

Základy petrologie sedimentárních hornin

1.roč., LS 2021

1) úvod, hydrodynamika,
transport, sedimentární struktury

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ÚGP

(Ústav geologie a paleontologie)

syllabus kurzu

1. Úvod

- procesy transportu a sedimentace, sedimentární struktury
- mechanika kapalin
- transport sedimentu
- sedimentární struktury
- gravitační procesy a sedimenty

2. Siliciklastika

- klasifikace
- mikrostruktury
- sedimentační prostředí
- provenience
- diagenese

Požadavky ke zkoušce:

test – znalostní kviz
výborně 85-100%
velmi dobře 70-84%
dobře 55-69%

3. Karbonáty

- mineralogie
- komponenty
- struktury
- sedimentační prostředí
- diagenese

k zápočtu:
poznávačka hornin (alespoň 70%)

4. Evapority, silicity, ferolity, fosfáty, kaustobiolity

Petrologie sedimentárních hornin

- řec. „**petra**“ – skála, kámen; „**logos**“ – slovo, vhled, porozumění, nauka
- eroze – transport – sedimentace
- *základní výzkum* – identifikace sedim.hornin, porozumění procesům vzniku těchto hornin
- *vztahy k ostatním oborům* – sedimentologie, pánevní analýza, paleoklimatologie, stratigrafie; geochemie, geofyzika, petrofyzika
- *aplikovaný výzkum* – porozita - rezervoárová geologie (voda, ropa, plyn, úložiště CO₂, ...); permeabilita – hydrogeologie; geomechanické vlastnosti – inženýrská geologie,

studium sedimentárních procesů v laboratoři



procesy &
produkty
(nezpevněný
sediment)

studium recentních sedimentárních systémů



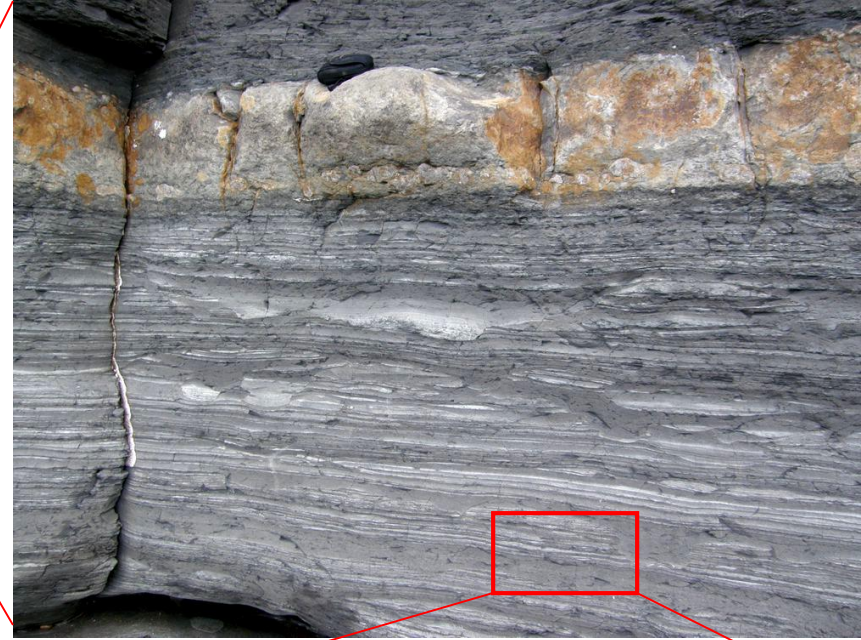
Esequibo River, Guyana

procesy & produkty (nezpevněný sediment)

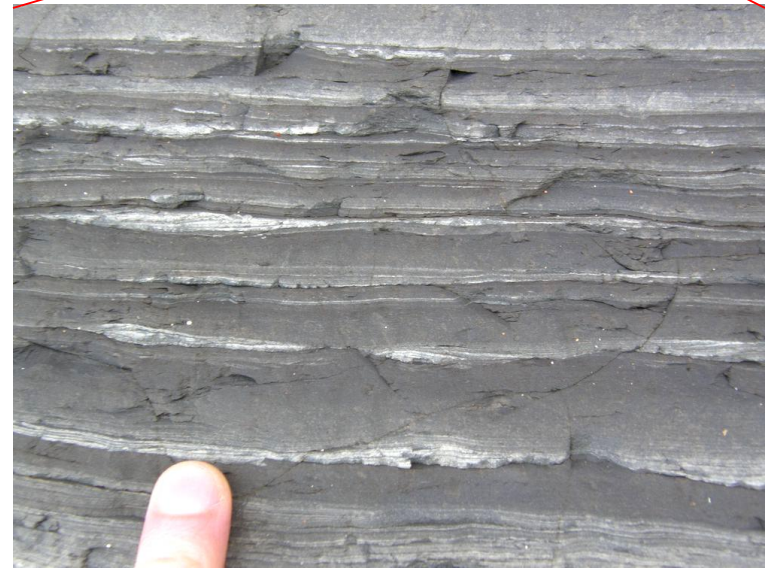
fosilní sedimentární systémy



Výchozy (Scarborough, s. Anglie)



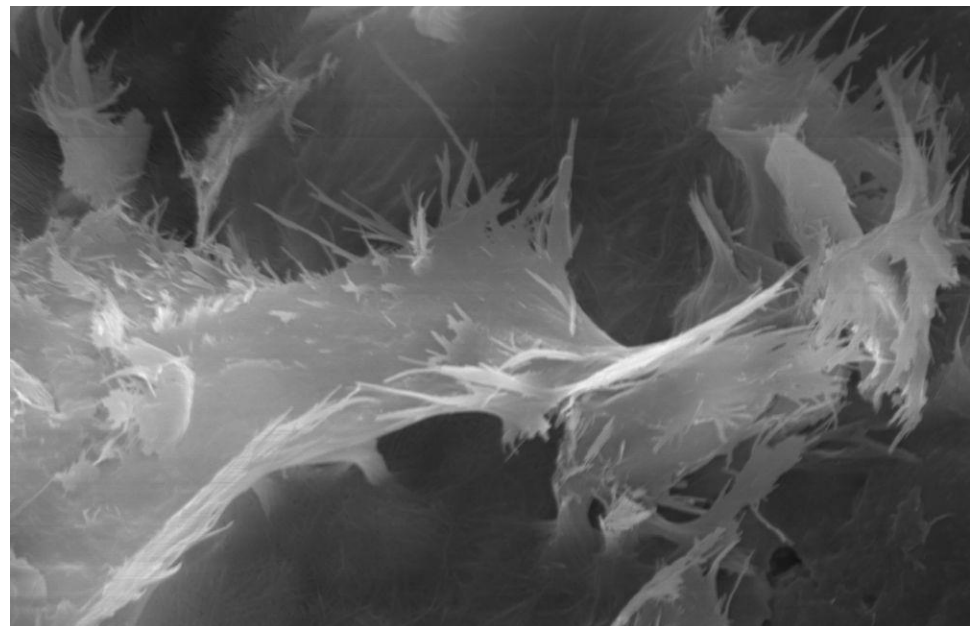
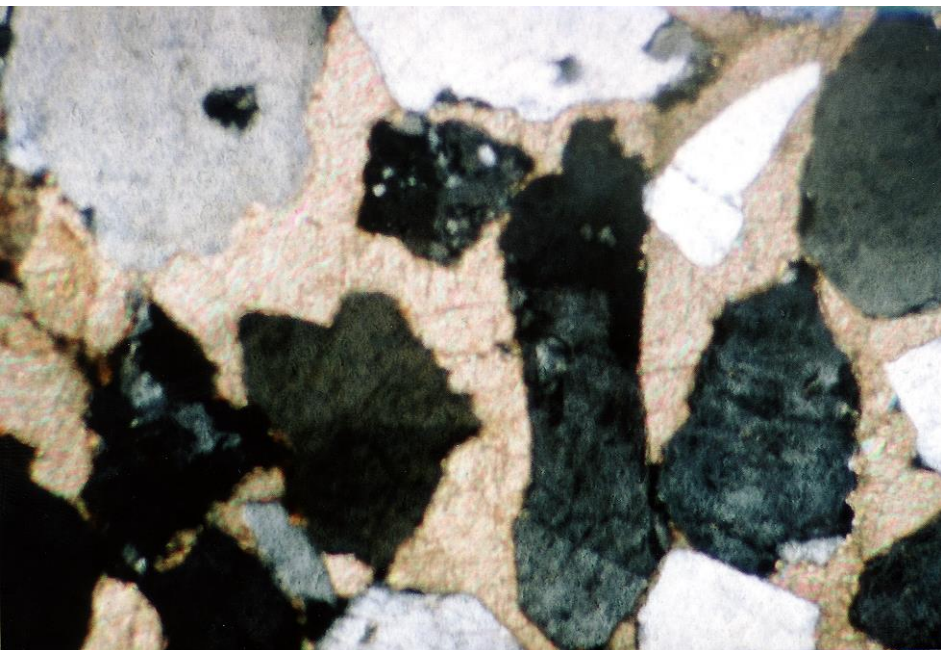
vrty procesy & produkty (zpevněný sediment)



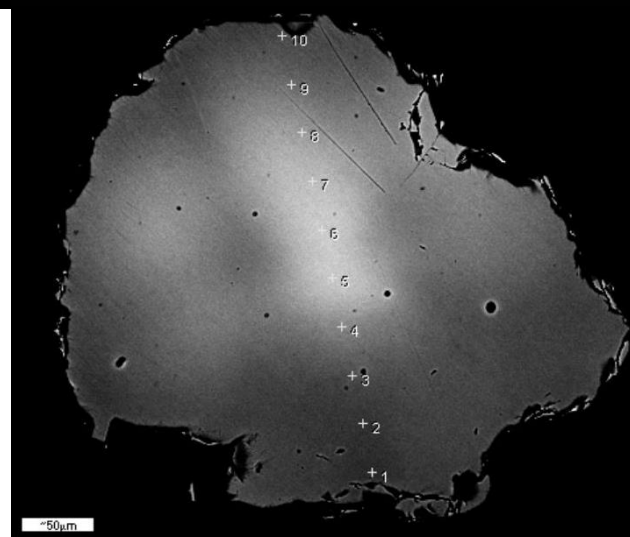
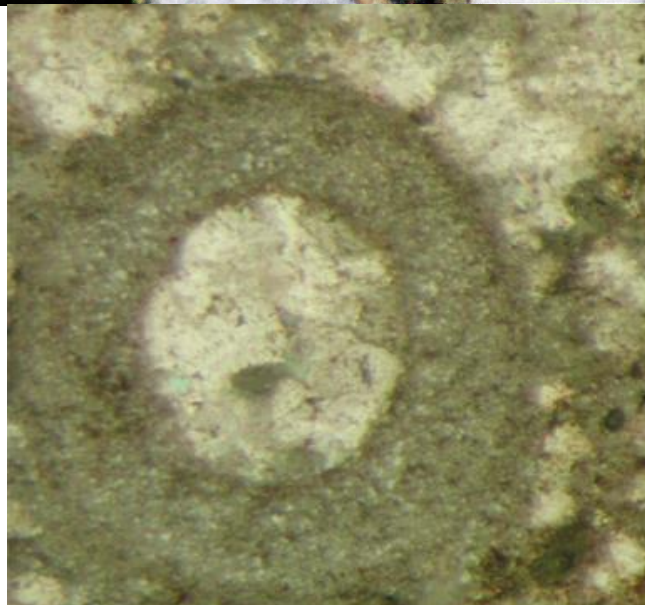
optický mikroskop

mikrostruktury

elektronový mikroskop

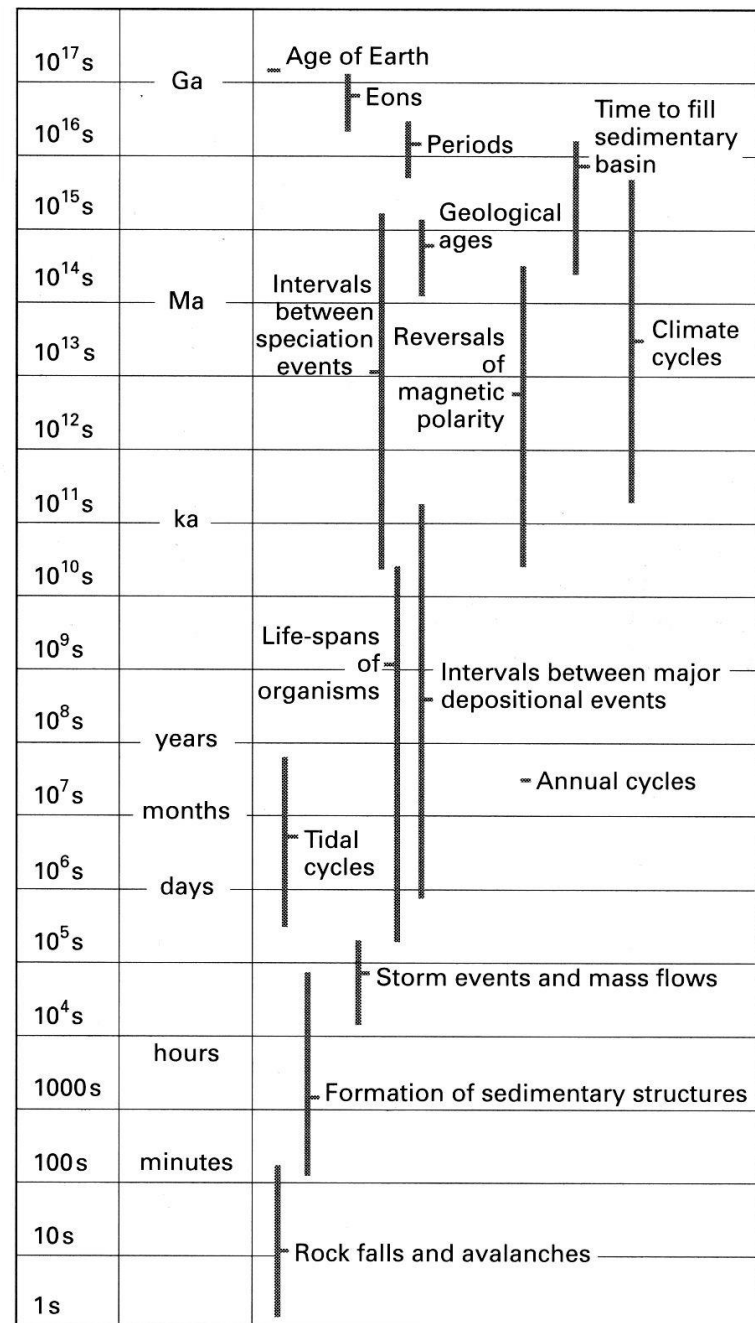
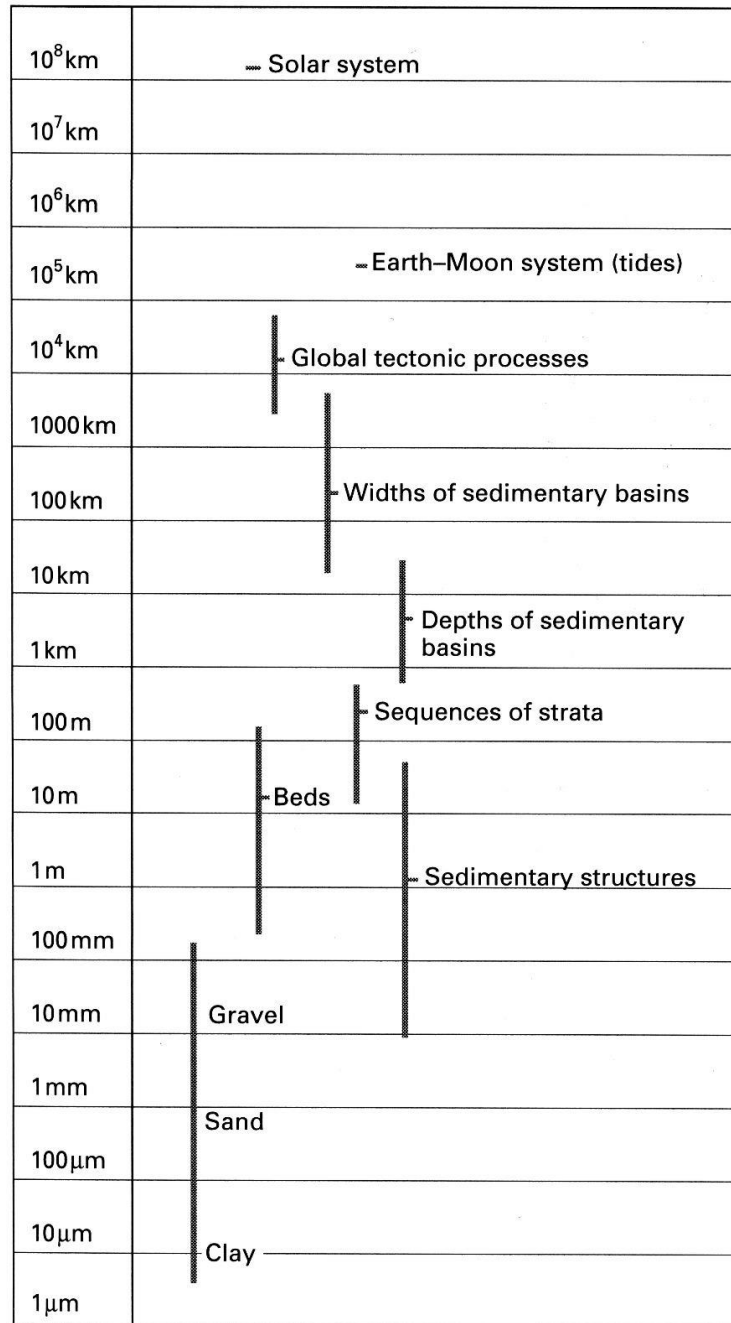


