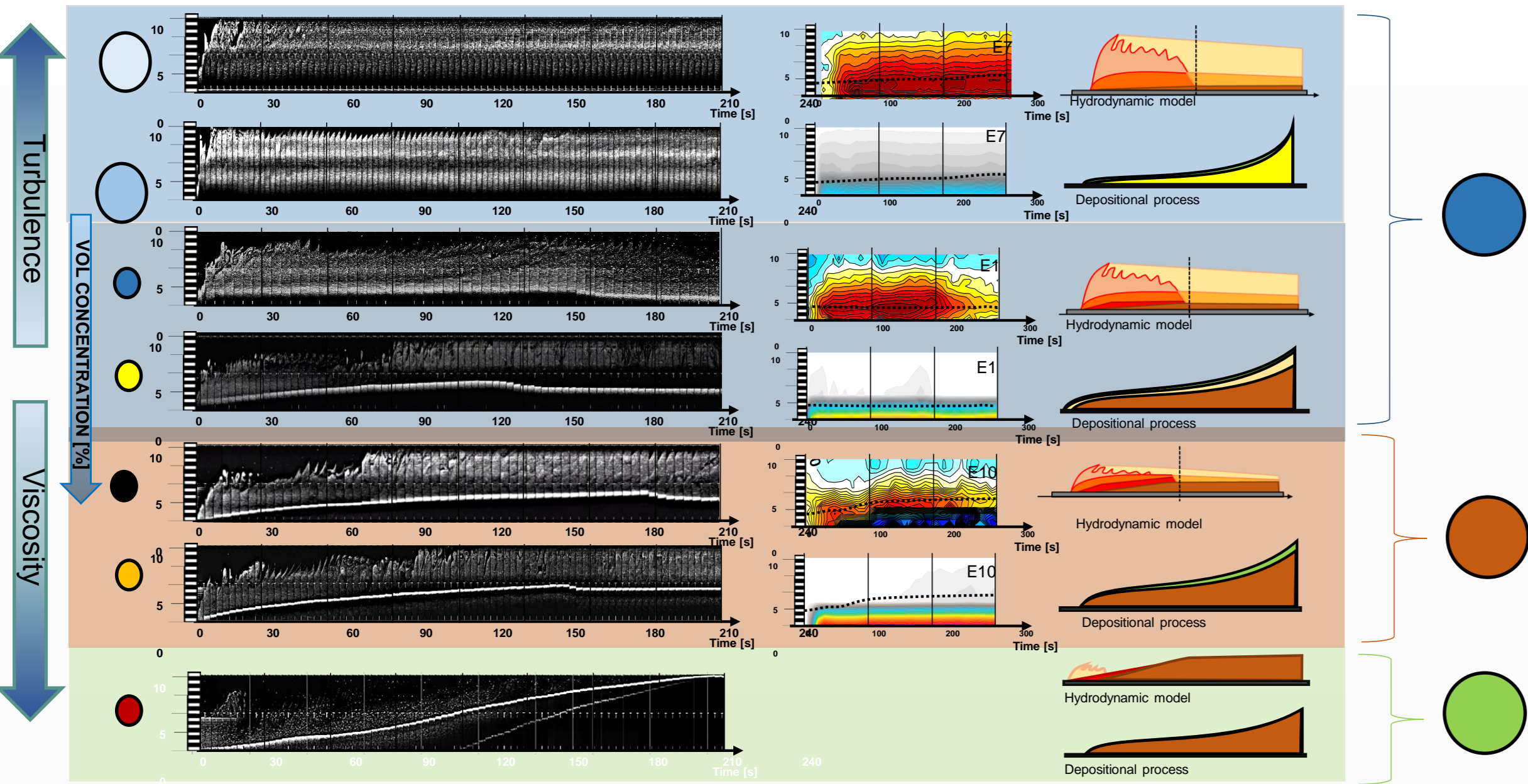




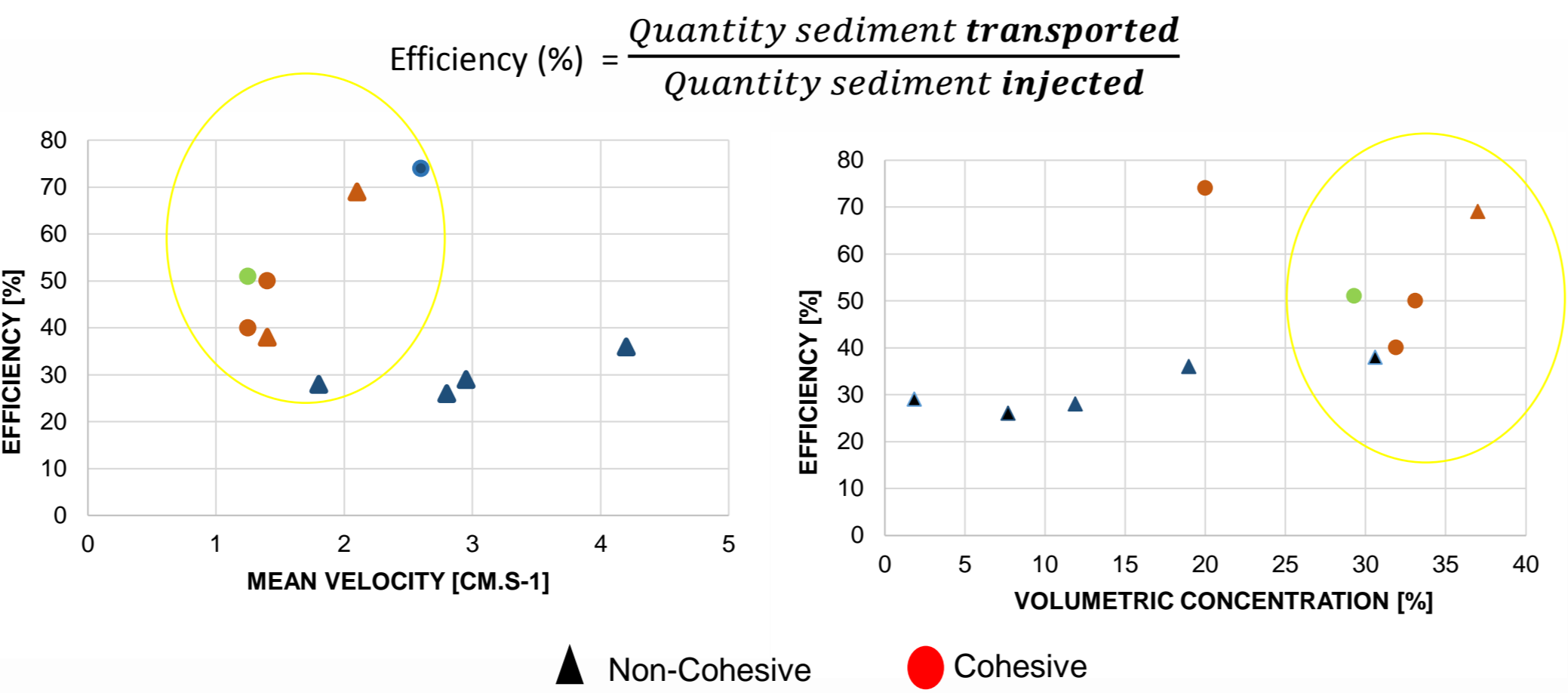
HYDRODINAMICAL & DEPOSITIONAL PROCESS

Results showed that significant changes occurred in the dynamics of flow as well as in the deposits generated as concentration/clay content increases. Low concentration flows (Cv < 7.5%) were thicker; lower velocity, and turbulence keep sediments in suspension. More concentrated flows (CV > 10%), a bipartite flow stratification was observed. In the top layer, the predominant sediment-support mechanism was turbulence. However, in the basal layer, mass transport became predominant (Cv > 20%). When the clay content was greater than 12.5%, the formation of a mixed layer was fully inhibited. The Sediment-support mechanism also drives the depositional process: the sediment transported by turbulent flows was deposited grain-by-grain as flow decelerates, whereas the mass transported sediment was deposited just after an abrupt stop (injection stop), characterizing to a frictional (no clay) and/or cohesive freezing (with clay). Increase in concentration provided greater flows competence, which can be identified by the larger sediment size in the most distal part of the channel. The increase in clay content, in turn, reduced the flow capacity of transport causing the formation of thicker deposits. Rheological aspects of these distinct flows can also explained the differences between SGF simulated.

