Laboratory measurements of sand/mud sediment erodability in the Longefan EDF retention basin

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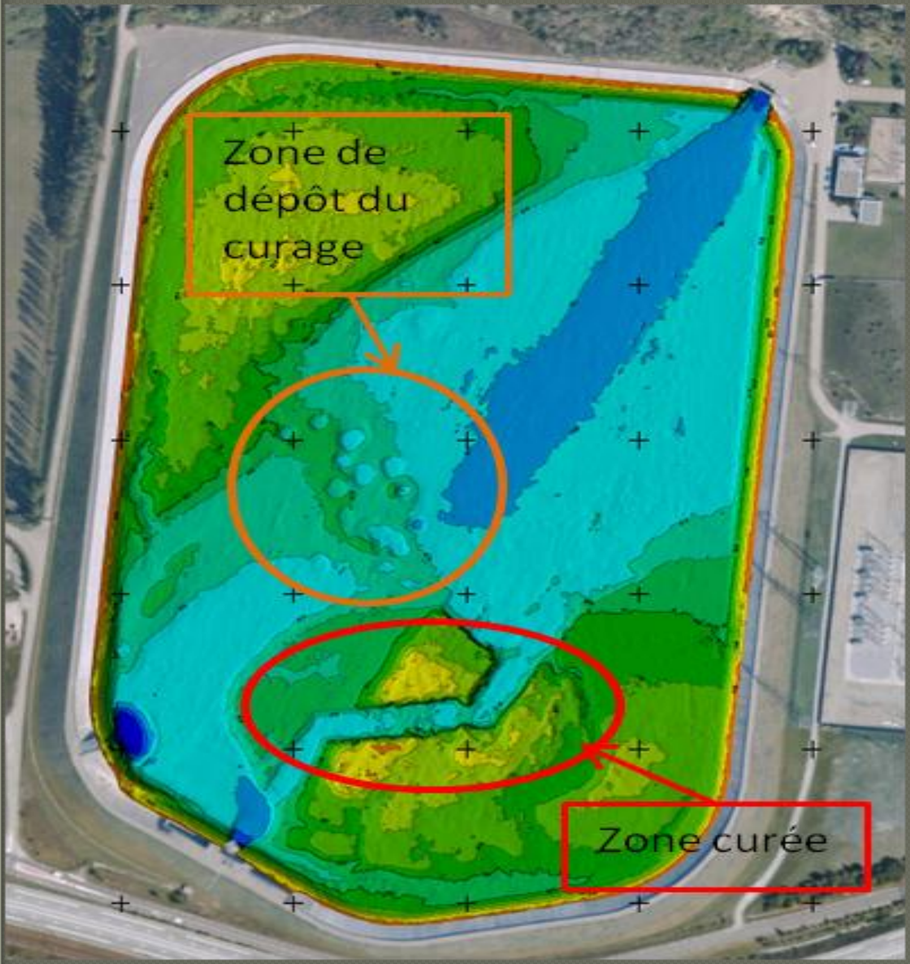
Objectives

- Measurements of sediment erodability provide an appropriate prerequisite to better evaluate the response of sediments beds to variations in bed hydraulics.
- In an attempt to improve erosion management and reduce the sediment load in a retention basin of an EDF ("Electricité De France") hydraulic dam, sediment samples were collected in this basin
- The objectives were to :
  - Determine erosion rates ($g/m^2/s$) and critical threshold for e rosion(Pa)
  - supply parameters in the hydrosedimentary model for better optimizing the bed transport management.
  - To Test different sediment preparation (consolidation status) for exploring scenarios that could increase ERODABILITY (to improve sediment management ?)

M & Ms:

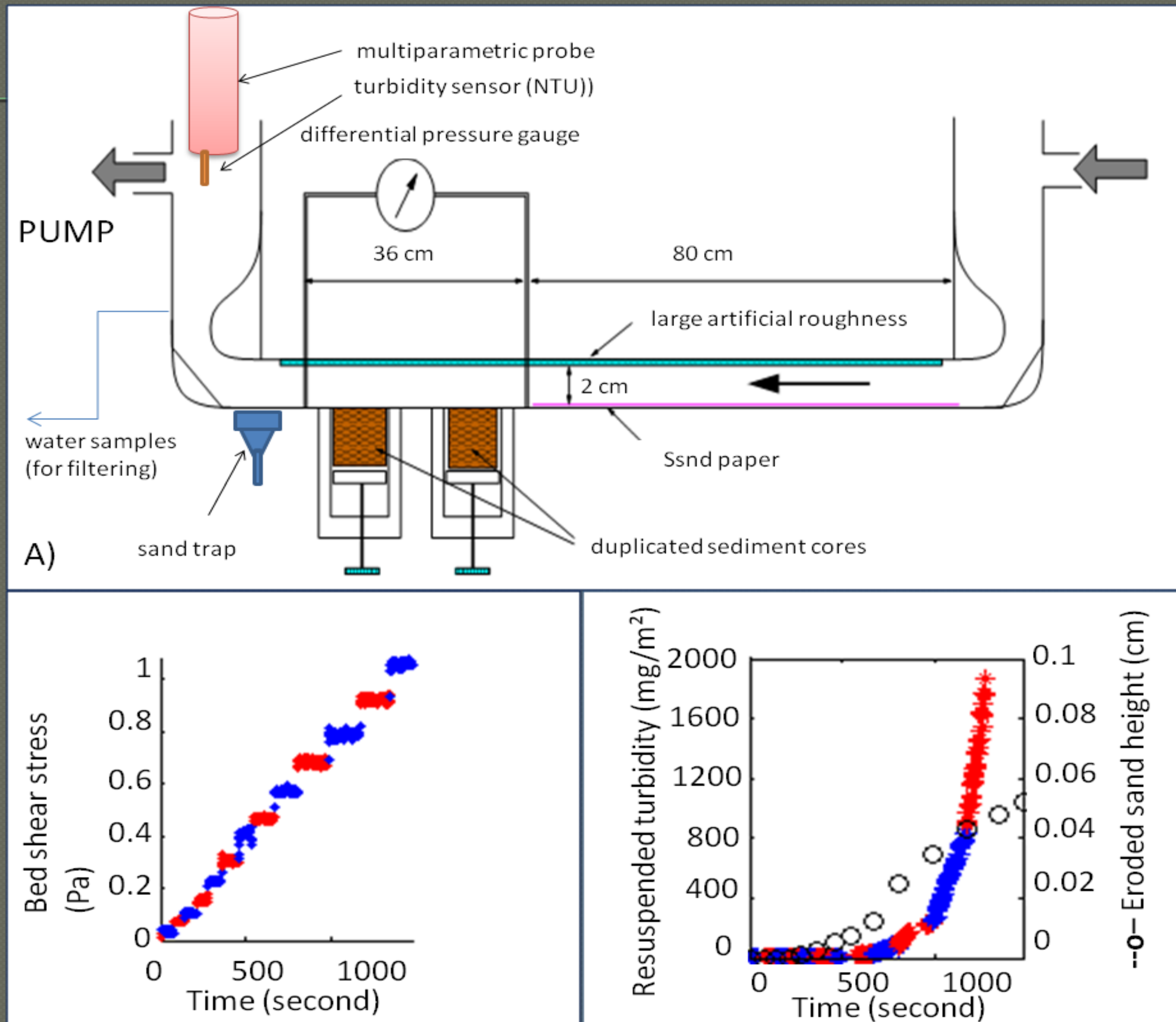
Longefan Basin (on the Arc River)