25kV X3,000 5µm 0025 13 49 SEI



rozsah geologických procesů v prostoru:

a v čase:



1. Úvod - *procesy transportu a sedimentace, sedimentární struktury*

1.1. mechanika tekutin

- usazování částic ze suspenze - Stokesův zákon

$$w = \frac{\Delta\rho d^2 g}{18\mu}$$

w - rychlost usazování částice

$\Delta\rho$ - rozdíl hustot částice a kapaliny

g – gravitační zrychlení

d – průměr zrna

μ - dynamická viskozita

[video v3.3](#)

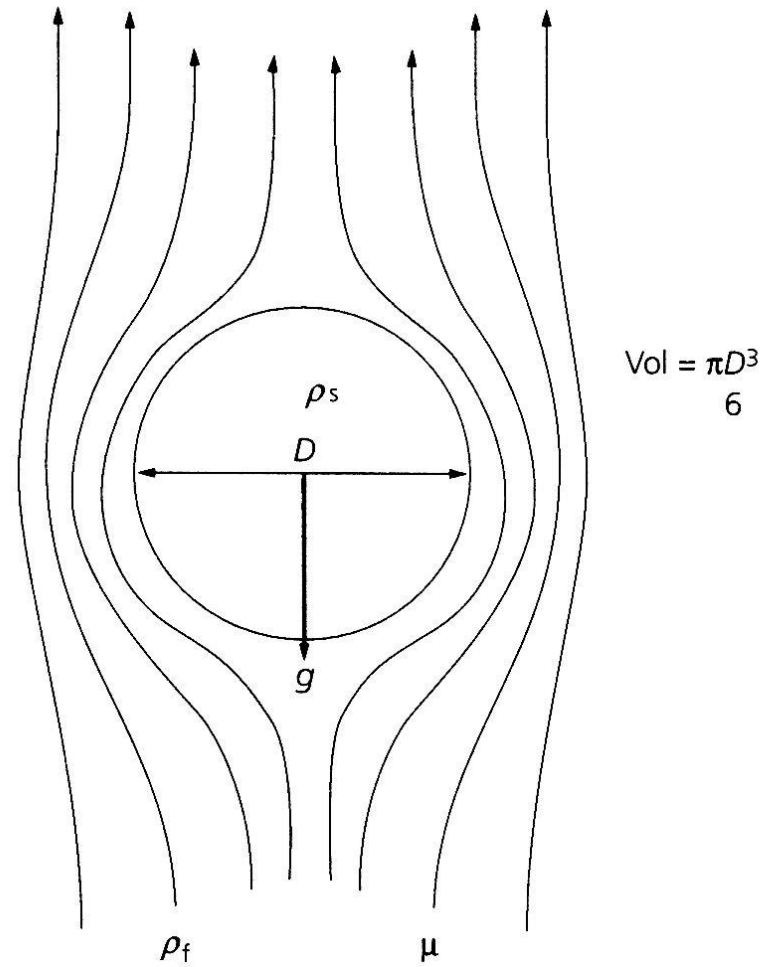
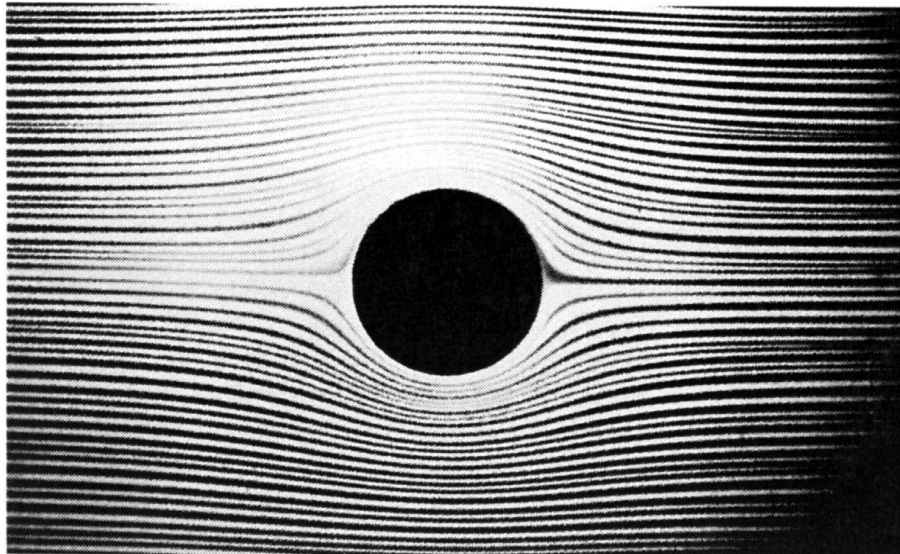


Fig. 4.6 Notation for a solitary spherical particle falling through a still fluid.

Fig. 4.8 Laminar flow is dominated by viscous effects. This can be visualized by water, streaked with dye, flowing at 1 mm s^{-1} through a narrow gap between two glass plates 1 mm apart (Hele–Shaw flow) past a circular object.

- laminární proudění

Laminar flow



At all points in flow all molecules are moving downstream

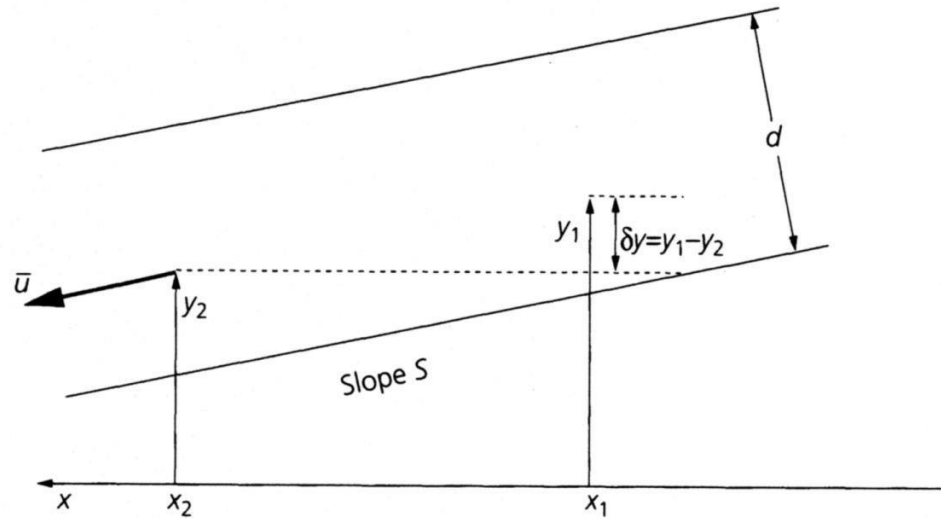
- turbulentní proudění

Turbulent flow



At any point in the flow a molecule may be moving in any direction, but the net flow is downstream

(a)



$$\begin{aligned} \text{Change in potential energy} &= \rho g d \delta y \\ \text{Rate of loss of potential energy per unit time} &= \rho g d (\bar{u} S) \end{aligned}$$

(b)

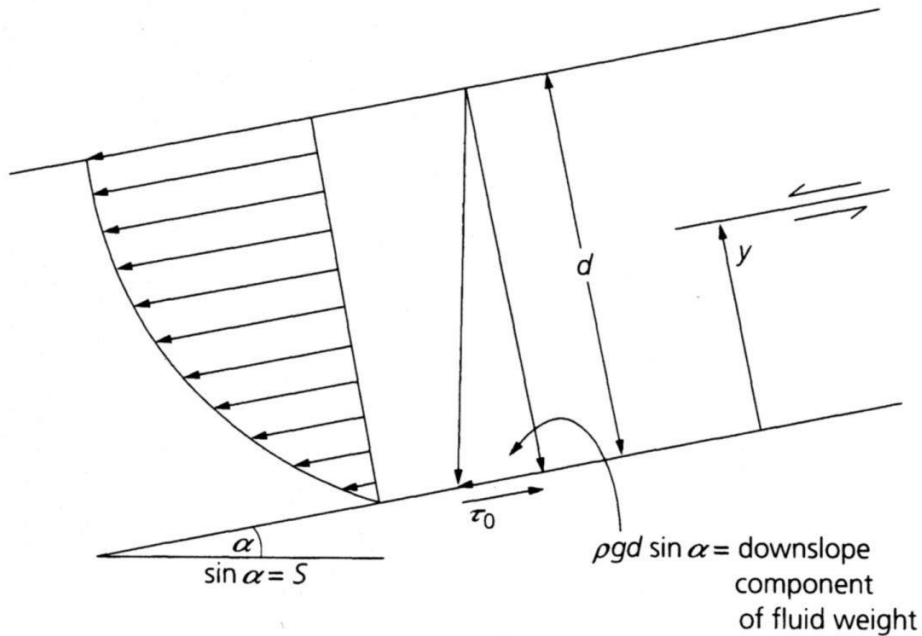


Fig. 4.12 (a) Schematic of the energy balance for a river flowing down a slope. (b) Notation used to derive the velocity profile in Practical Exercise 4.2.

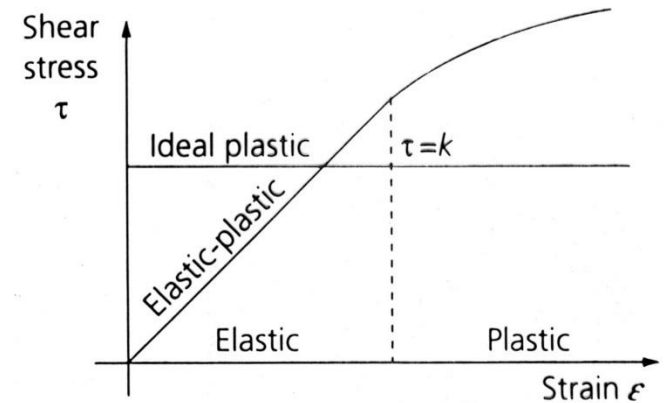
chování tekutin (fluid)

Newtonovské (např. voda)

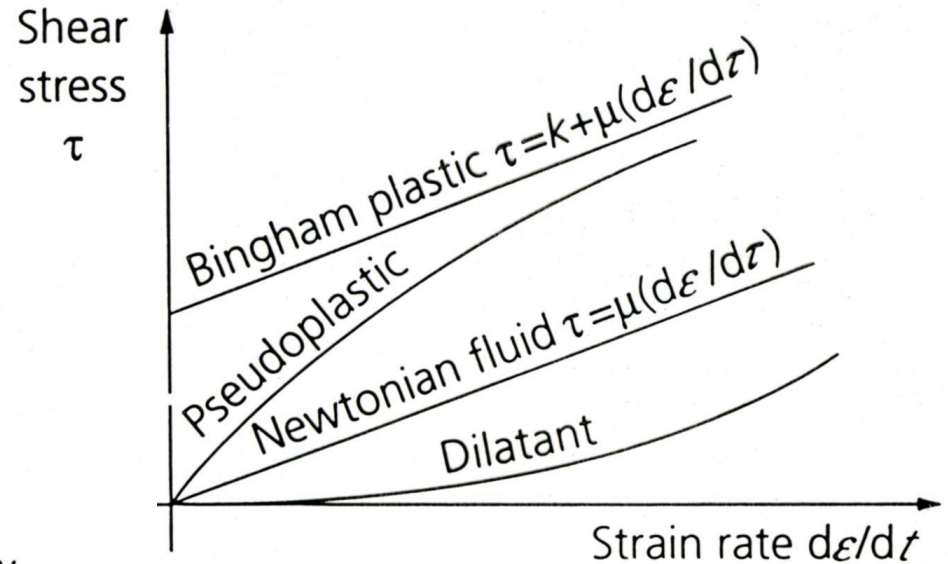
ne-Newtonovské

Binghamova plastická tekutina
(např. syntetická barva)

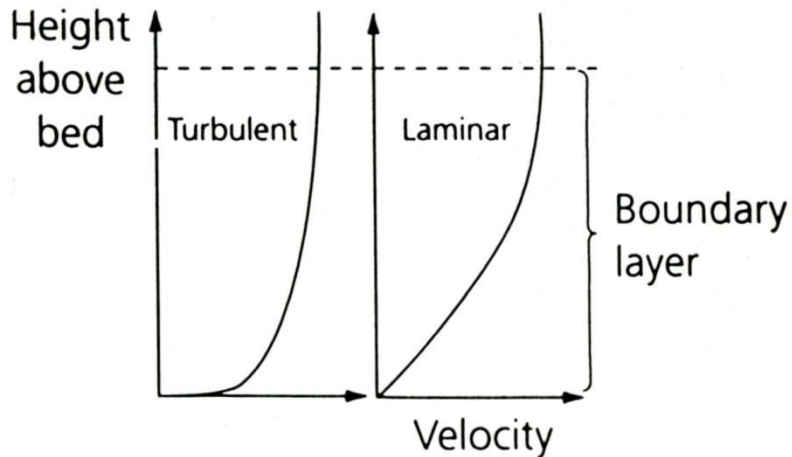
(a)



(b)



(c)



- Reynoldsovo číslo $Re = UL / \nu$

U - střední rychlost proudění

L – hloubka

ν – kinematická viskozita (μ/ρ)

[video v6.6](#)

[video v7.1](#)

[video v8.3](#)

