

GEOMORFOLOGÍA DINÁMICA (GL54C)
SEMESTRE OTOÑO 2004
LUISA PINTO L.

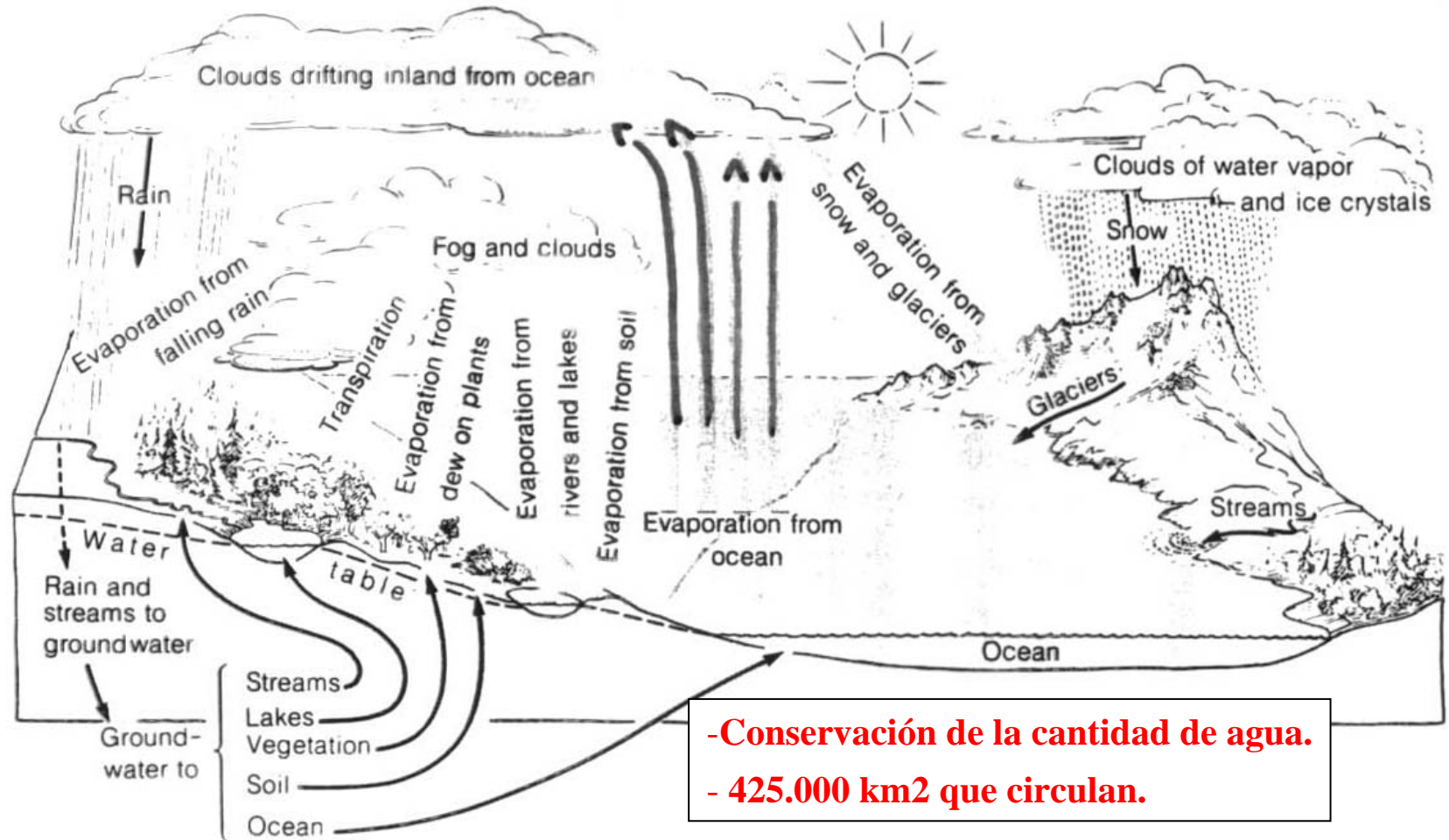
Aguas superficiales y subterráneas (Parte 1)

TEMAS A TRATAR

- Ciclo hidrológico
- erosión y sedimentación en sistemas fluviales
- tipos de sistemas fluviales
- terrazas fluviales
- patrones de drenaje
- tazas de alzamiento, erosión y sedimentación
- abanicos aluviales