M & Ms:

ERODIMETRE DESCRIPTION

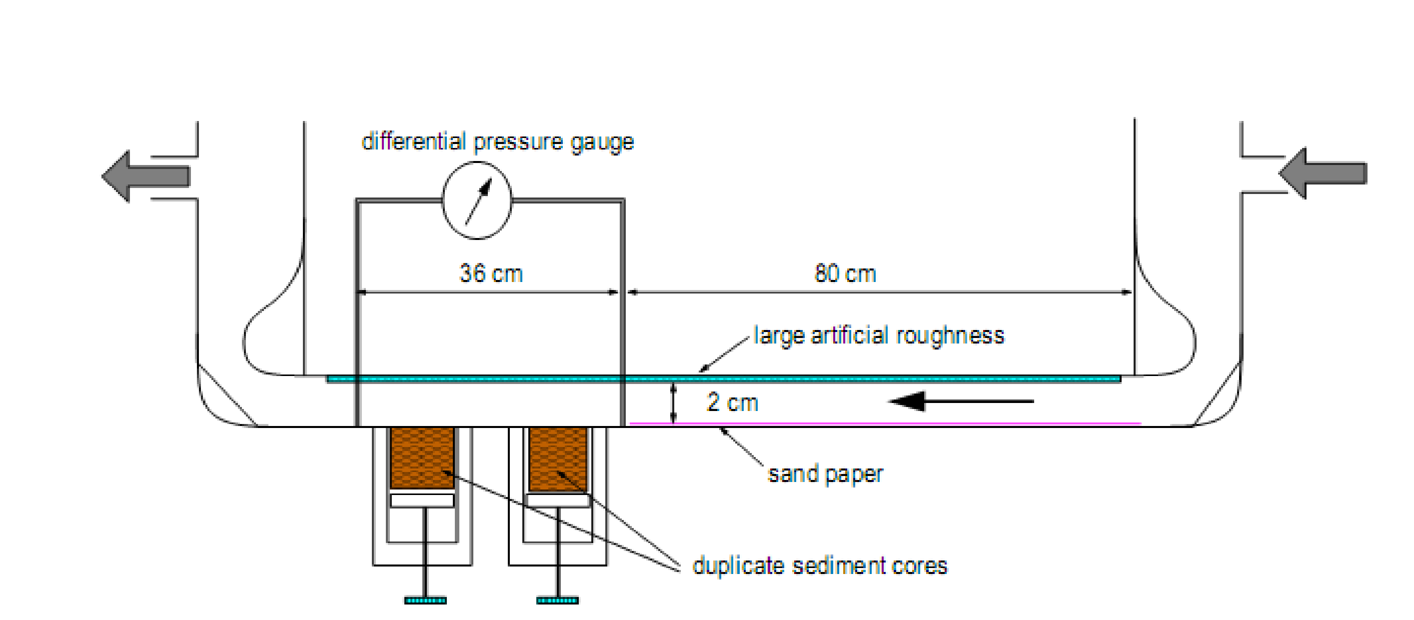
Erodimetre measurement

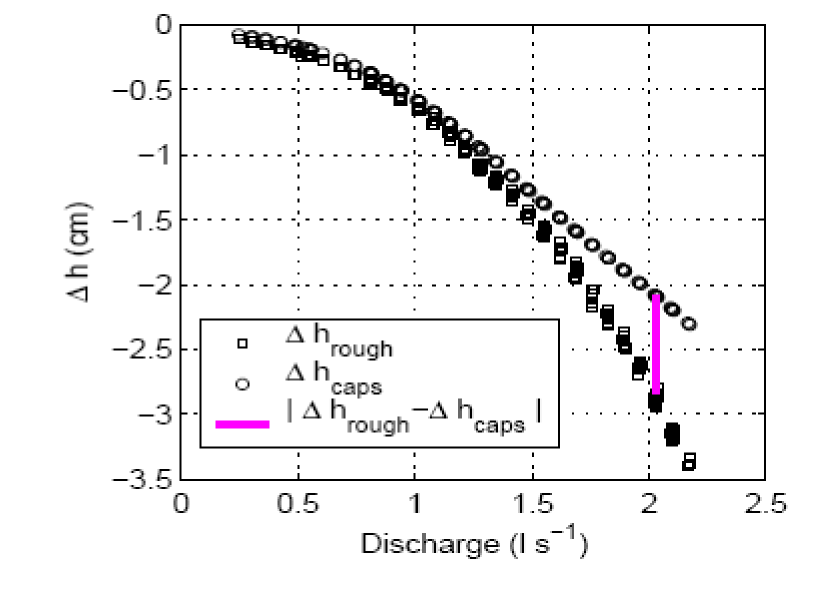


Orvain et al. (2007) and Le Hir et al. (2008).

M & Ms:

Erodimetre tests

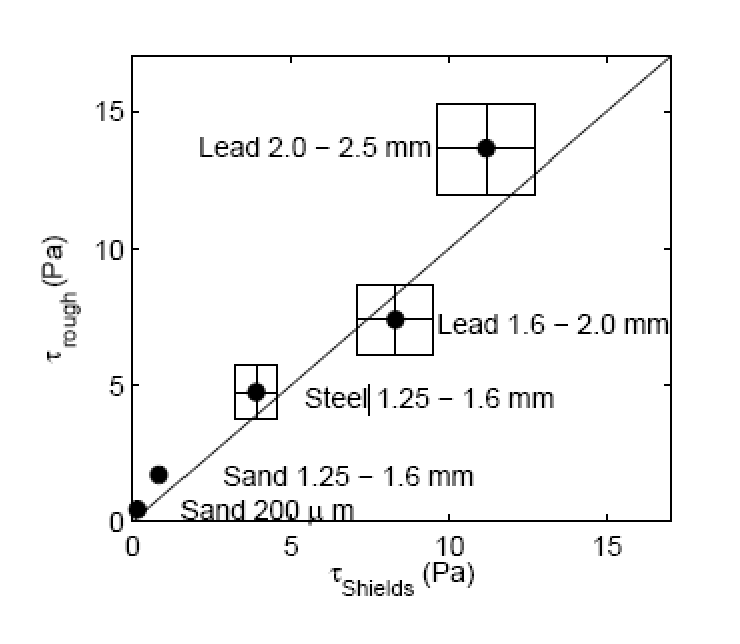


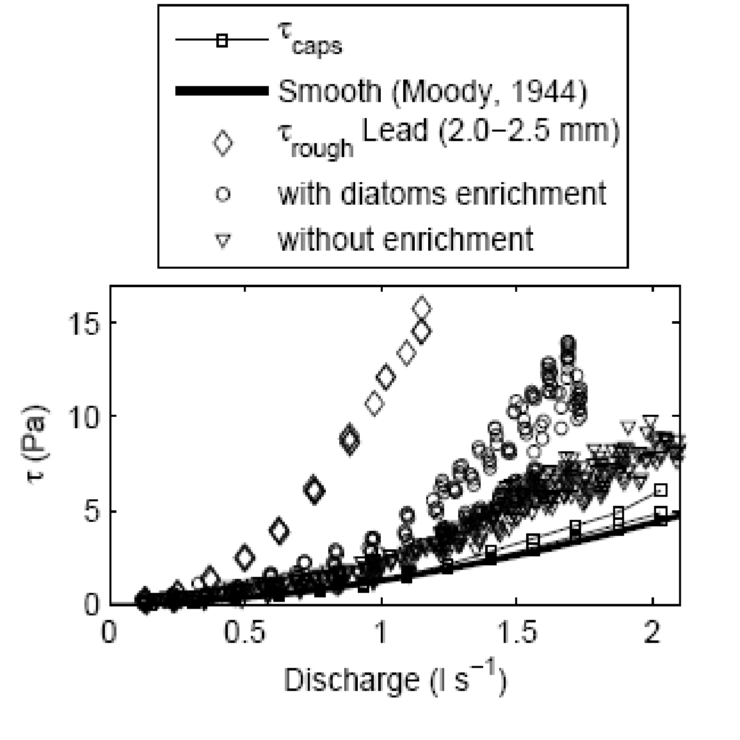


Head loss for increasing flow discharge with plexiglass caps (circle) and with sediment cores (square): excess of bed shear stress due to mud roughness for a given discharge is proportional to the distance between the two curves as displayed by the thick vertical line.

M & Ms:

Guizien K, Orvain F, Le Hir P, Duchêne JC (J. Hydraul. eng.): Bed shear stress derived from head loss measurements (rough) (filled circle) versus bed shear stress for incipient motion according to Shields criteria of five calibrated particles





Bed shear stress versus pump discharge in the mesocosm experiments. Bed shear stress measured in three different experiments with plexiglass caps (open squares), in the experiment with a plane bed formed by 2.25 mm calibrated particles (open diamonds), and the smooth bed reference (thick line, using Moody (1944)

Sediment treatment

Different consolidation durations (1h, 2 weeks, 3 weeks) and sediment depth (0, 5, 10 and 15 cm) were tested by extracting sediment cores that were inserted in the erosion device to explore the potential sources of variations caused by consolidation.

We also tested the potential effect of differing emersion/immersion treatments to explore if such a procedure could reinforce or diminish the sediment resistance to erosion.