- Froudovo číslo

$Fr < 1$ subkritický tok

$Fr > 1$ superkritický tok

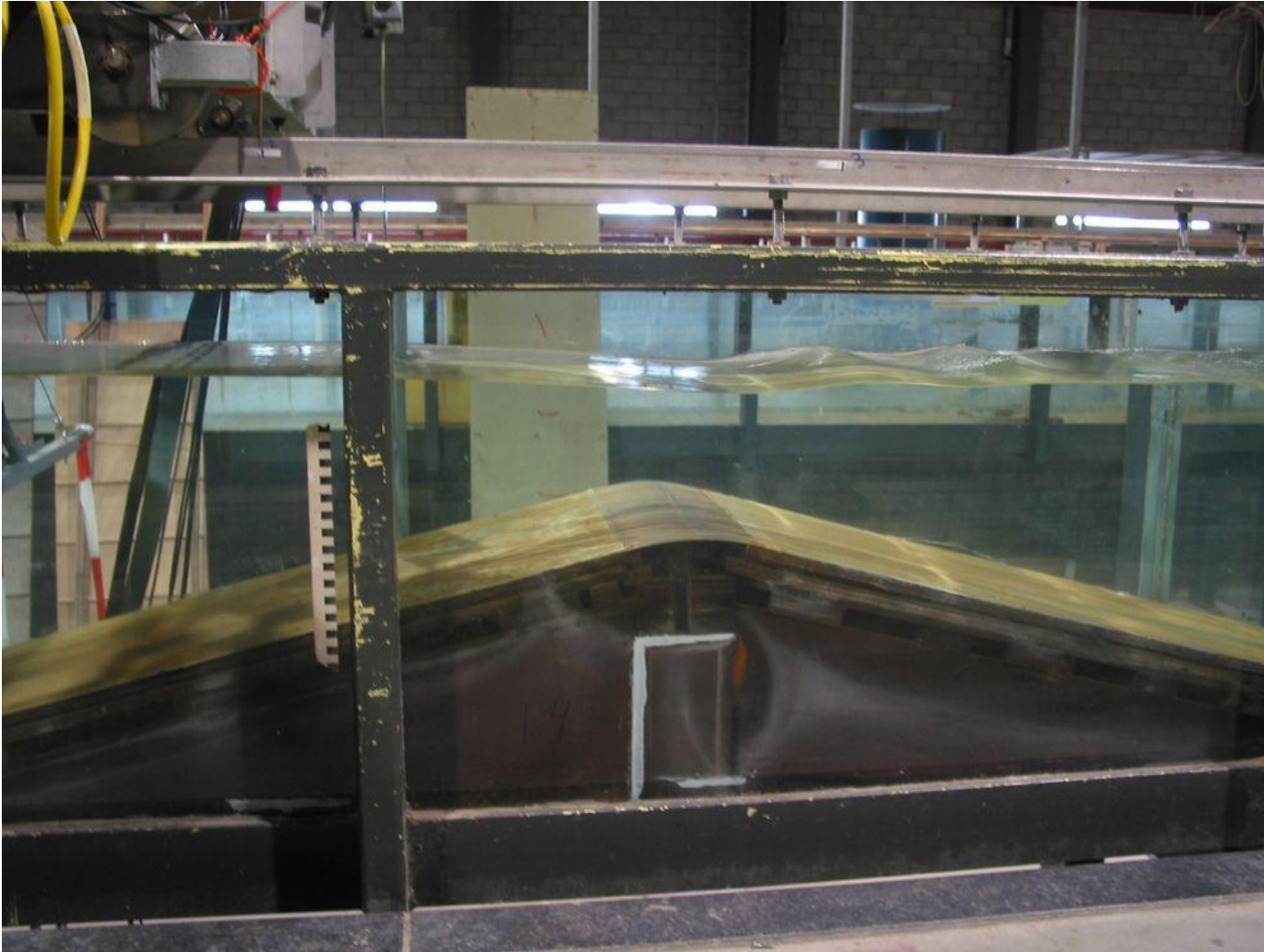
$$Fr = U / \sqrt{gh}$$

- energie proudu (stream power) $U\tau_0$

τ_0 - průměrná síla působící na jednotku plochy sedimentu

hydraulický skok

– přechod od superkritického ($Fr > 1$) do subkritického ($Fr < 1$) toku



video [v10.6](#)

video [v10.5](#)

video [v10.4](#)

1.2. transport sedimentu

- jednosměrné proudění
- typy transportu
 - bedload (trakce – traction carpet, saltace, rolování), v suspenzi

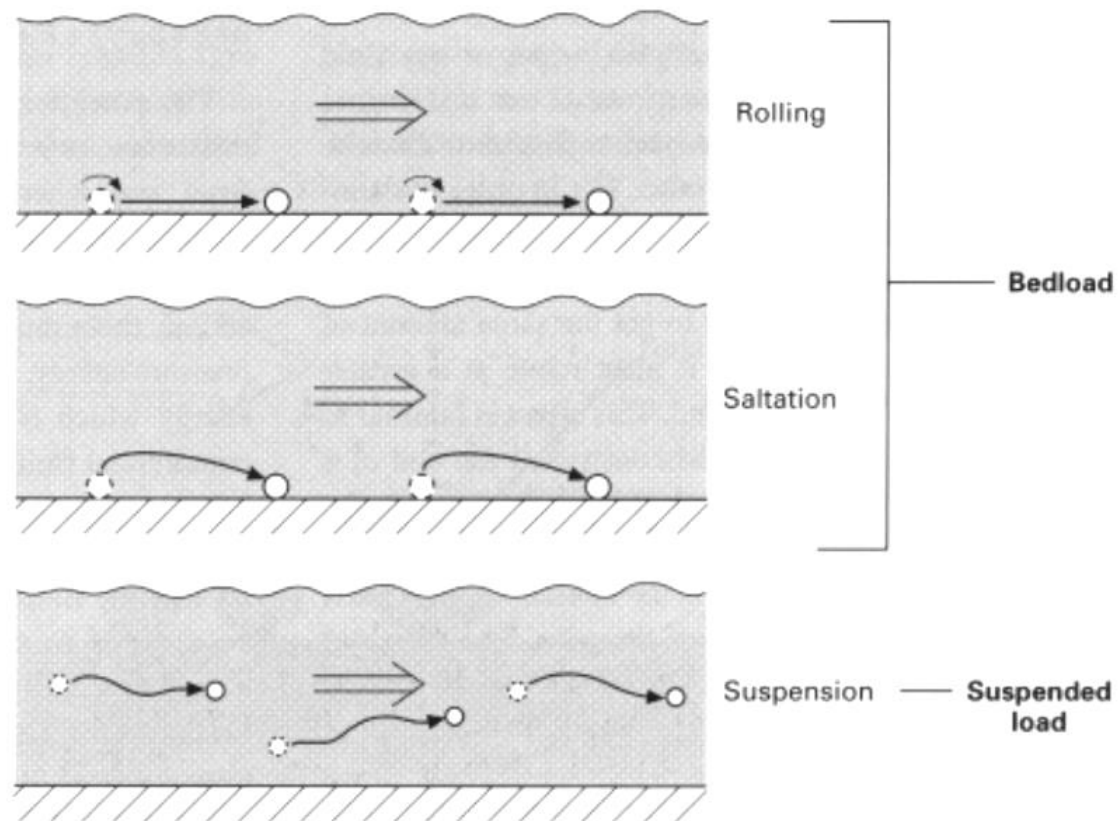
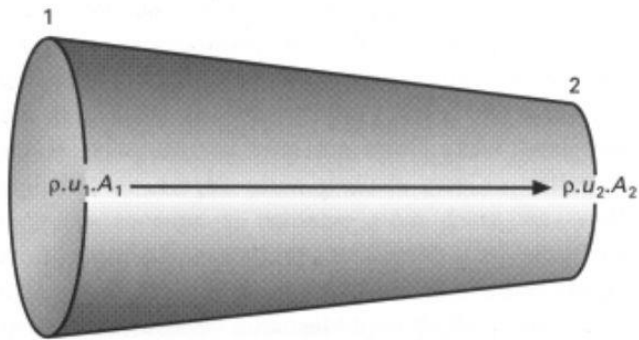


Fig. 4.2 Mechanisms of transport of particles in a flow: rolling and saltation (bedload); and suspension (suspended load).



Mass of fluid at '1' = mass at '2'

$$\rho \cdot u_1 \cdot A_1 = \rho \cdot u_2 \cdot A_2$$

$$u_1 \cdot A_1 = u_2 \cdot A_2$$

Area A_1 has decreased to A_2

Velocity u_1 must increase to u_2

Bernoulli's equation

$$\text{Total energy} = 0.5\rho u^2 + \rho gh + P$$

If u increases P must decrease

= Pressure drop

Fig. 4.3 The Bernoulli effect illustrated by a fluid passing through a tapered cylinder.

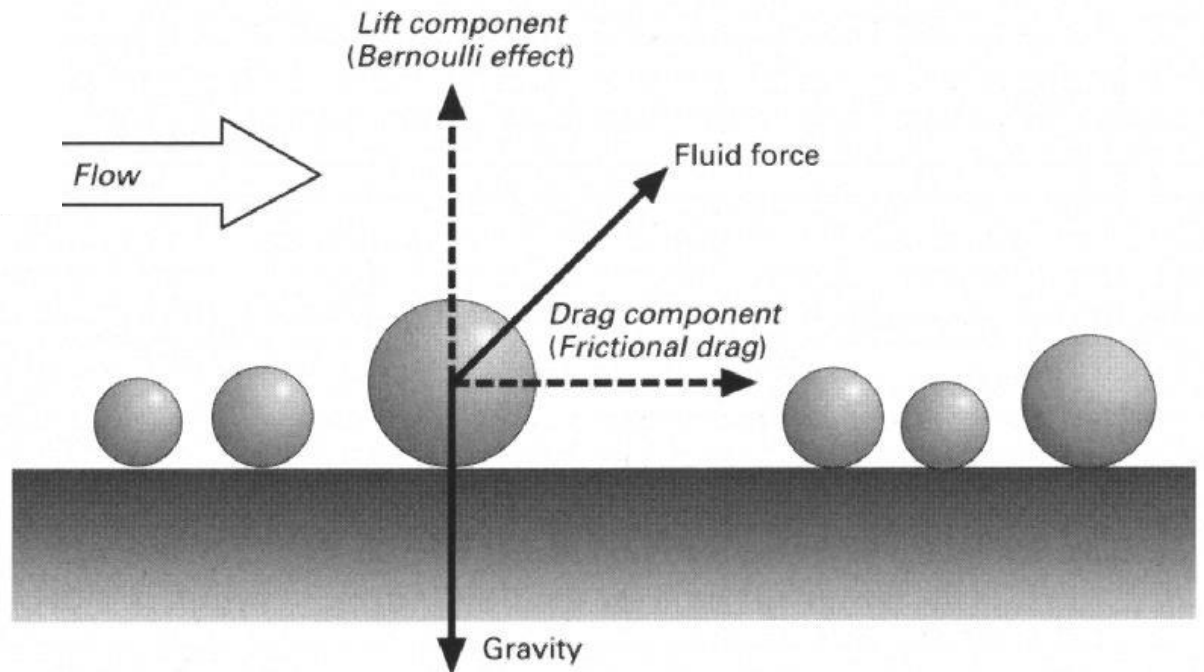
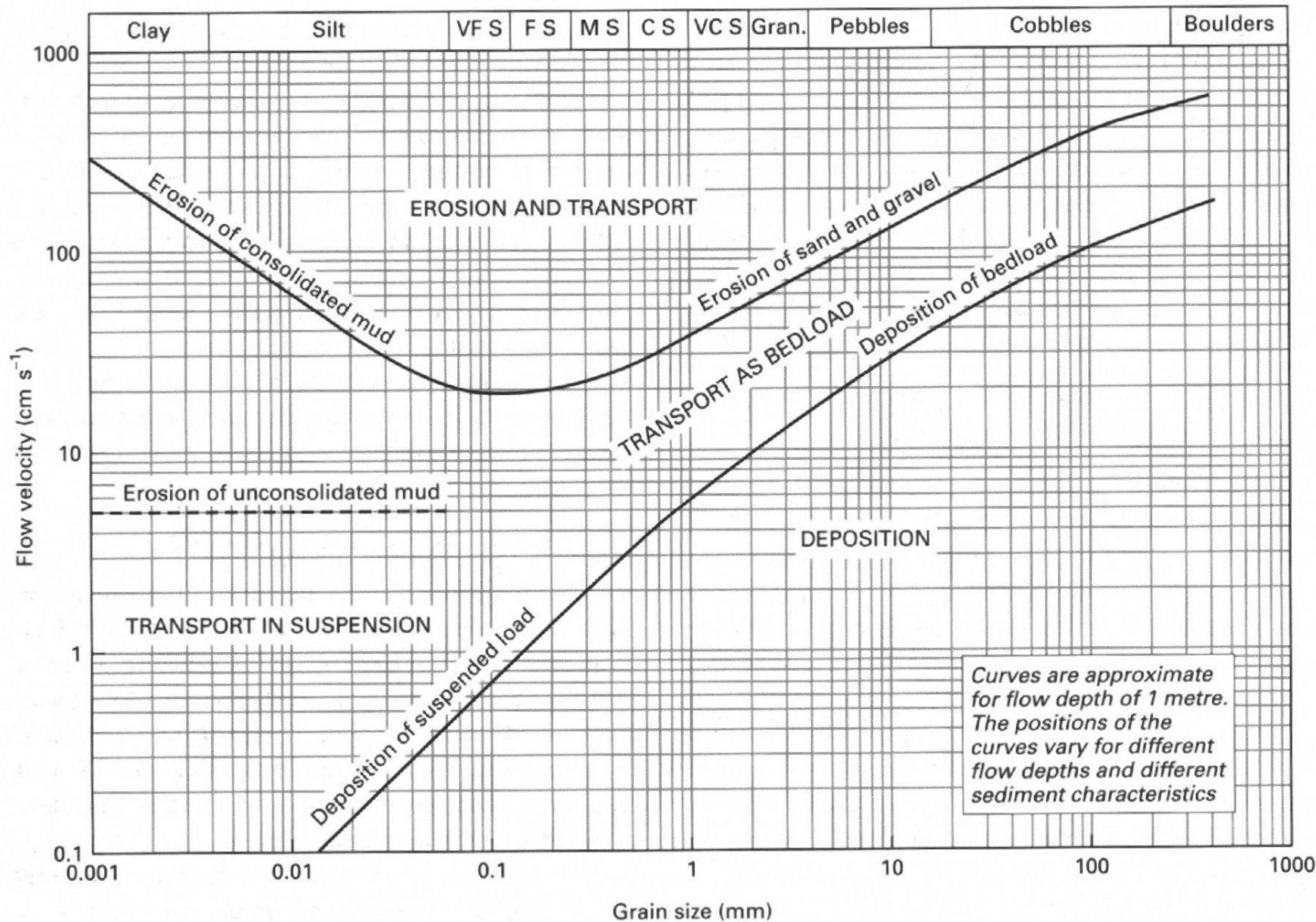


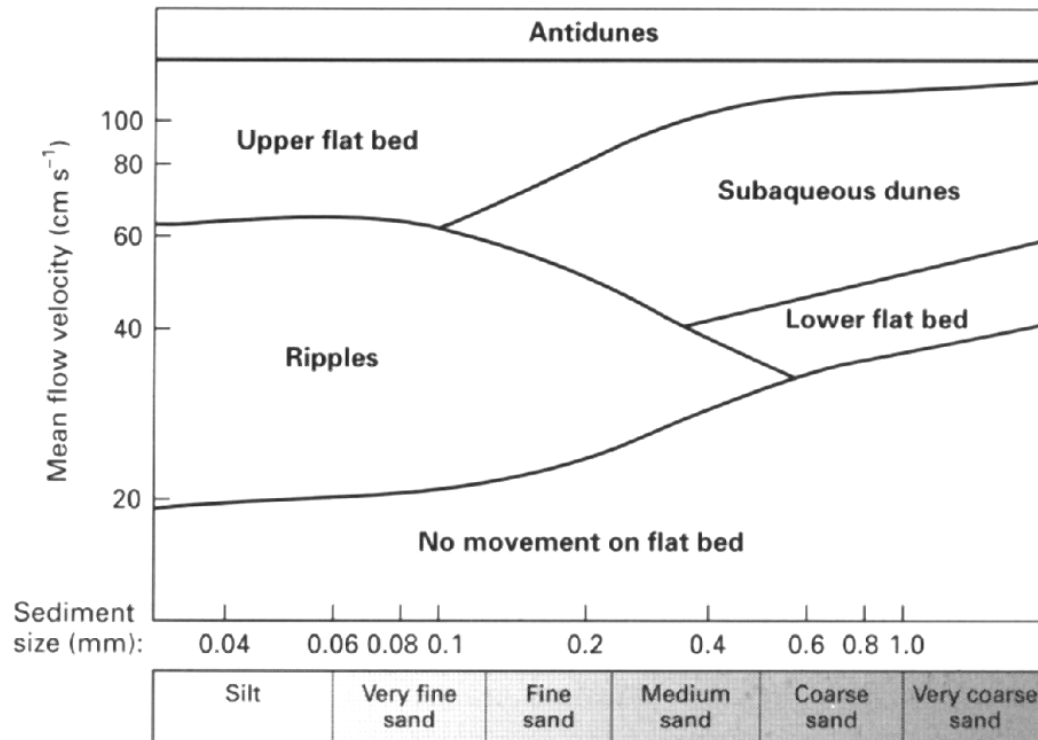
Fig. 4.4 Forces acting on a grain in a flow. (After Middleton & Southard 1978; Collinson & Thompson 1982.)



