

processus d'érosion des sédiments cohésifs

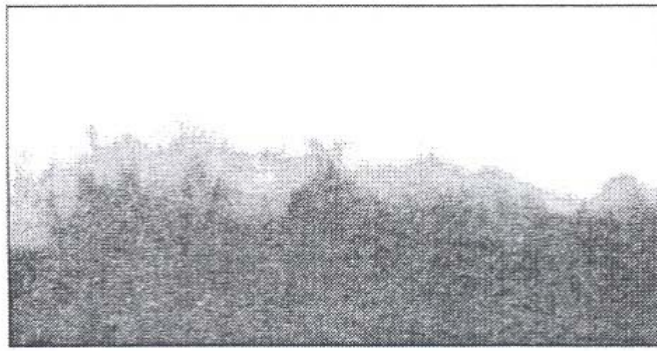


Fig. 9.1a: Entrainment of a dense mud layer by turbulent water flow (entrainment = "one-way" mixing).

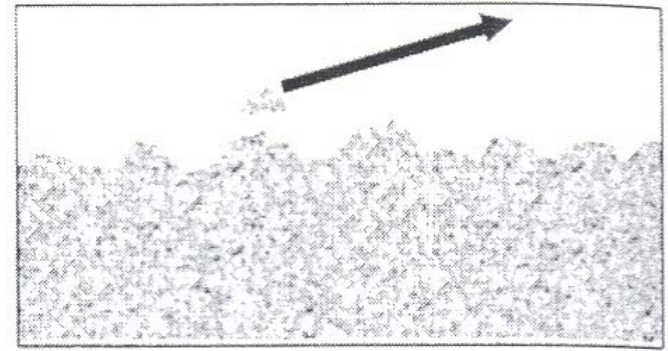


Fig. 9.1b: Floc erosion = disruption and break-up of individual flocs or part of flocs from the bed surface.

*Winterwerp &
Kesteren, 2004*

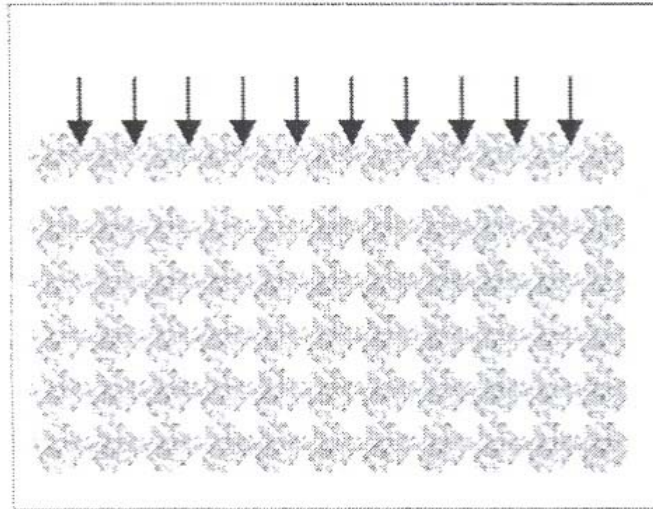


Fig. 9.1c: Surface erosion = drained process: eroding sediment particles are replaced by water.

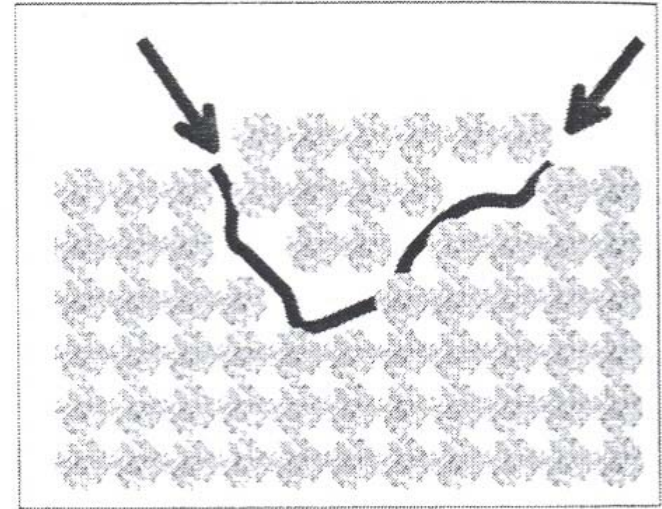


Fig. 9.1d: Mass erosion = undrained process: local failure within the bed (crack formation).