The idea was to test whether any pretreatment could facilitate sediment management by increasing the bed erodability to avoid sediment dredging and electricity production impairments.

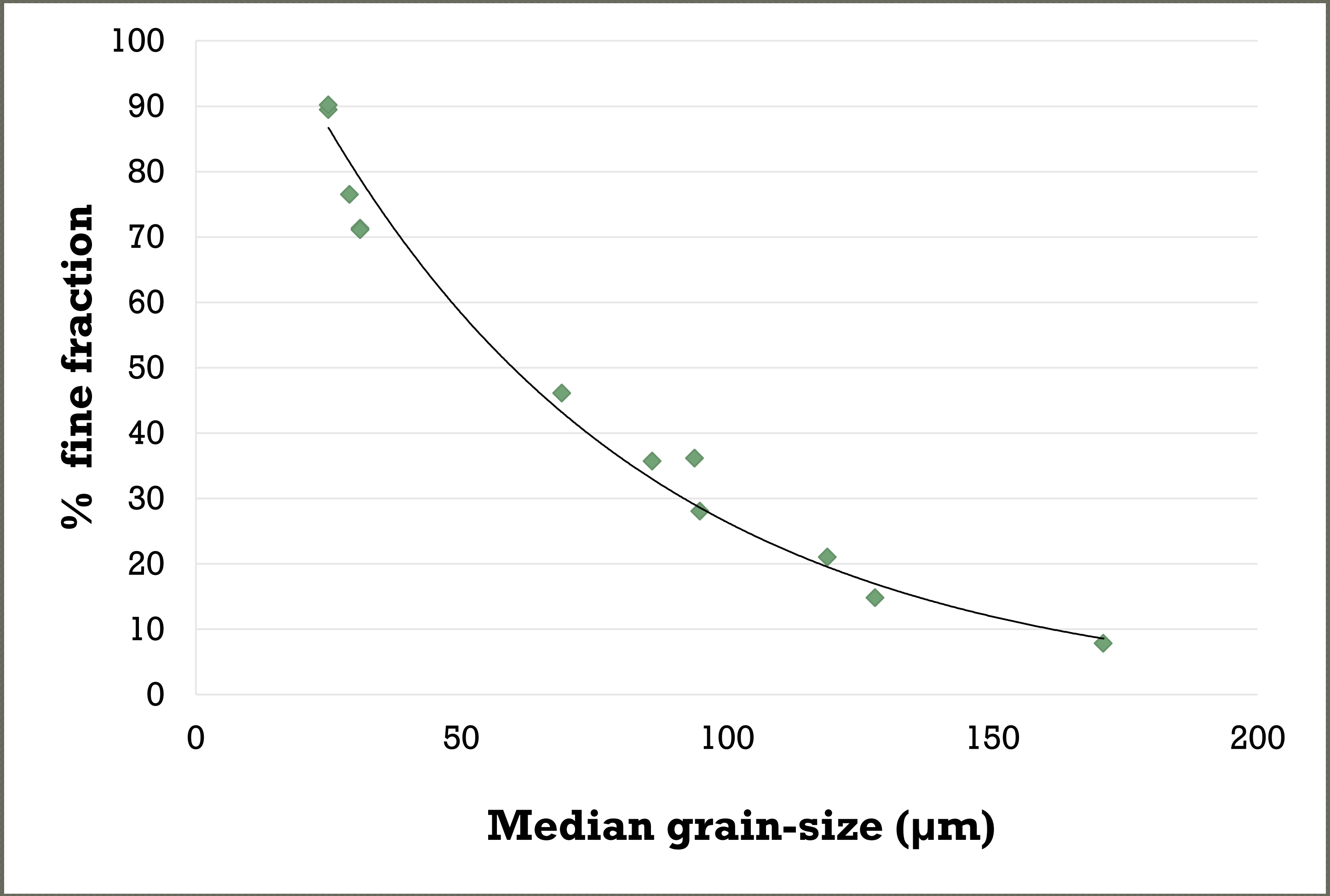
Results:

Sediment preparation

Sample	Consolidation duration (weeks)	Site	Depth	Emersion Condition	Grain-size		Water content (% of total weight)
					Median diameter (µm)	Fine fraction (< 63 µm) %	
A1	3	L	0	E/I	25	89,46	45,91
A2	3	L	5	E/I	42	76,50	73,00
A3	3	L	10	E/I	86	35,69	38,43
B1	3	R	0	E	29	76,5	44,26
B2	3	R	5	E	31	71,3	32,18
B3	3	R	10	E	31	71,09	38,92
C1	2	L	0	I	25	90,16	41,97
C2	2	L	5	I	95	28,03	24,77
C3	2	L	10	I	171	7,82	23,95
C4	2	L	15	I	69	46,12	32,65
C5	2	L	20	I	128	14,83	25,27
C6	2	L	25	I	119	21,03	24,05
D	0	Mixed	0	I	94	36,16	-