Hjulstromuv diagram (eroze-transport-sedimentace)

bedformy v nekohezním substrátu

koncept proudového režimu, čeřiny, duny, migrace bedforem



$Fr > 1$
 $Fr < 1$

Fig. 4.19 A bedform stability diagram showing the stability fields of different bedforms formed in sediment of different grain sizes at different flow velocities. (After Harms *et al.* 1975; Walker 1992b.)

1.3 sedimentární struktury

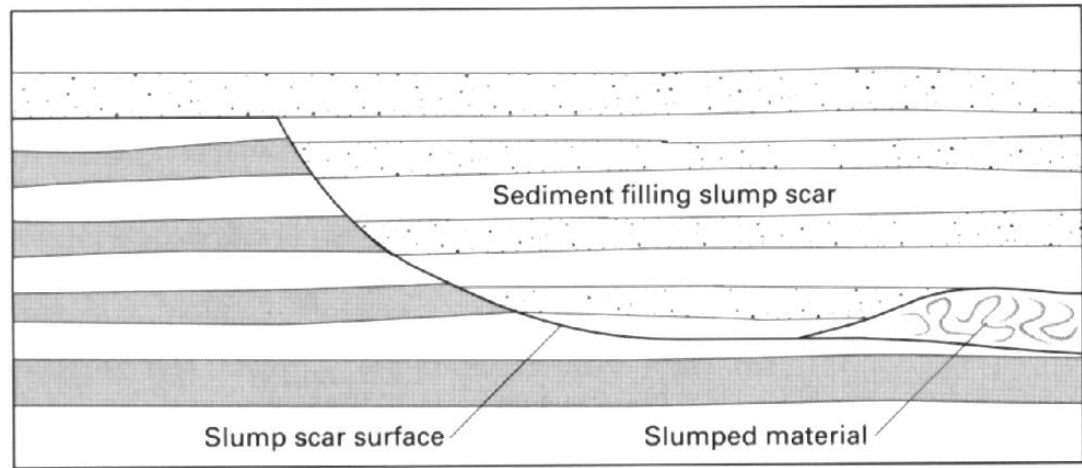
presedimentární

- otisky (tool marks,
- otisky dešťových kapek)

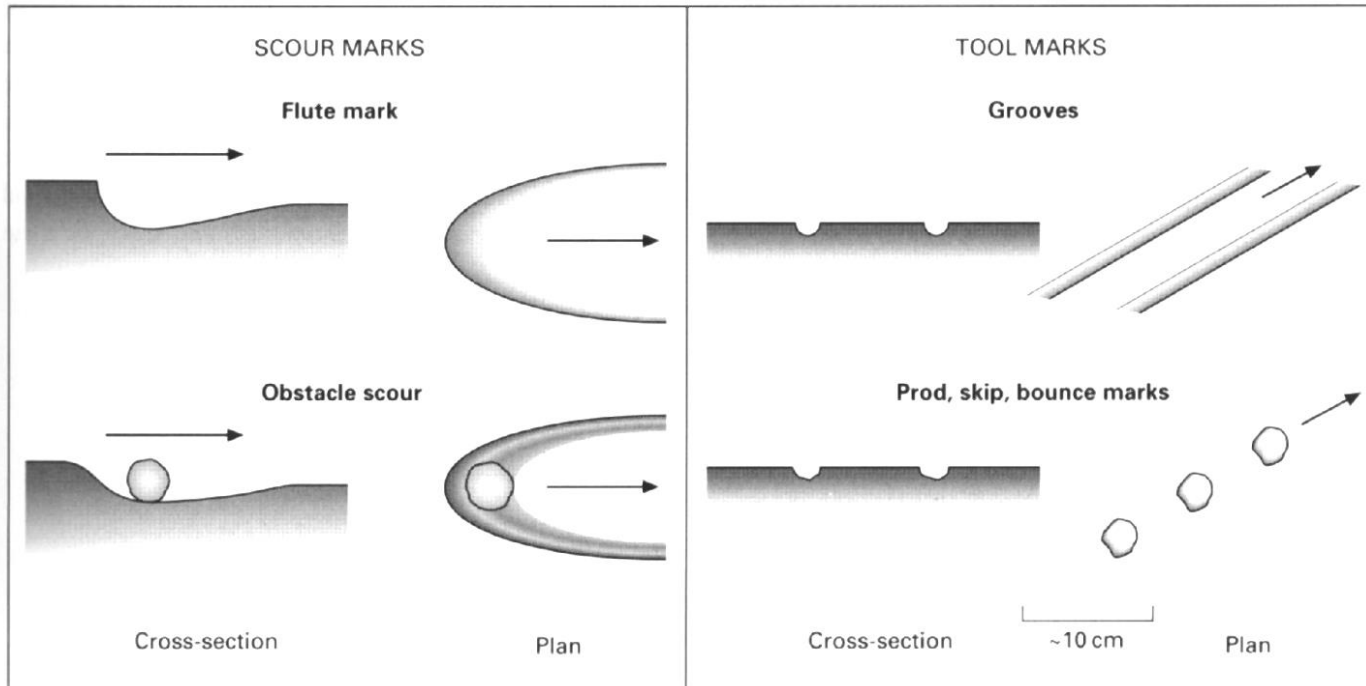


bauxitový lom, Britská Guyana

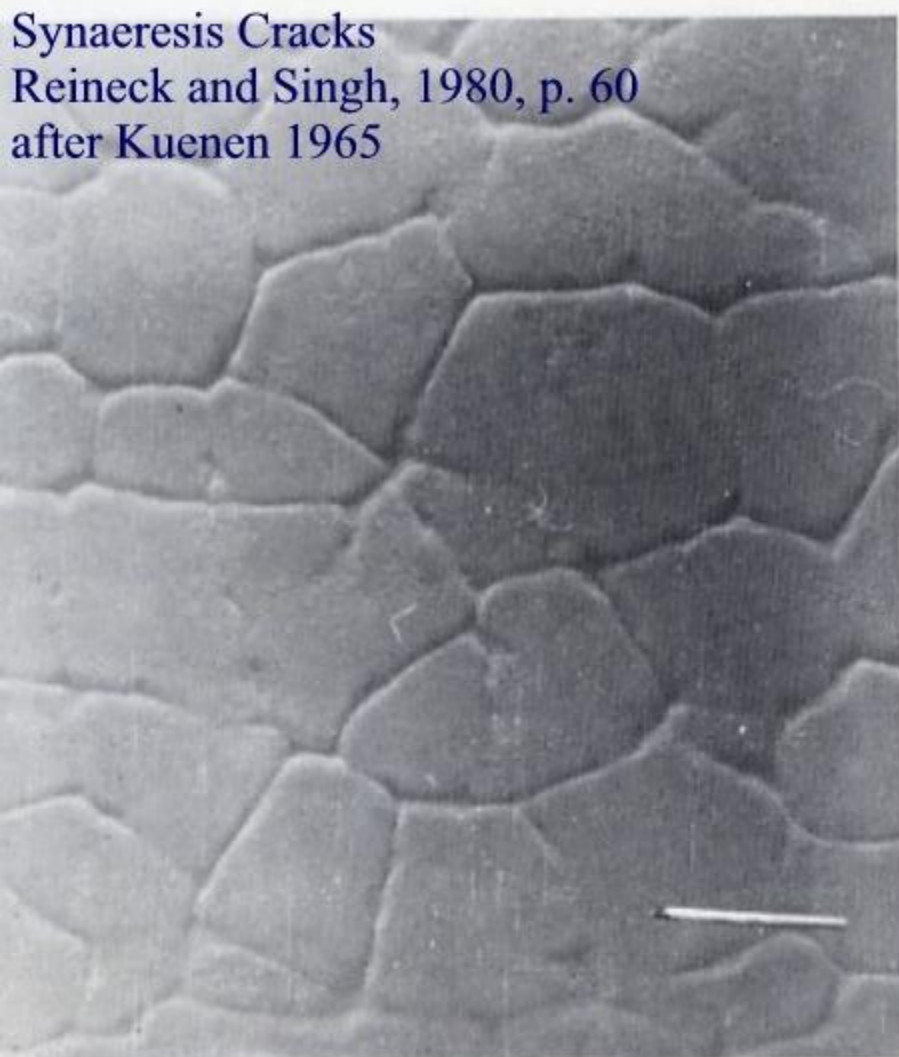
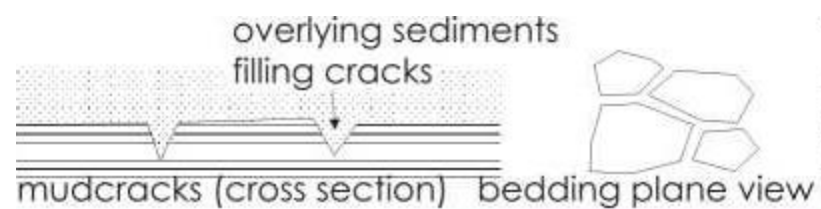
erozní struktury



proudové stopy (flute casts, gutter casts, groove marks, proudová lineace)



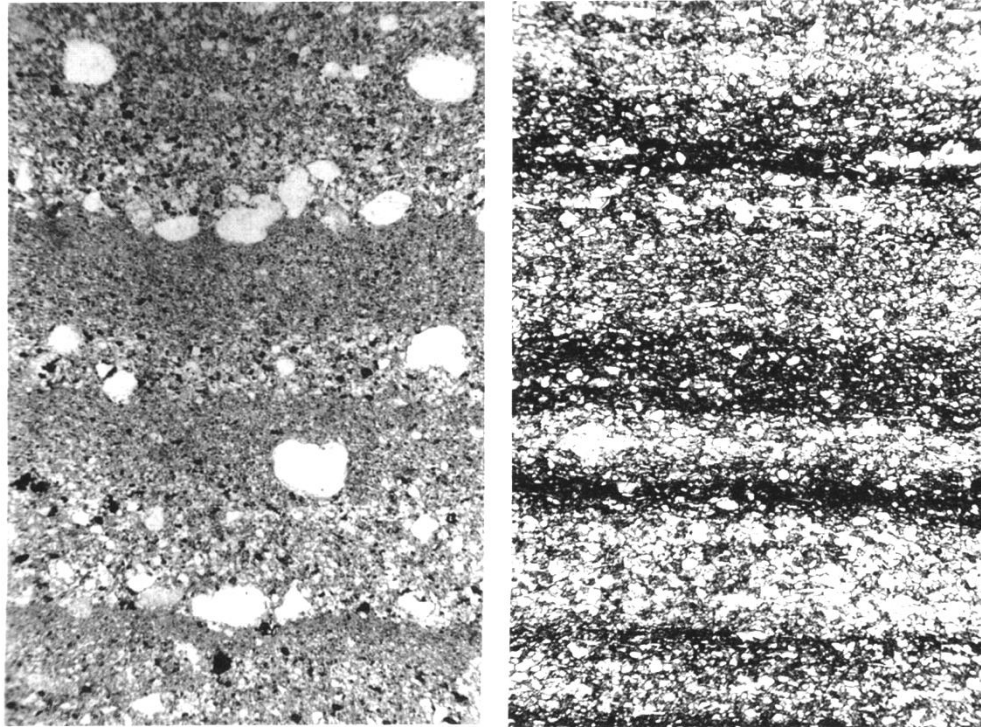
odtokové stružky (rill marks)
deformační (bahenní praskliny,
synerezní praskliny, větrné svaštění
(wrinkle marks))



vysychání

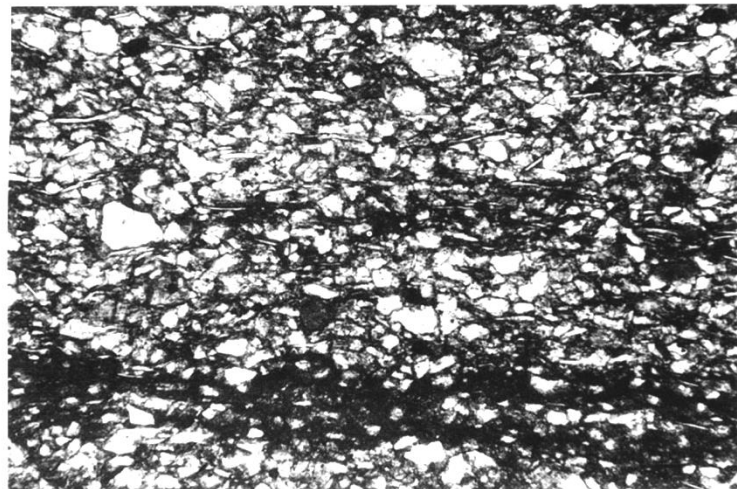
ztráta vody např. při seismických otřesech

synsedimentární struktury



laminace (jíl, prach)

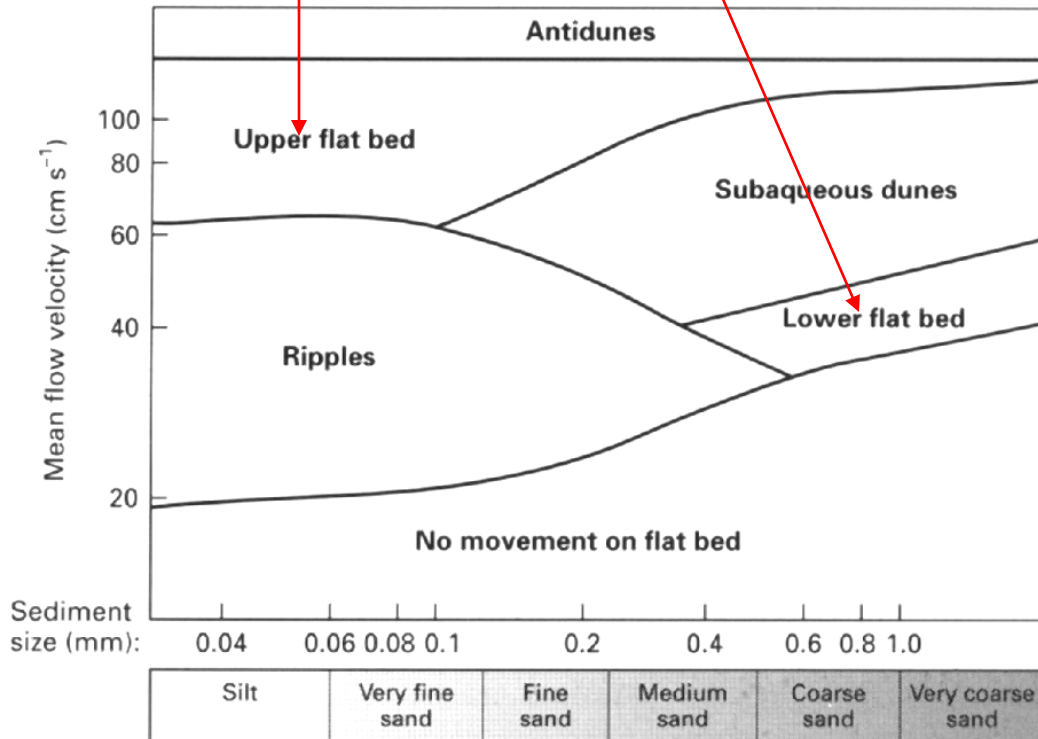
Fig. 3.4 Lamination in mudrocks. (a) Rhythmites, which are probably glacial varves. Consisting of graded silt passing up into clay-grade material. Late Precambrian, Islay, Scotland. (b) Rhythmites consisting of alternations of silt-grade quartz (in calcareous cement) and clay-organic matter, the result of seasonal deposition in a non-glacial lake. Caithness Flagstones, Devonian, Scotland (Fig. 2.16). In plane-polarized light.



horizontální zvrstvení (písek)



Fig. 4.20 Parallel laminated sandstone deposited in an overbank environment (Cretaceous, Alexander Island, Antarctica).