érosion des sédiments fins

- vase fraîchement déposée, crème de vase : entraînement

$$E = V_e \cdot C_{\text{vase}}, = f(Ri), \text{ pas de seuil d'érosion}$$

$$Ri = g \cdot (\rho_{\text{vase}} - \rho_{\text{eau}}) / \rho_{\text{eau}} \cdot ep / \Delta u^2$$

$$V_e : \text{vitesse d'entraînement} = 0.1 \Delta u / (1 + 63 Ri^2)^{0.75}$$

- vase en cours de consolidation :

$$E = E_0 \exp [\alpha (\tau - \tau_e)^{1/2}] \text{ Mehta., Sanford \& Maa, } \tau_e \sim 0.1 \text{ to } 1 \text{ Pa ?}$$

- vase consolidée : *loi de Partheniades* :

$$E = E_0 (\tau - \tau_e) / \tau_e, \quad E_0 \sim 0.01 \text{ to } 1 \text{ g.m}^{-2}.\text{s}^{-1} \quad \tau_e \sim 1 \text{ to } 10 \text{ Pa ?}$$

- sables fins : *Shields* :

D :	100μ	1mm	1 cm
τ _e :	0.1 Pa	0.4 Pa	7 Pa

Érodabilité

dépend de l'état de consolidation du sédiment

$$u_{*e} = a \rho_{sol}^b$$

(ρ_{sol} , en kg.m^{-3})

Mitchener & Torfs, 1996: $\tau_e = a (\rho_b - 1000)^b$

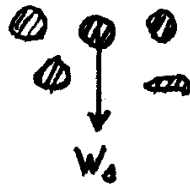
$a = 0.015$, $b = 0.73$

Consolidation / tassement

Sédimentation

équation de continuité

$$\frac{\partial C}{\partial t} + \frac{\partial C \cdot W_s}{\partial z} = 0$$



relation constitutive du sol

$W_s(C)$ "super-entravement"

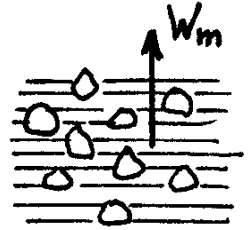
Kynch (1952)

$$\frac{\partial C}{\partial t} + W(C) \frac{\partial C}{\partial z} = 0$$

Consolidation

équation de continuité

$$\frac{\partial e}{\partial t} + \frac{\partial W_m}{\partial \xi} = 0 \quad \xi : \text{coordonnée matérielle}$$



équation dynamique

$$W_m = -ki = -\frac{1}{\rho} \frac{k}{1+e} \frac{\partial v}{\partial \xi} \quad v = \sigma - \sigma' - \rho g (\zeta - z)$$