CLICO HODROLÓGICO

EL CICLO HIDROLÓGICO

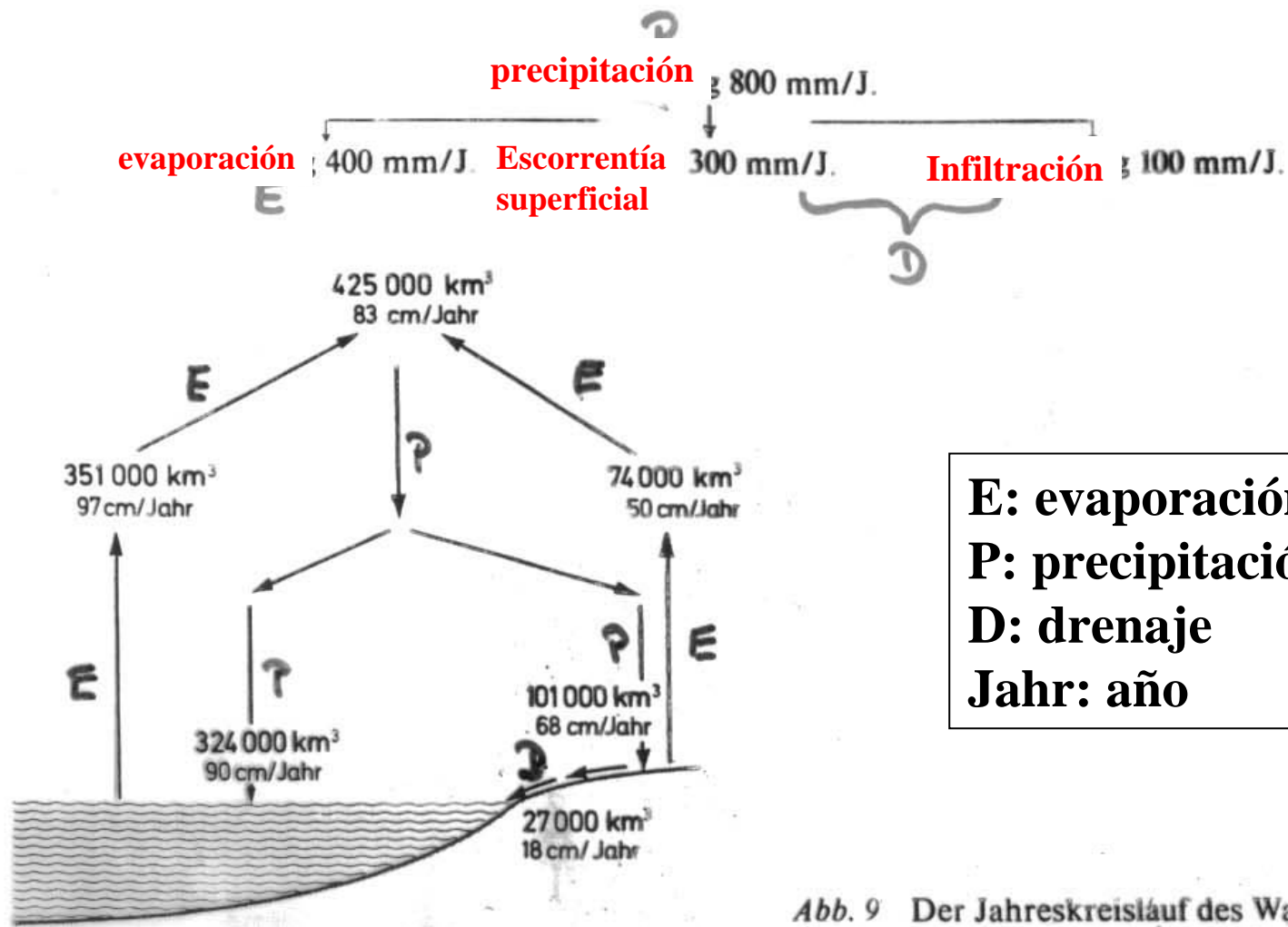


-Conservación de la cantidad de agua.
- 425.000 km² que circulan.

Figure 7-3

The hydrologic cycle. Movement into the atmosphere by evaporation is matched by precipitation as rain and snow. [After *Principles of Geology*, 4th ed., by J

Gilluly, A. C. Waters, and A. O. Woodford. W. H. Freeman and Company. Copyright © 1975.]



E: evaporación,
P: precipitación,
D: drenaje
Jahr: año

Abb. 9 Der Jahreskreislauf des Wassers auf der Erde (nach G. Dietrich & W. Kalle)

CLASIFICACIÓN HIDROLÓGICA DEL SUBSUELO

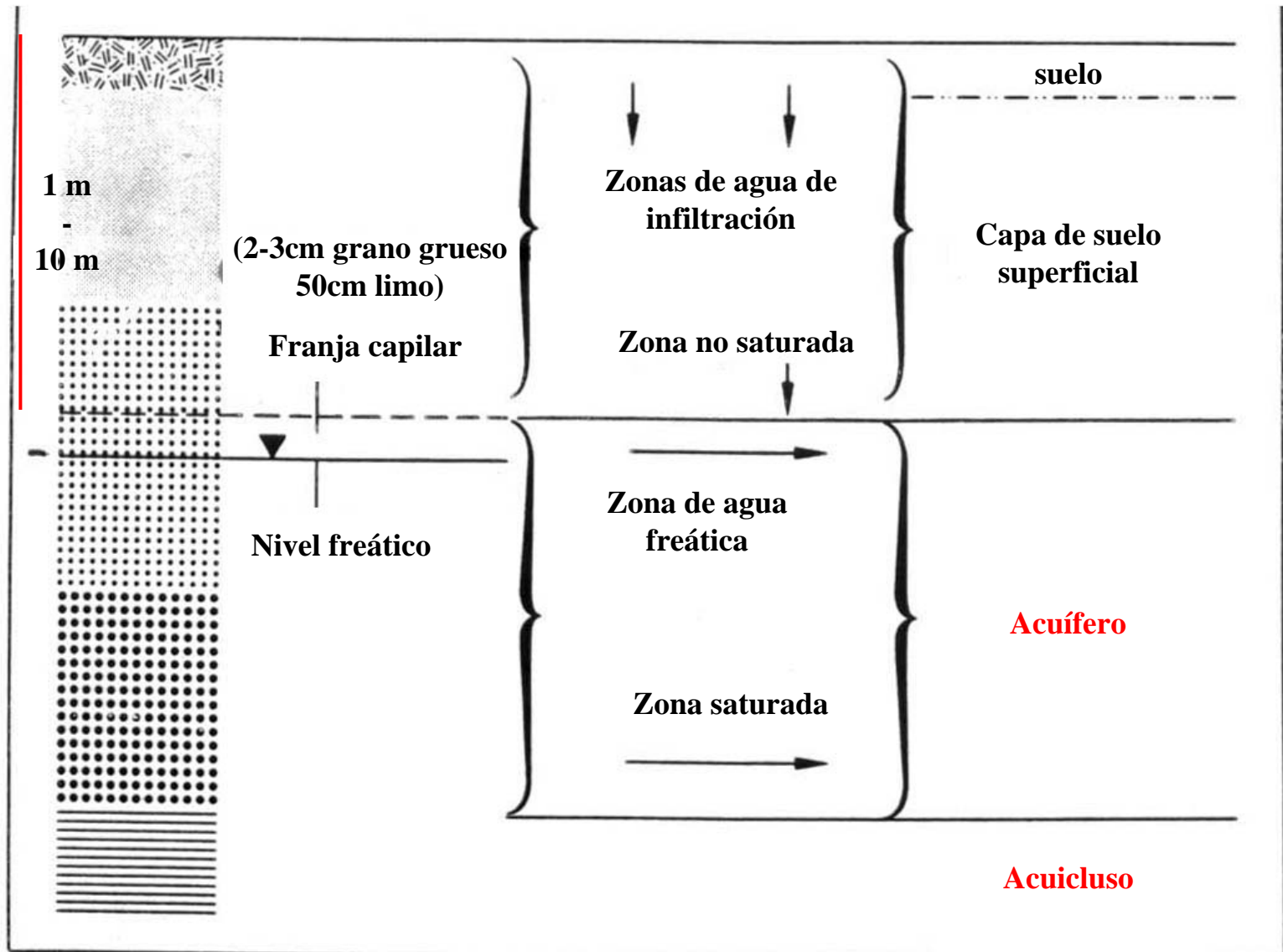
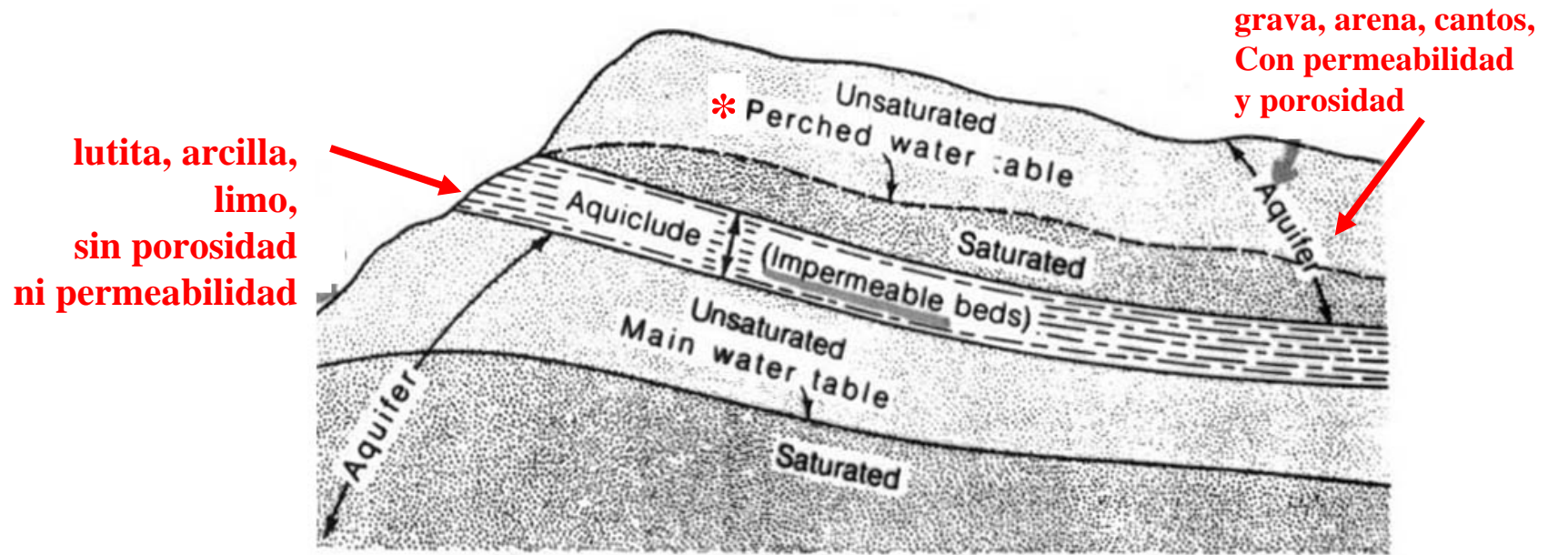