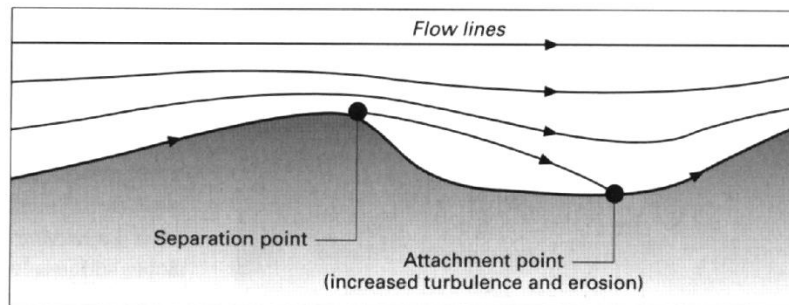
$Fr > 1$

$Fr < 1$

proudové čeřiny duny

Fig. 4.8 Flow over a bedform: imaginary streamlines within the flow illustrate the separation of the flow at the brink of the bedform and the attachment point at which the streamline meets the bed surface where there is increased turbulence and erosion. A separation eddy may form in the lee of the bedform and produce a minor counter-current (reverse) flow.

1. Erosion in the trough of a bedform



2. Development of counter-currents in lee of bedform

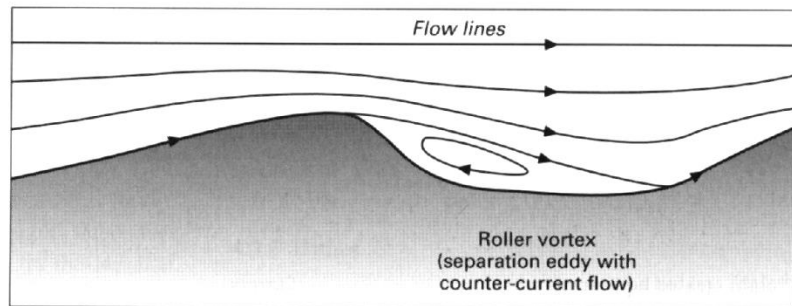
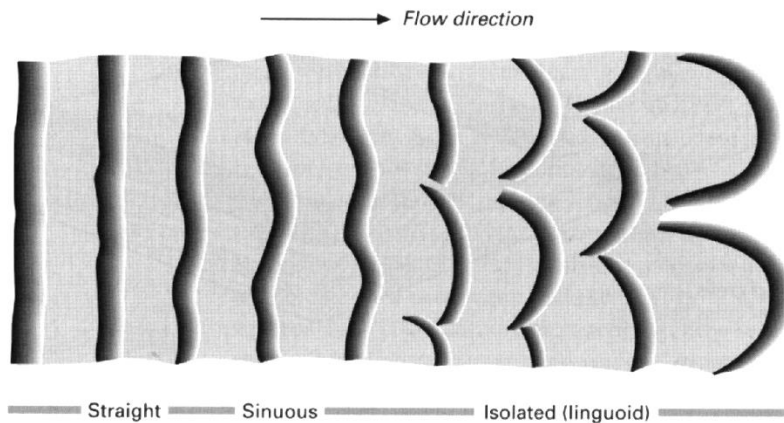


Fig. 4.9 Current ripples in plan view with straight, sinuous and isolated crests.



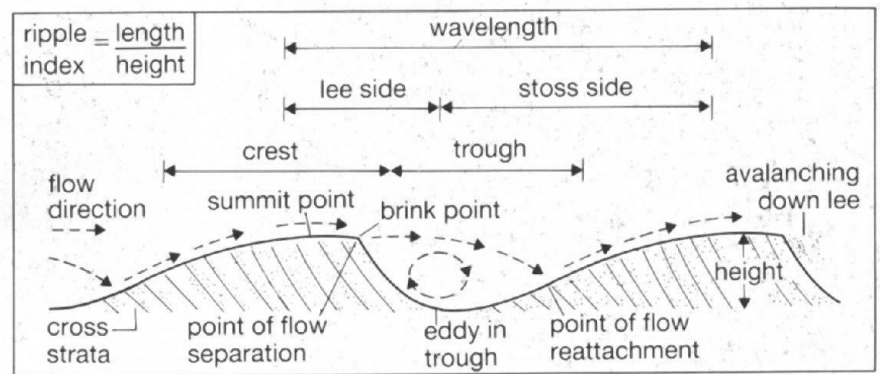


Fig. 2.18 Ripple terminology and flow pattern.

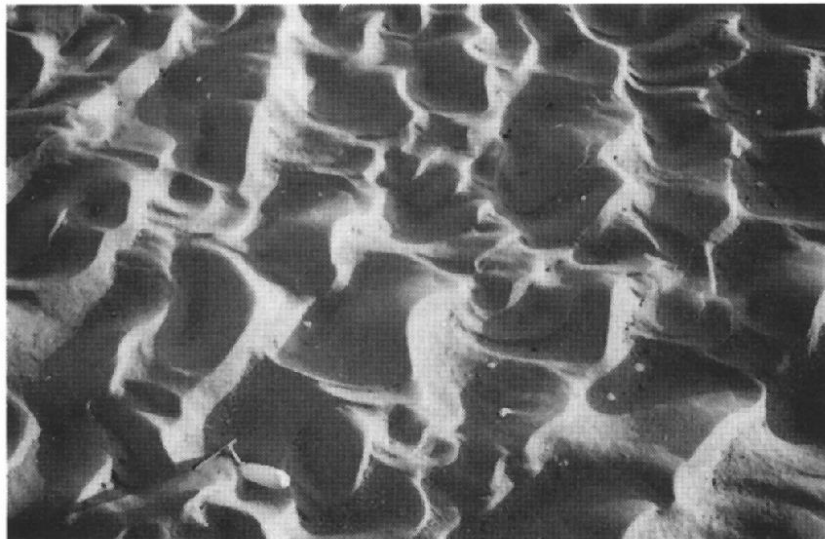


Fig. 4.10 Current ripples formed in sand in an estuary: field of view 1 m.

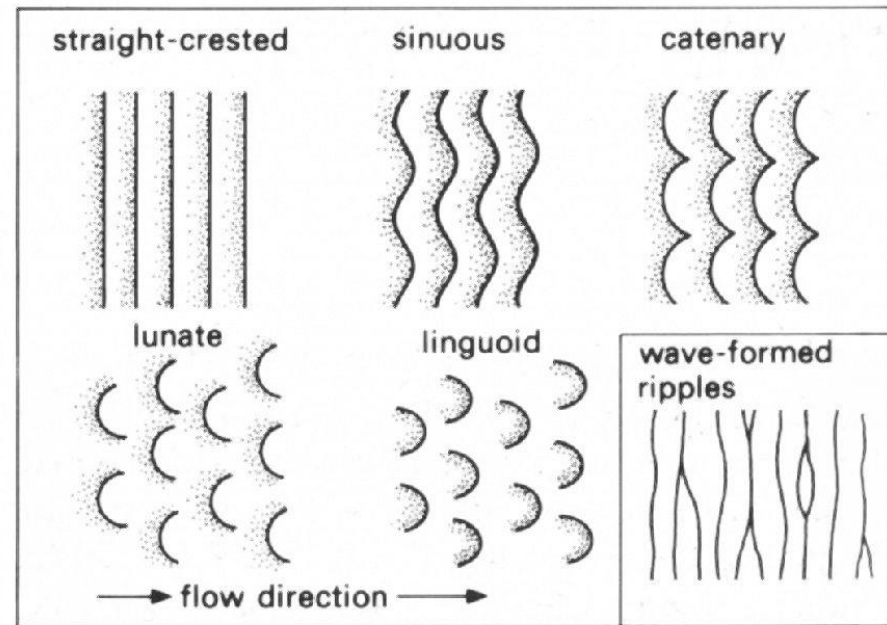
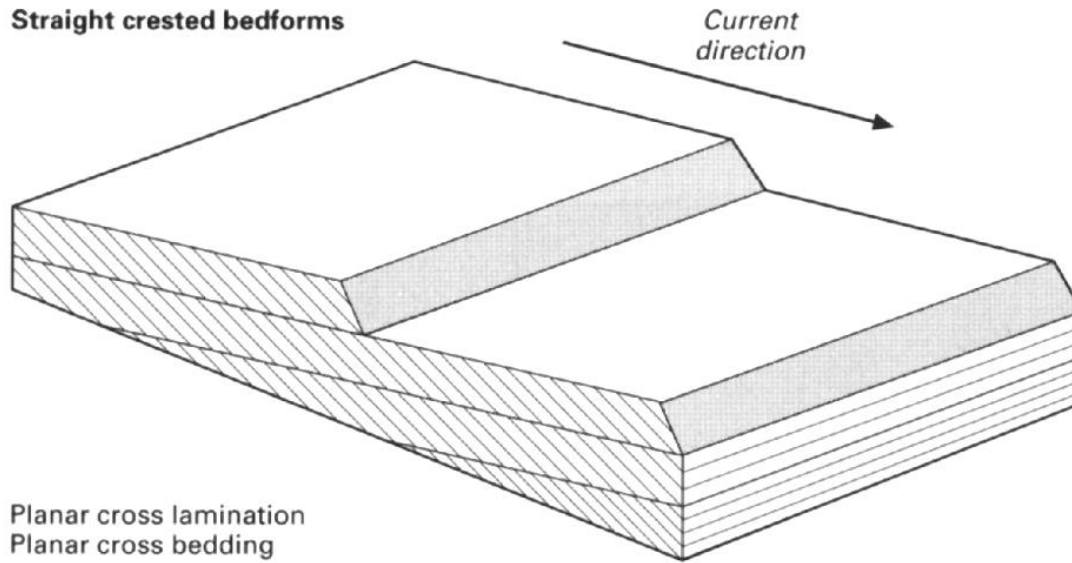


Fig. 2.19 Terminology for the shape of the crests of ripples and dunes formed by unidirectional currents. For comparison, the typical crest pattern of wave-formed ripples is also shown.

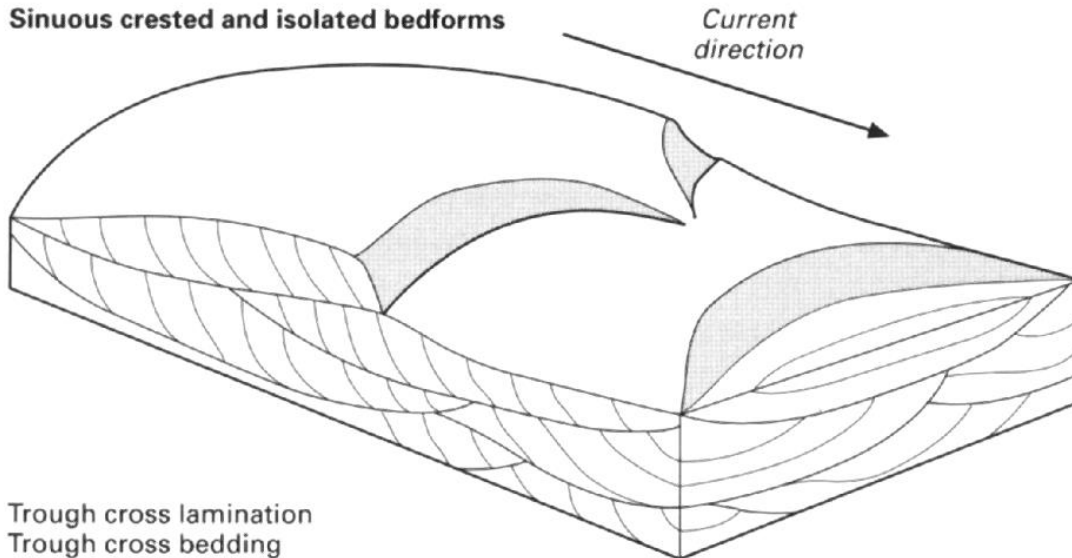
šikmé zvrstvení – planární, korytovité

Straight crested bedforms



Planar cross lamination
Planar cross bedding

Sinuus crested and isolated bedforms



Trough cross lamination
Trough cross bedding

Fig. 4.11 Migrating straight crested ripple and dune bedforms form planar cross lamination and planar cross bedding. Sinuous or isolated (linguoid or lunate) ripple and dune bedforms produce trough cross lamination and trough cross bedding. (After Tucker 1991.)

