

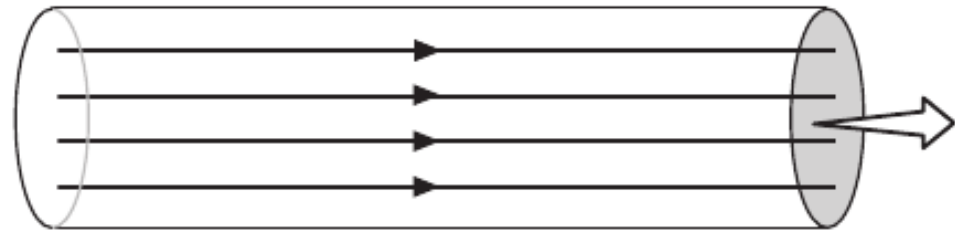
Transporte de sedimentos

Transporte de partículas por fluidos

Tipos de fluxo

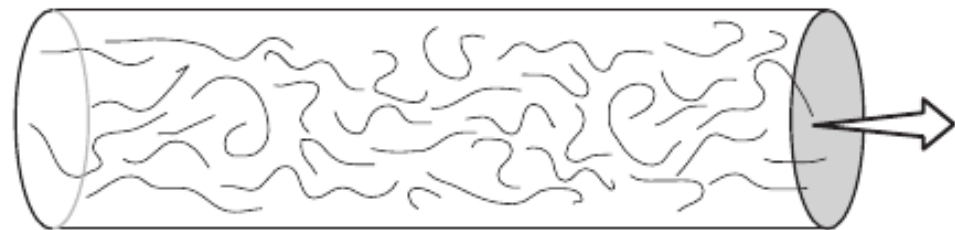
- Fluxo laminar
- Fluxo turbulento

Laminar flow



At all points in the flow all molecules are moving downstream

Turbulent flow



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

Número de Reynolds:

$$\mathbf{Re = V \times L \times d / u}$$

Onde V = velocidade do fluxo

L = Profundidade do canal ou diâmetro de um cano

u = viscosidade

D = densidade do fluido

Se $\mathbf{Re} < 500$ o fluxo é laminar

Se $\mathbf{Re} > 2000$ é turbulento

Há uma faixa de transição.

Fluxos naturais laminares incluem fluxos de lama e derrames de lava (devido a sua alta viscosidade).

Água e ar são normalmente turbulentos.

Fluxos canalizados

Número de Reynolds (Re):

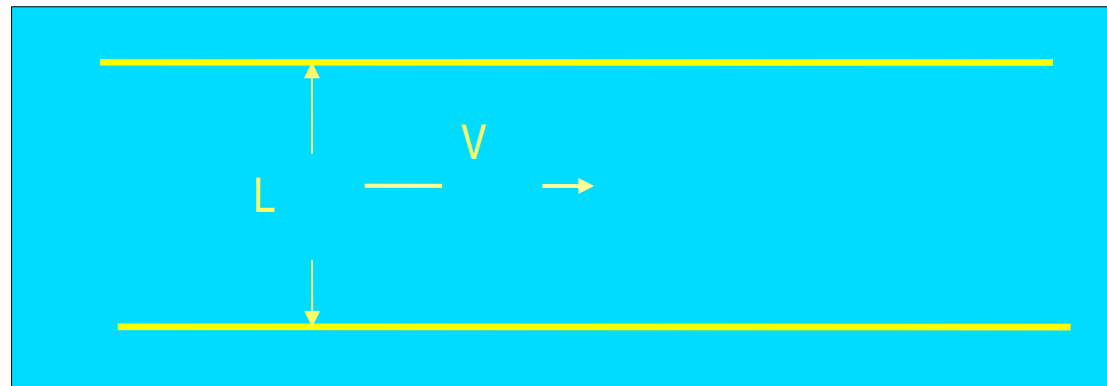
$Re < 500$ (laminar)

$500 < Re < 2000$ (transição)

$Re > 2000$ (turbulento)

$$Re = VLd/u$$

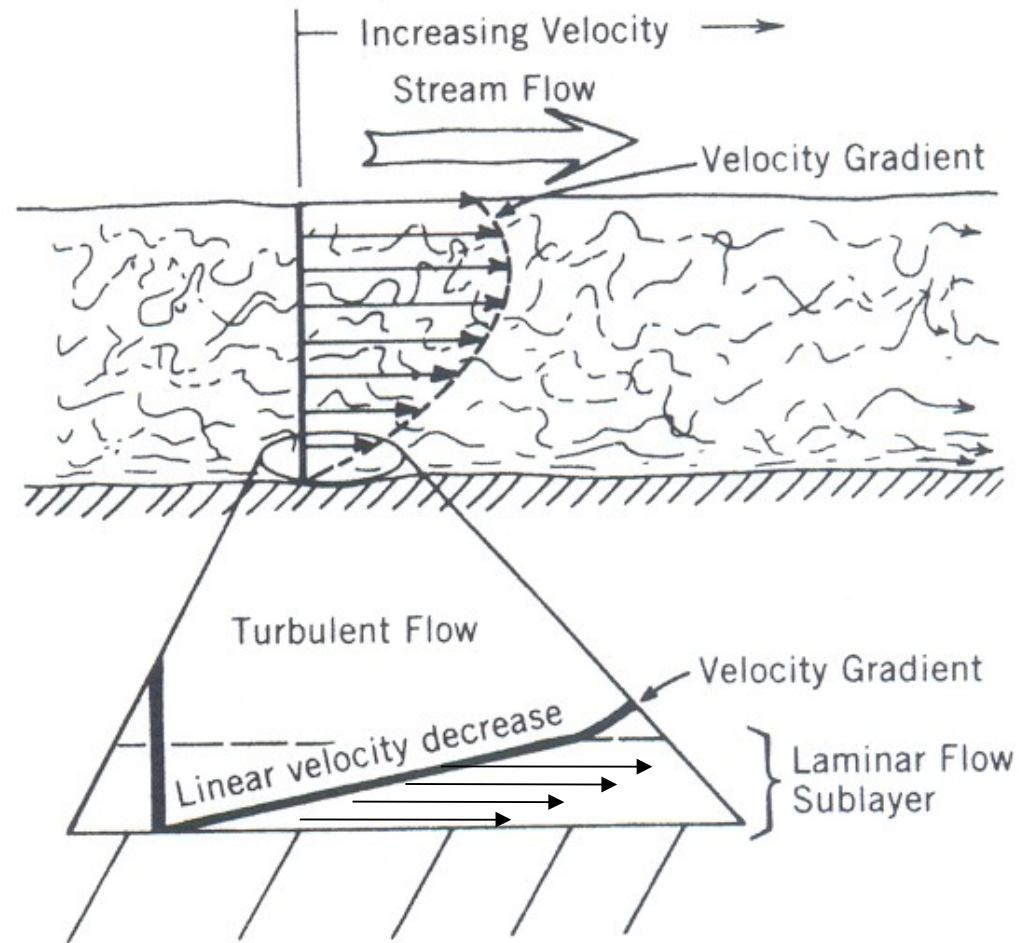
d – densidade
u - viscosidade



Fluxo laminar passando a turbulento



Fluxo de água em um canal



Subleito viscoso e turbulência

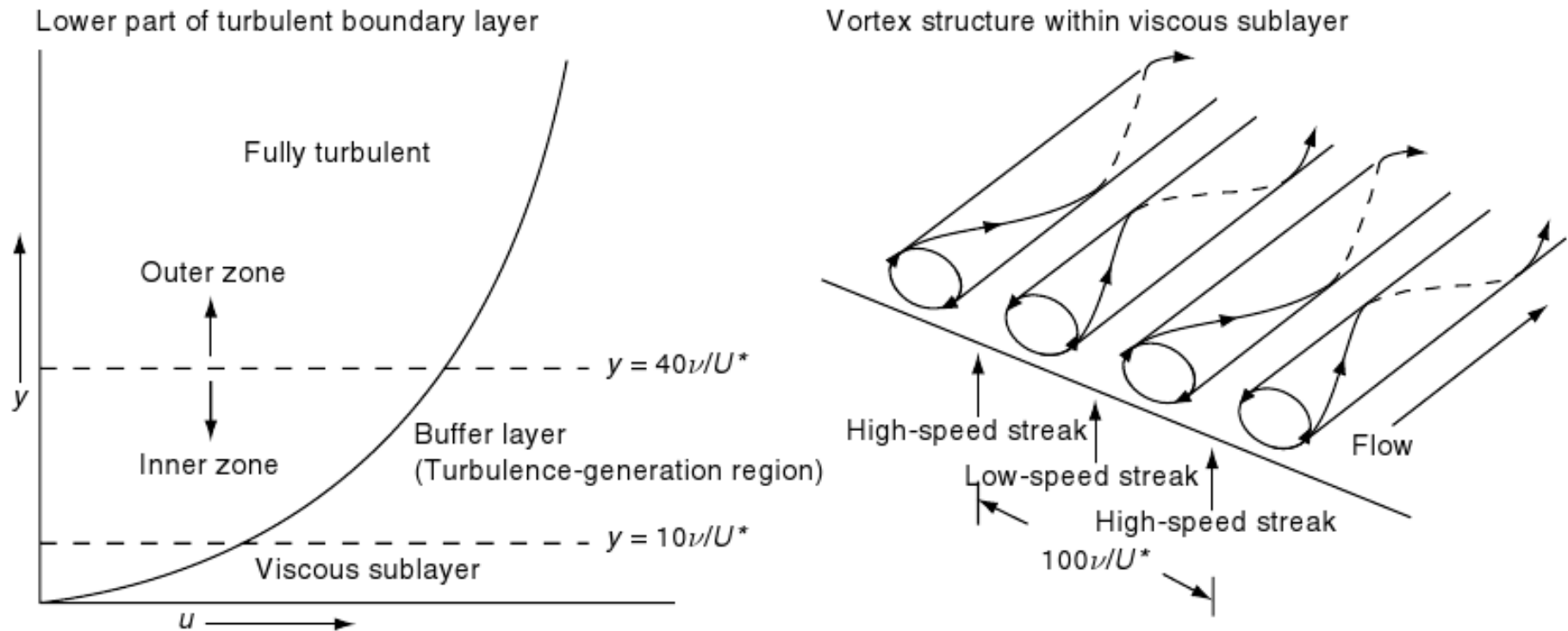
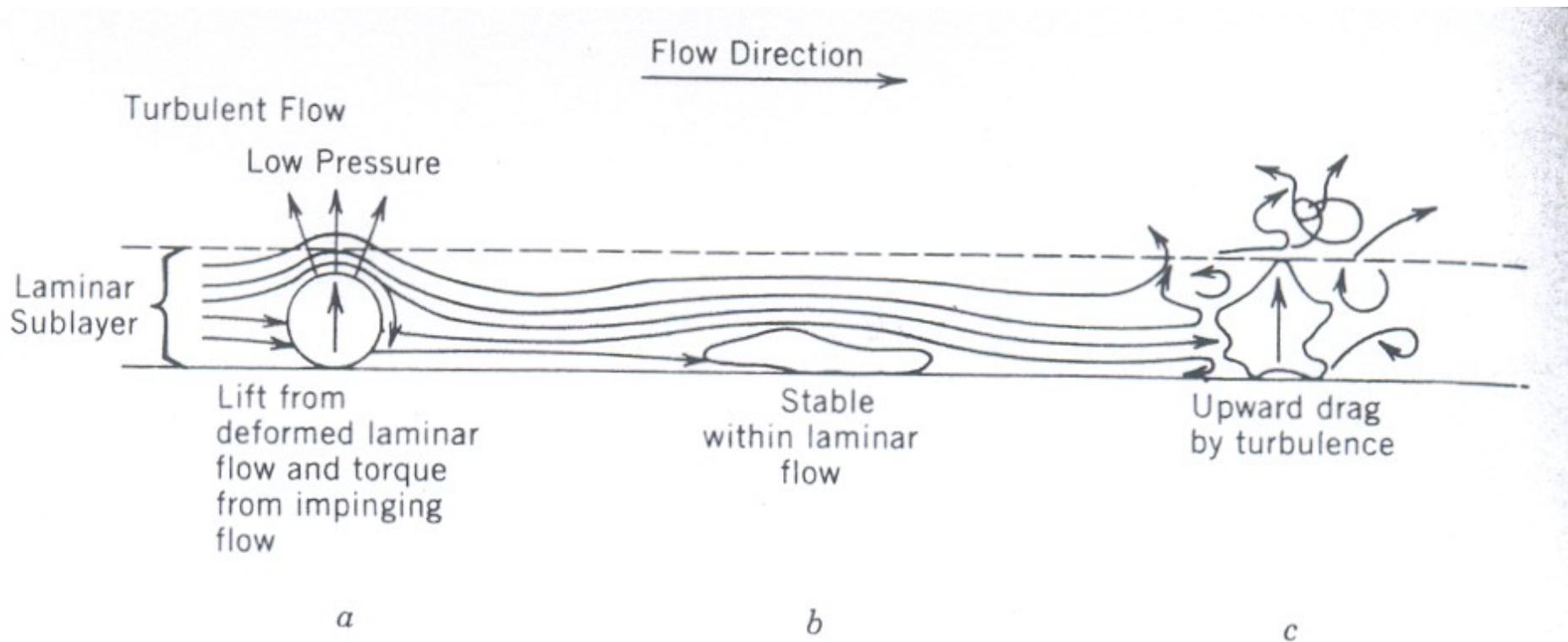


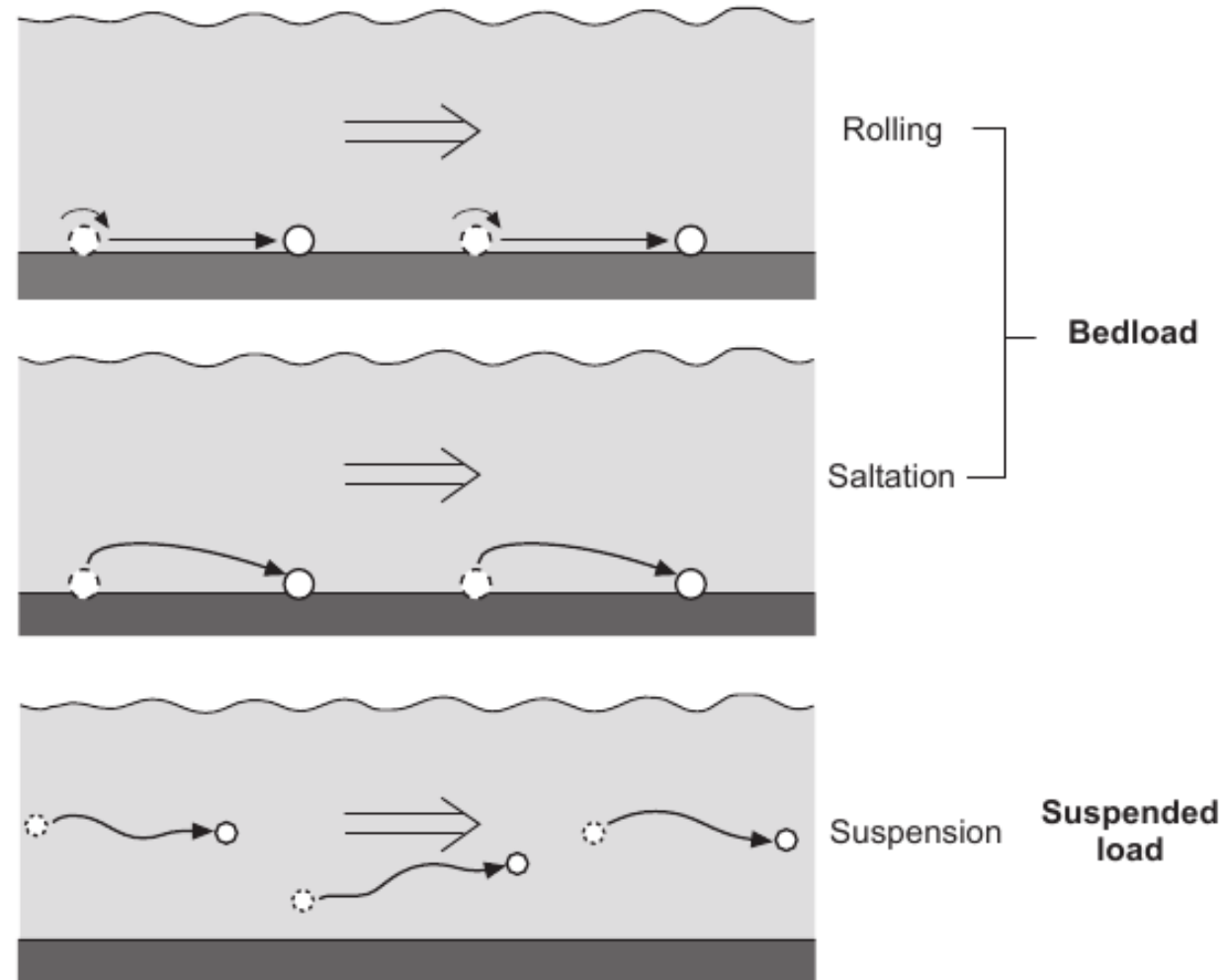
FIGURE 5.8. Main features of the structure of turbulent boundary layers. Modified from Bridge (2003).