GROUPING IN 3 MAIN REGIONS



FLOW EFFICIENCY



Volumetric Concentration controls Efficiency

Vol. Conc Efficiency

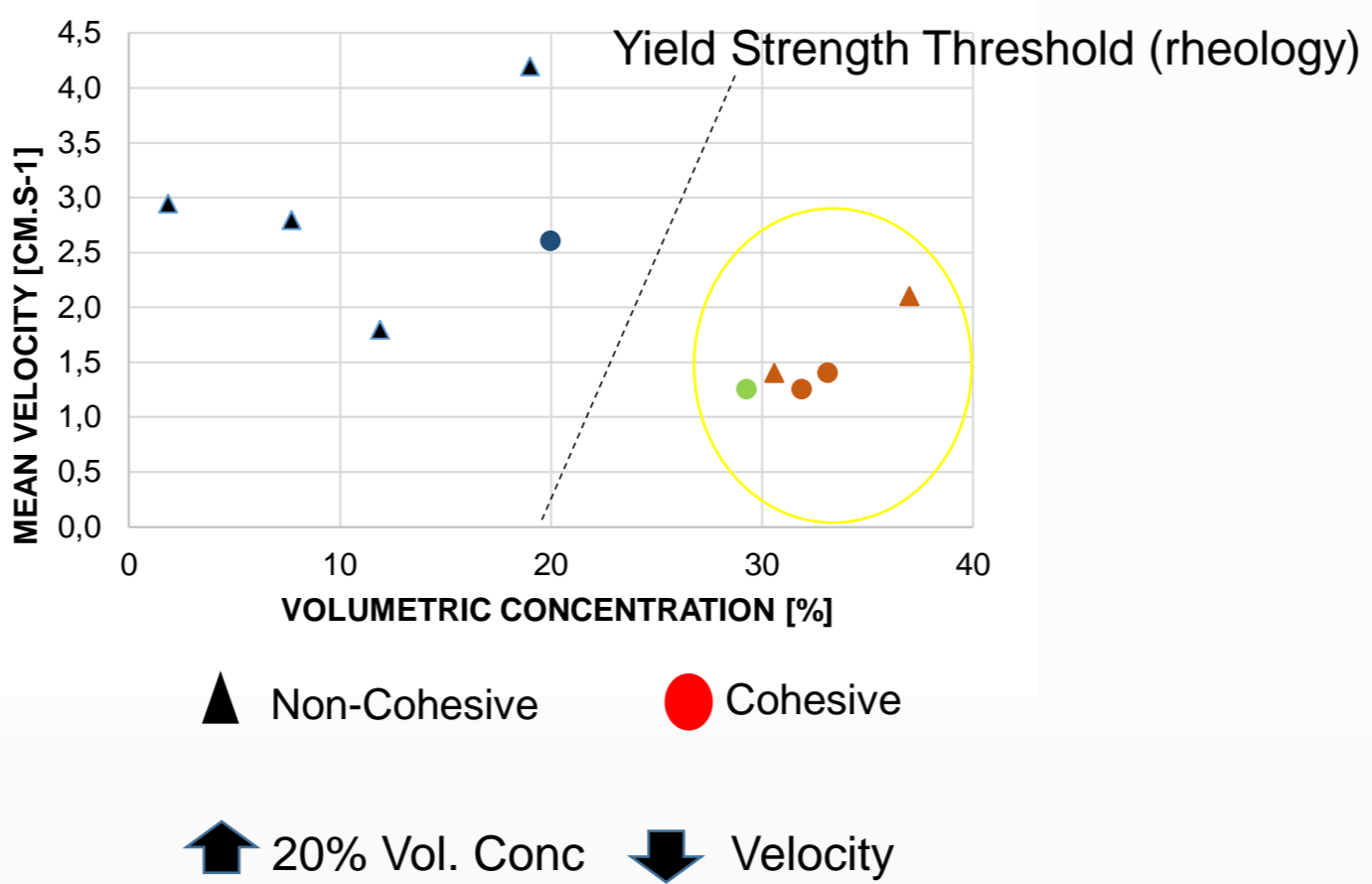
Mean Velocity vs Efficiency ( 2 patterns)