M& Ms:

grain-size distribution

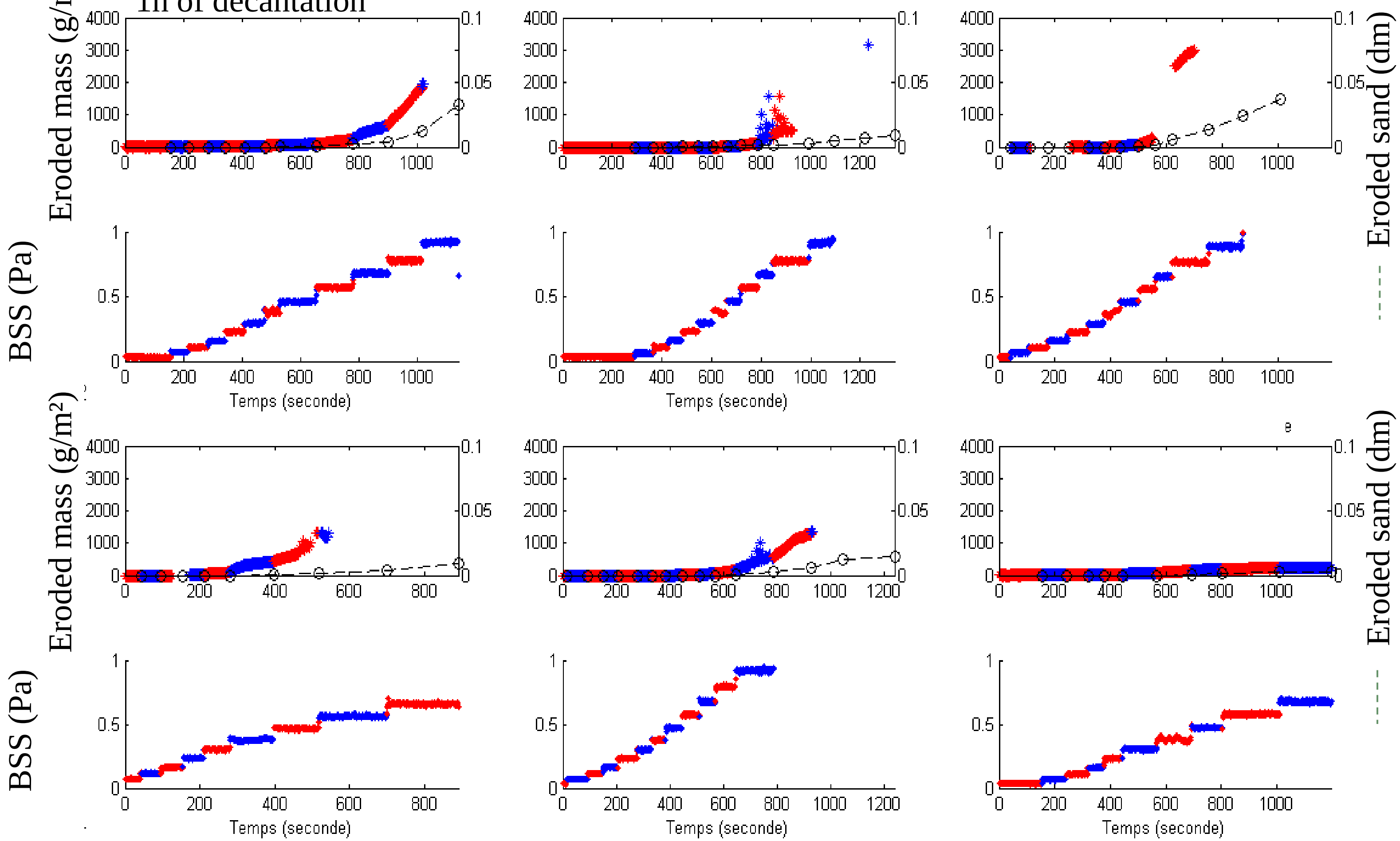


Erosion results

D : mixed sediment; surface
1h of decantation

A1: Left site; surface
Cyclic immersion (12/12);3 wks

A3: Left site; 10 cm in depth
Cyclic immersion (12/12); 3 wks

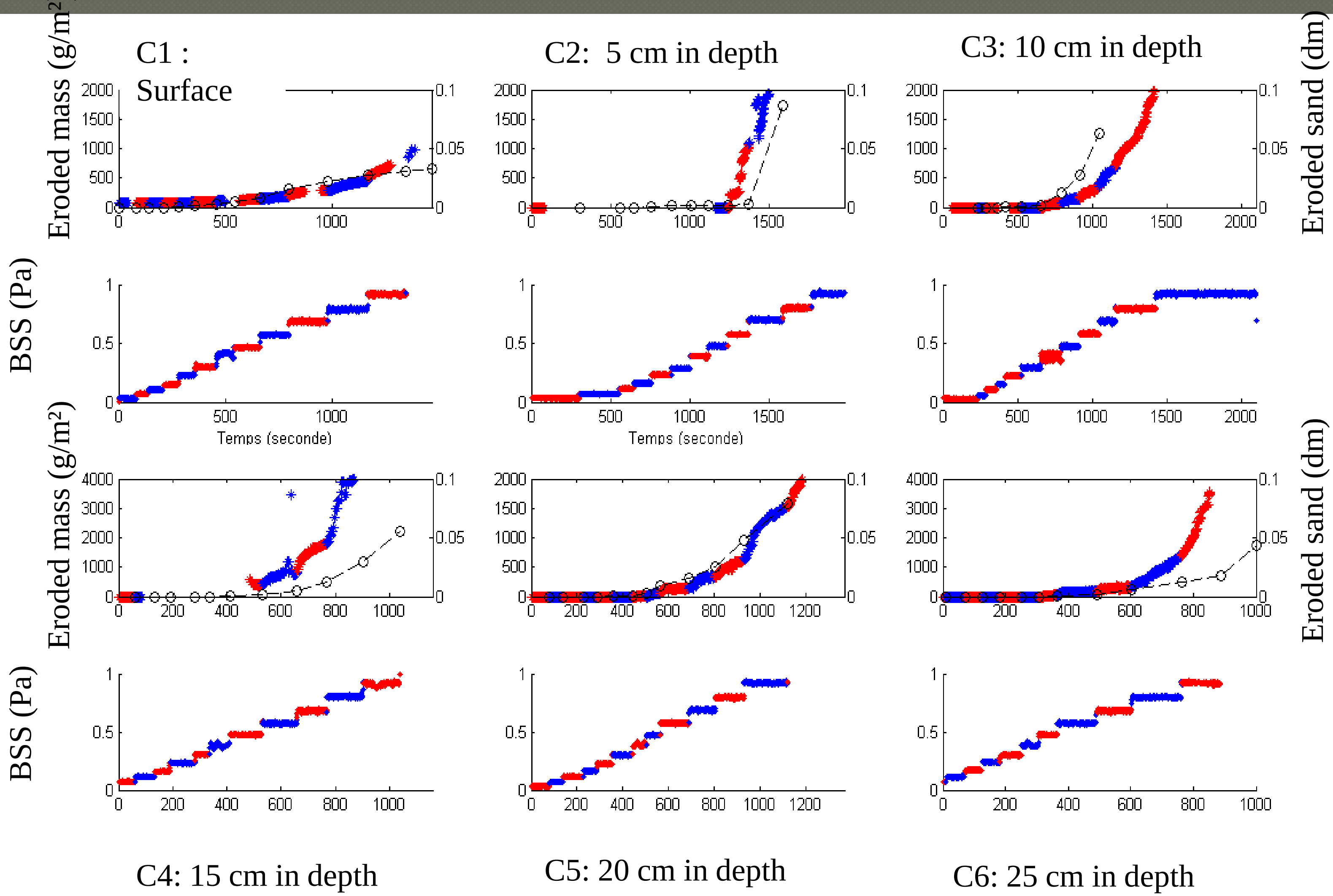


B1 : Right station; surface