Abb. 10 Hydrogeologische Gliederung des Untergrundes (nach Mattheß 1979)

acuiclusos y acuíferos



***nivel freático colgante**

Porosidad de arenisca: 30-40%

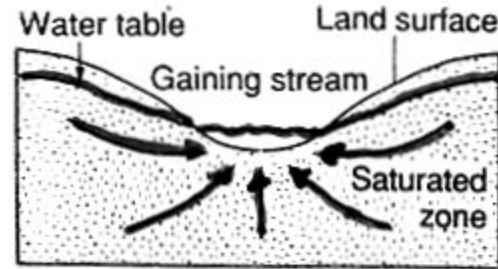
Roca ígnea y metamórfica: 2-3%

Permeable: arena

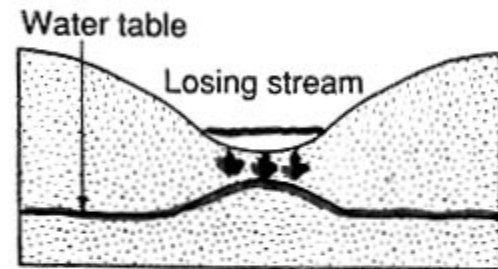
Impermeable: arcilla, arcillolita

Figure 7-15

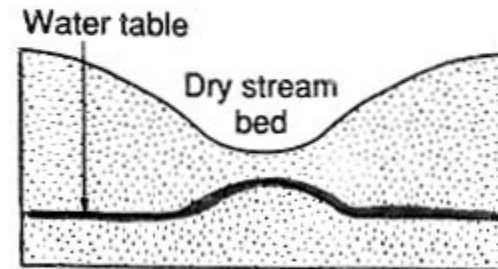
A perched water table is separated from the main water table by an aquiclude composed of shale or other impermeable beds.