20% Vol. Conc Efficiency

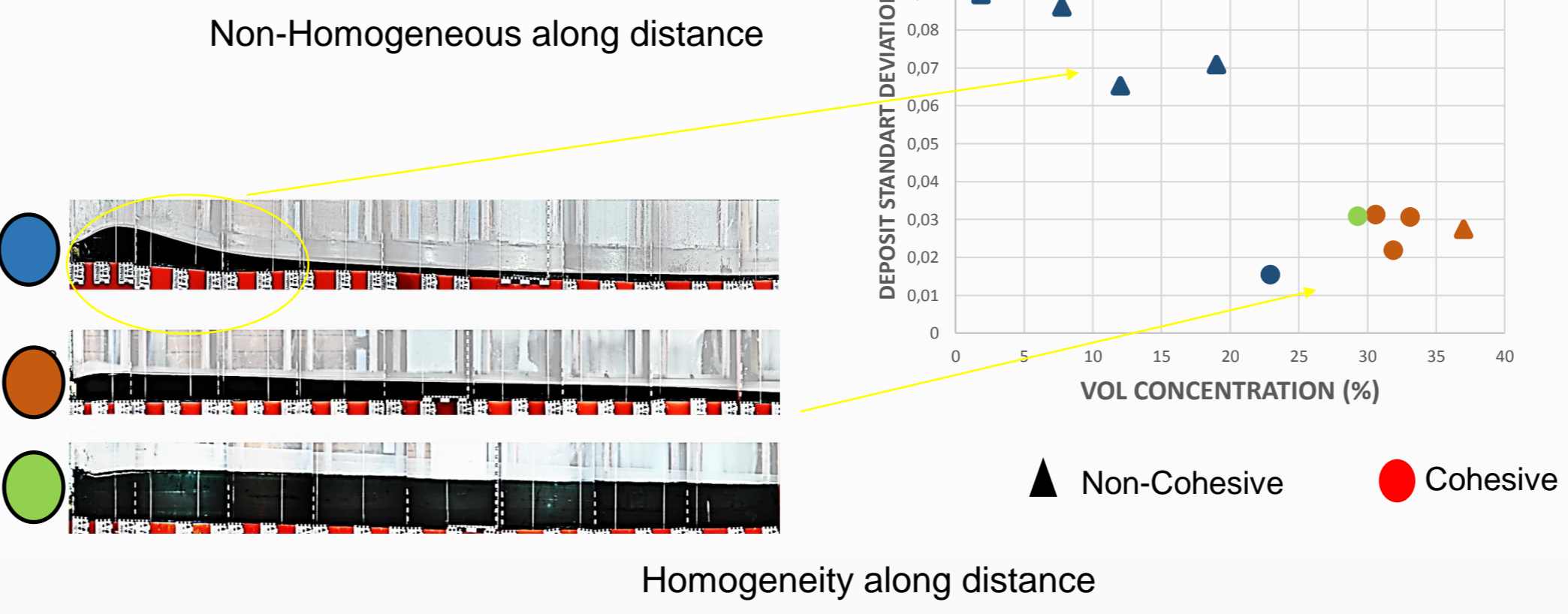
20% Vol. Conc Efficiency

Non-Cohesive Cohesive

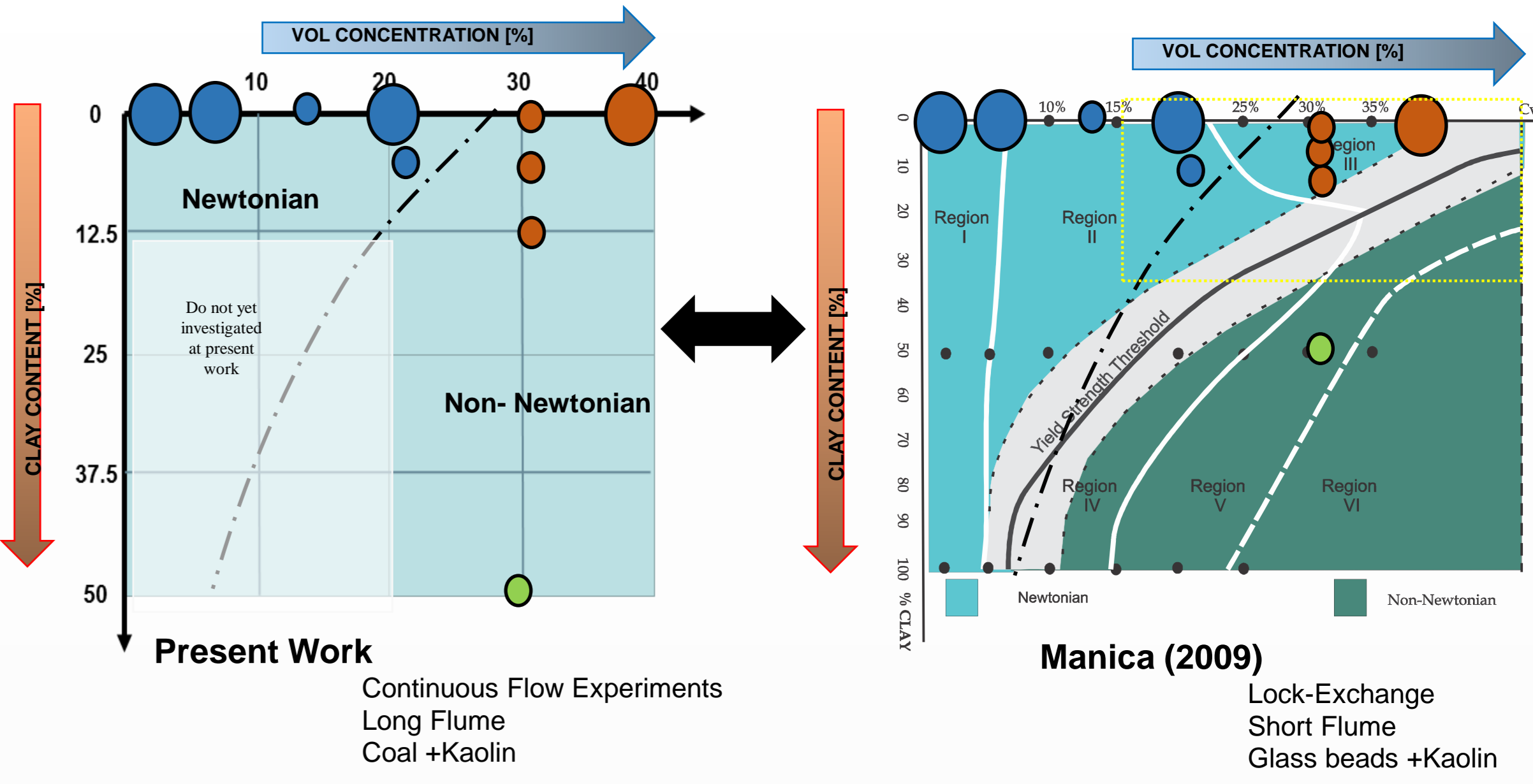
“RHEOLOGY” EFFECT



DEPOSIT HOMOGENEITY