Constant air exposure
3 wks of consolidation

B2 : Right station; 5 cm in depth
Constant air exposure
3 wks of consolidation

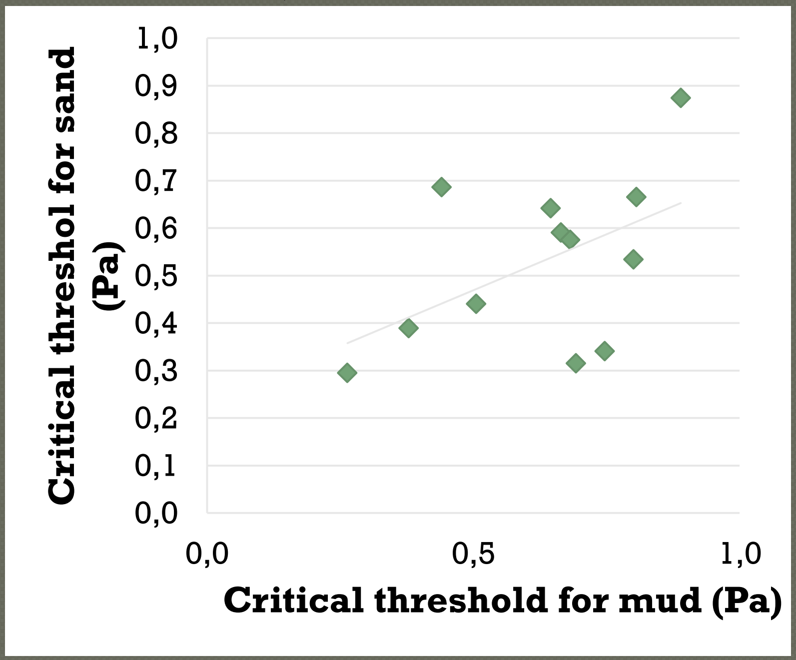
B3: Right station; 10 cm in depth
Constant air exposure
3 wks of consolidation

Erosion results

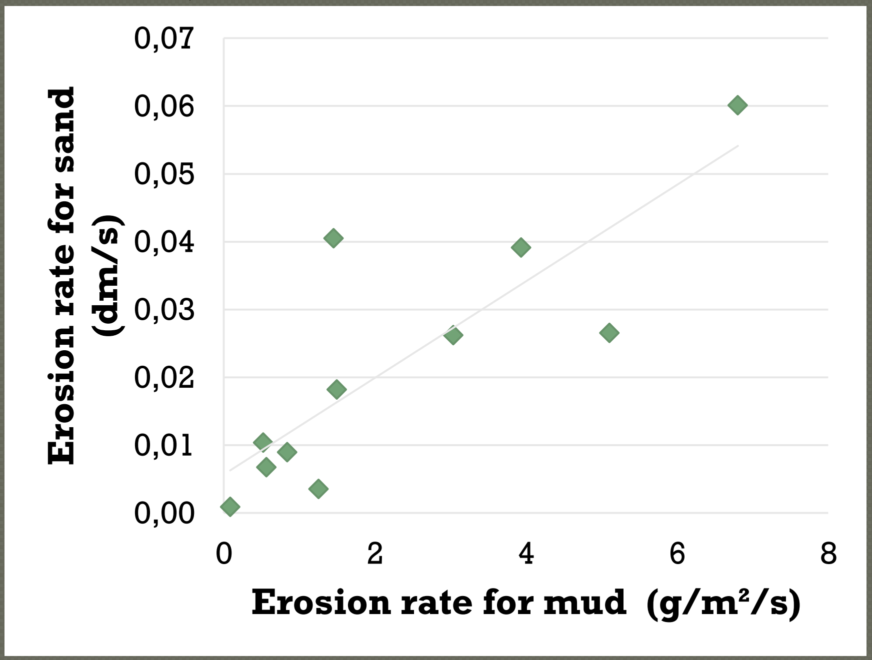


Erosion of fine and broad fractions

A)