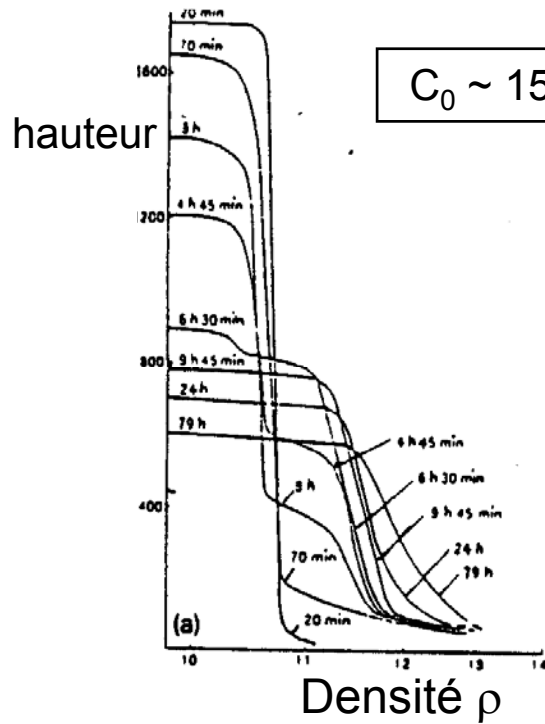
relations constitutives

$k(e)$ et $\sigma'(e)$

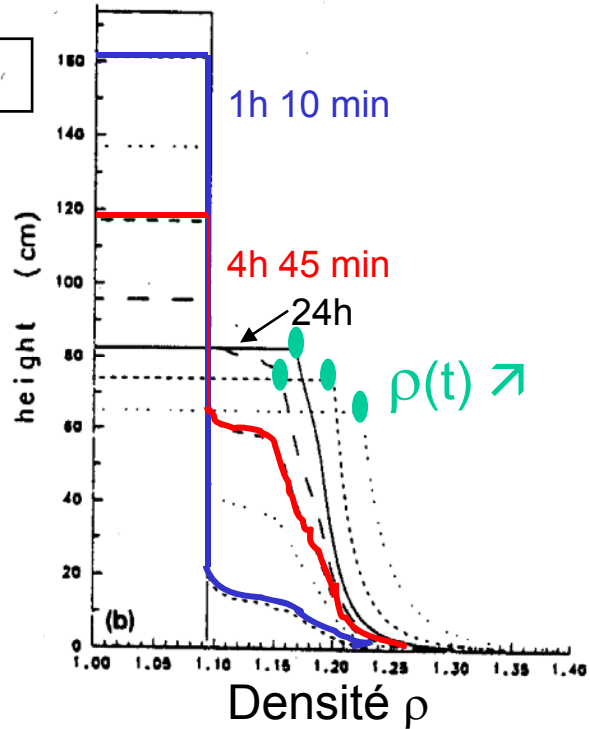
Gibson (1967):

$$\frac{\partial e}{\partial t} + \frac{\rho_s - \rho}{\rho} \frac{d}{de} \left(\frac{k}{1+e} \right) \frac{\partial e}{\partial \xi} + \frac{1}{\rho} \frac{\partial}{\partial z} \left[\frac{k}{1+e} \frac{d\sigma'}{de} \frac{\partial e}{\partial \xi} \right] = 0$$

Simulation du tassement



Expérience (Been & Sills, 1981)

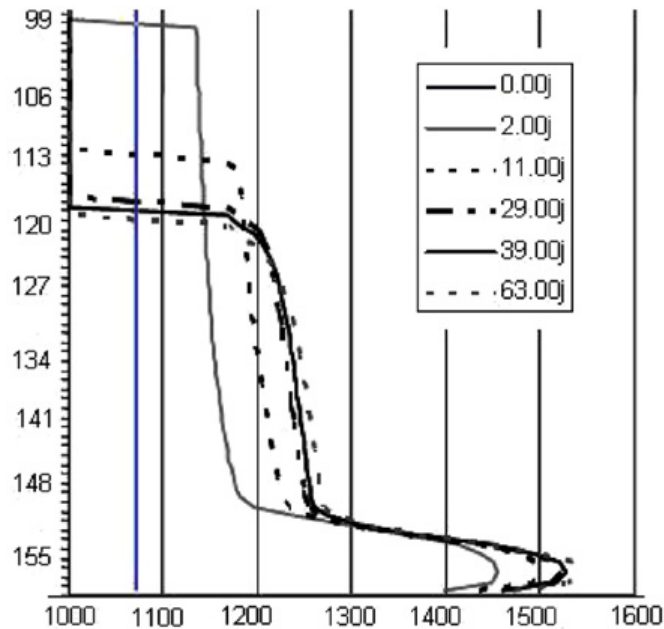


Calcul

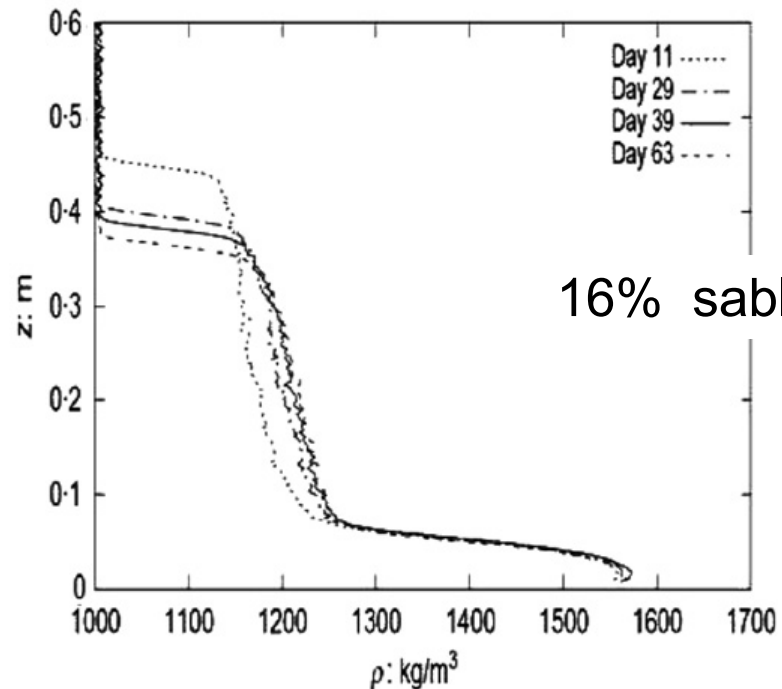
Consolidation d'un mélange sable et vase

$$\frac{\partial C_i}{\partial t} = \frac{\partial}{\partial z} \left[C_i \max \left(\frac{k}{\rho_w} \Delta(\text{load}), W_{S_{i,hindered}} \right) \right]$$

$$\text{with } \Delta(\text{load}) = \left(C \frac{\rho_s - \rho_w}{\rho_s} + \frac{1}{g} \frac{\partial \sigma'}{\partial z} \right)$$