COMPLIMENTARY RESULTS ON EXPERIMENT DERIVED CLASSIFICATION



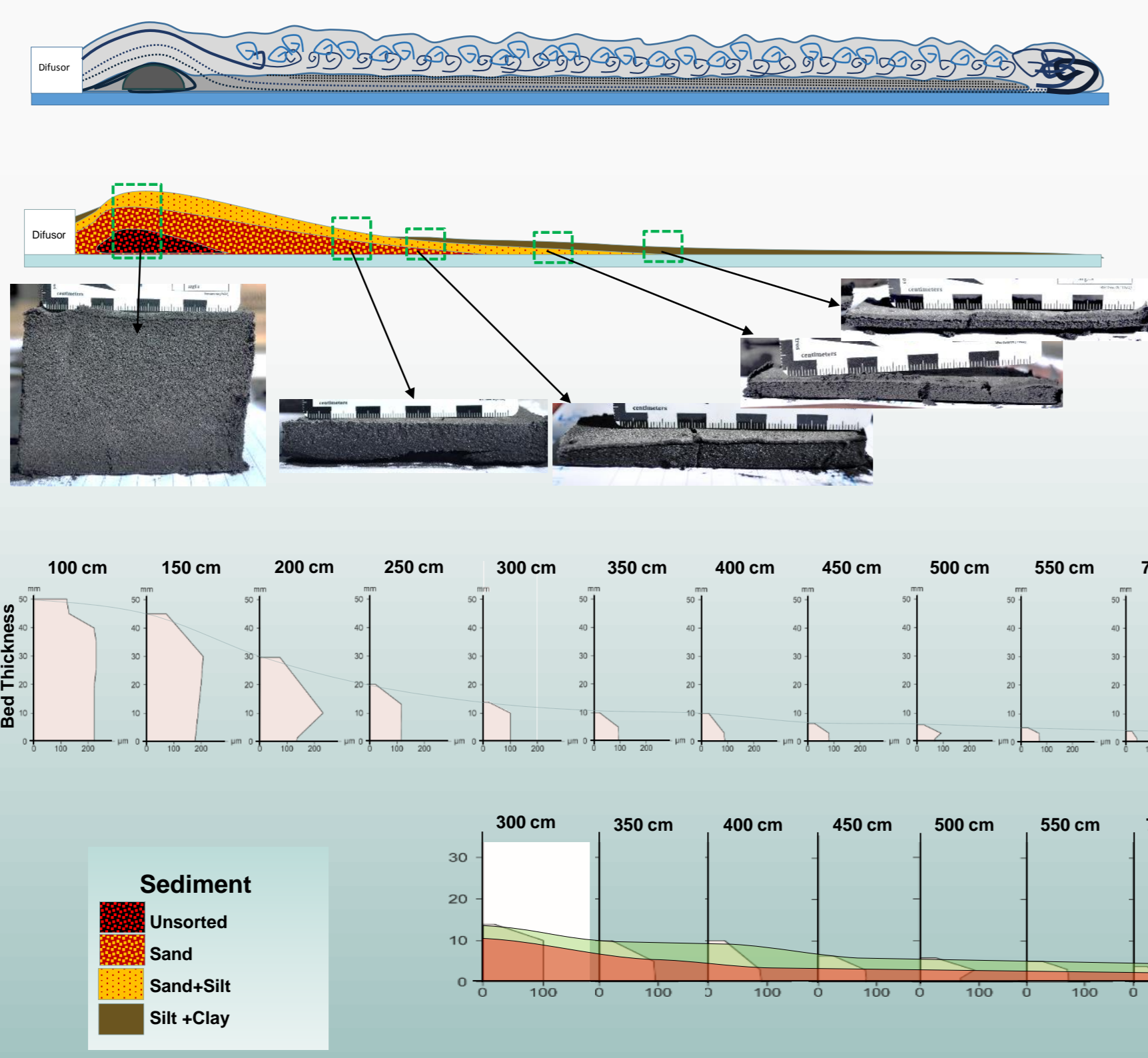
Experiments increases the understanding on High-Density currents like flow (with a little clay on it < 12%) is governed by other sediment support mechanism than Turbulence (hindered settling). Yet, Rheology behavior of the mixtures confirmed as a key aspects on the flow-deposits model.

Classical low-density flows and debris flows behavior were also confirmed.