A



B



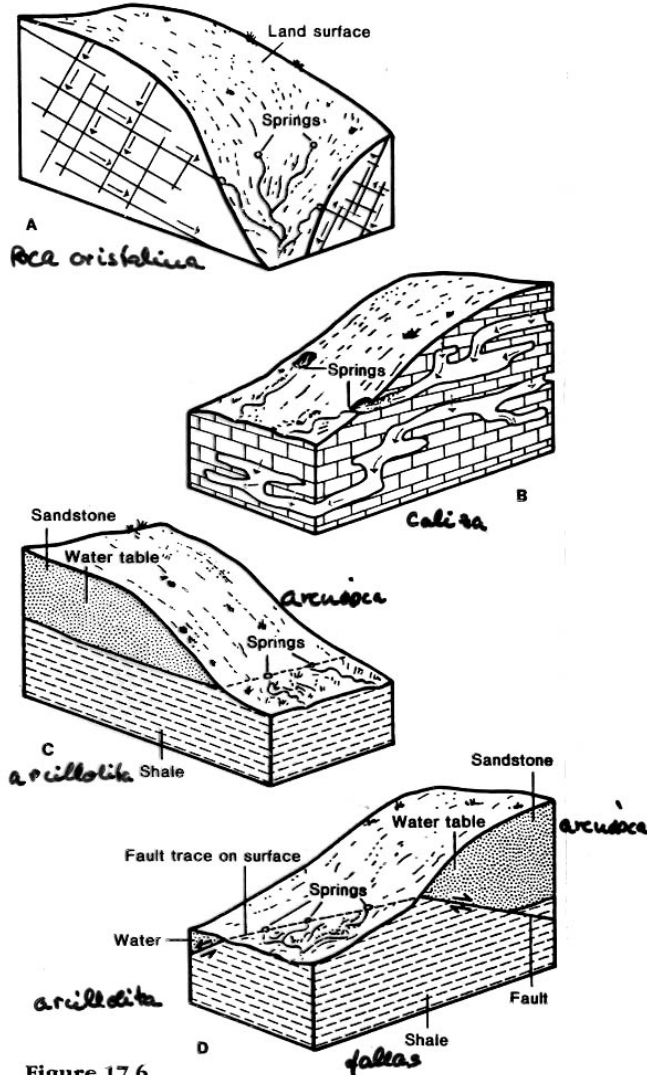
C

ganancias y
pérdidas de agua

Figure 17.8

Gaining and losing streams. (A) Stream gaining water from saturated zone. (B) Stream losing water through stream bed to saturated zone. (C) Water table can be close to land surface beneath dry stream bed.

FUENTES (*springs*)



roca cristalina

caliza

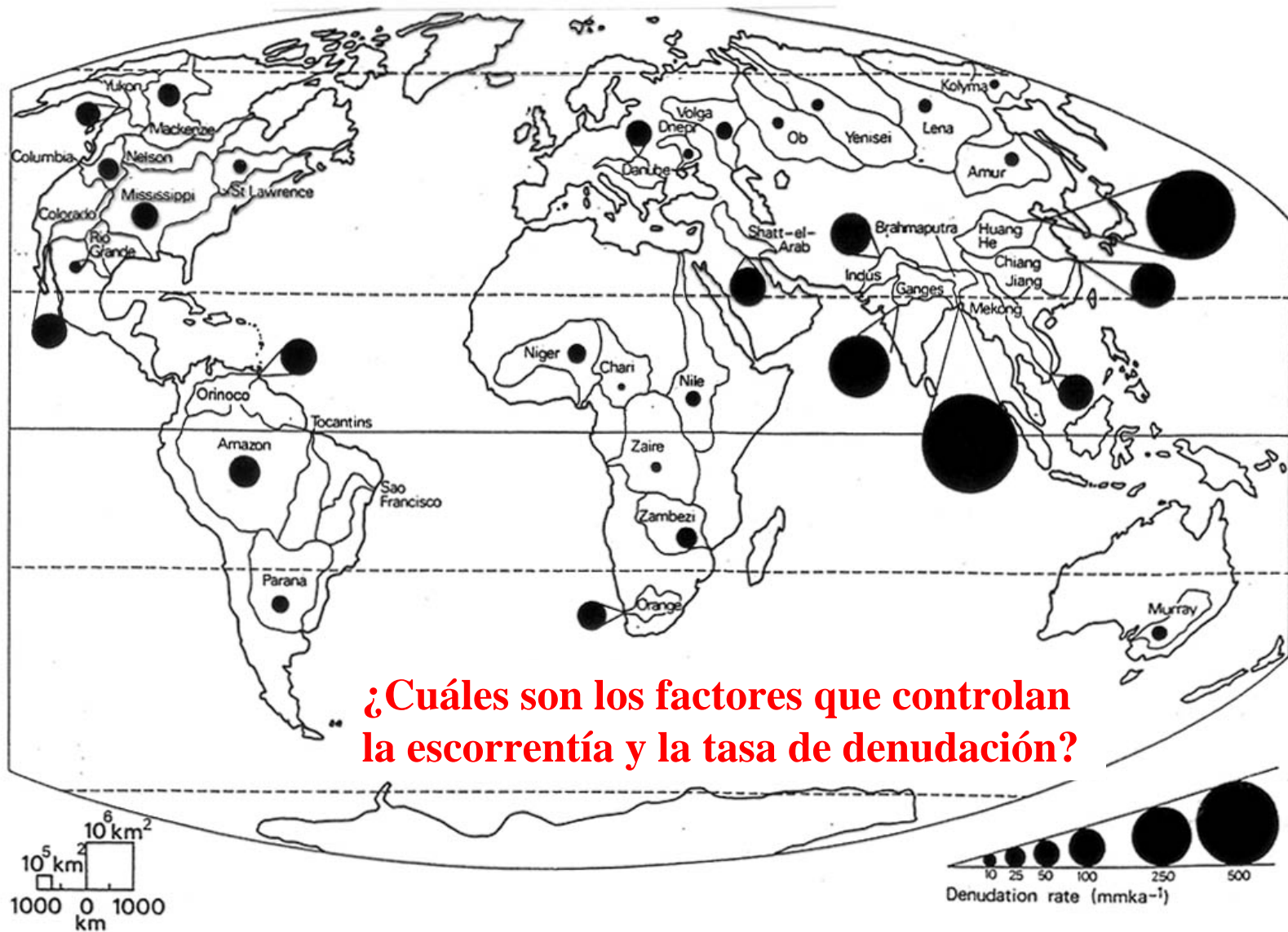
arenisca /
arcillolita

Falla
arenisca /
arcillolita

Figure 17.6

Springs can form in many ways. (A) Water moves along fractures in crystalline rock and forms springs where fractures intersect the land surface. (B) Water enters caves along joints in limestone and forms springs at the mouths of caves. (C) Springs form at the contact between a permeable rock such as sandstone and an underlying impermeable rock such as shale. (D) Springs can form along faults when permeable rock has been moved against impermeable rock. Fault motion shown by arrows.

**TASAS DE DENUDACIÓN
RELACIONADAS A
ESCORRENTÍA
SUPERFICIAL
*factores***



¿Cuáles son los factores que controlan la escorrentía y la tasa de denudación?