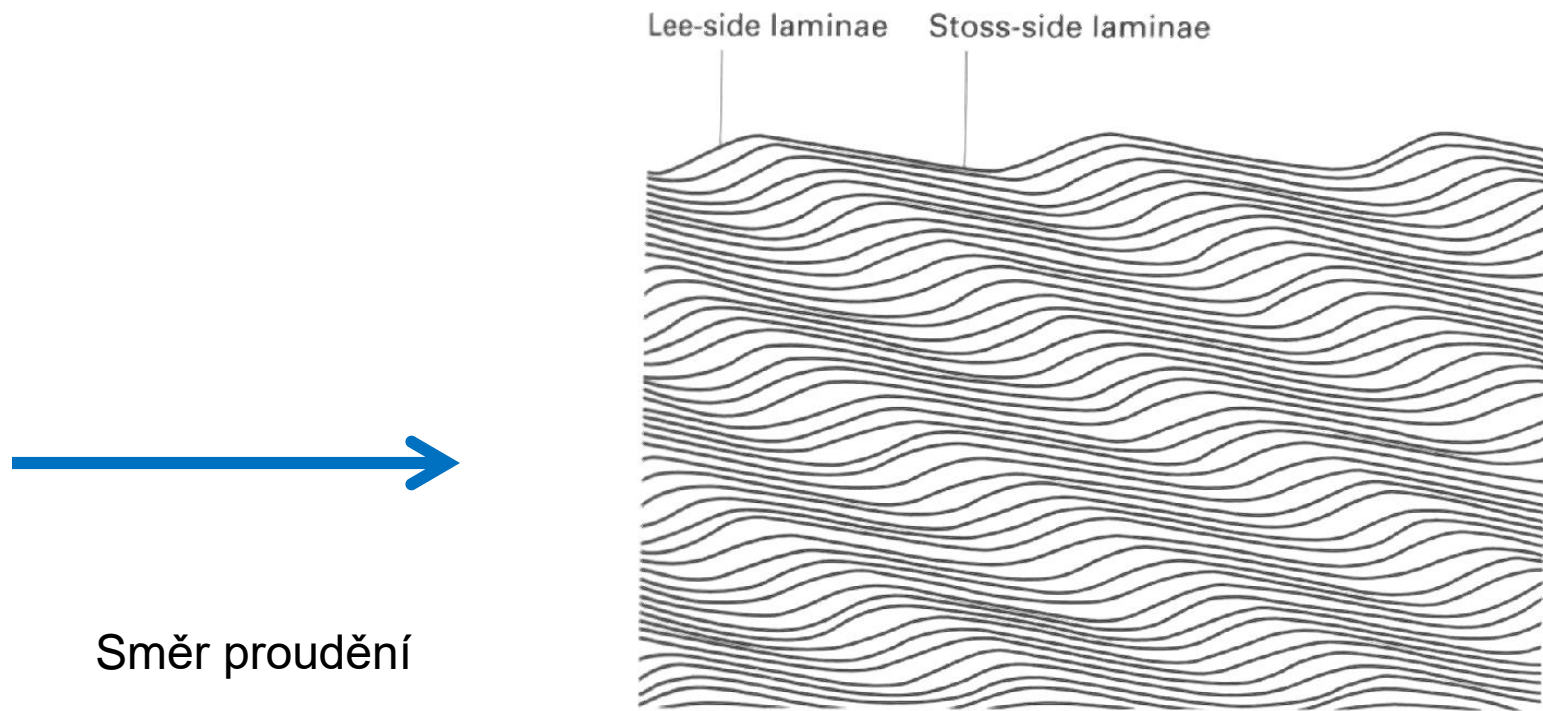
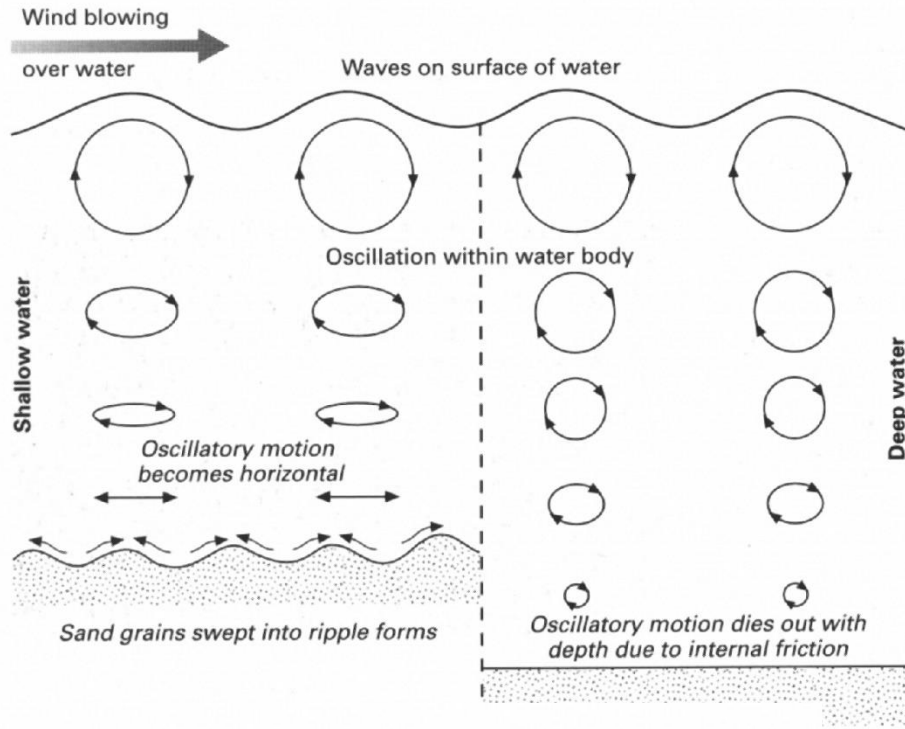


Fig. 4.12 Climbing ripple cross lamination produced by rapid deposition from a flow carrying a high proportion of sand. (After Collinson & Thompson 1982.)

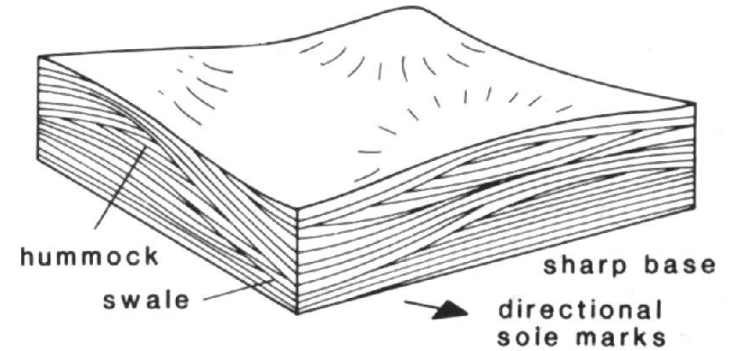
šplhavé čeřiny (rychlý proud, velká rychlost sedimentace)

oscilační čeriny



HCS zvrstvení

A HUMMOCKY CROSS STRATIFICATION (HCS)
wavelength 0.5-5m



B SWALEY CROSS STRATIFICATION (SCS)

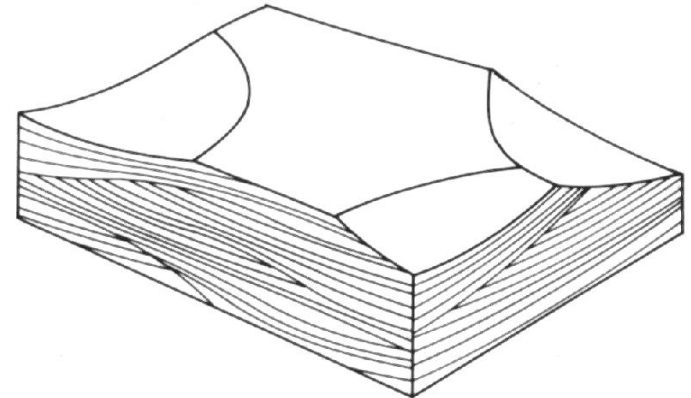
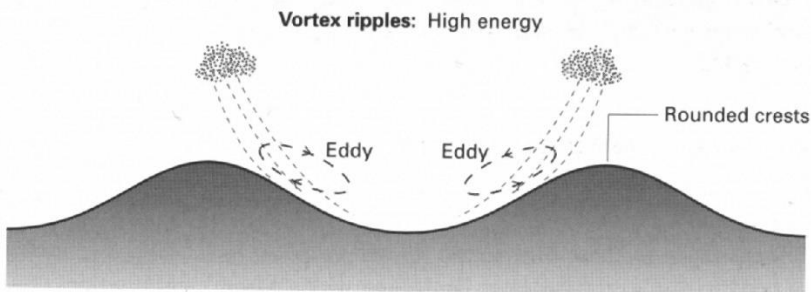
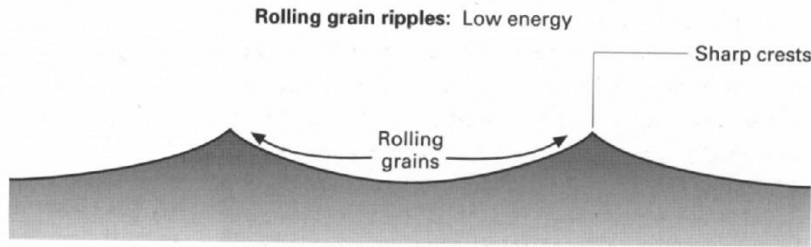


Fig. 2.30 Hummocky cross stratification (HCS) and swaley cross stratification (SCS).





heterolitické zvrstvení

mázdřité

Sand

zvlňné

čočkovit

Mud

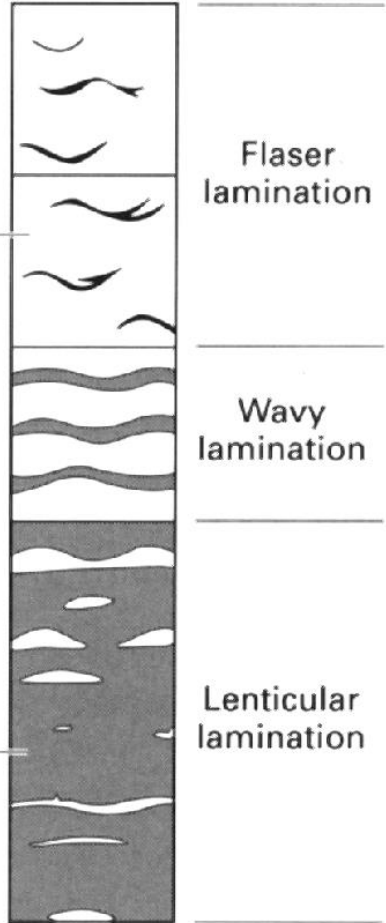


Fig. 4.25 Mixtures of sand and mud in different proportions produce different forms of lenticular and wavy bedding. (After Reineck & Singh 1973.)

tidální rytmy

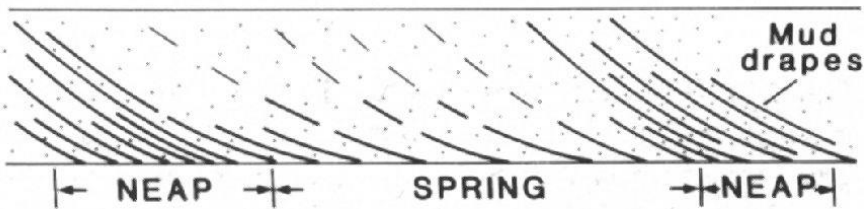


Fig. 2.25 Schematic sketch of tidal cross bedding with tidal bundles defined by mud drapes upon foresets. Spacing of the sand/mud couplets can be indicative of spring–neap tidal cycles: thick layers = spring tides, thin layers = neap tides. After Allen (1982).



gradační zvrstvení – normální, inverzní

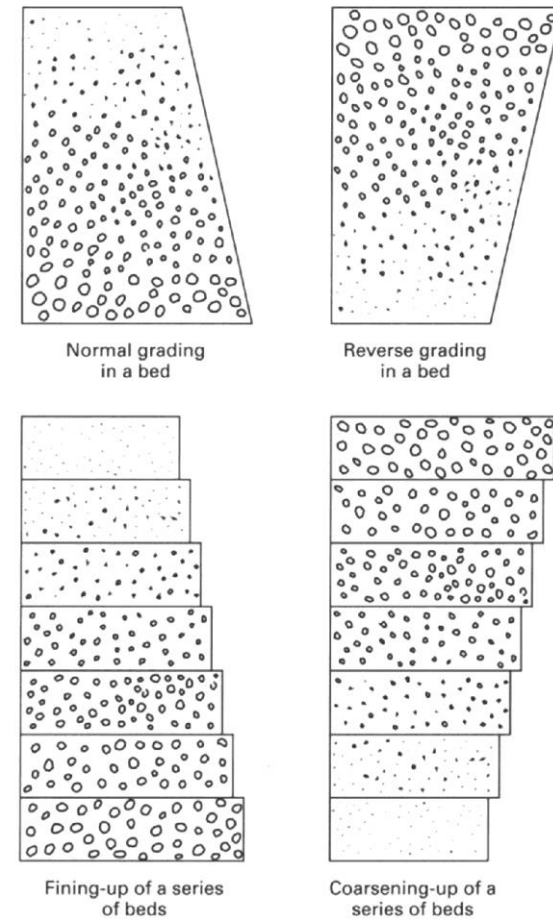
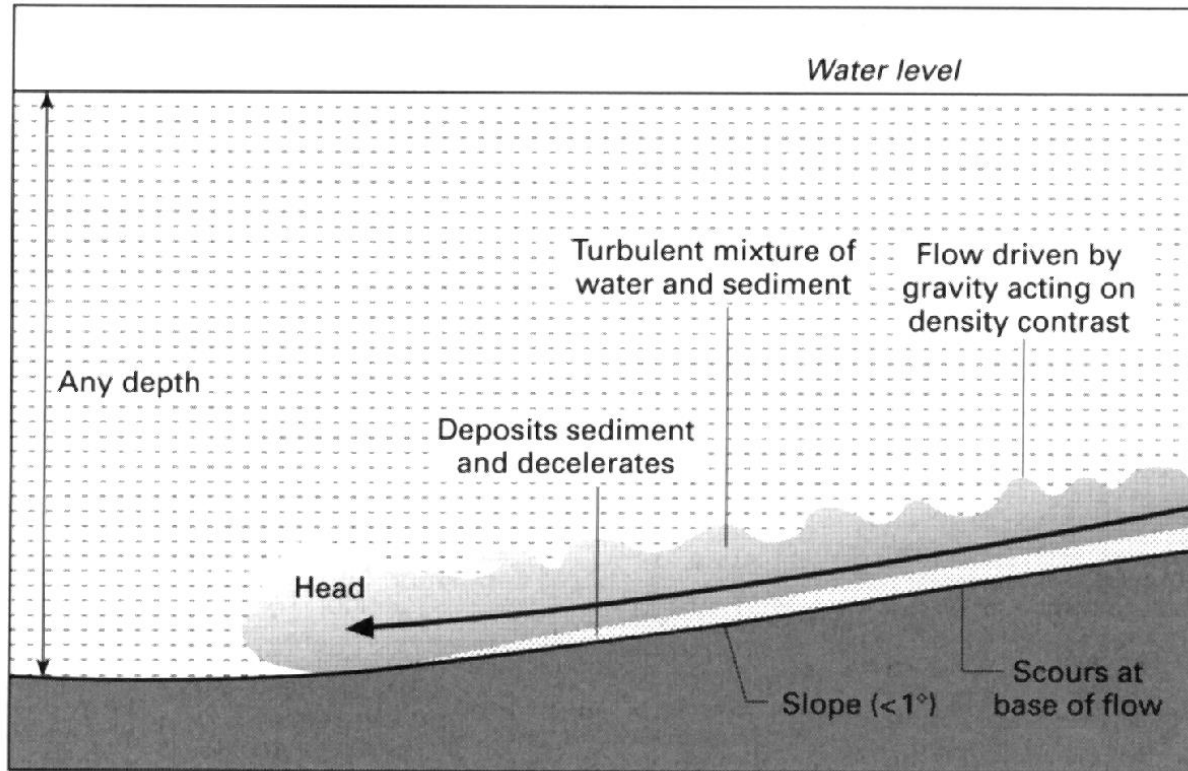


Fig. 4.6 Normal and reverse grading in single beds; fining-upward and coarsening-upward patterns in a series of beds.