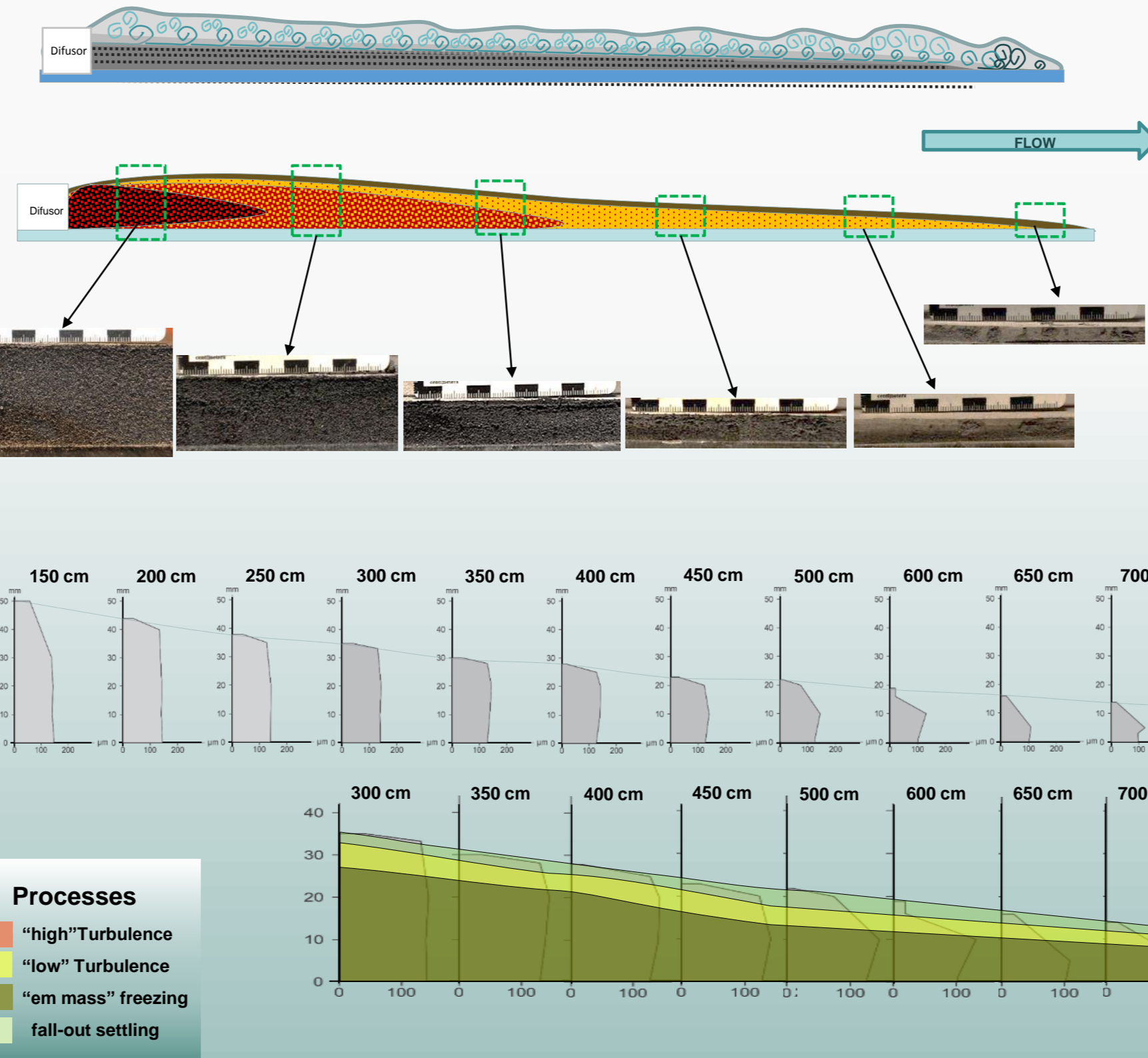
This Experimental-Derived classification aims no create other synonyms, but keep focus on the hydrodynamic and depositional processes based only.