Transporte de partículas sedimentares



Modos de transporte

- Arrasto e rolamento
- Saltação
- Suspensão



Modos de transporte

- Arrasto e rolamento
- Saltação
- Suspensão

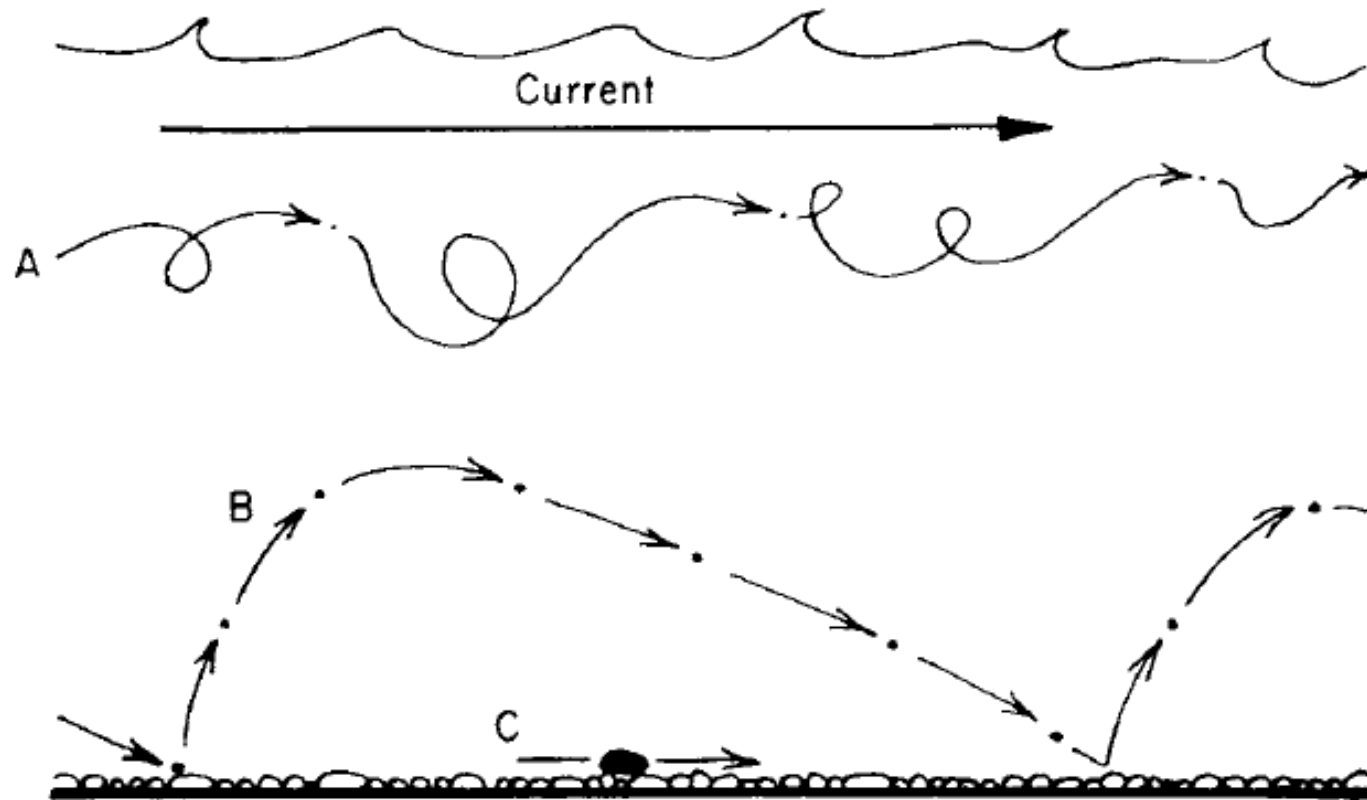


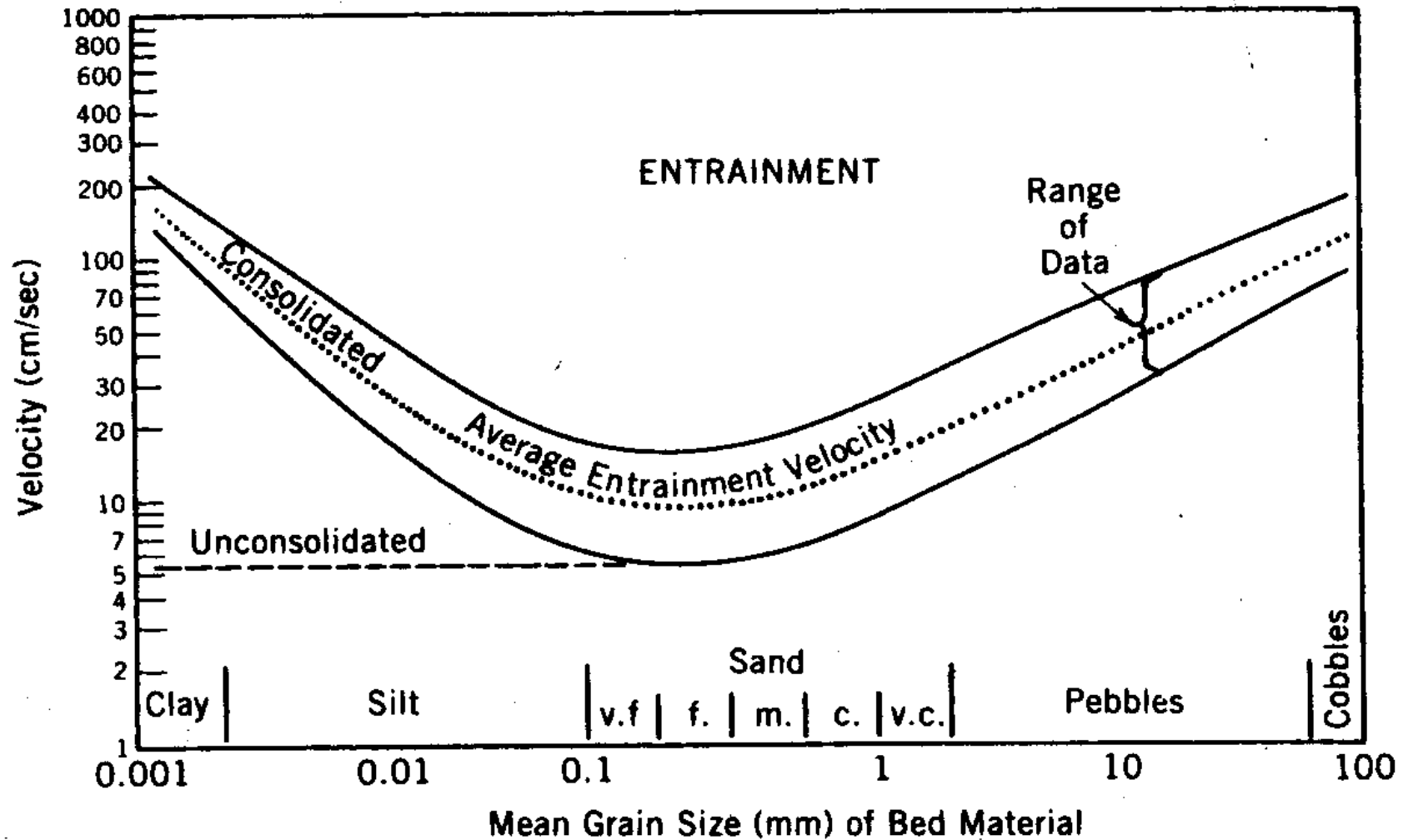
Fig. 4.3. The mechanics of particle movement. (A) Suspension. (B) Bouncing (saltation). (C) Rolling.

Filmes

Carga de fundo

Rolamento

Diagrama de Hjulström-Sundborg



*Leito coesivo

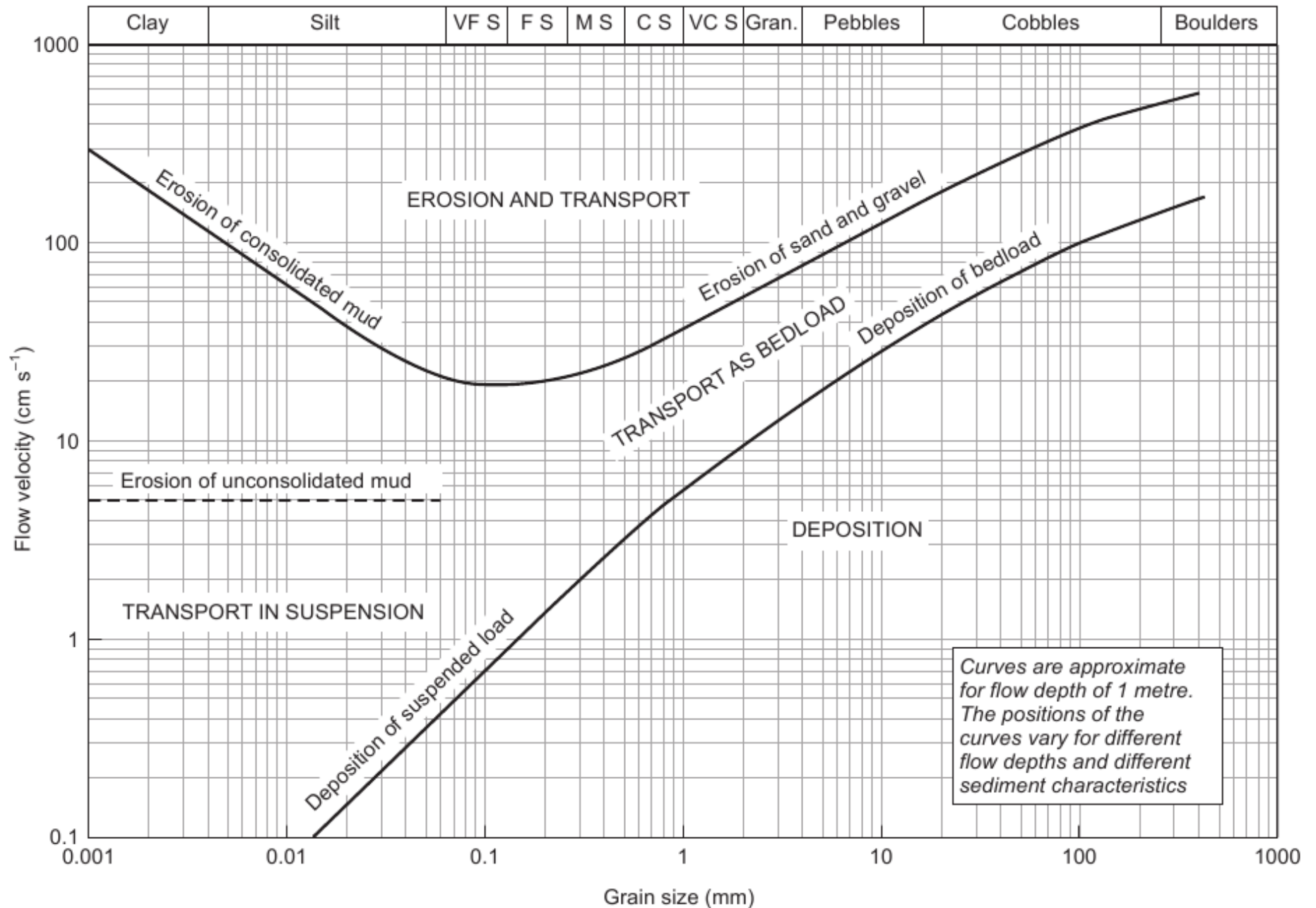
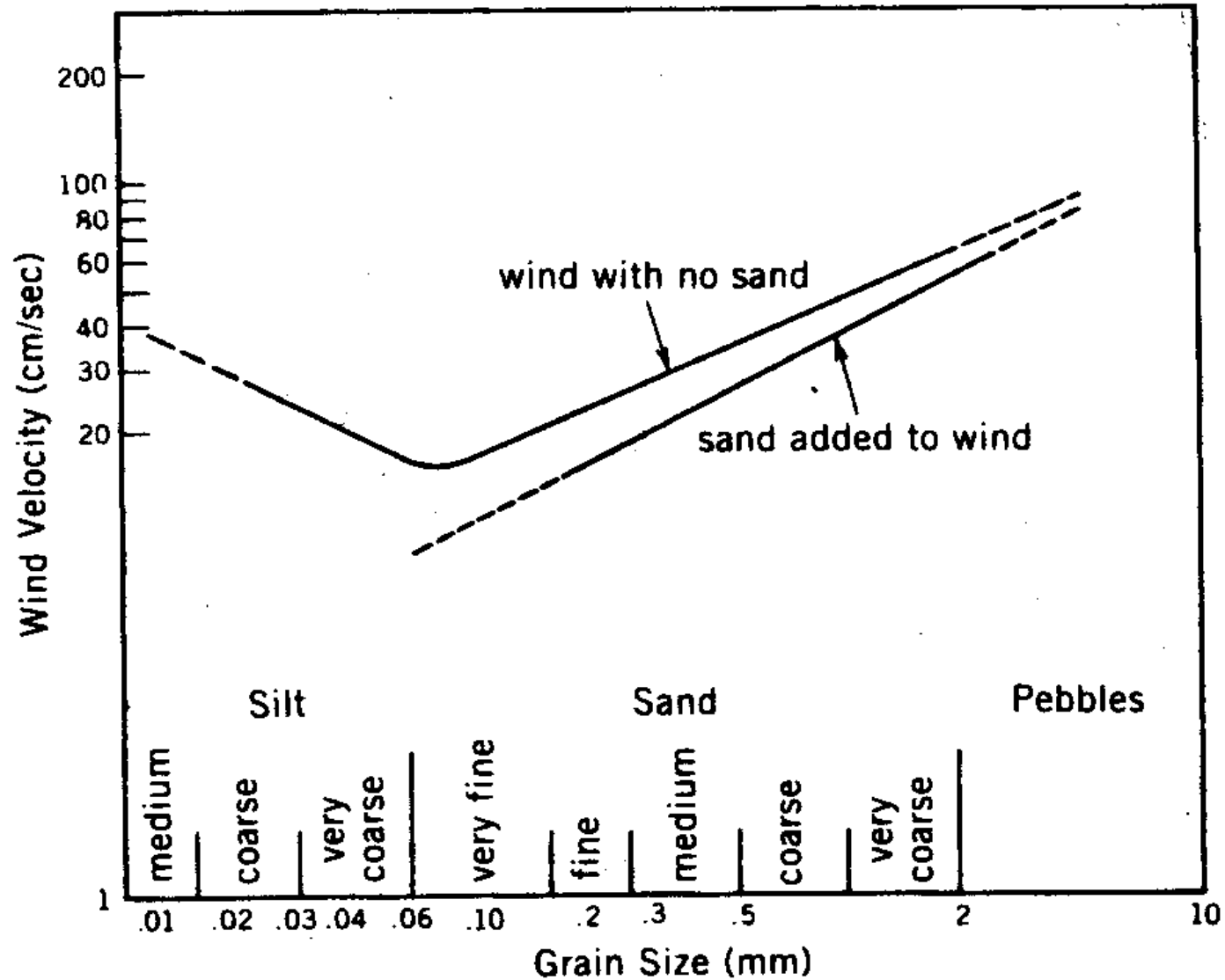
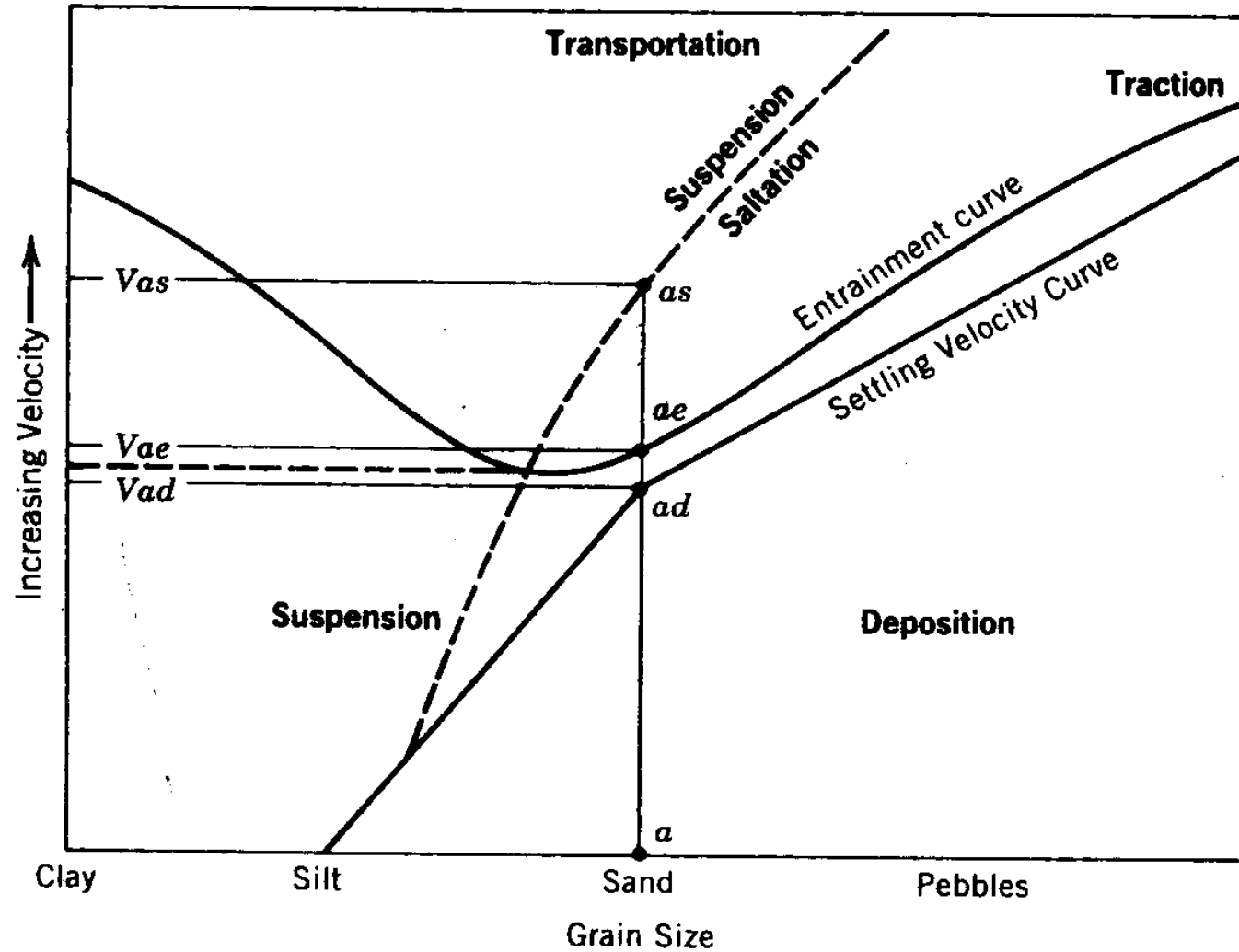


Fig. 4.5 The Hjulstrom diagram shows the relationship between the velocity of a water flow and the transport of loose grains. Once a grain has settled it requires more energy to start it moving than a grain that is already in motion. The cohesive properties of clay particles mean that fine-grained sediments require relatively high velocities to re-erode them once they are deposited, especially once they are compacted. (From Press & Siever 1986.)

Diagrama de Bagnold



Velocidades de transporte e deposição



*Segregação granulométrica

Regimes de Fluxo

Se um fluxo tem velocidade superior à velocidade de propagação de ondas em sua superfície, ele é chamado supercrítico. Se não, é subcrítico.

Esses dois tipos de fluxo têm características diferentes e implicam em formas de leito diferentes.

Para reconhecer o regime de um fluxo, basta determinar seu número de Froude.

Se $Fr > 1$, o fluxo é supercrítico.