Fig. 15.10 Denudation rates for the world's 35 largest drainage basins based on solid and solute load data. Allowance has been made for the non-denudational component of solute loads. Source rock density is assumed to be 2700 kg m⁻³ (Based on data in Table 15.6.)

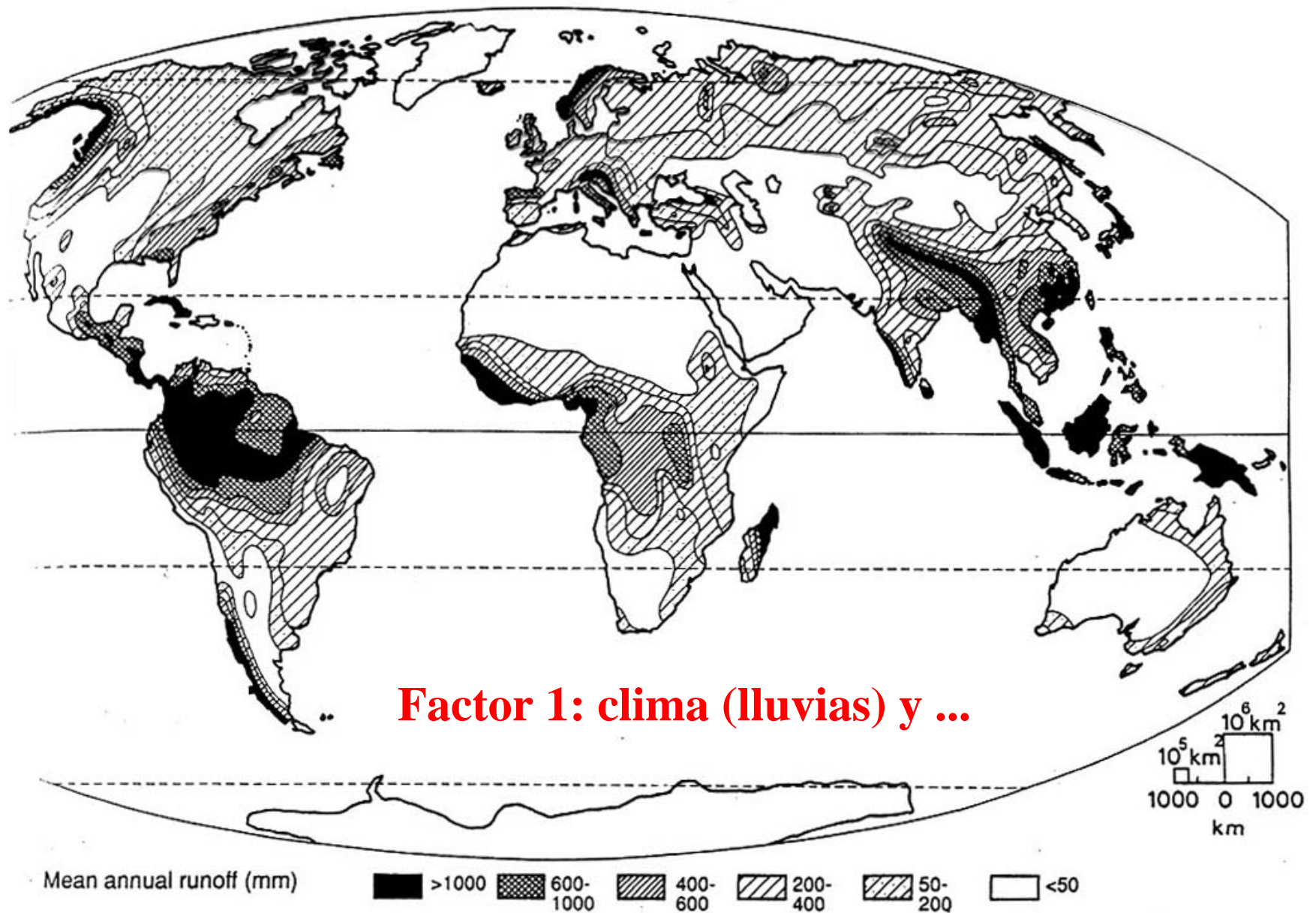


Fig. 8.3 Global variation in mean annual runoff expressed as depth-equivalent discharge. (Based on Unesco (1978) Atlas of the World Water Balance, Unesco, Paris.)

Table 15.8 Solid and denudational solute load of major rivers and total denudation in relation to climate and relief

CLIMATE AND RELIEF ZONE	SOLID LOAD (t km ⁻² a ⁻¹)	DENUDATIONAL SOLUTE LOAD (t km ⁻² a ⁻¹)	TOTAL LOAD (t km ⁻² a ⁻¹)	TOTAL DENUDATION (mm ka ⁻¹)	TYPICAL SOLUTE LOAD AS % OF TOTAL
Mountainous high precipitation	200–1500	70–350	250–2000	95–740	10
Mountainous, low precipitation	100–1000	10–60	120–1000	45–370	10
Moderate relief, temperate or tropical climate	40–200	25–60	80–300	30–110	35
Low relief, dry climate	10–100	3–10	15–100	5–35	10
Low relief, temperate climate	20–50	12–50	40–80	15–30	65
Low relief, subarctic climate	1.5–15	5–35	5–40	5–15	80
Low relief, tropical climate	1–10	2–15	4–30	1.5–10	50

c. sólida

c. solución

Factor 2: tectónica

- manera en que escurre el agua y la cantidad de agua que cae.
- la pendiente y naturaleza de la roca.
- La escorrentía depende de la permeabilidad de la superficie (vegetación implica mayor meteorización).
- a) factor que modelarán la curva de pendiente: TECTÓNICO.
- b) Factor que modifica la base de desembocadura : EUSTÁTICO.