PROCESS BASED MODEL FOR EACH GROUP

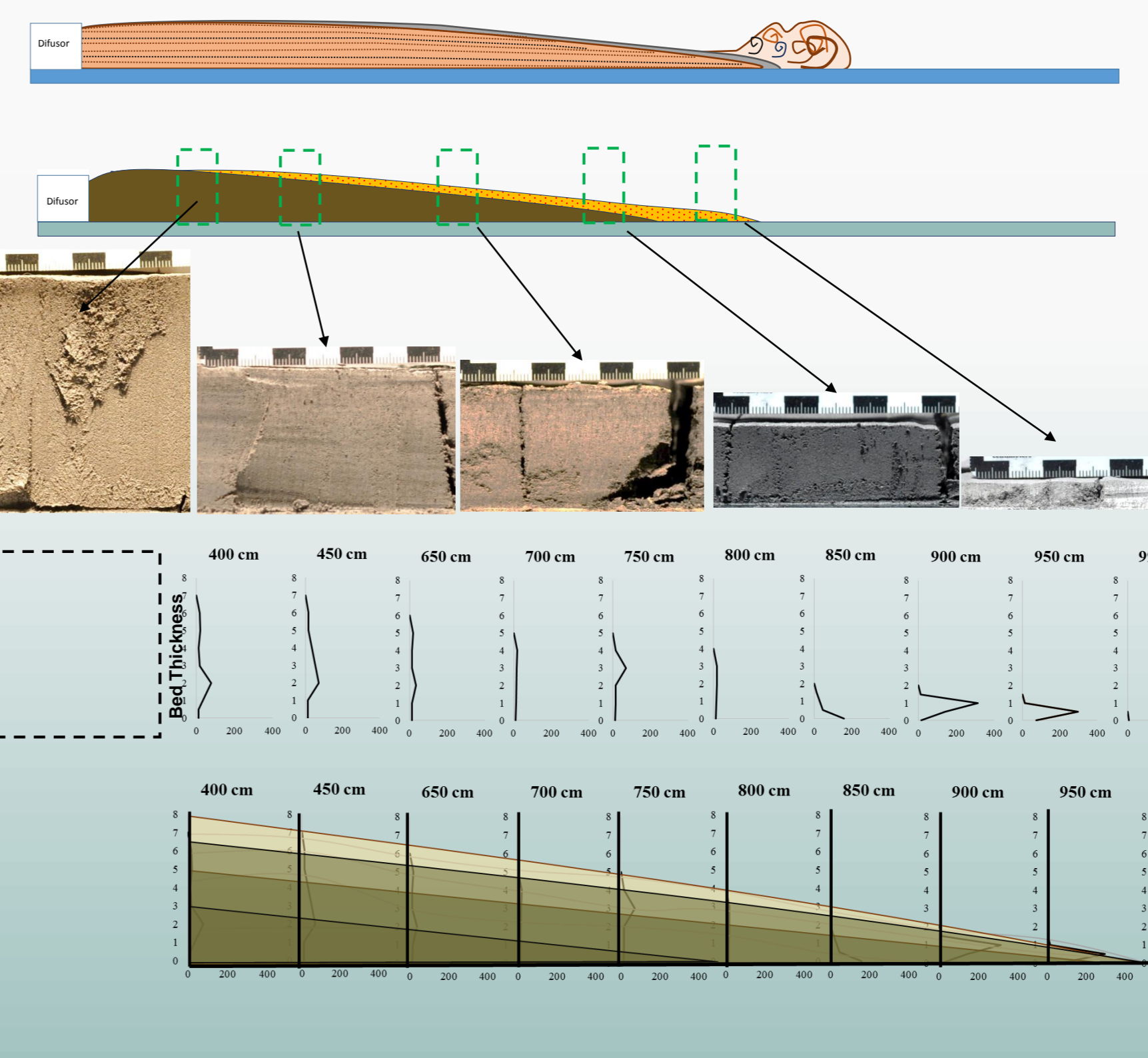
LOW-DENSITY CURRENTS LIKE FLOWS



HIGH-DENSITY CURRENTS LIKE FLOWS



DEBRIS FLOW



Newtonian Low-Density Currents like flow develops high velocity however low efficiency (non homogeneity). Normal gradation deposits Turbulence controls the flow for Newtonian Flows then Yield Strength (Rheology) takes over.

Non-Newtonian High-Density Currents like flow develops low velocities however a high-efficiency (homogeneity) Massive (and/or inverse gradation ) followed by normal gradation Hindered settling seems to rule the depositional process (frictional freezing)

Non Newtonian Debris flow develops low velocities with high efficiency at proximal areas (non travel so far) with homogeneity Massive deposits and coarse tail grading Plug Flow Cohesive strength rules the flow with a top turbulent head