Merckelbach & Kranenburg, 2004



Le Hir et al., 2011

Flux de dépôt

Loi de Krone, 1962 :

Probabilité de dépôt

$$Dép \text{ (en kg/m}^2 \text{ / s)} = W_f C \left(1 - \frac{u_*^2}{u_{*d}^2} \right) \text{ pour } u_* < u_{*d}$$

U^* : vitesse de frottement critique pour le dépôt, de l'ordre de 1 cm/s

Si tassement explicitement pris en compte : ***inutile***

Modélisation de la dynamique des sédiments fins

transport en **suspension**

$$\mathbf{u}_{\text{particules}} = \mathbf{u}_{\text{eau}}$$

→ équation d'advection/dispersion (*bilan de masse*)

$$\frac{\partial c}{\partial t} = - \frac{\partial c u_i}{\partial x_i} + \frac{\partial c W_s}{\partial z} + \frac{\partial}{\partial z} \left(K_z \frac{\partial c}{\partial z} \right) + E - D$$

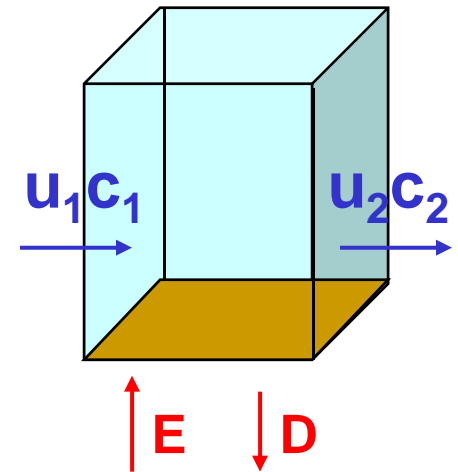
↑
évolution

↑
transport par
les courants

↑
chute

↑
Mélange
- moléculaire
- turbulent

↑
érosion
↓
dépôt



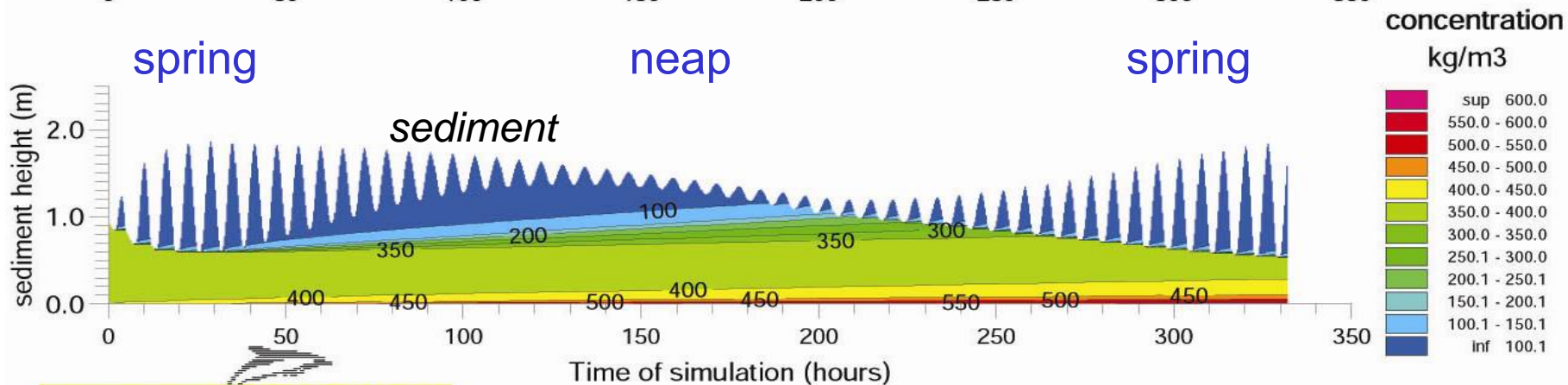