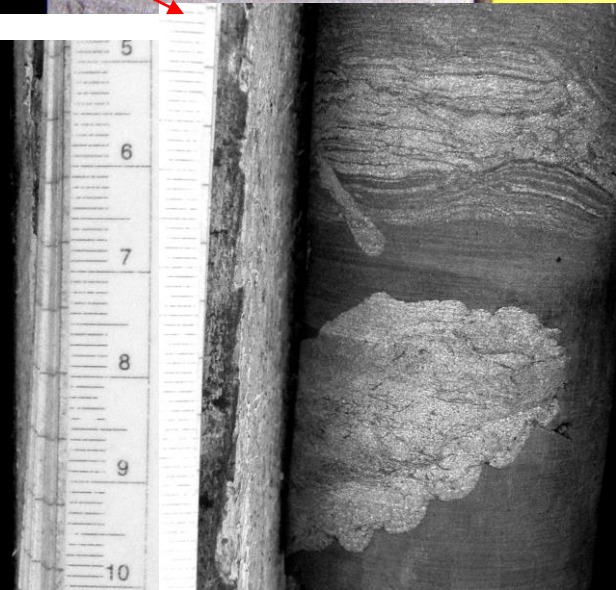
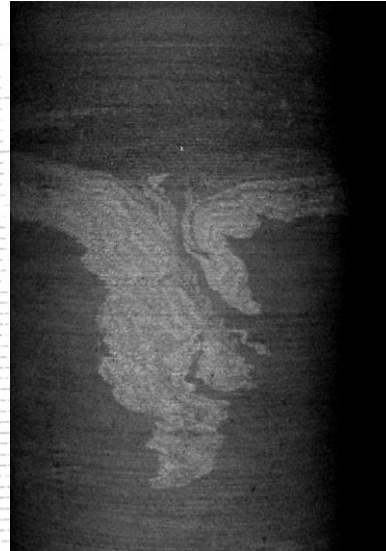
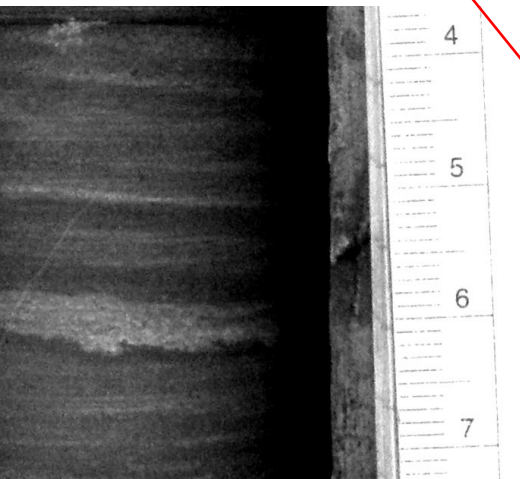
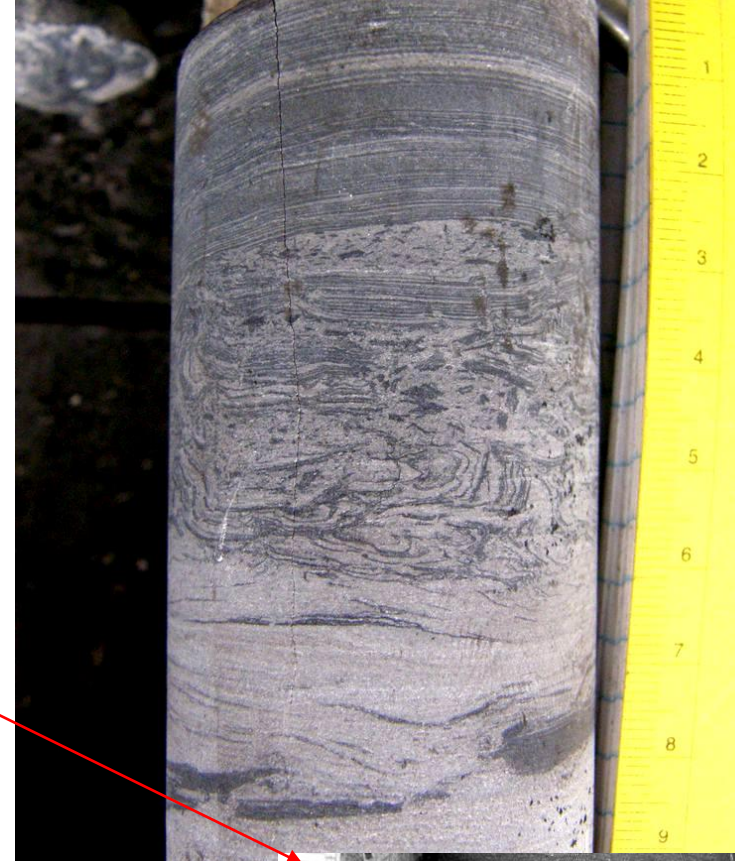
turbiditní proud

postsedimentární struktury

deformace nezpevněného sedimentu

- konvolutní zvrstvení
- stopy po úniku vody
- plaménková str.

vtiskové stopy, ball and pillow



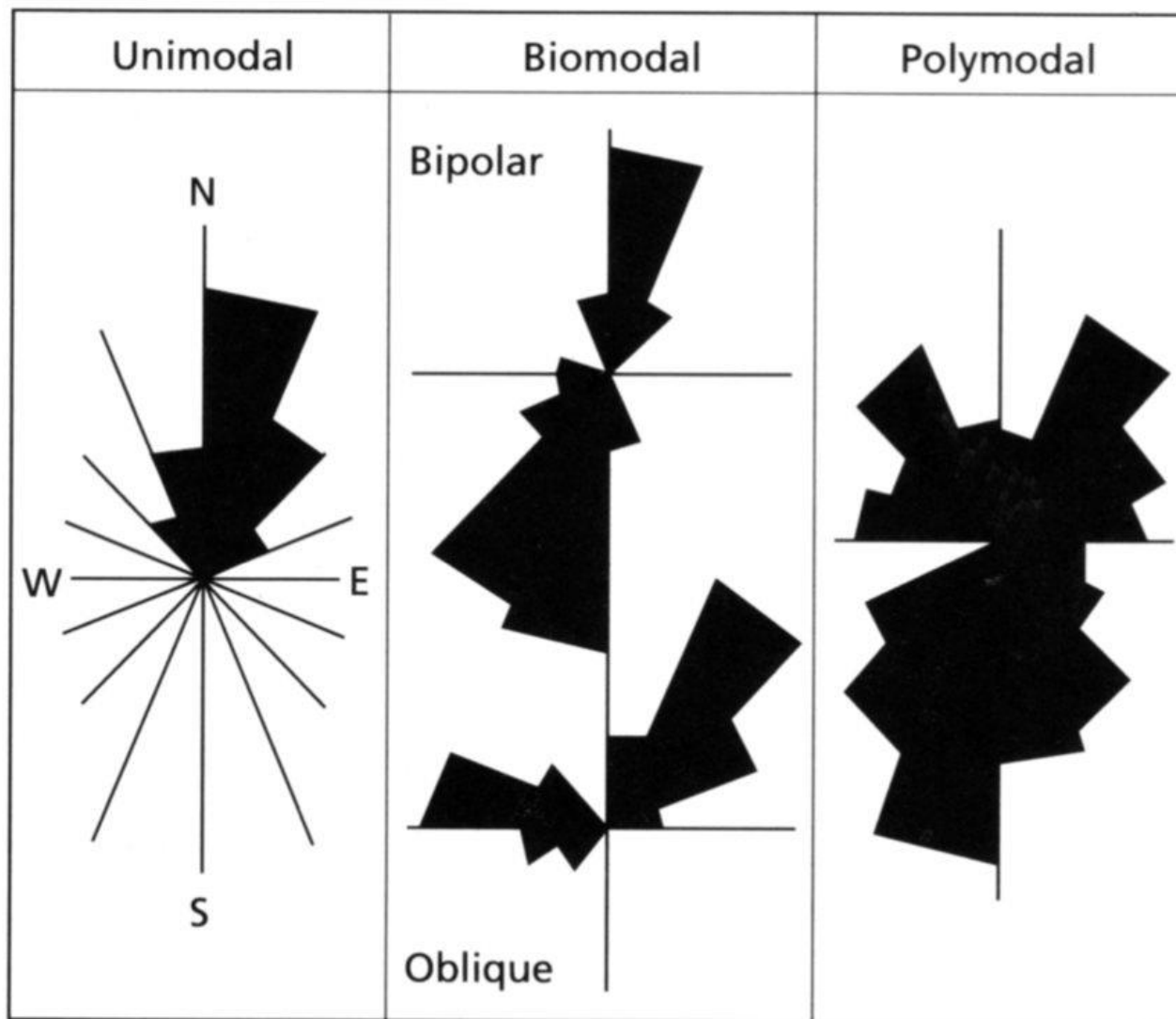


Fig. 2.45 The four common palaeocurrent patterns.

biogenní struktury – fosilní stopy (ichnofosílie, bioturbace)

Feeding structures

Chondrites

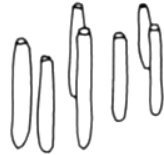


Zoophycos



Dwelling structures

Skolithos



Ophiomorpha



Grazing traces

Nereites



Helminthoides



Common in deep-water sequences

Crawling traces

Cruziana



Vertebrate footprints



Thalassinoides

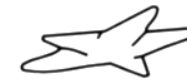


Diplocraterion



Common in shallow-marine deposits

Resting traces



Asteriacites
starfish
impression

Shrimp Burrow Jungle

KREWETKOWA
DZUNGLA



gravitační procesy

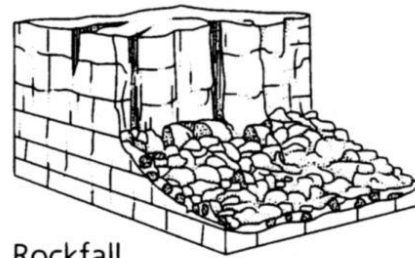
subaerické

skalní řícení (rockfall, debris slide, toppling failure, block glide)

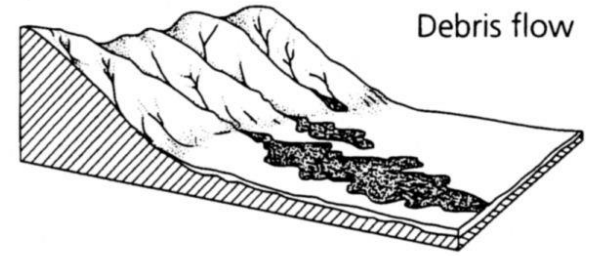
rotační sesuv (slump)

translační skluz (slide)

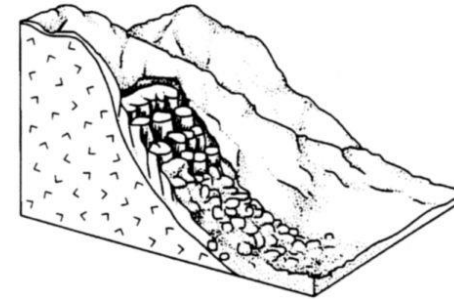
úlomkotok (debris flow)



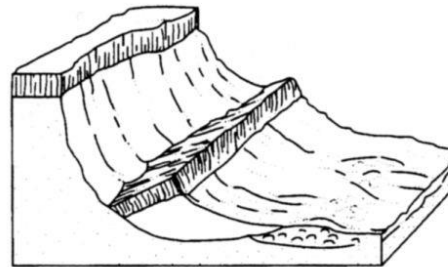
Rockfall



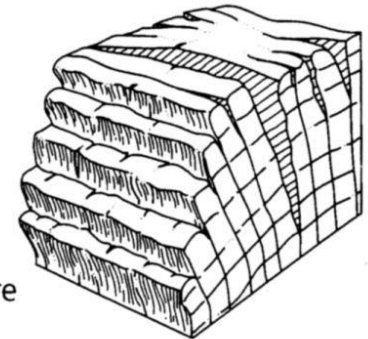
Debris flow



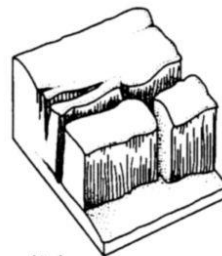
Debris slide



Slump



Toppling failure



Block glide



Rock slide

Fig. 6.1 The primary mechanisms for mass movements based on Varnes (1978) [3].

translační skluz

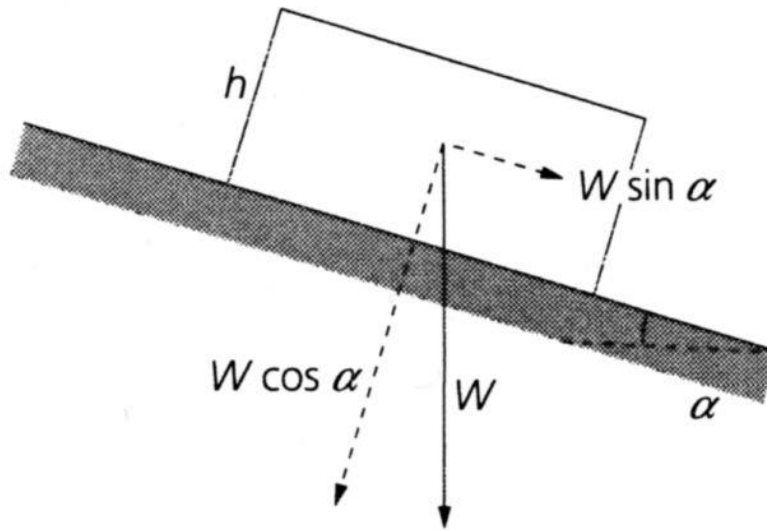


Fig. 6.6 A block of weight W sliding down an inclined plane at an angle α .