Se $Fr < 1$, o fluxo é subcrítico.

$$Fr = \frac{V}{\sqrt{gh}}$$

Regimes de Fluxo

Deduzindo regimes de fluxo:

$$E_k = mv^2/2$$

$$E_p = mgh$$

Considerando-se a lâmina d'água para uma dada posição do canal, com a altura do fundo fixa.

$$E_t = hL\rho v^2/2 + hL\rho gh$$

$V \cdot h$ é constante para vazão constante = Q

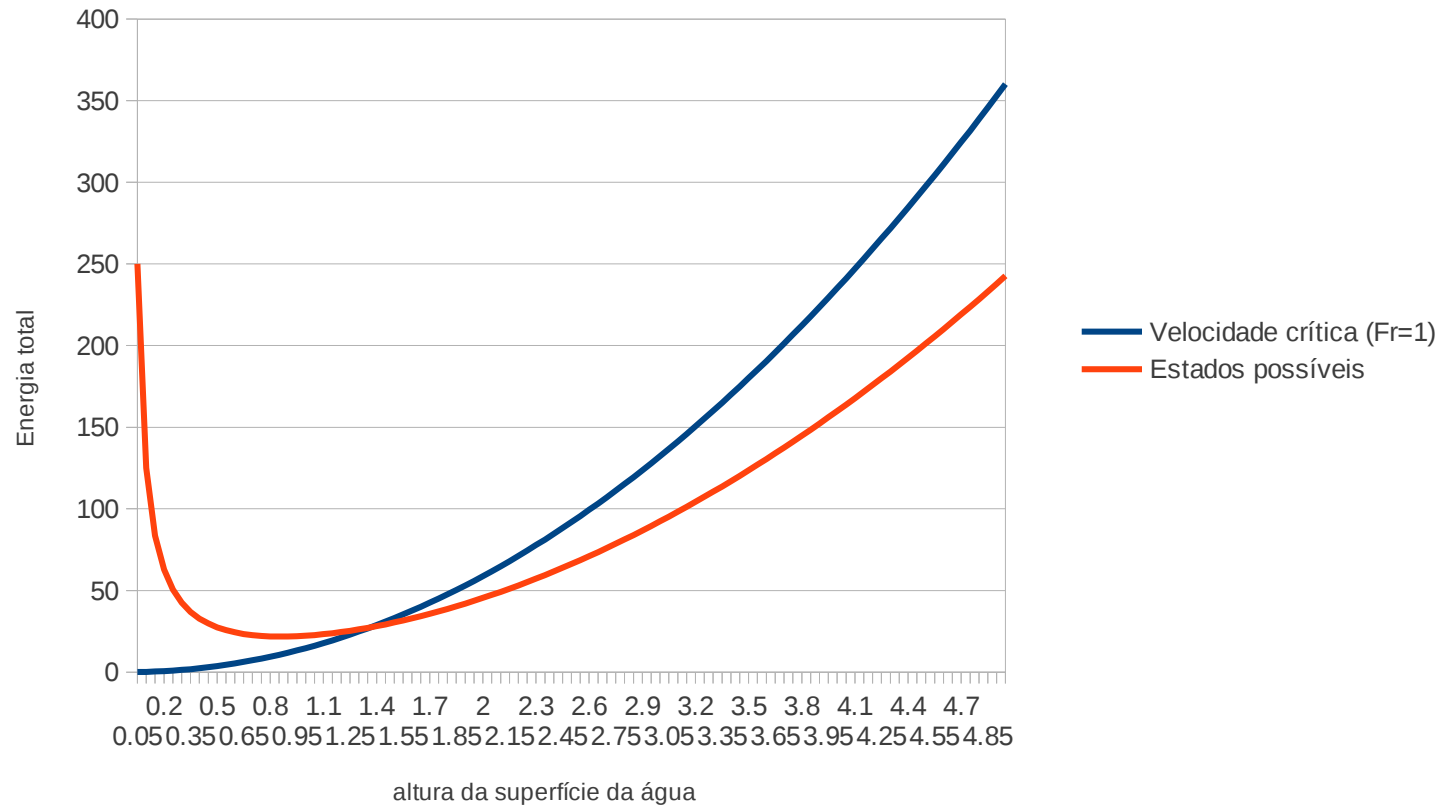
$$v = Q/hL$$

$$E_t = (hL\rho \cdot (Q/h)^2 \cdot 1/2) + (Lg\rho h^2)$$

$$E_t = L\rho \cdot ((Q^2/2h) + (h^2g))$$

Regimes de Fluxo

Energia total por altura



Comparando com o gráfico do h crítico para $Fr=1$

$$V_c = 1 \cdot (gh)^{1/2}$$

Então:

$$E_t = 3/2 \cdot h^2 \cdot g$$

Salto Hidráulico

A passagem do fluxo supercrítico para o subcrítico é brusca, causando o salto hidráulico



Velocidade de ondas de superfície

Velocidade de ondas de superfície na água:

Se a profundidade é maior que $L/2$ - Ondas de águas profundas $\rightarrow C=(gL/2\pi)^{1/2}$

Onde L é o comprimento de onda.

Se a profundidade é menor que $L/2$ – Ondas de águas rasas $\rightarrow C=(gD)^{1/2}$

Onde D é a profundidade

Wave Type	Typical Wavelength	Disturbing Force	Restoring Force
Capillary wave	< 2 cm	Wind	Surface tension
Wind wave	60-150 m (200-500 ft)	Wind over ocean	Gravity
Seiche	Large, variable; a function of basin size	Change in atmospheric pressure, storm surge	Gravity
Seismic sea wave (tsunami)	200 km (125 mi)	Faulting of sea floor, volcanic eruption, landslide	Gravity
Tide	Half the circumference of Earth	Gravitational attraction, rotation of Earth	Gravity

Regimes de Fluxo

	Fluxo Superior	Fluxo Inferior
N Froude	> 1	< 1
relação superfície da água / topografia do fundo	Em fase	Fora de fase
turbulência	alta	moderada
ocorrência	Águas muito rasas ou grandes enchurradas	Maior parte das correntes naturais

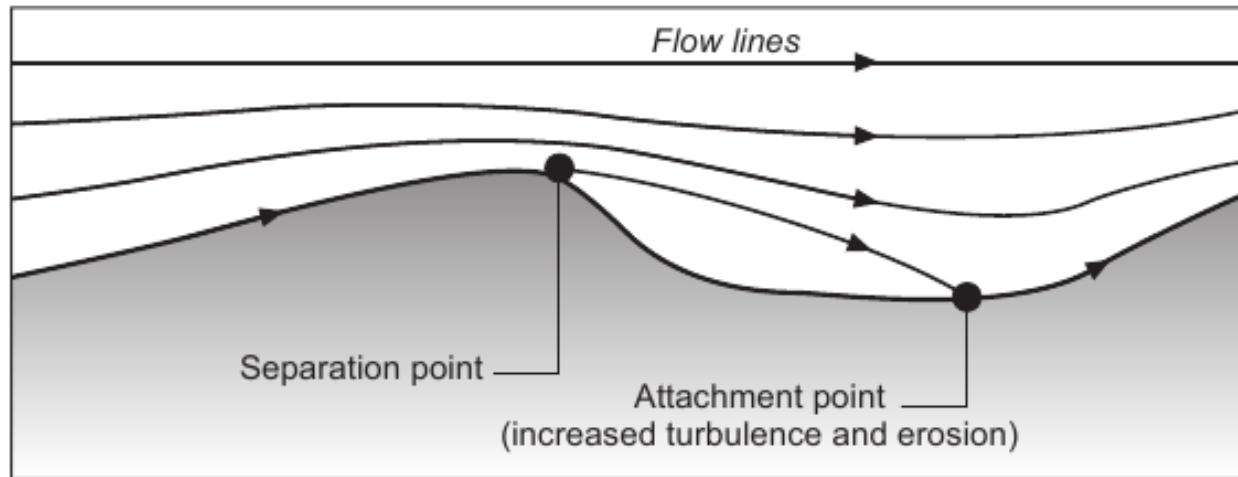
Formas de leito e estratificações geradas por fluxo unidirecional

Origem das formas de leito

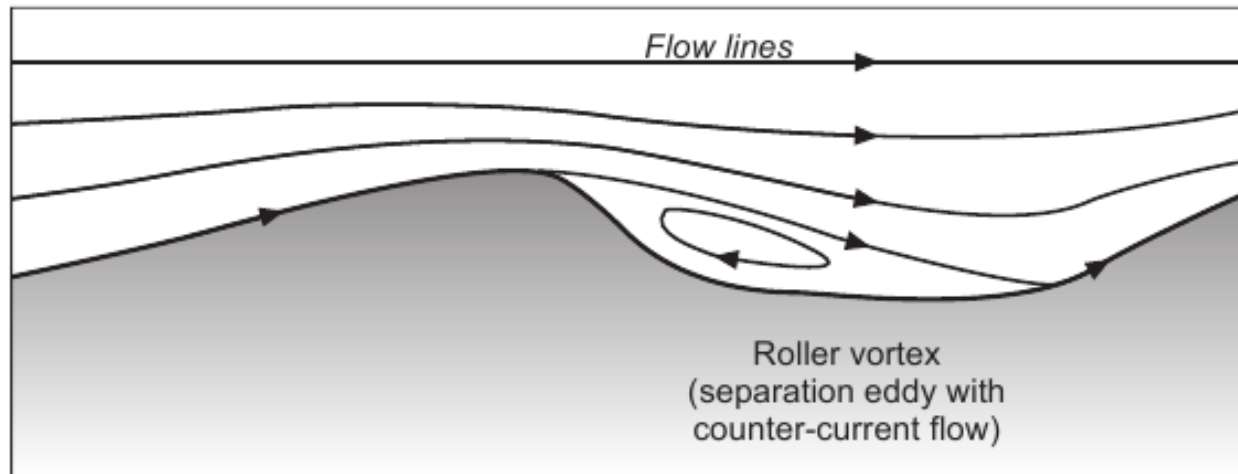
O transporte de grãos por saltação gera acumulações provisórias de Sedimento no fundo, conhecidas como formas de leito.

Os fluxos estáveis geram formas de leito previsíveis, relacionadas Às características do fluxo (velocidade, profundidade, regime de fluxo)

1. Erosion in the trough of a bedform



2. Development of counter-currents in lee of bedform



Separação de fluxo

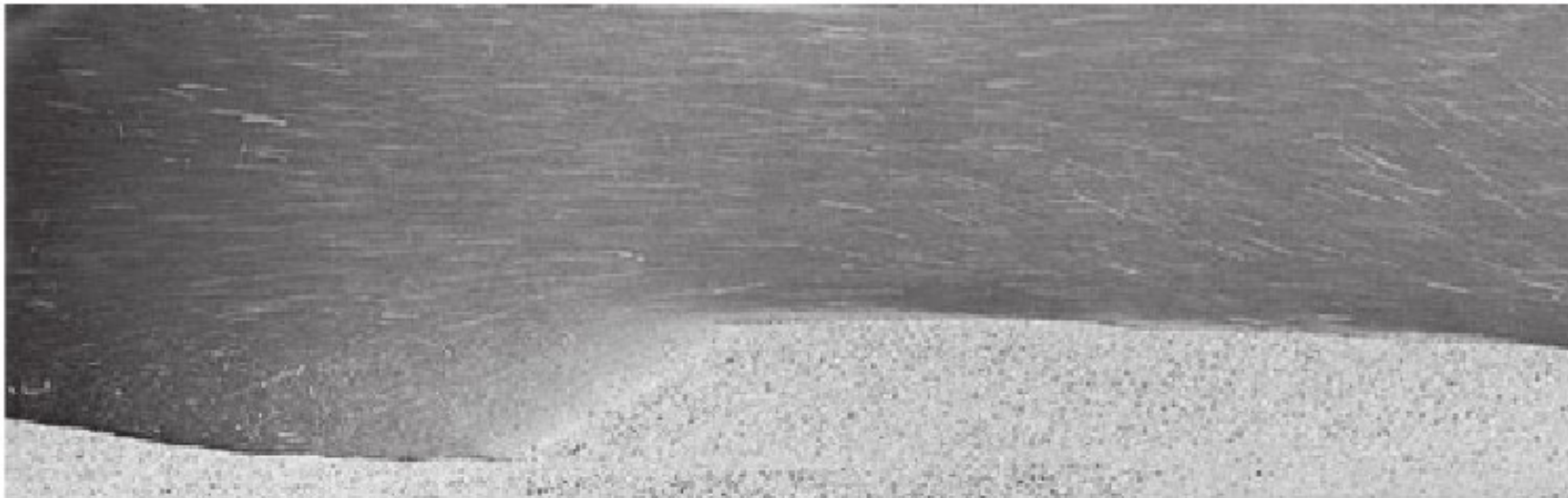


FIGURE 5.14. (A) Vertical profiles of time-averaged flow velocity and hydrostatic pressure associated with flow separation. (B) Flow separation on the lee side of a dune. Tracers show the flow pattern in the separation vortex. Flow is to the left. Modified from Bridge (2003).

A separação do fluxo pelas formas de leito gera áreas de deposição preferencial.

Formas de leitos comuns

- Ondulações

 - Por corrente

 - Por ondas

- Dunas subaquáticas

- Leito plano

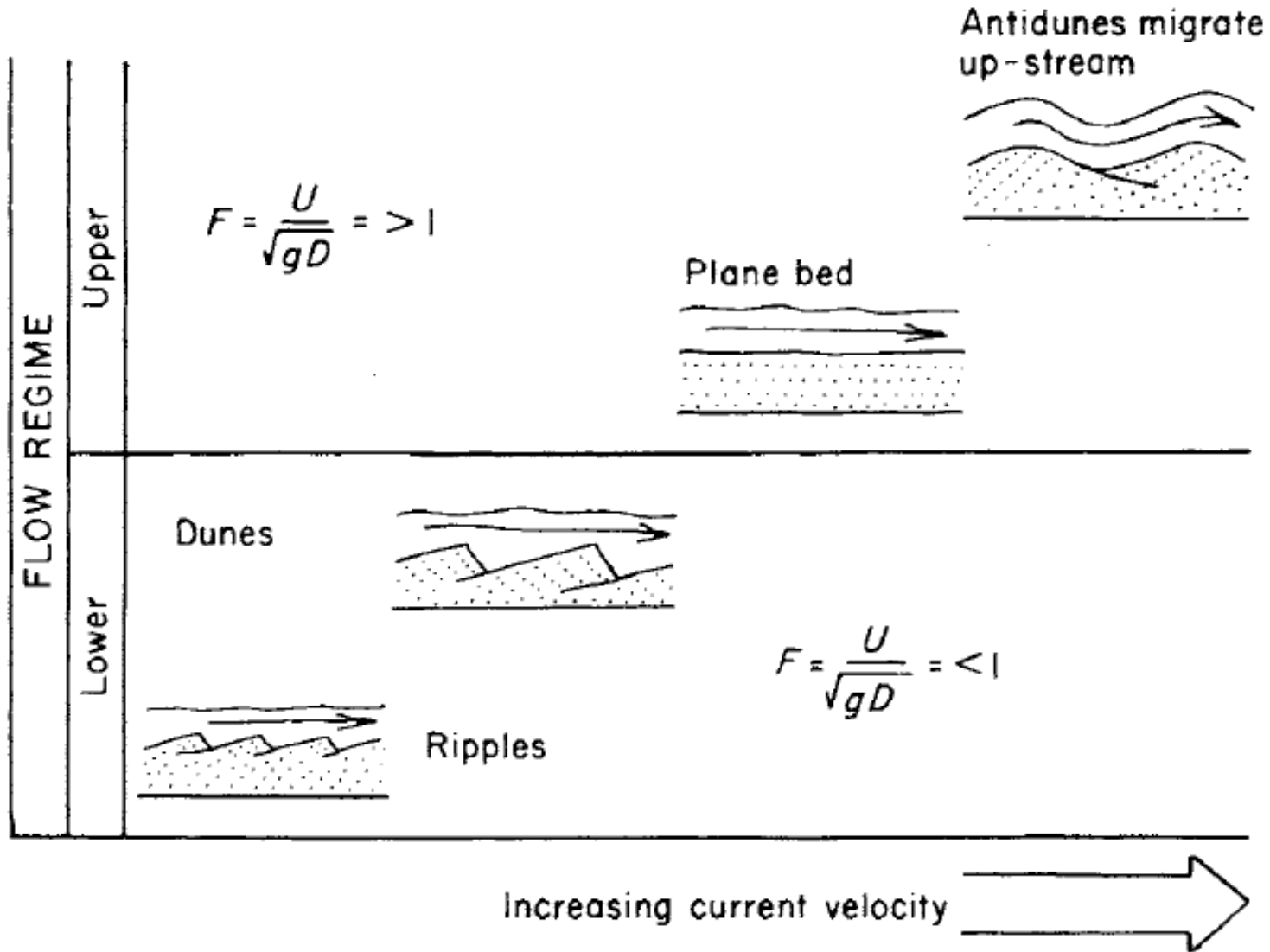
- Antidunas

- Barras compostas

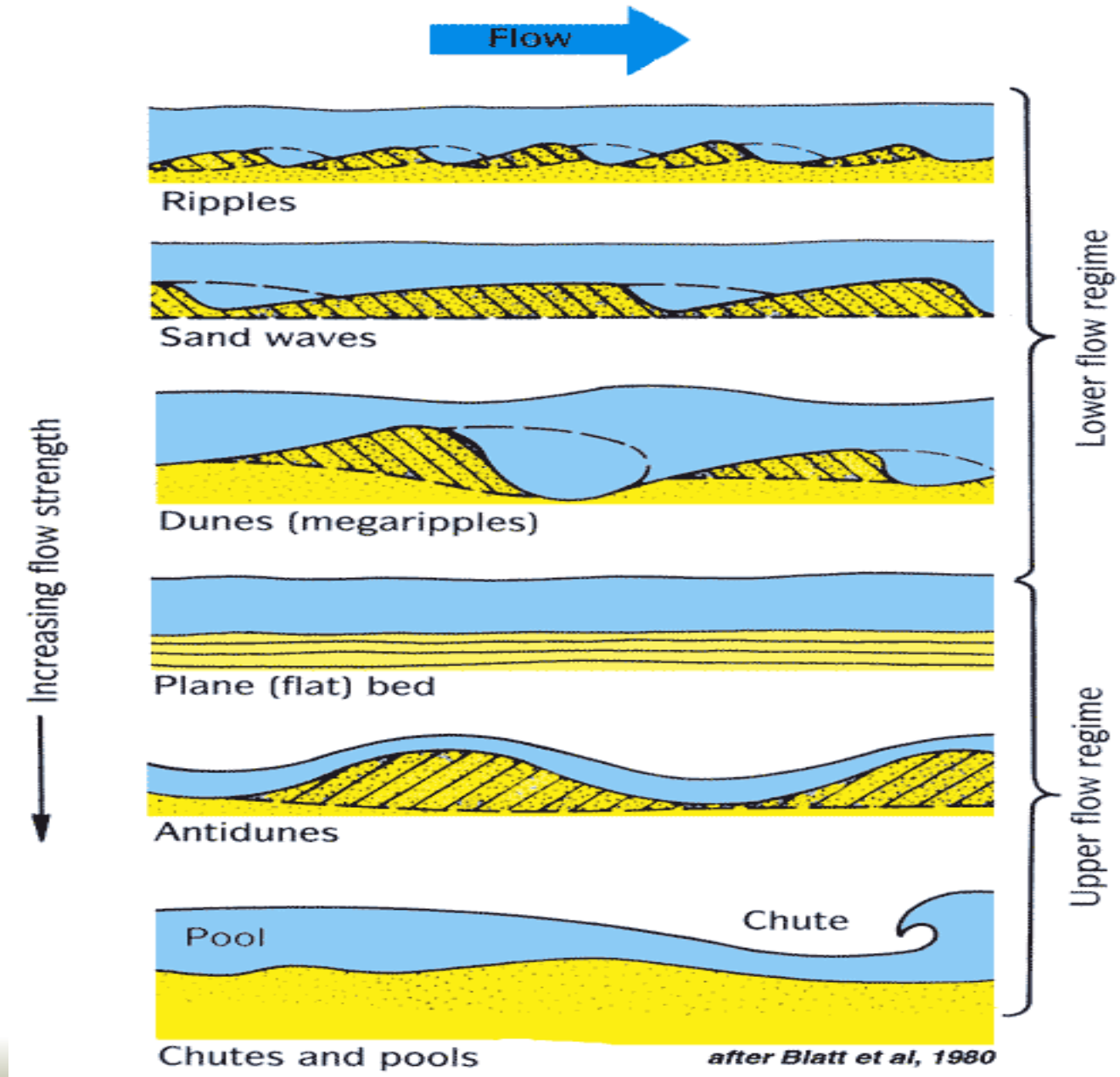
 - Normais (monolitológicas)