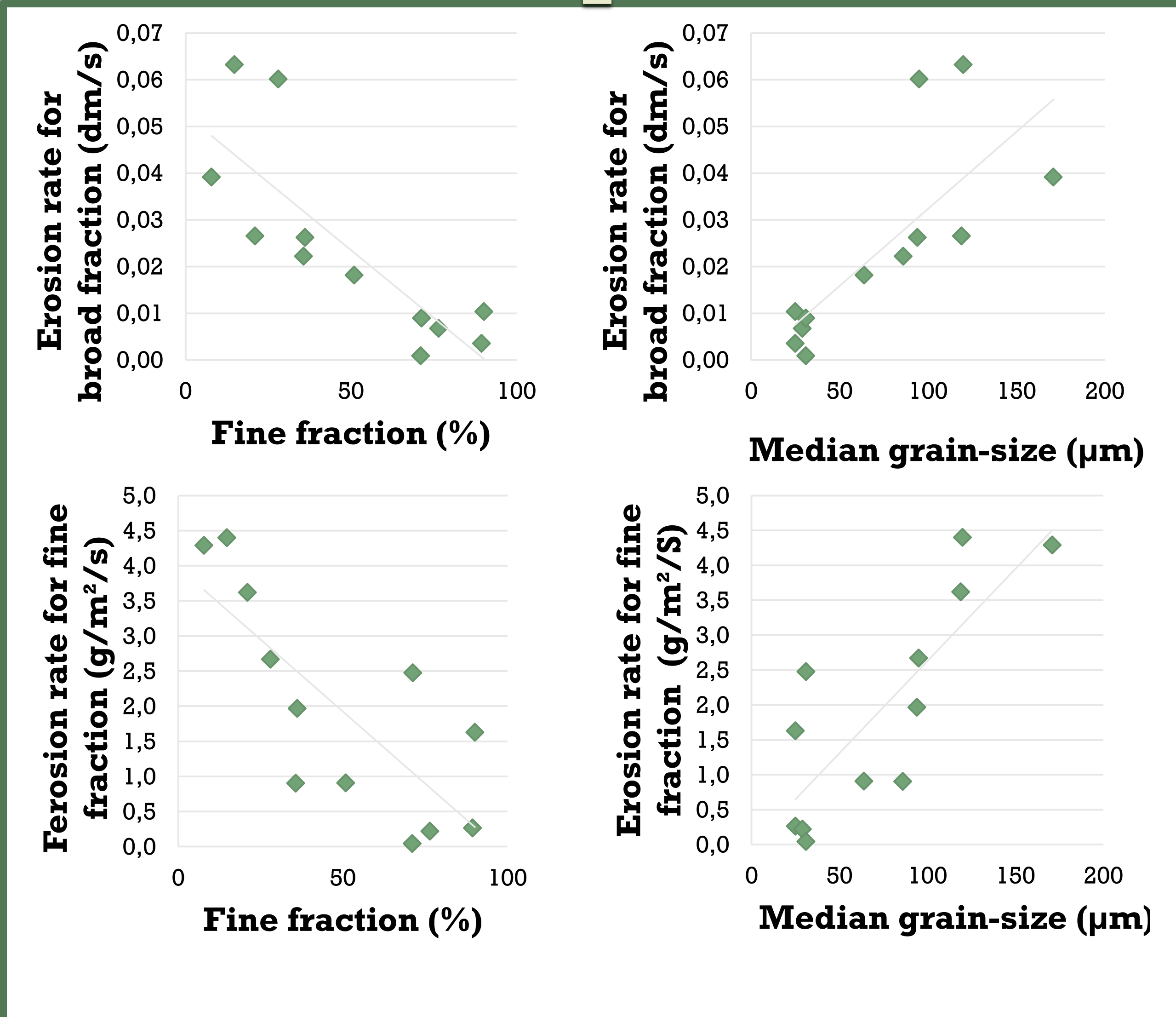


B)



Significant relationship between: A) the critical thresholds for erosion of fine and broad sediment fractions ($Y = 0.4711X + 0.2338$; $R^2 = 0.25$) and B) the erosion rates of the 2 same fractions ($y = 0{,}0071x + 0{,}0056 R^2 = 0{,}6892$).

Erodability versus sedimentary parameters



the response of bed resistance to the relative enrichment in mud that could reinforce the cohesiveness of the sediment.

The erosion behavior of the sediment is explained by the cohesive properties, mostly related to the mud proportion in the bulk mixture (>0.3).

Erodability

Sample	Consolidation duration (weeks)	Site	Depth	Emersion Condition	Critical threshold (BSS) (Pa)		Erosion rate		Grain-size	
					Sand	Silt	Sand (dm/s)	Silt (g/m²/s)	Median diameter (µm)	Fine fraction (< 63 µm) %
A1	3	L	0	E/I	0,64	0,65	0,0035	1,254	25	89,46
A2	3	L	5	E/I	-	-	-	-	42	76,50
A3	3	L	10	E/I	0,69	0,44	0,0405	1,453	86	35,69
B1	3	R	0	E	0,39	0,38	0,0067	0,563	29	76,5
B2	3	R	5	E	0,87	0,89	0,0089	0,839	31	71,3
B3	3	R	10	E	-	-	-	-	31	71,09
C1	2	L	0	I	0,34	0,75	0,0103	0,522	25	90,16
C2	2	L	5	I	0,44	0,51	0,0601	6,802	95	28,03
C3	2	L	10	I	0,32	0,69	0,0391	3,933	171	7,82
C4	2	L	15	I	0,57	0,68	0,0182	1,496	69	46,12
C5	2	L	20	I	0,53	0,80	0,0632	1,676	128	14,83
C6	2	L	25	I	0,66	0,81	0,0265	5,103	119	21,03

The erosion behavior of the sediment is explained by the cohesive properties, mostly related to the mud proportion in the bulk mixture.