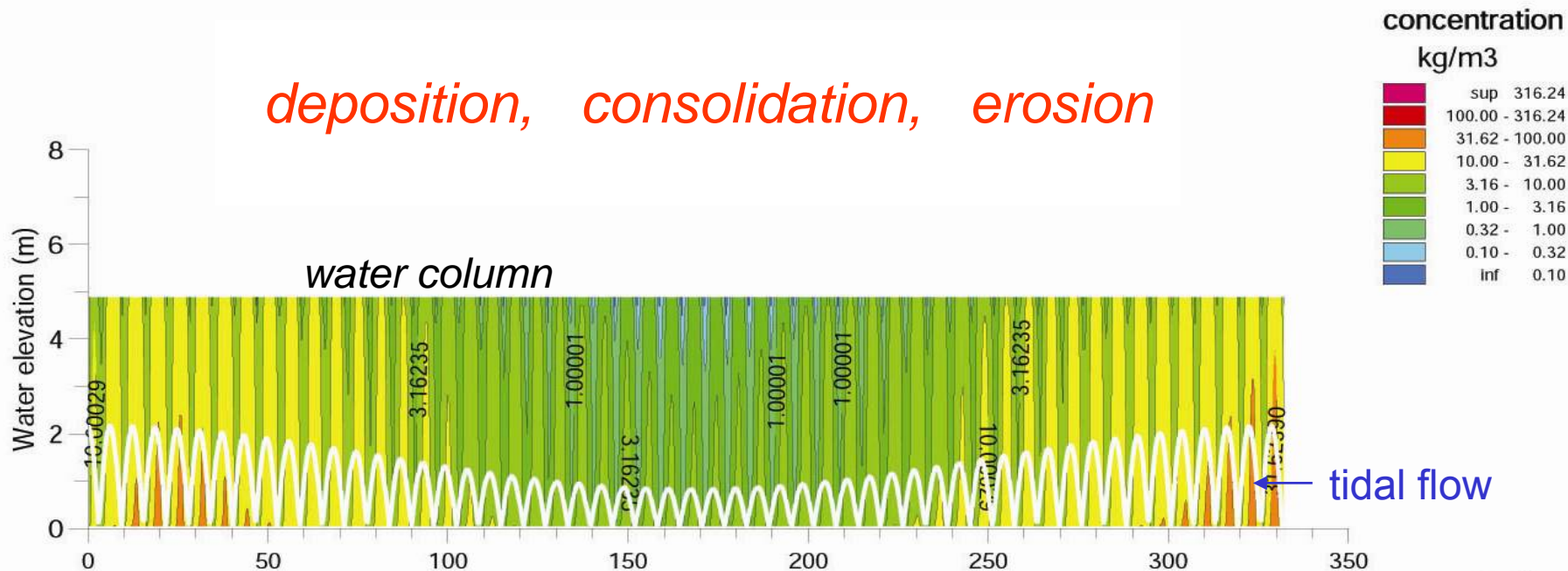
« cohésion » →

floculation

consolidation

Simulating a tidal cycle (15 days) with a 1DV model

deposition, consolidation, erosion



Concept de modélisation continue eau/sédiment - 1DV

bilan de masse

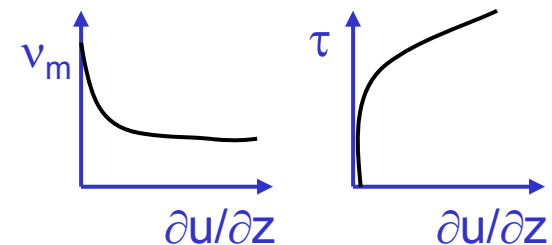
$$\frac{\partial c}{\partial t} = \frac{\partial c W_s}{\partial z} + \frac{\partial}{\partial z} \left(K_z \frac{\partial c}{\partial z} \right)$$

W_s : floculation / chute entravée / consolidation
 K_z : mélange turbulent
 effet des stratifications

équilibre dynamique

$$\frac{\partial u_i}{\partial t} = -\frac{1}{\rho} \frac{\partial P}{\partial x_i} + \frac{\partial}{\partial z} \left(-\overline{u_i' w'} + T_{iz} \right)$$

fermeture turbulente → $v_t \frac{\partial u_i}{\partial z}$
 amortissement par stratifications → $v_m \frac{\partial u_i}{\partial z}$
 rhéologie → $v_m = \alpha C^\beta f(du/dz)$



→ E, D : flux « diffusifs » et flux de chute, calculés $\forall z$