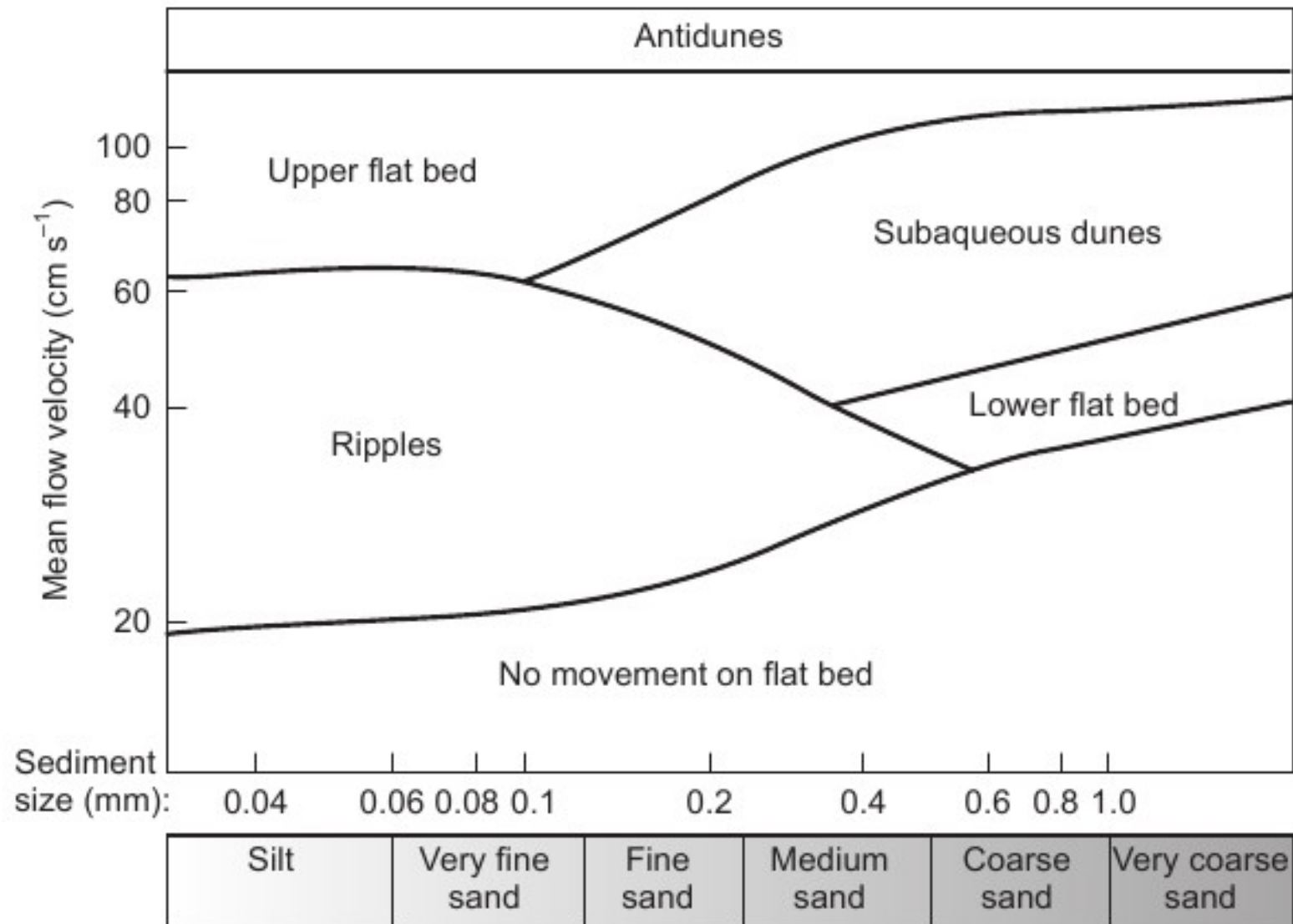
 - Heterolíticas

Formas de leitos comuns



Velocidade do fluxo e formas de leito





Filmes

Migração de ondulações de corrente

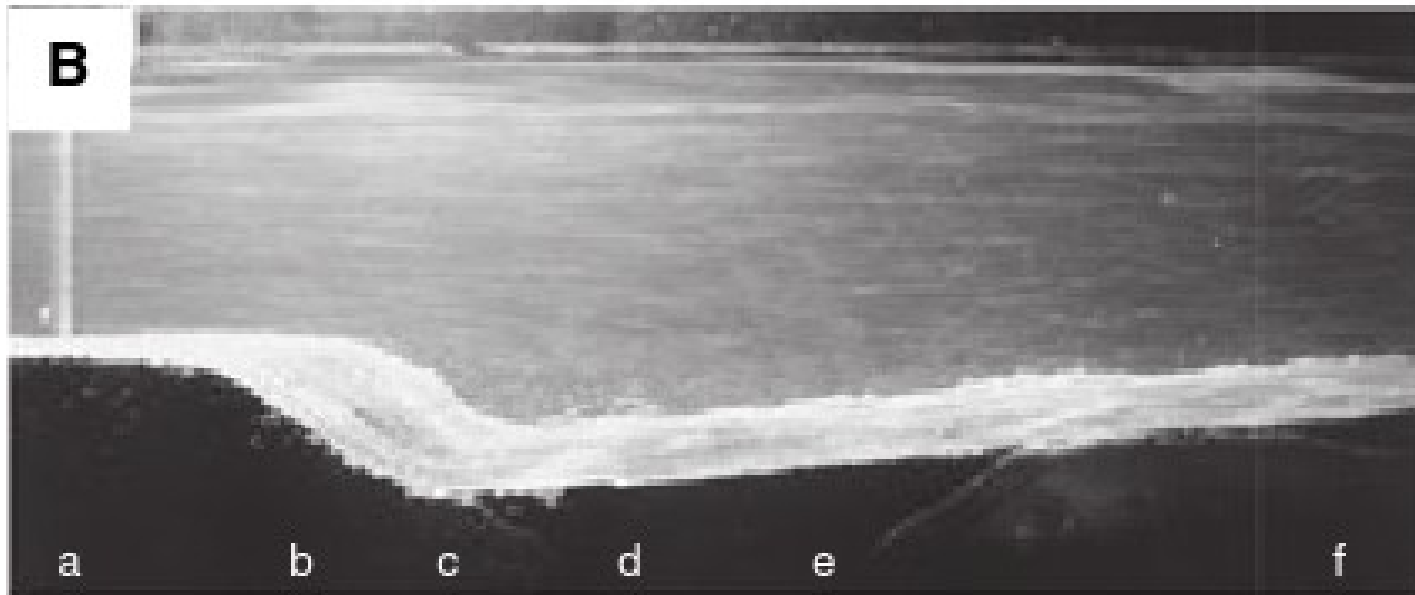
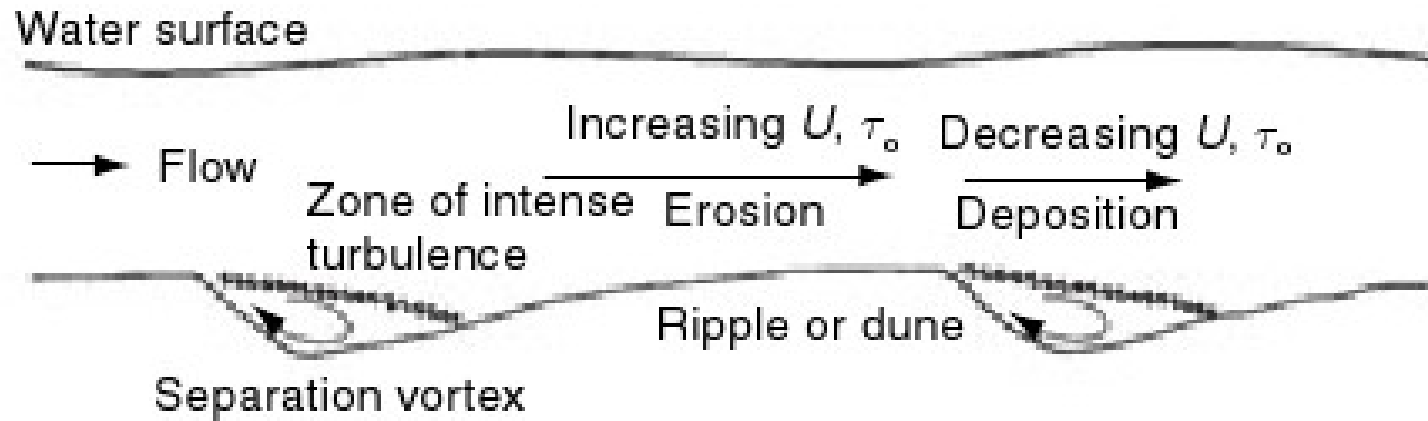
Ondulações cavalgantes

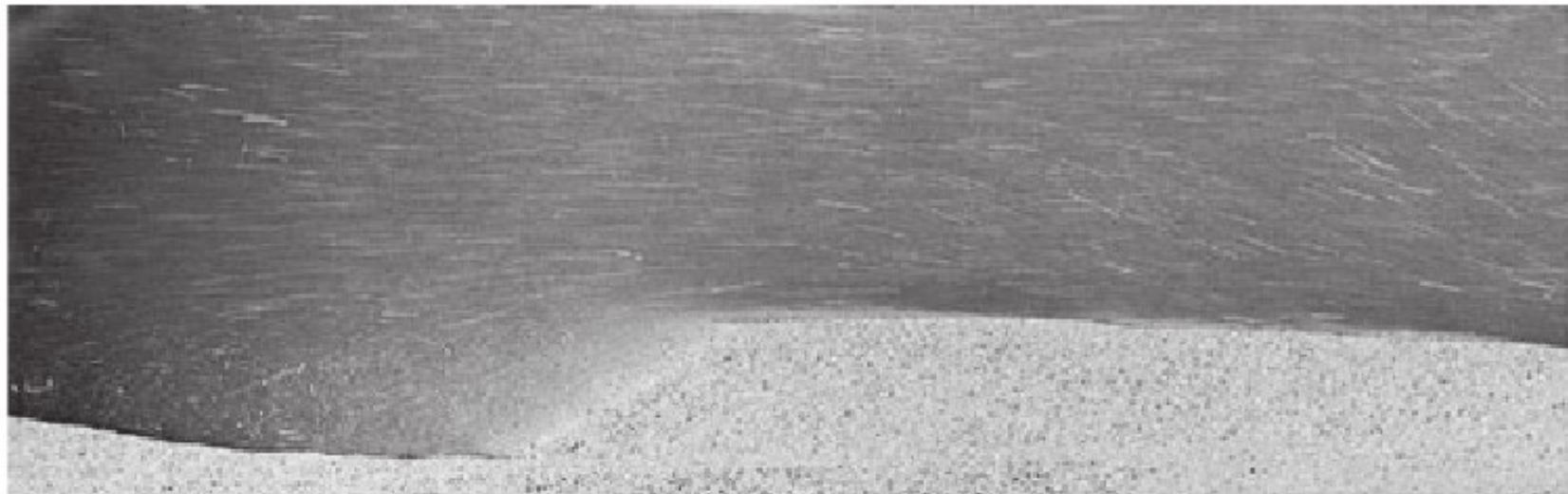
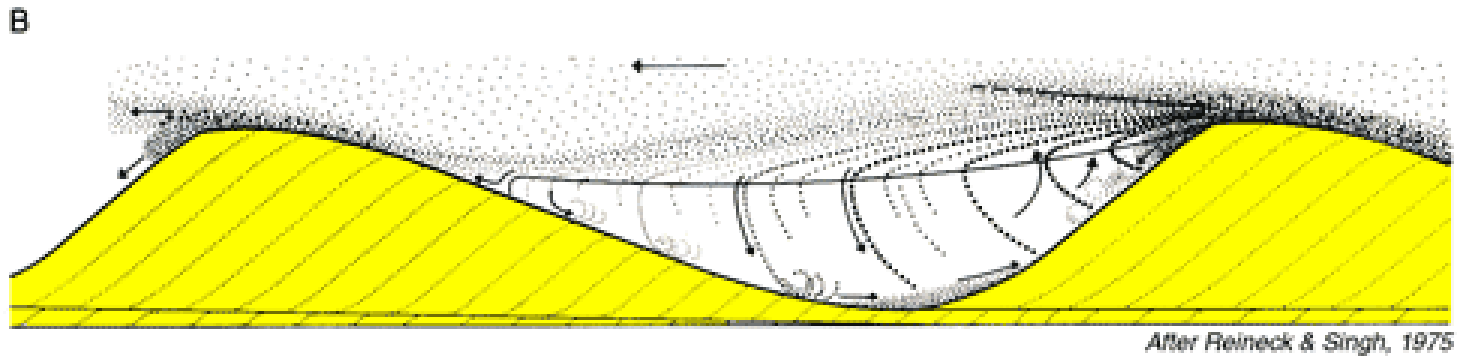
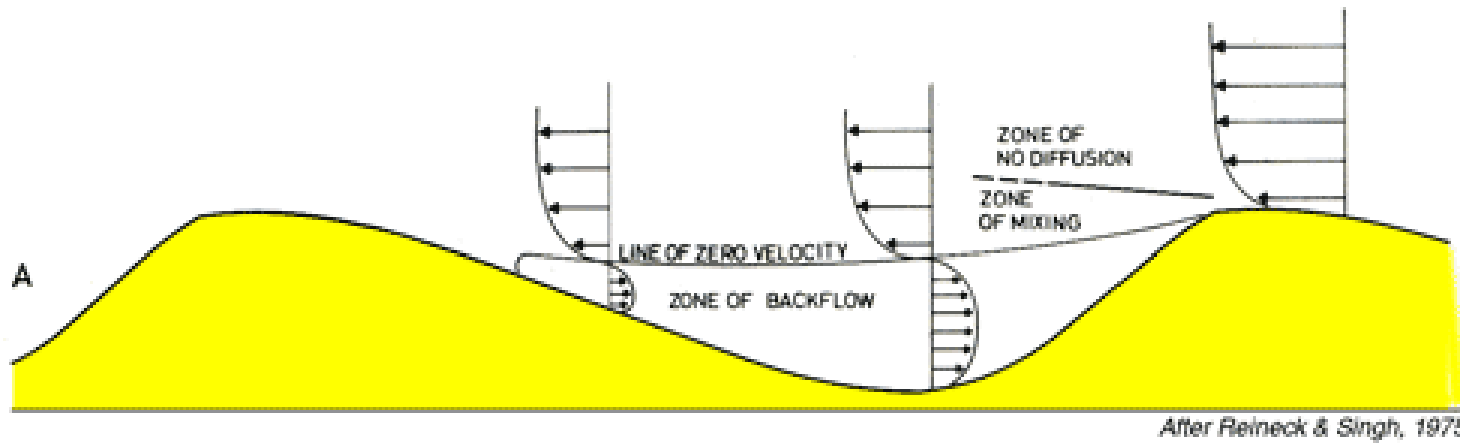
Anti-dunas

Leito Plano

Migração de formas de leito e formação de estratificações

A





Estruturas sedimentares formadas por migração de formas de leito

-Acamadamento – planos visíveis, marcados por diferença de granulação ou composição.

Estratificação – camadas de mais de 1 cm de espessura.