**EROSIÓN Y
SEDIMENTACIÓN
EN SISTEMAS FLUVIALES**

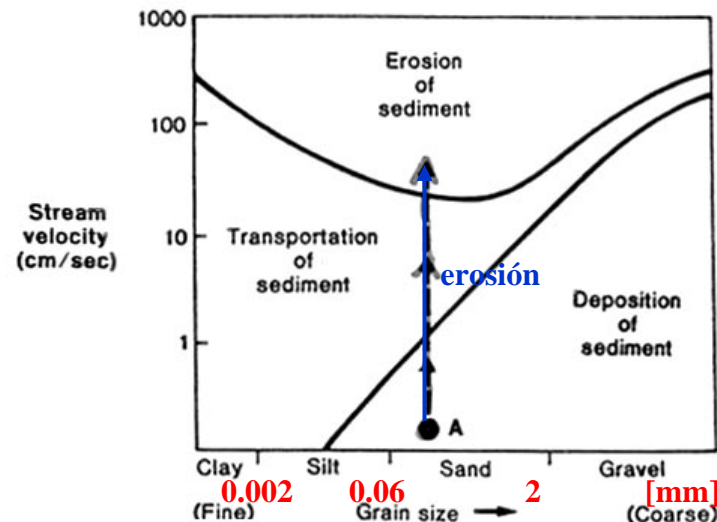
Procesos y mecanismos

Stream Velocity and Competence

Box figure 1 shows the stream velocities at which sediments are eroded, transported, and deposited. For each grain size, these velocities are different. The upper curve represents the minimum velocity needed to erode sediment grains. This curve shows the velocity at which previously stationary grains are first picked up by moving water. The lower curve represents the velocity below which deposition occurs, when moving grains come to rest. Between the two curves the water is moving fast enough to transport grains that have already been eroded. Note that it takes a higher stream velocity to erode grains (set them in motion) than to transport grains (keep them in motion).

Let's assume a stream that is moving fast enough to erode sediment because the velocity is high enough. The vertical

velocity is gradually increasing stream velocity, perhaps as the stream starts to flood. No sediment moves as the velocity rises through the lower curve and through the region marked "transportation of sediment." Only when the velocity is high enough to intersect the upper curve do sand grains begin to move. As the flood recedes and the velocity decreases, the velocity falls below the upper curve and into the transportation region. Under these conditions the sand that was



Box 16.2 Figure 1

Curves showing the stream velocities at which erosion and deposition of sediment occur. These velocities vary with the grain size of the sediment. See text for a discussion of point A and the dashed red line above it.

already eroded continues to be transported, but no new sand is eroded. As the velocity falls below the lower curve, the sand, coming to rest, is deposited.

Para remover material fino (arcilla) comparado con arena se necesita mayor energía, ya que la superficie es mayor. Por lo tanto, la arcilla tiene mayor cohesión.

eroded also rises toward the left of the diagram, however. This shows that fine-grained silt and clay are actually harder to erode than sand. The reason is that molecular forces tend to bind silt and clay into a cohesive mass that resists erosion. Once silt and clay are eroded, however, they are easily transported. As you can see from the lower curve, the silt and clay in a river's suspended load are not deposited until the river virtually stops flowing.

Table 23. Classification of alluvial channel patterns incorporating sediment type and channel stability. (After Schumm 1977)

Mode of sediment transport and type of channel	Channel sediment (M) (%)	Bedload (percentage of total load)	Channel stability		
			Stable (graded stream)	Depositing (excess load)	Eroding (deficiency of load)
Suspended load	> 20	< 3	Stable suspended-load channel. Width/depth ratio < 10; sinuosity usually > 2.0; gradient, relatively gentle	Depositing suspended load channel. Major deposition on banks cause narrowing of channel; initial streambed deposition minor	Eroding suspended-load channel. Streambed erosion predominant; initial channel widening minor
Mixed load	5-20	3-11	Stable mixed-load channel. Width/depth ratio > 10, < 40; sinuosity usually < 2.0, > 1.3; gradient, moderate	Depositing mixed-load channel. Initial major deposition on banks followed by streambed deposition	Eroding mixed-load channel. Initial streambed erosion followed by channel widening
Bed load	< 5	> 11	Stable bed-load channel. Width/depth ratio > 40; sinuosity usually < 1.3; gradient, relatively steep	Depositing bed-load channel. Streambed deposition and island formation	Eroding bed-load channel. Little streambed erosion; channel widening predominant

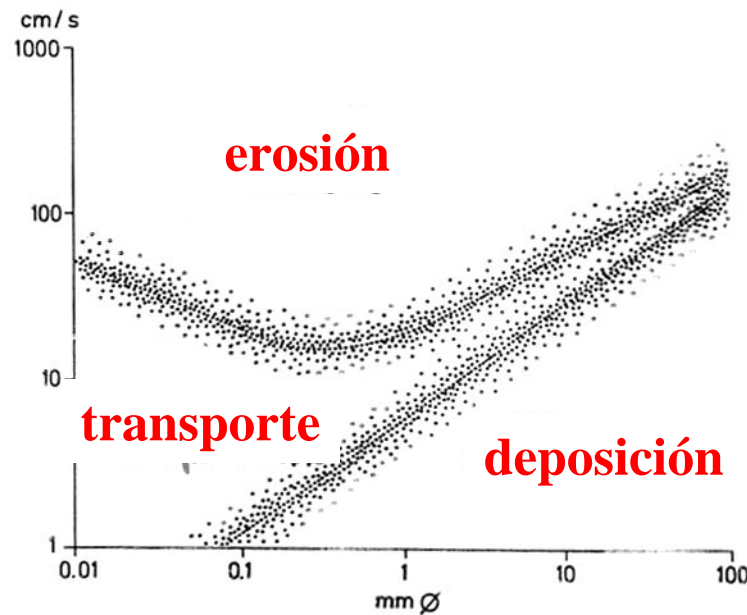


Abb. 19 Das Frachtvermögen des fließenden Wassers in Abhängigkeit von der Korngröße und Strömungsgeschwindigkeit. Die Teilchen im Felde „Ablagerung“ sind stets in Ruhe, die im Felde „Abtragung“ stets in Bewegung. Im Felde „Verfrachtung“ bleiben ruhende Teilchen in Ruhe, bewegte in Bewegung. Um ein ruhendes Korn in Bewegung zu bringen, ist also eine höhere Geschwindigkeit notwendig als diejenige, bei der es sich abgesetzt hatte. Infolge der Kohäsion steigt dieser Unterschied gegen feinere Korngrößen (nach F. Hjølström)