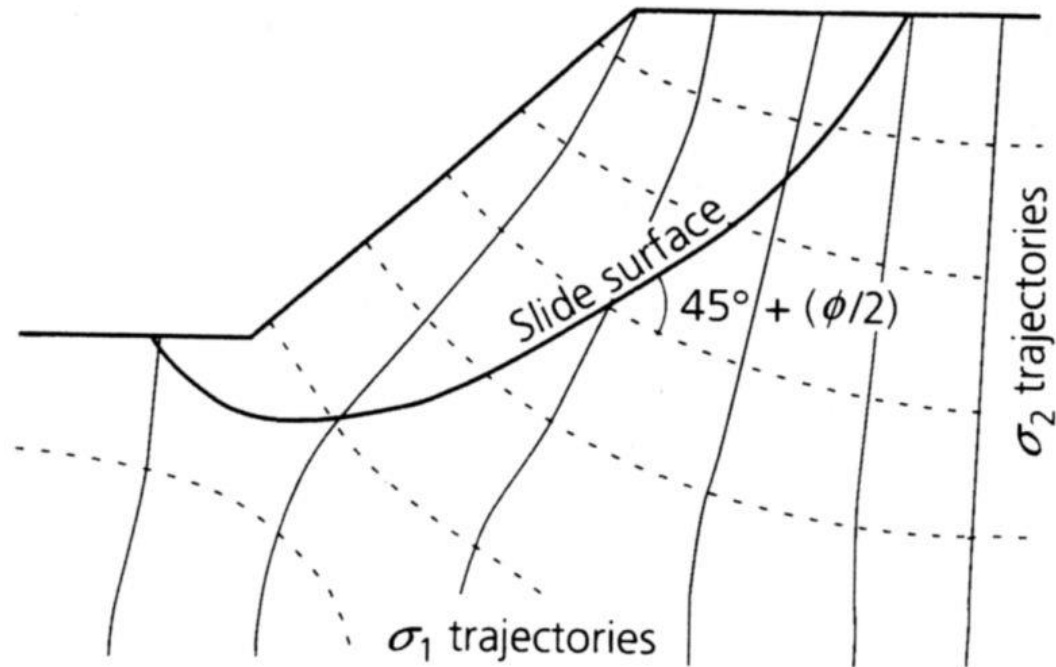
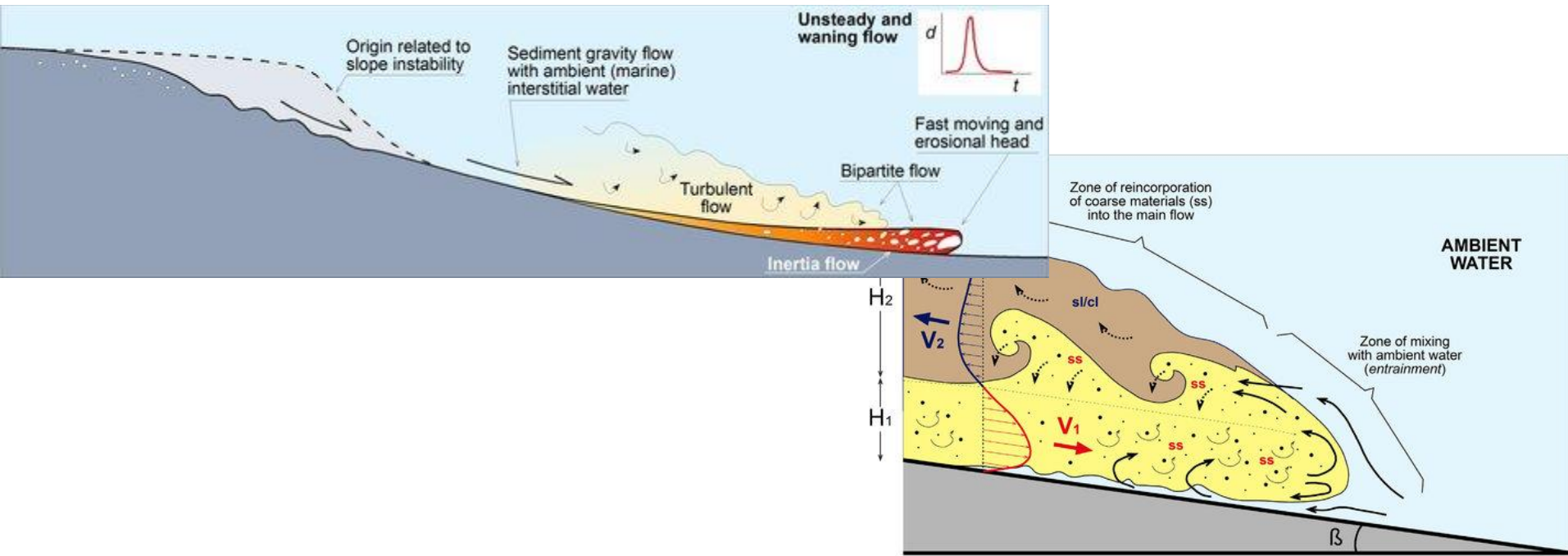
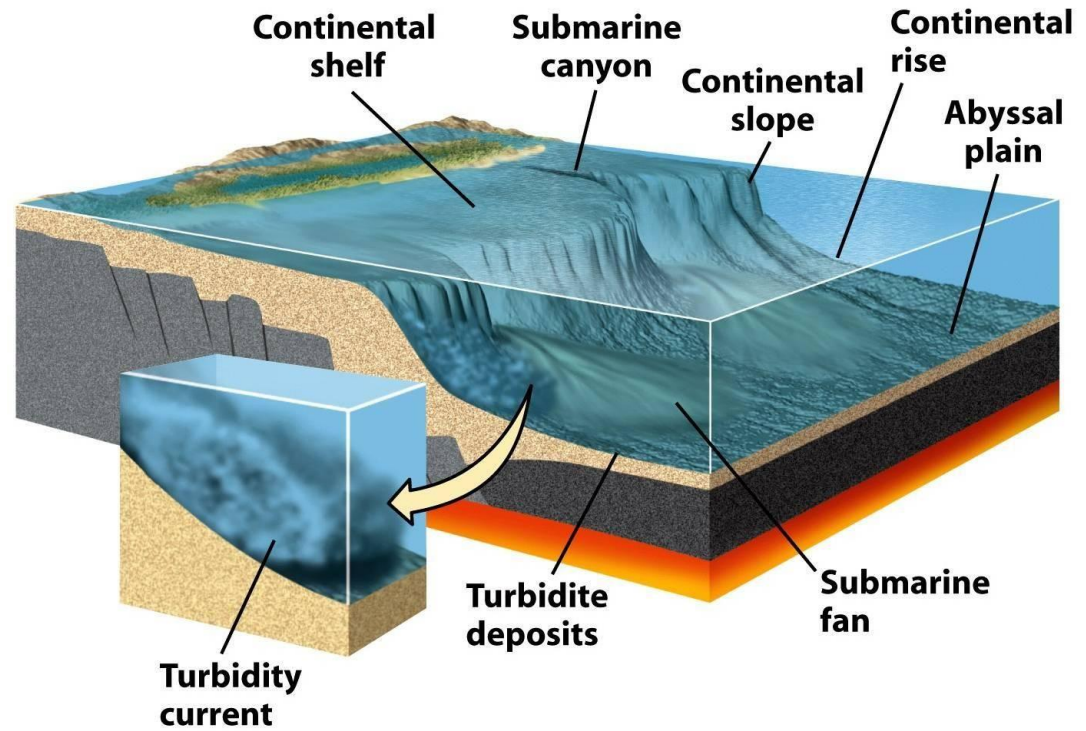


Fig. 6.9 Stress trajectories and failure plane for a short slope. The slide surface is drawn so as to make an angle of $45^\circ + \phi/2$ with the σ_2 trajectories (dashed lines). After Middleton & Wilcock (1994), p.140, [11].

gravitační procesy

subakvatické

turbiditní proud



Boumova sukcese

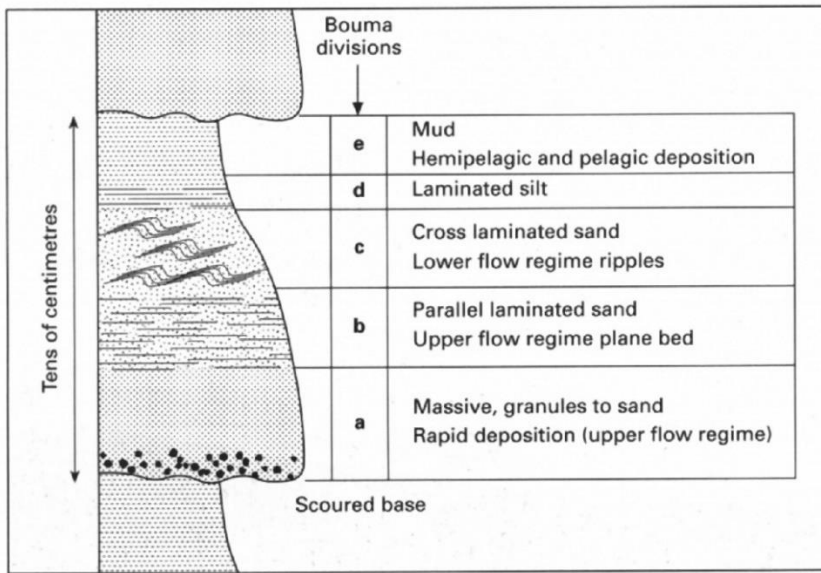
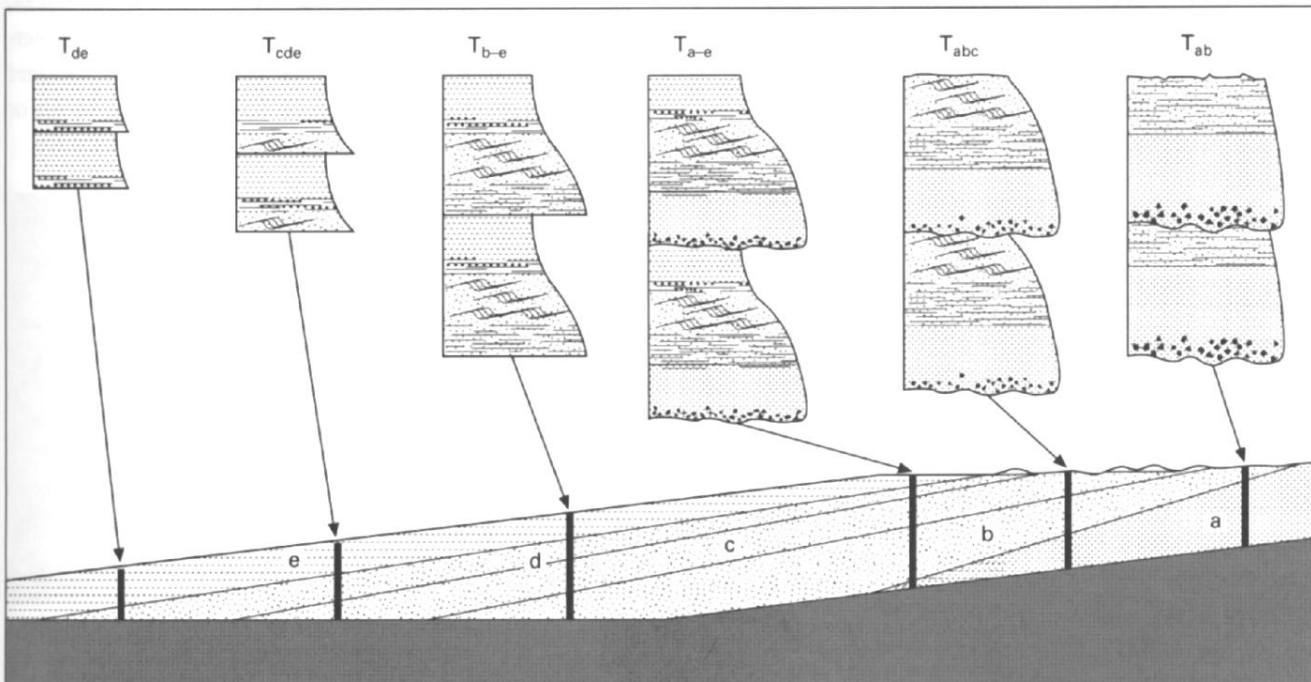
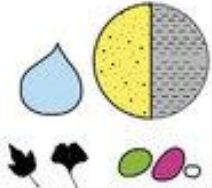
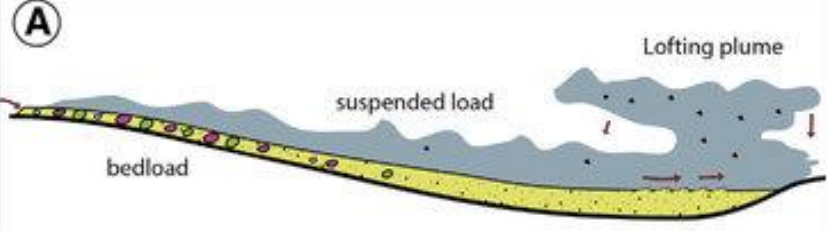
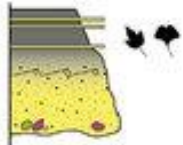
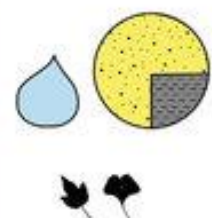
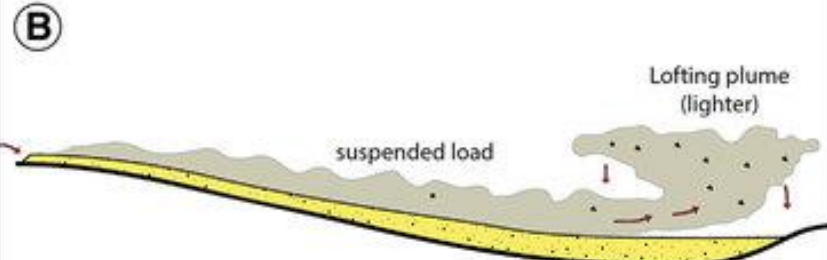
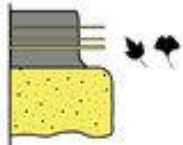
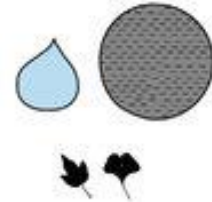





Fig. 4.27 The vertical pattern of grain size variation and sedimentary structures formed in a typical medium-grained turbidite. This is the Bouma sequence, consisting of five divisions: a, b, c, d and e. (After Bouma 1962.)



Flow type & components	Flow behaviour	Deposit
<p style="writing-mode: vertical-rl; transform: rotate(180deg);">SHF</p> 	<p>(A)</p>  <p>bedload</p> <p>suspended load</p> <p>Lofting plume</p>	
<p style="writing-mode: vertical-rl; transform: rotate(180deg);">SHF</p> 	<p>(B)</p>  <p>suspended load</p> <p>Lofting plume (lighter)</p>	
<p style="writing-mode: vertical-rl; transform: rotate(180deg);">MHF</p> 	<p>(C)</p>  <p>suspended load</p> <p>Lofting plume absent</p>	
 <p>sand silt/clay freshwater clasts leaves</p>		

Úlomkotok (debris flow)

- silně jílovitá matrix, masivní
- mechanismus transportu – kohezivita matrix působí binghamovské chování
- produkt – žádné zvrstvení, masivní

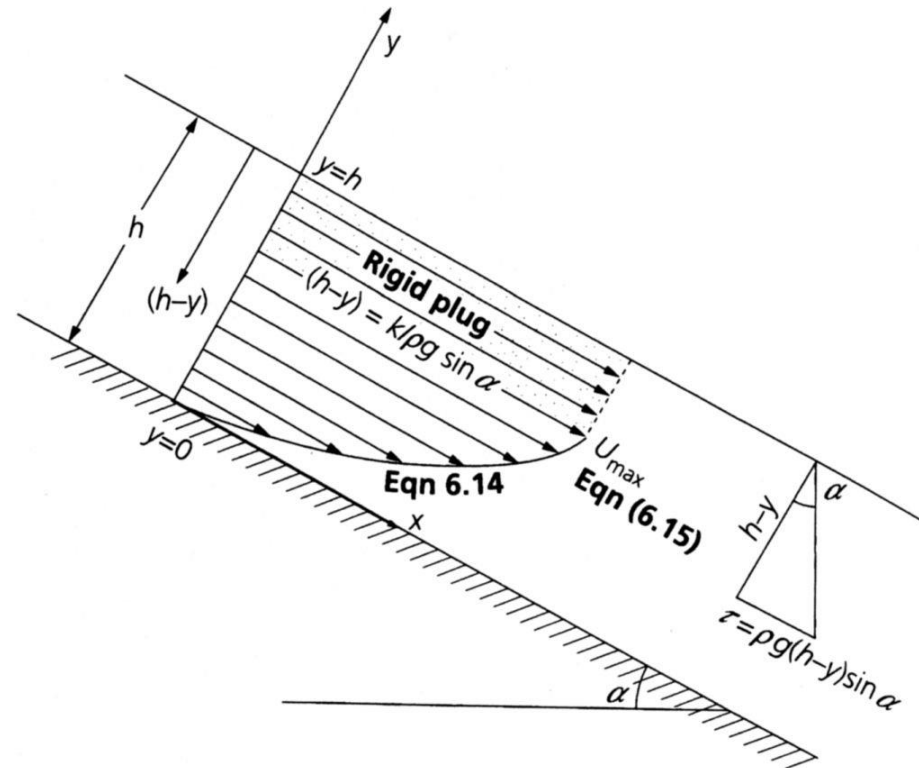


Fig. 6.10 Velocity profile and rigid plug for a Bingham plastic model of debris flows.



Zrnotok (grain flow)

- žádná matrix, nekohezivní
- mechanismus transportu – interakce zrn
- produkt – negativní gradace