Laminação – camadas de menos de 1 cm de espessura (lâminas)

Série – conjunto de lâminas ou estratos

Estruturas sedimentares formadas por migração de formas de leito

- Marcas onduladas (preservadas)

Laminação cruzada

Laminação cruzada cavalgante

- Dunas subaquáticas – estratificação cruzada

Acanalada

Tabular

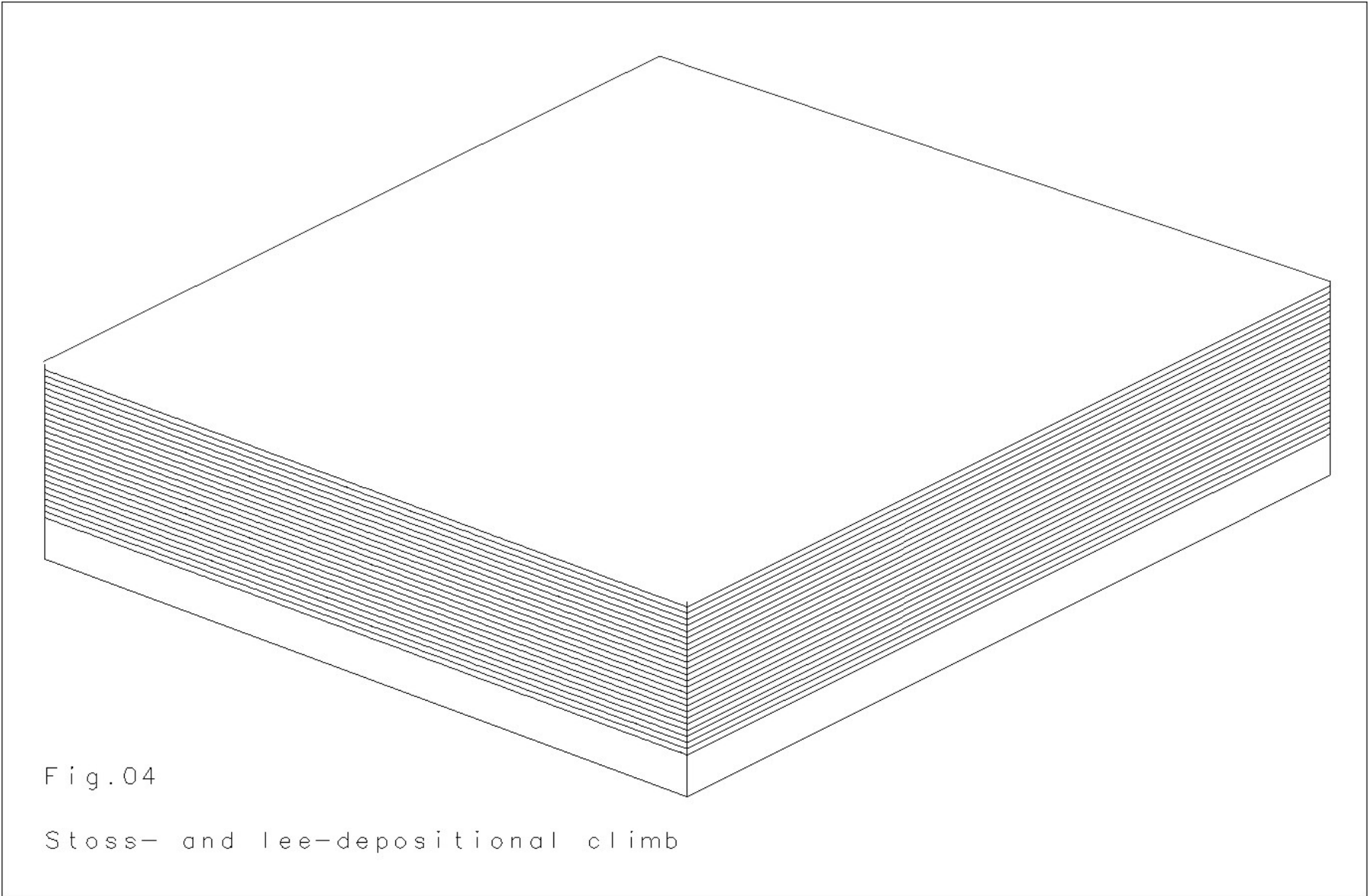
-Dunas eólicas

Acanalada Tabular

- Leito plano – laminação plana

- Praia – estratificação inclinada

Leito plano



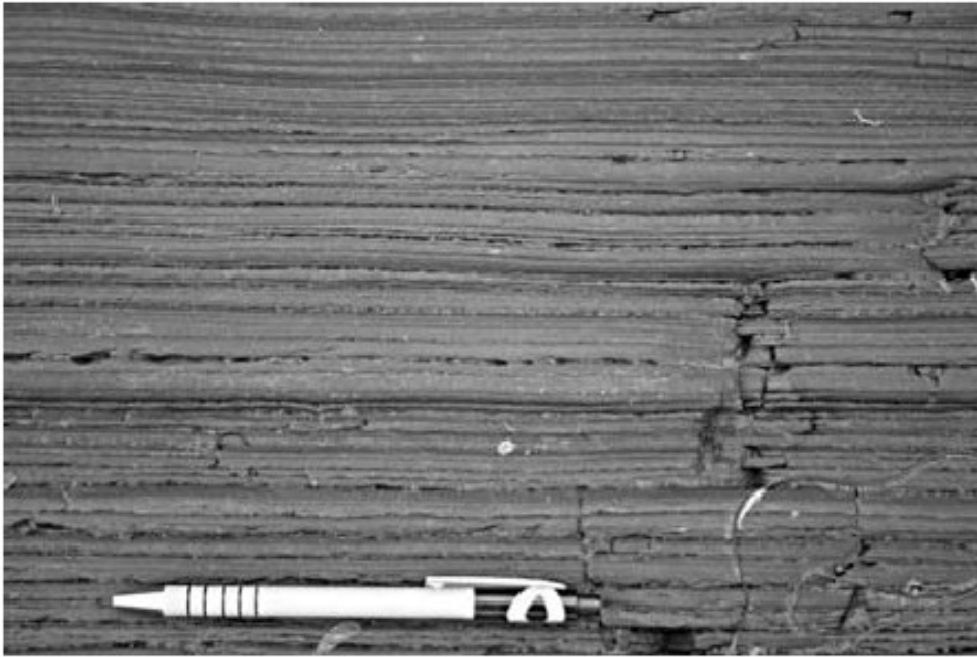
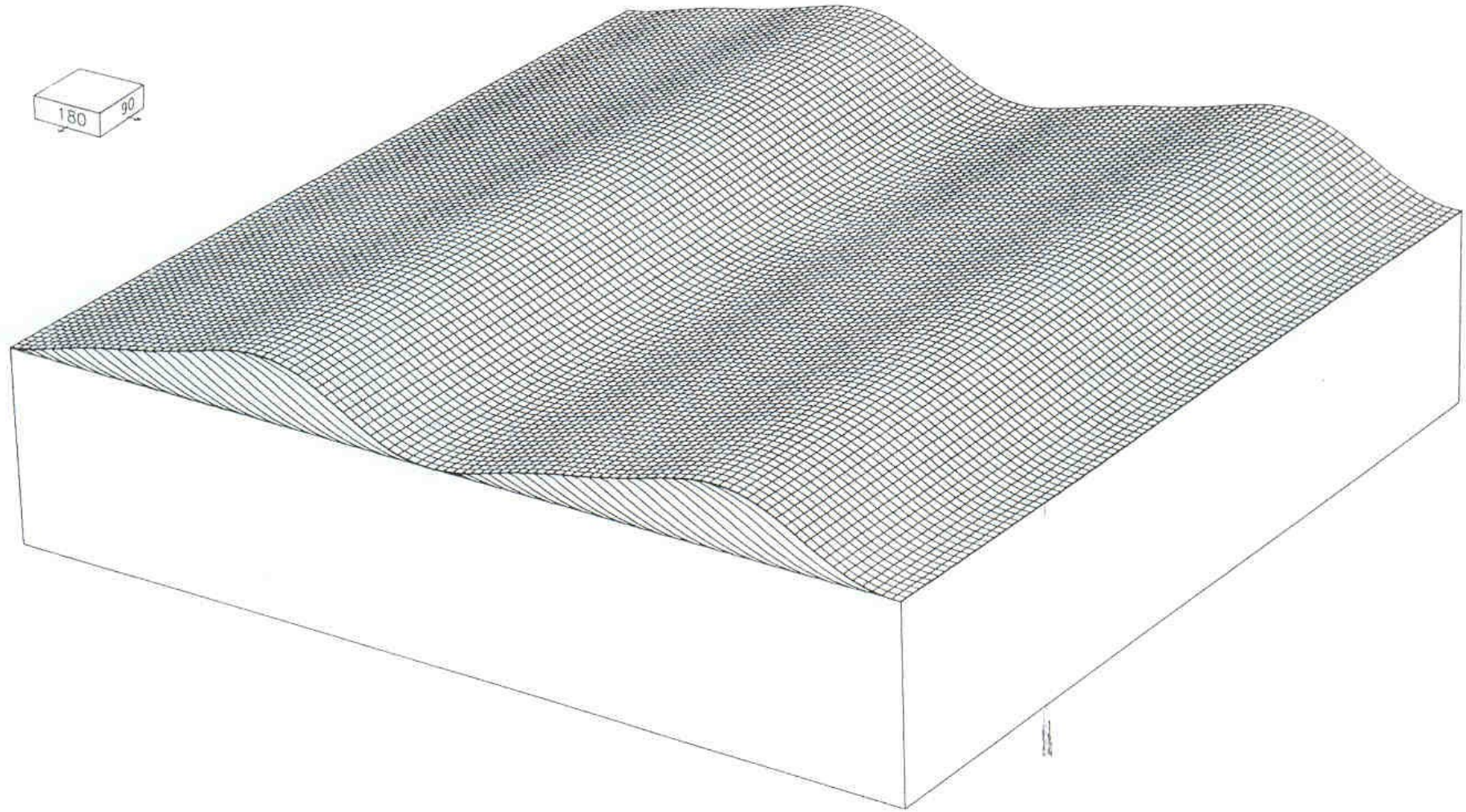


Fig. 4.19 Horizontal lamination in sandstone beds.

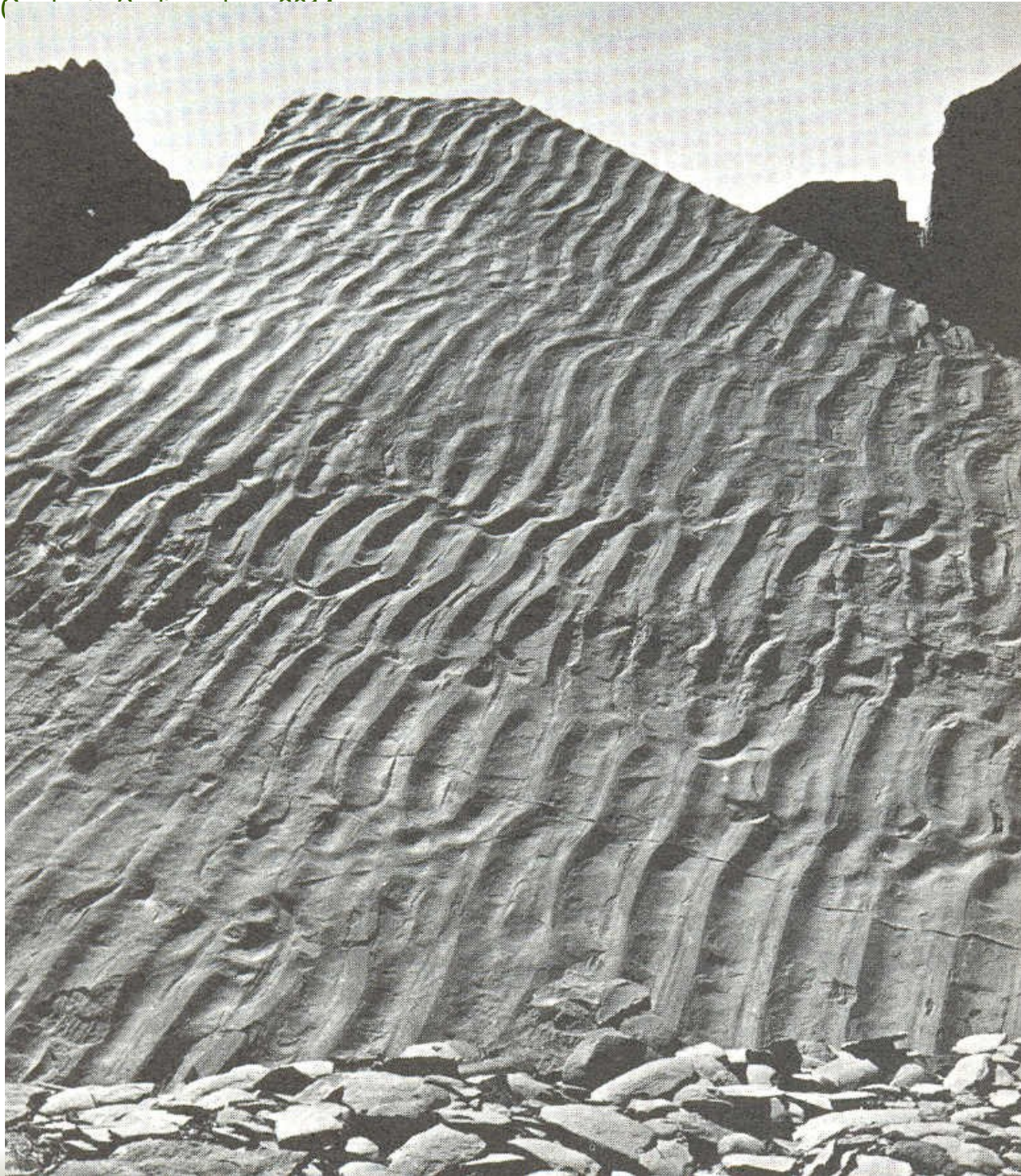


Lineação de corrente

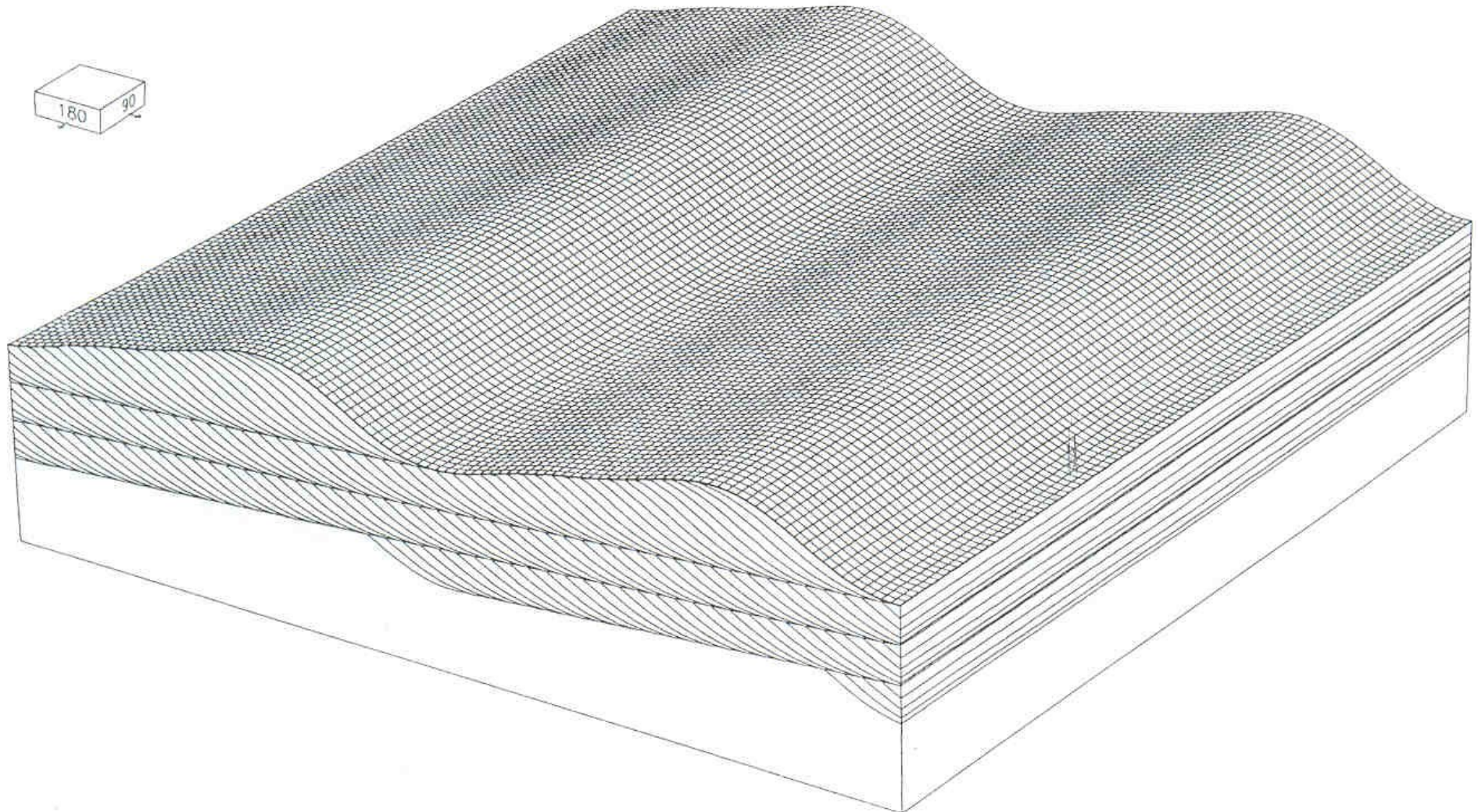
Ondulação e laminação cruzada







Laminação cruzada cavalgante





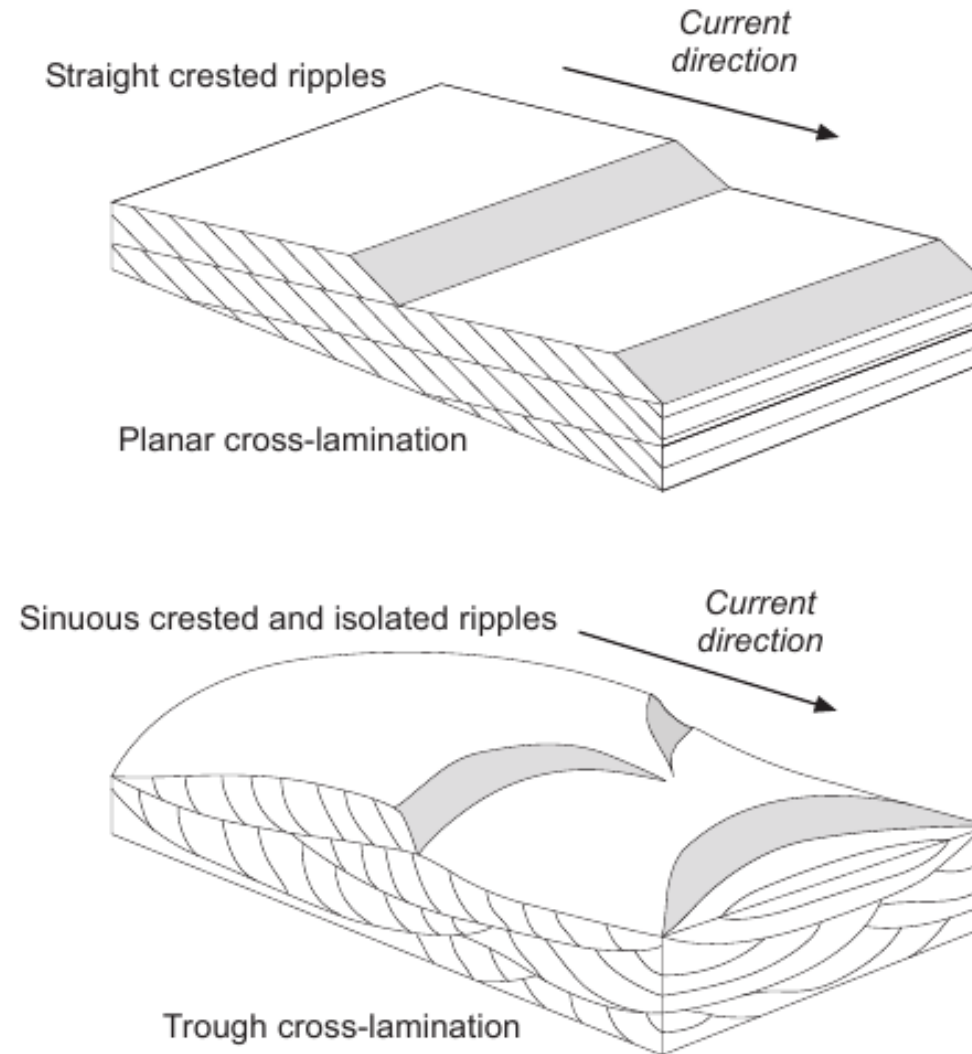


Fig. 4.10 Migrating straight crested ripples form planar cross-lamination. Sinuous or isolated (linguoid or lunate) ripples produce trough cross-lamination. (From Tucker 1991.)