PROCESOS DE TRANSPORTE

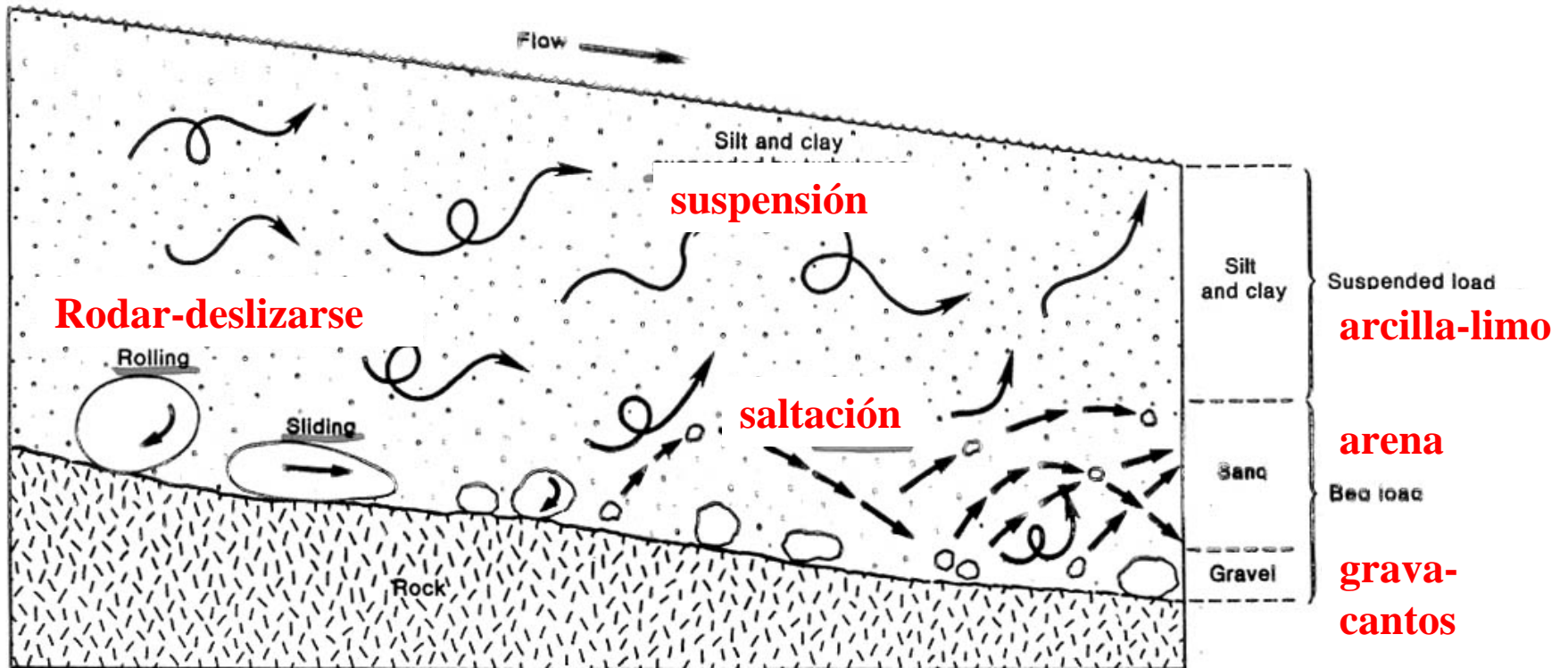


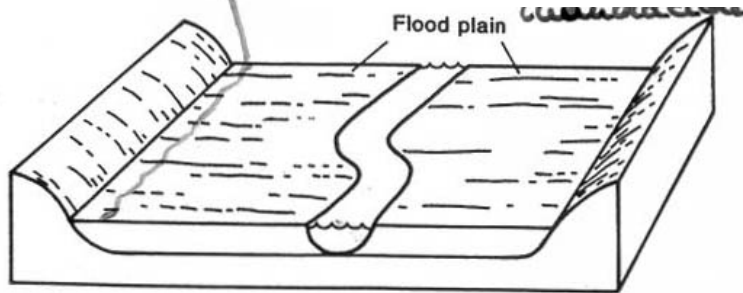
Figure 16.15

A stream's bed load consists of sand and gravel moving on or near the stream bed by traction and saltation. Finer silt and clay form the suspended load of the stream.

LEVEES NATURALES DURANTE CRECIDAS

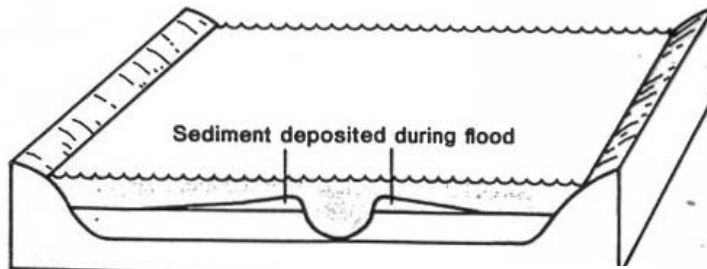
Yazoo tributario

llanura de inundación



Flujo normal

A



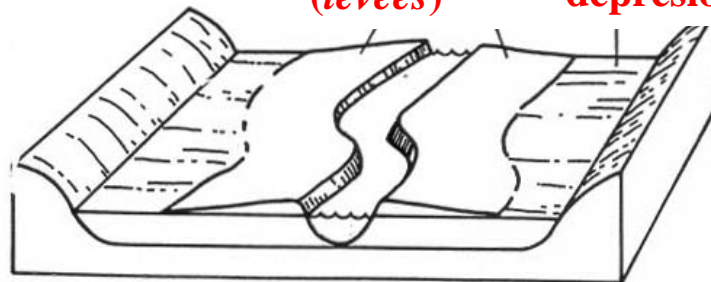
Durante una crecida

B

diques naturales

(levees)

depresión lateral



Después de la
crecida

C

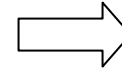
Figure 16.29

Natural levee deposition during a flood. Levees are thickest and coarsest next to the river channel and build up from many floods, not just one. (Relief of levees is exaggerated.)

(A) Normal flow. (B) Flood. (C) After flood.