Erosion model tested:
The sediment module was a multilayer model where the sediment bed was divided into several layers with varying thick ness

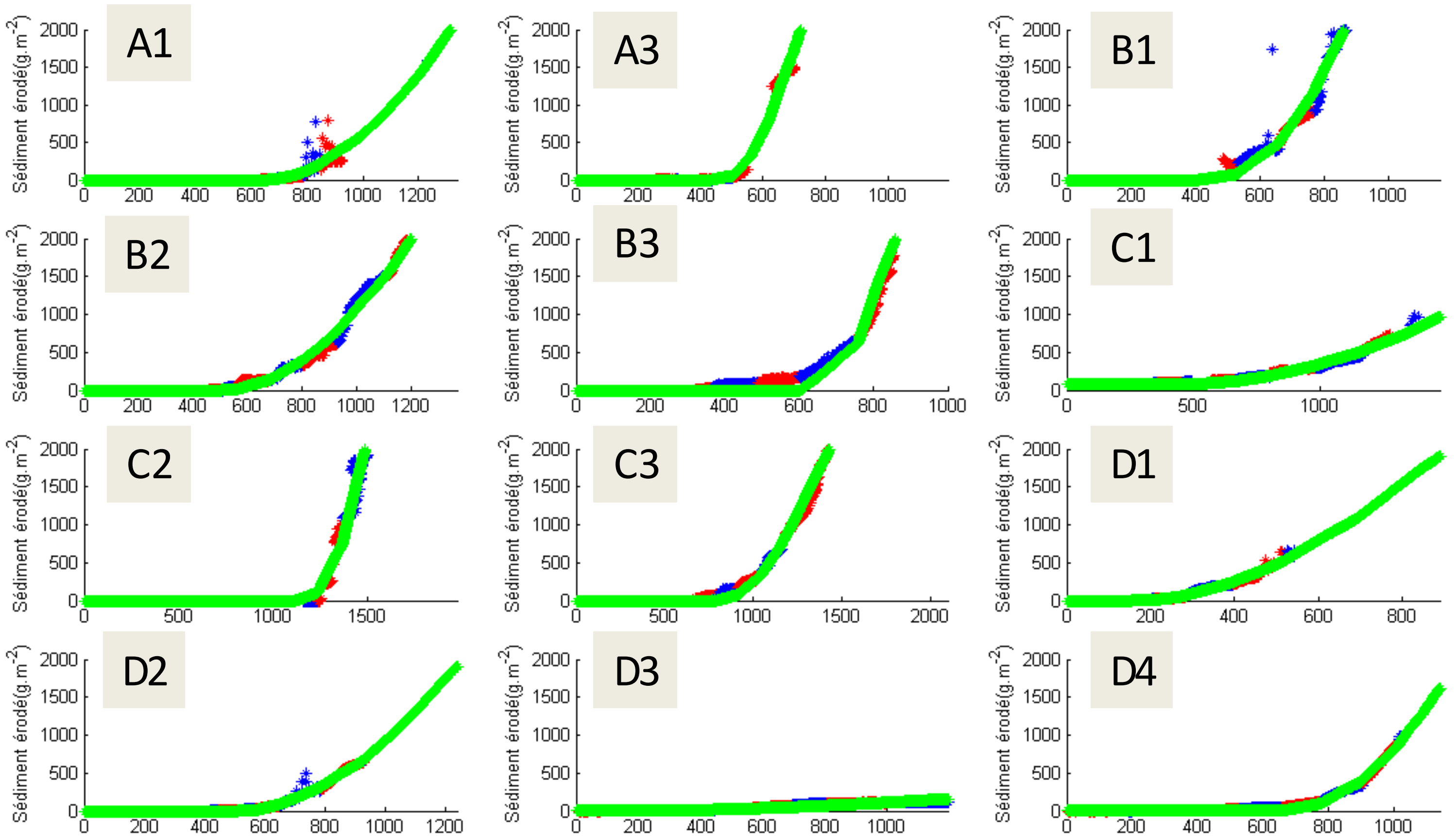
Mehta formulation (1982)

$$Q_E = E_0 \times \left(\frac{\tau_f}{\tau_{CRIT}} - 1 \right)$$

when $\sigma_f > \sigma_{CRIT}$; $Q_E=0$ when $\sigma_f < \sigma_{CRIT}$

Krone formulation (deposition)

$$Q_D = w_s . SPM$$



Parameterization tests of the classical Partheniades erosion law in a sediment budget model provided accurate values of 0.53 Pa for critical threshold and 2.31 g/m²/s for the averaged erosion rate.

Conclusion

•sand and mud from the bulk mixture were eroded together
•The mud enrichment decreases erosion rates

•Observation confirmed that a proportion of silt content > to 0.3 induce a cohesive behavior of sand/mud mixtures. Critical threshold were most of the time weak and did not show a dependence upon depend the sediment features. Settling time did not affect sediment erodability, likely because of a very fast consolidation that could reach an equilibrium point in a few hours.

• Erosion laws (Mehta) were directly parameterised and applied in the sediment transport model (artelia)
• The mud proportion can explain the differences of sediment erodability
• No sediment treatment was found to induce a decrease of bed erodabilily (emersion, Emersion/immersion alternance)
•Difficulties for relating sediment consolidation to erodability (paraller cores)

Thank you for your attention

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