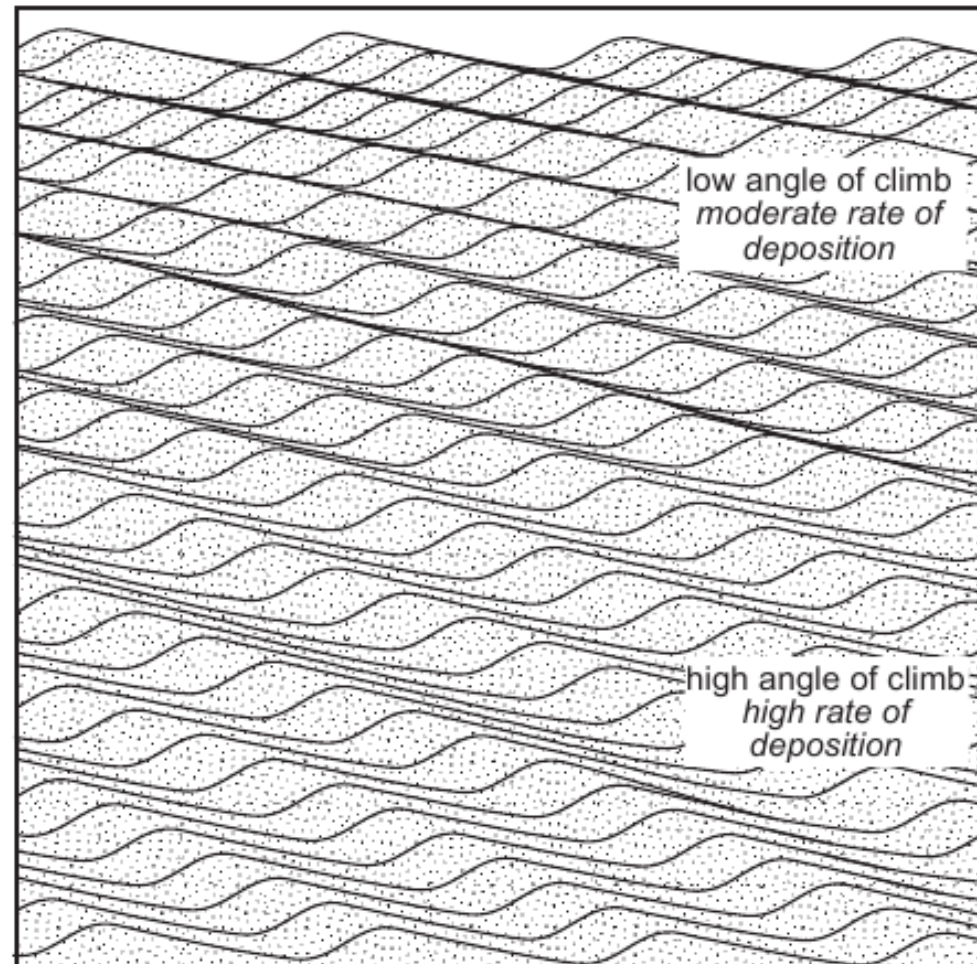


Fig. 4.12 Climbing ripples: in the lower part of the figure, more of the stoss side of the ripple is preserved, resulting in a steeper 'angle of climb'.

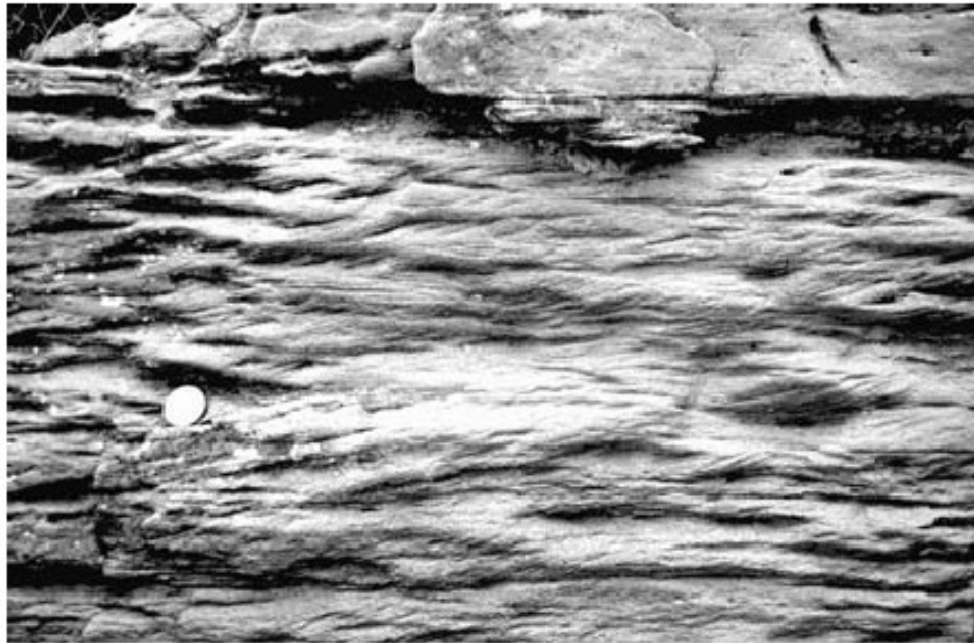
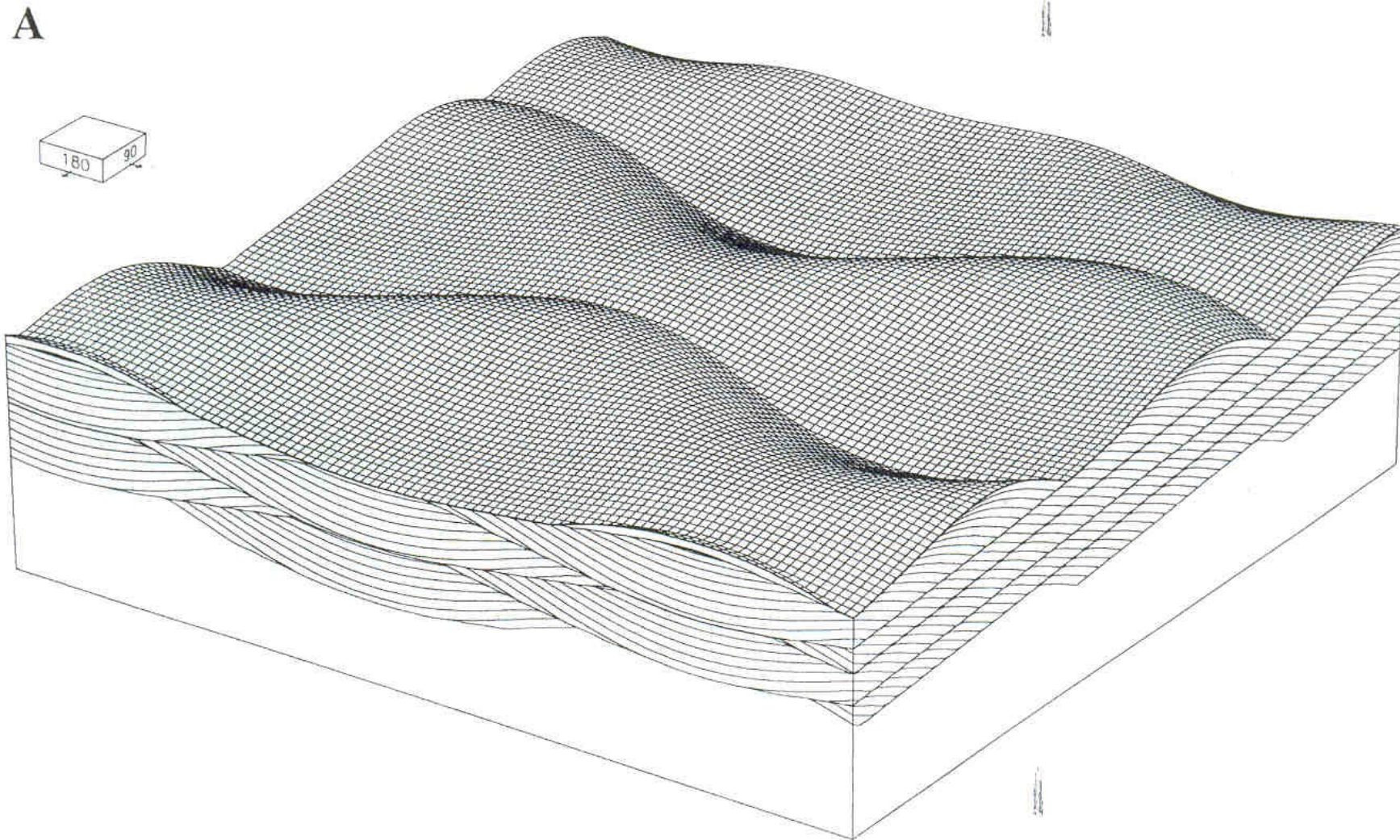
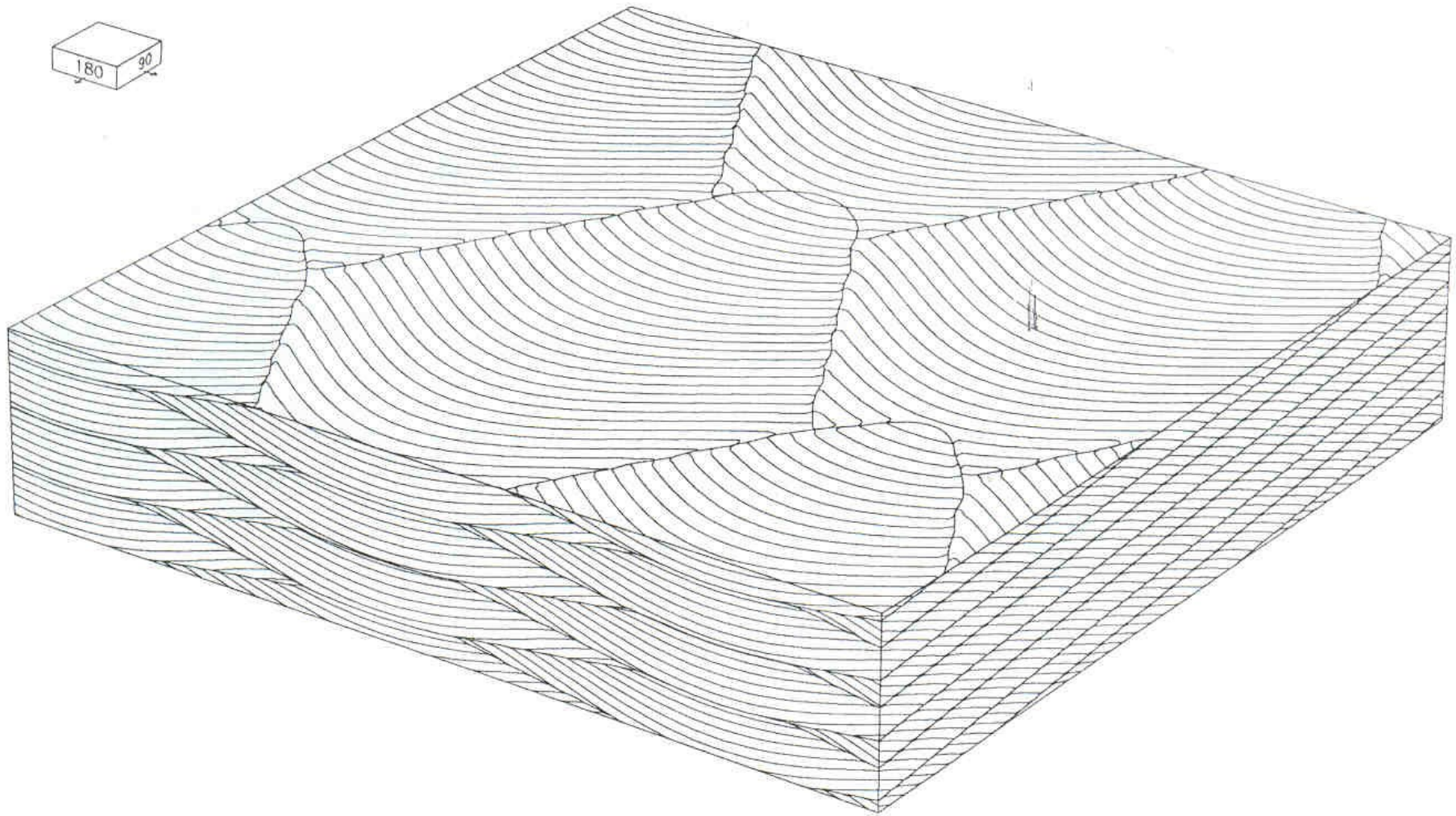


Fig. 4.9 Current ripple cross-lamination in fine sandstone: the ripples migrated from right to left. The coin is 20 mm in diameter.

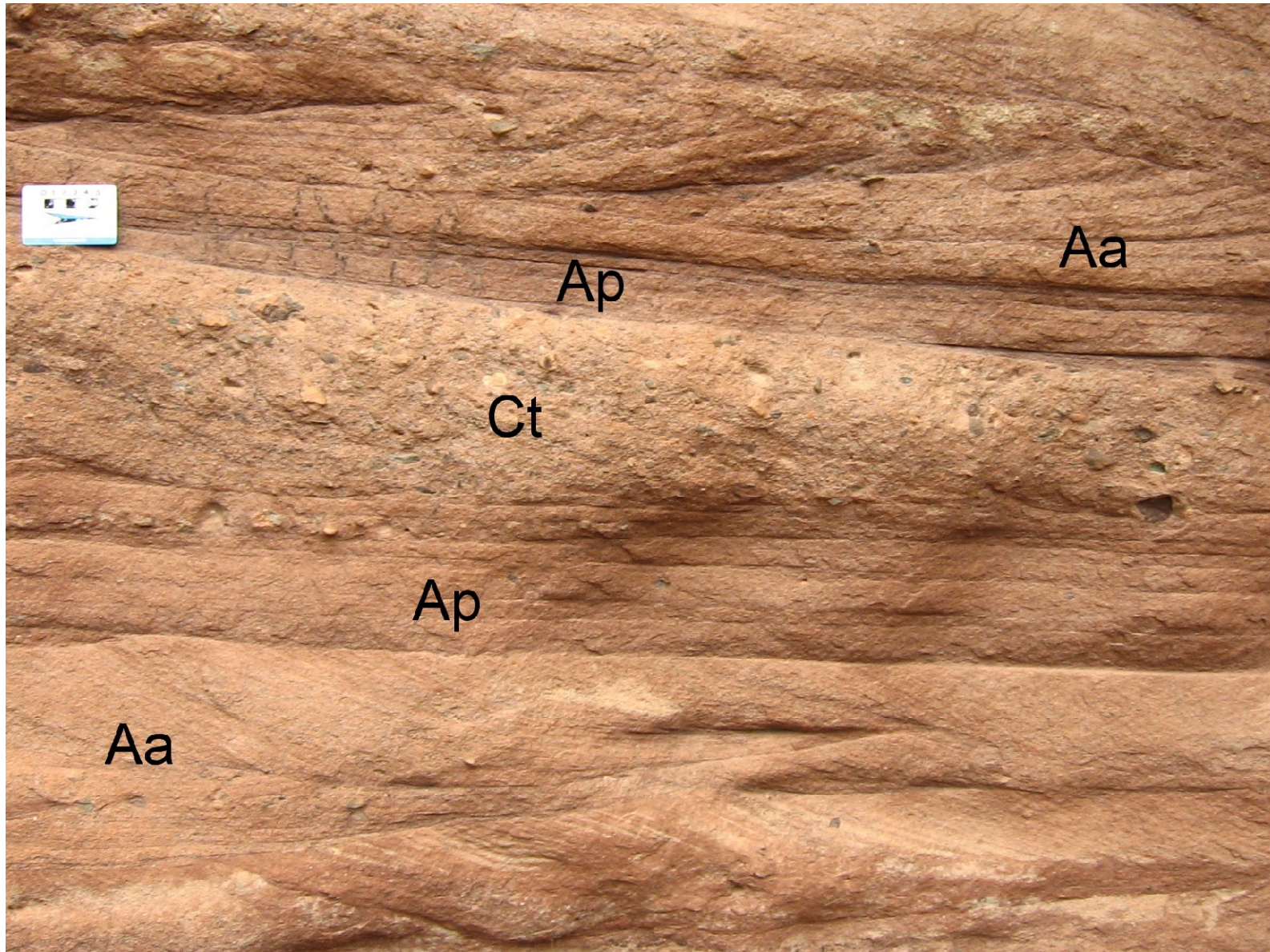
Duna de crista sinuosa



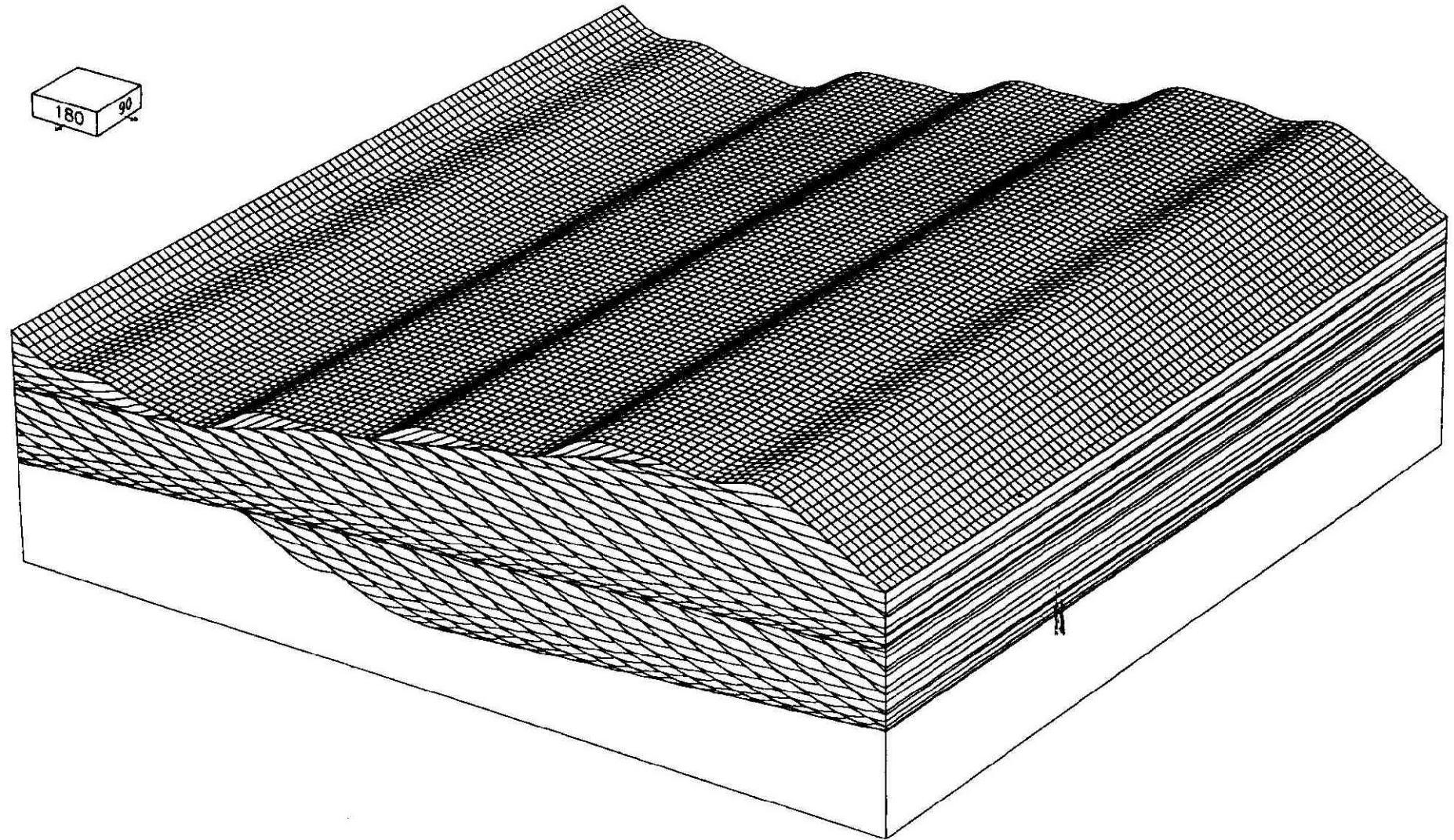
Estratificação cruzada acanalada



Estratificação cruzada acanalada (Aa)



Dunas de cristas retas





Estratificação cruzada tabular

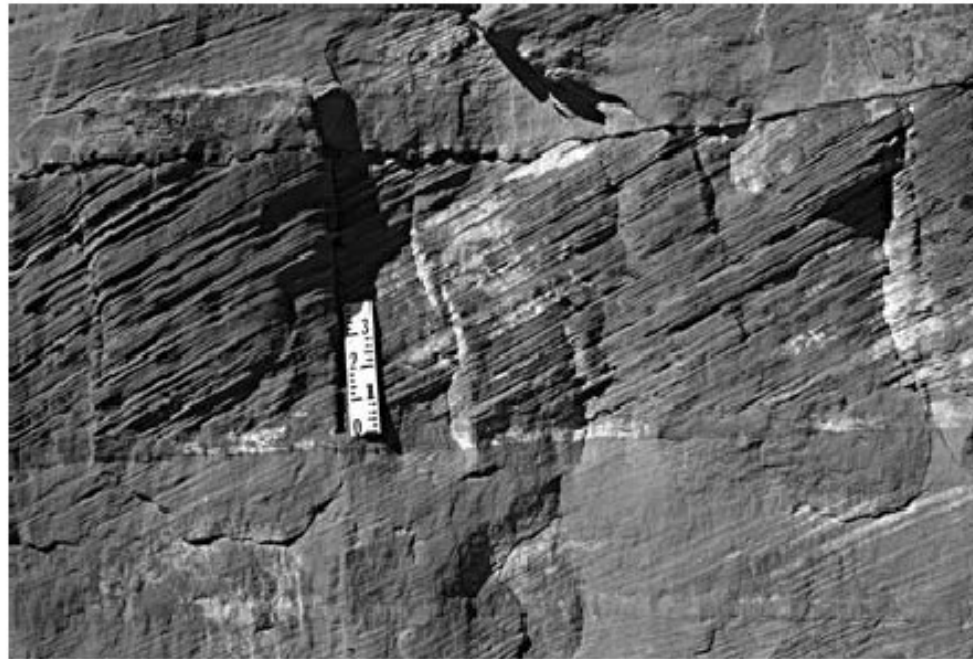


Fig. 4.18 Planar tabular cross-stratification with tangential bases to the cross-beds (the scale bar is in inches and is 100 mm long).

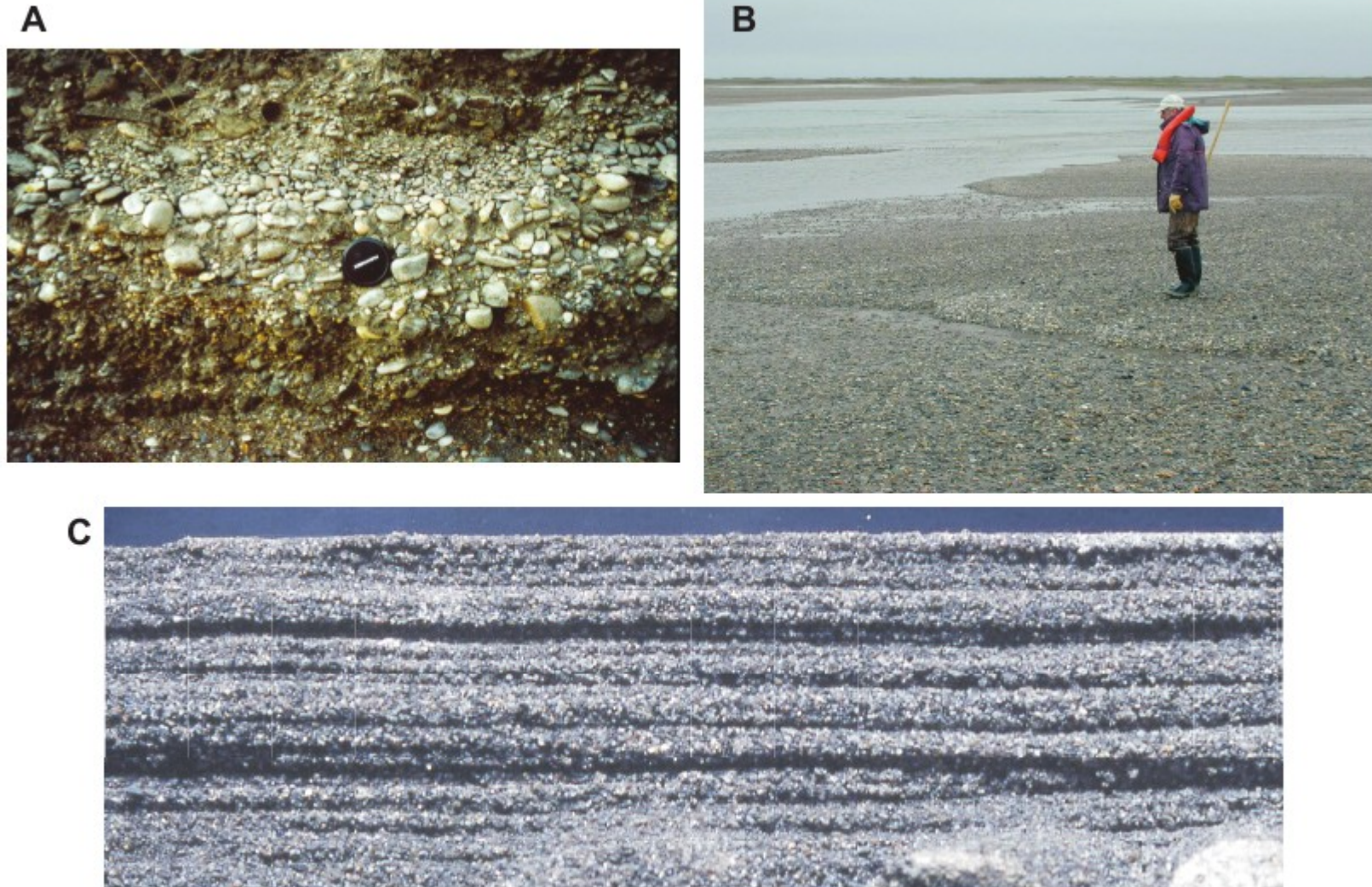
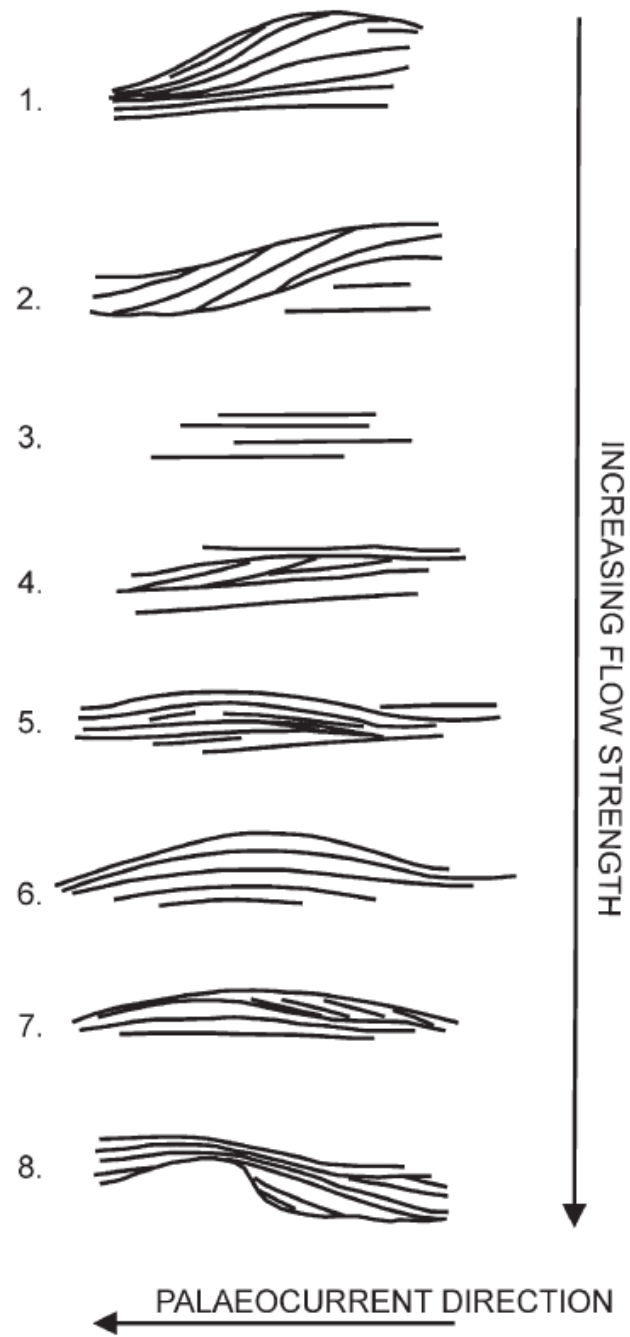


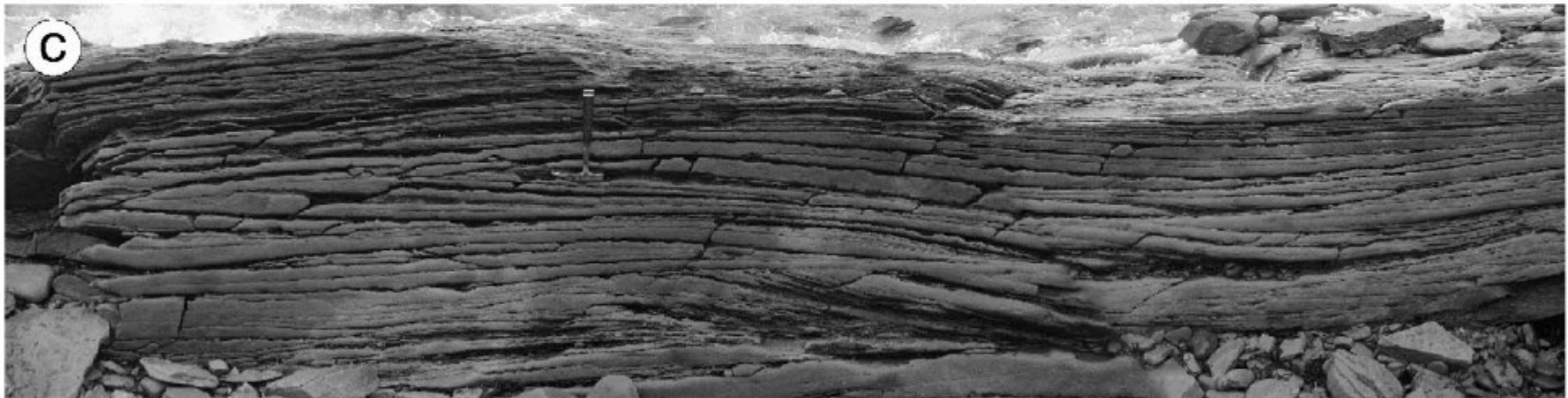
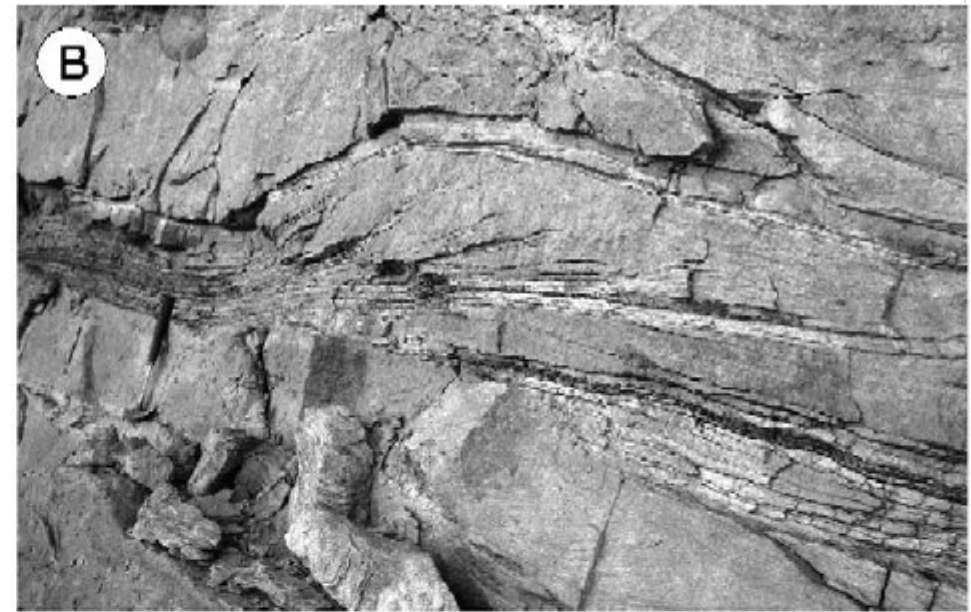
FIG. 3—**A)** Planar strata in gravel formed by migration of bedload sheets. A planar stratum composed of open-framework gravel occurs in the middle of the photo. The base of this stratum is relatively coarse grained and contains imbricated pebbles dipping to the left. The upper part of the stratum is finer grained and contains pseudo-imbricated pebbles dipping to the right. **B)** bedload sheets on a bar in the Sagavanirktok River, Alaska. **C)** Planar strata in sand formed by migration of low-relief bed waves (bedload sheets) on upper-stage plane beds. Section is 30 mm thick. The dark boundaries of the planar laminae are formed of relatively fine-grained sediment deposited from suspension in the troughs of bed-load sheets. From experiments of J.S. Bridge and J.L. Best.



Transição entre os regimes de fluxo e estruturas de RFS

Line drawings to show an interpreted spectrum of sedimentary structures representative of the upper flow regime, from transitional dunes, through plane bed, transitional antidunes and antidunes, to chute and pool bedform states. Note that the drawings are intended to be scale-independent. Parting lineation is present on the bedding planes of many if not all of these structures.

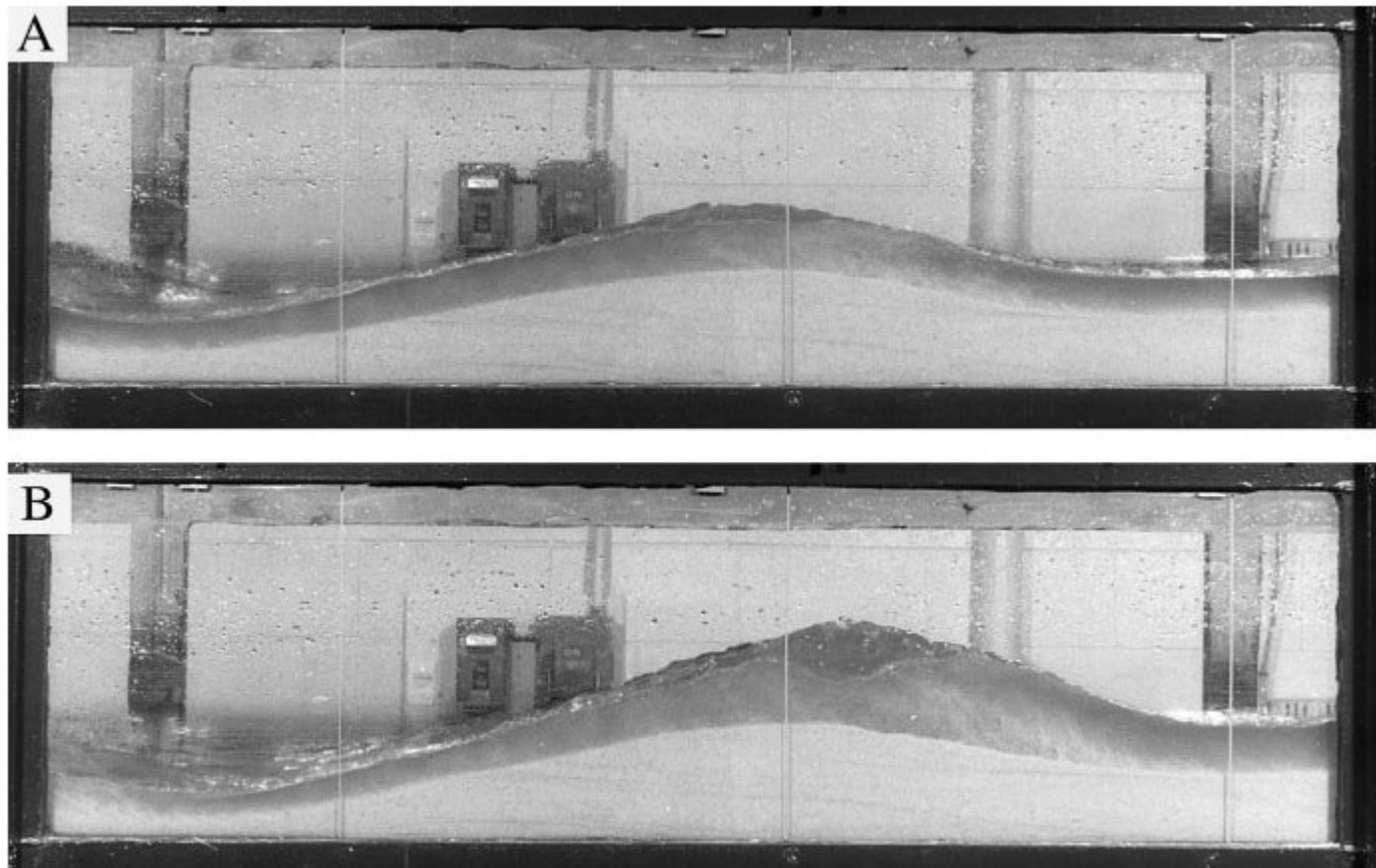
Fielding (2006)



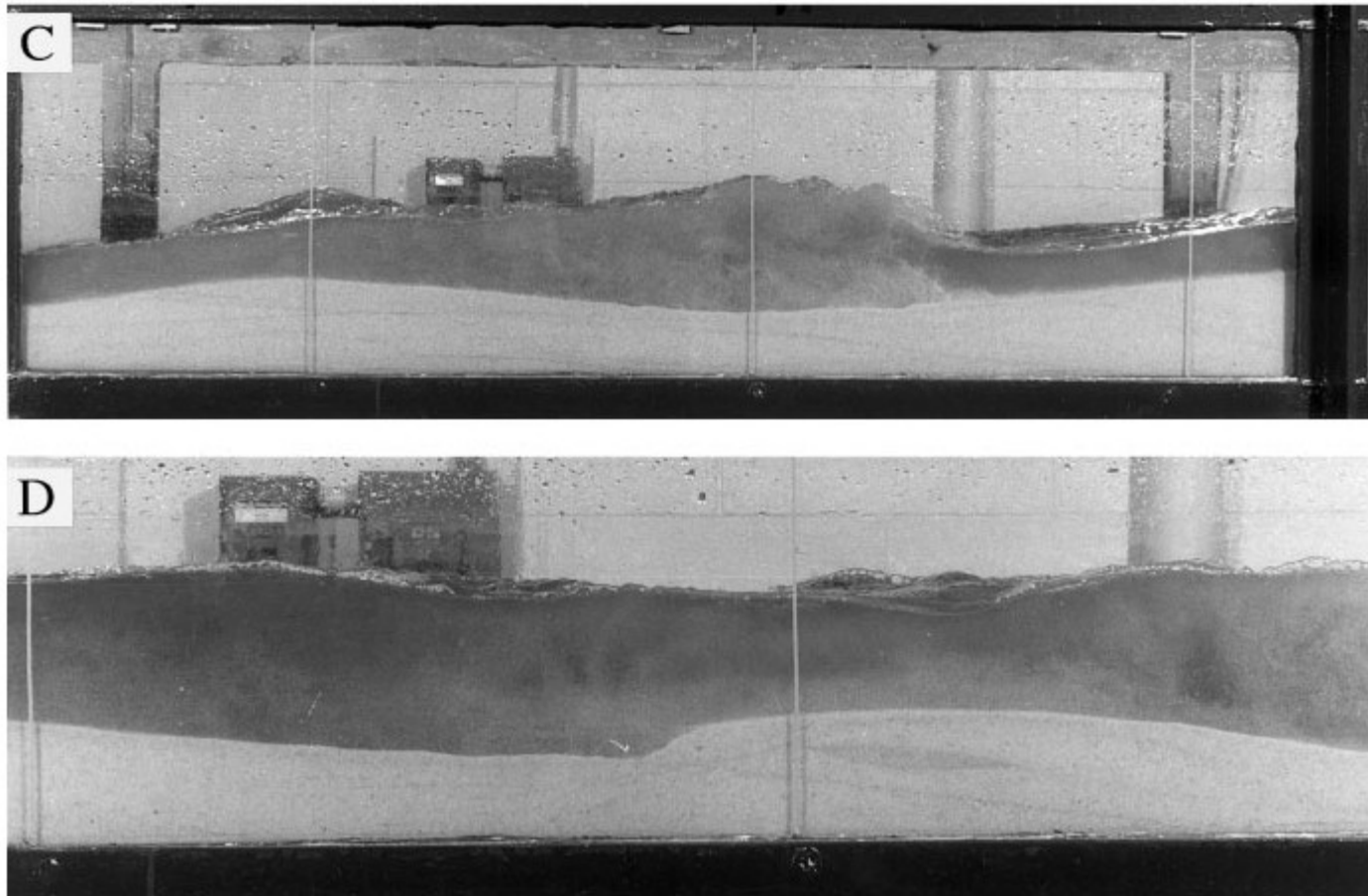
Photographs of cross-bedding structures considered representative of the transition from dune to upper plane bed phase. A) Small-scale, washed out dunes, showing flat, eroded tops. B) "Humpback cross-bedding" set, showing preservation of the complete bedform, reworking of the stoss side by small dunes or ripples, sigmoidal foreset geometry and flattening out of the lee side into an extensive bottomset. C) Example of humpback cross-bedding transitional to flat lamination, showing flattening out of foreset bedding downdip and upward through the set, culminating in a convex upward (hummocky) bedform.



Bacia do Tucano

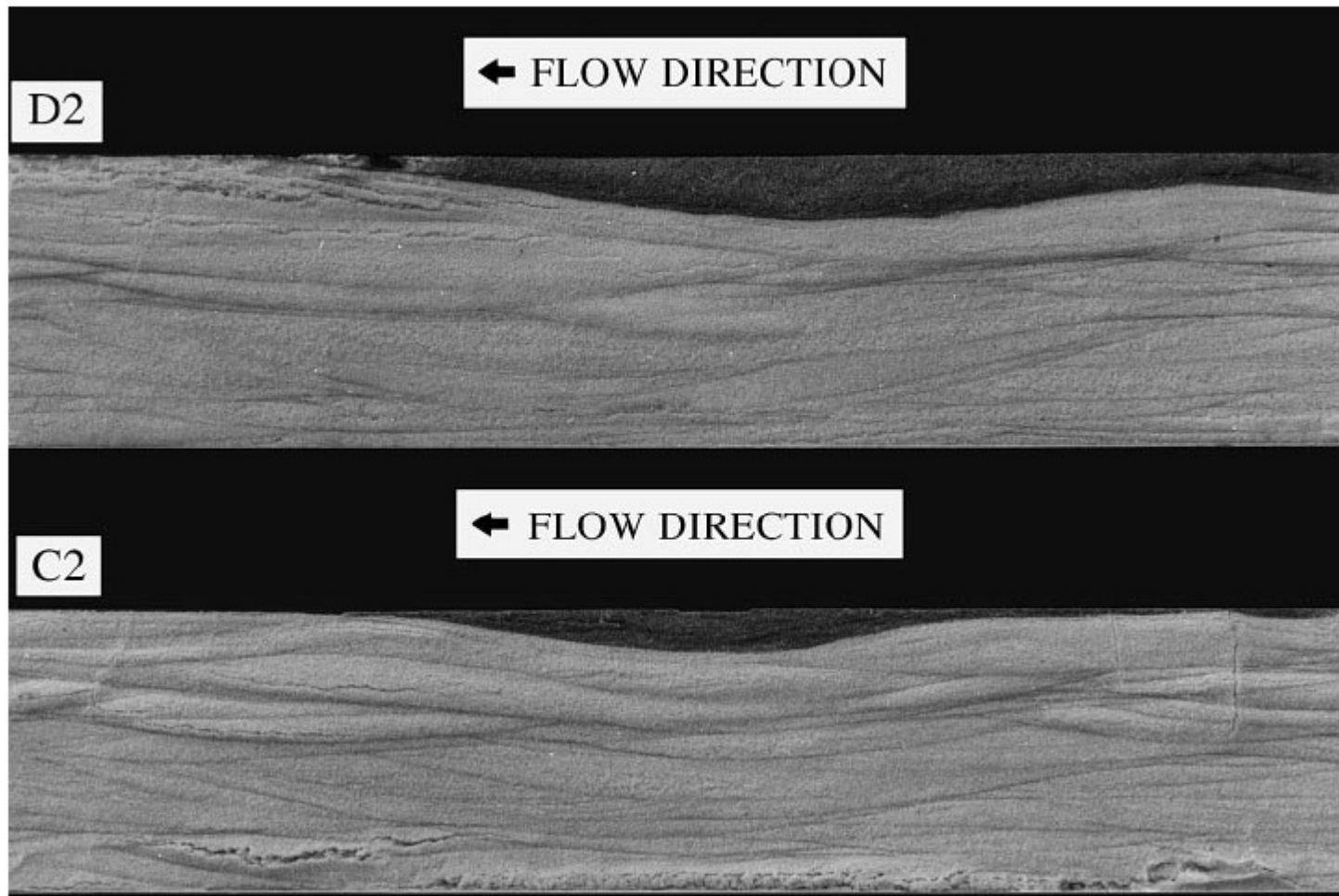


Photographs of test section (1.5 m wide) in Run 2 with water flow from right to left. (A) standing water-surface wave and developing antidune, (B) asymmetrical water-surface wave and antidune, with flow separation zone on upstream side of antidune prior to wave breaking,



(C) a breaking wave and (D) asymmetrical bedform migrating into antidune trough after wave breaking.

Alexander et al. (2001)



Estratificação por desestabilização de antidunas (Alexander, 2001)

Formas de leito - Exemplos





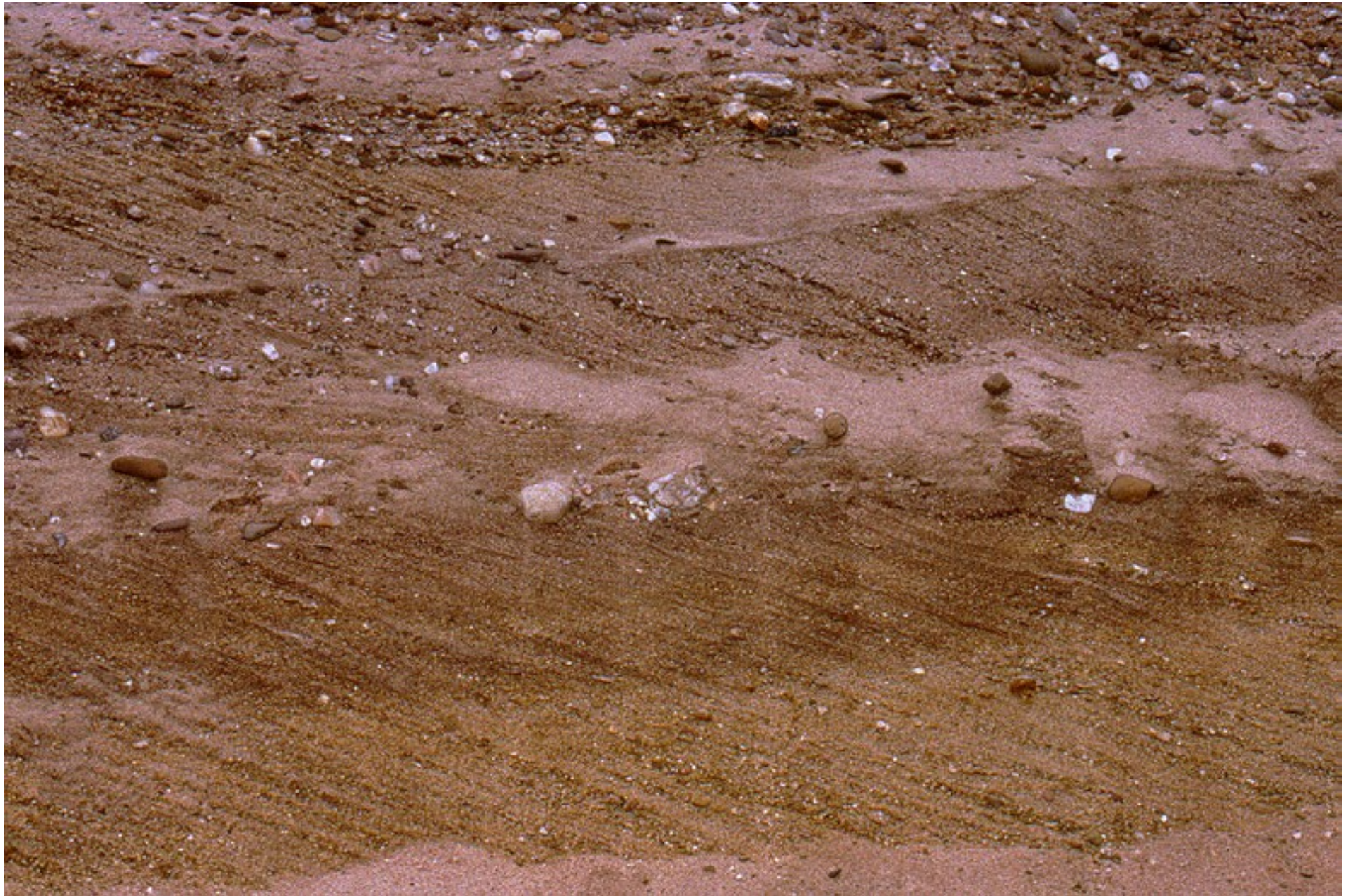


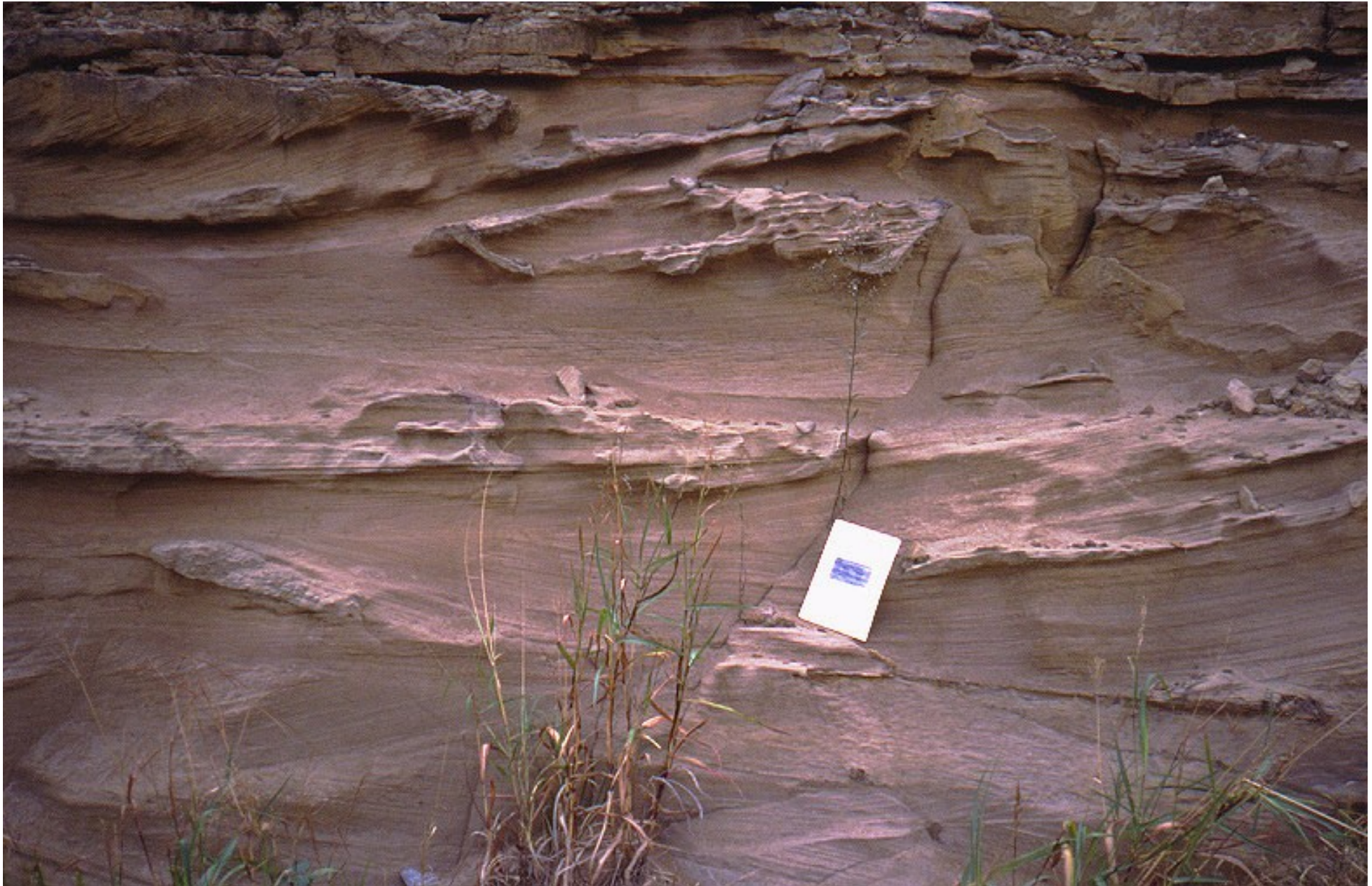


Estratificações – Exemplos









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