VELOCIDAD DE UN RÍO

Cambios en curvatura del sistema meandriforme



Aumento del gradiente y velocidad del río

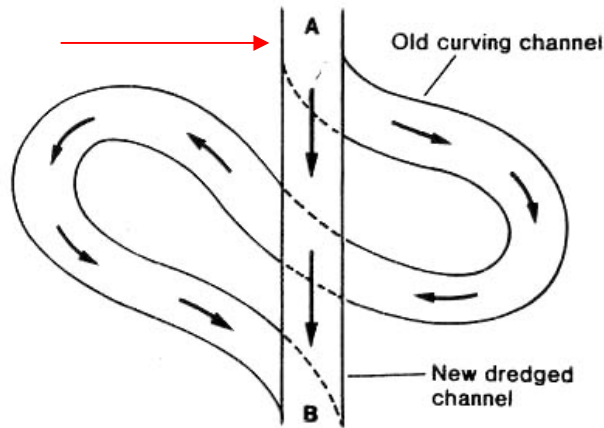


Figure 16.9

Channelization can increase a river's gradient (and velocity) by shortening the distance between two points.

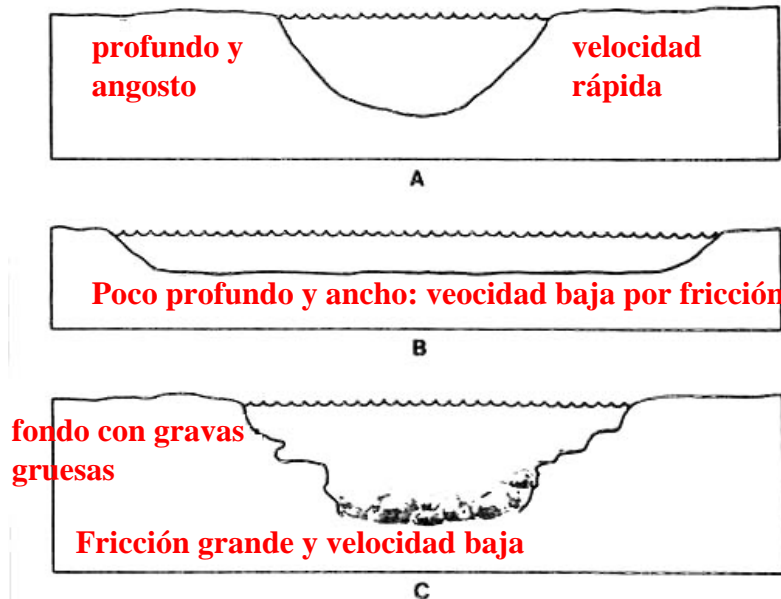


Figure 16.10

Channel shape and roughness influence stream velocity. (A) Narrow, deep channel with semicircular cross section allows stream to flow rapidly. (B) Wide, shallow channel increases friction, slowing river down. (C) Rough, boulder-strewn channel slows river.

Influencia de la forma y rugosidad del lecho del río en la velocidad de la corriente.

Talweg: línea de profundidad máxima

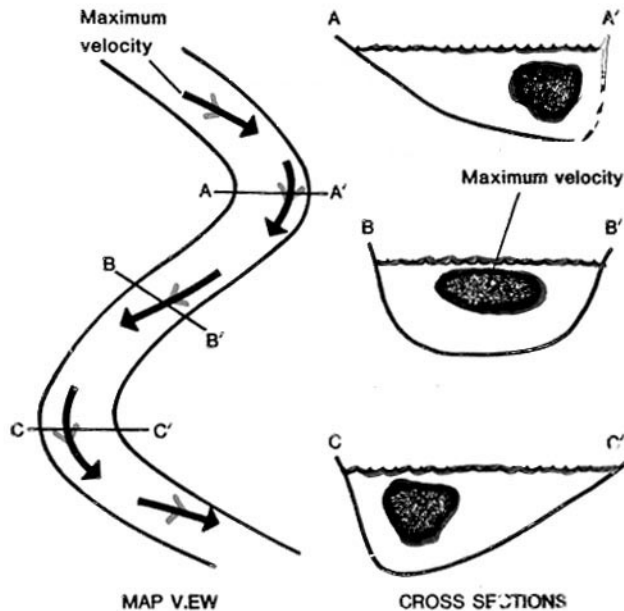


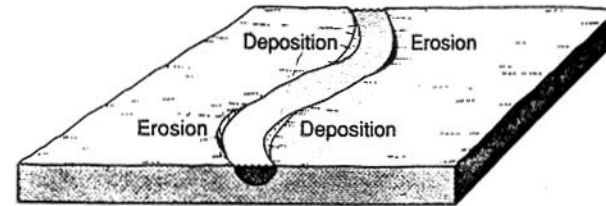
Figure 16.6
Regions of maximum velocity in a stream. Arrows on the map show how the maximum velocity shifts to the outside of curves. Sections show maximum velocity on outside of curves and in the center of the channel on a straight stretch of stream.

-Las máximas velocidades están en las partes externas de las curvas,
-y al centro del canal en una línea recta del río.

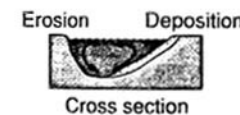
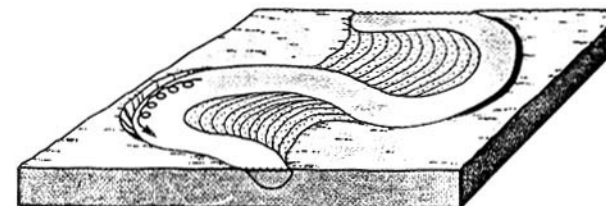
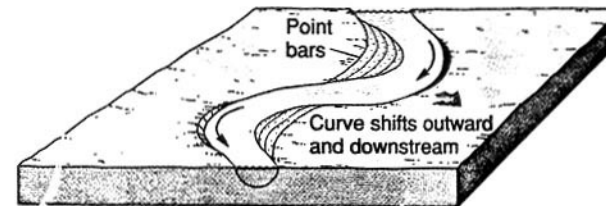


Se produce erosión en la parte externa y depósito en la parte interna de las curvas.

Depósito y erosión en un cauce de río



Lobus: barra de punta de depósito



Corkscrew water motion on a curve helps cause erosion and deposition.

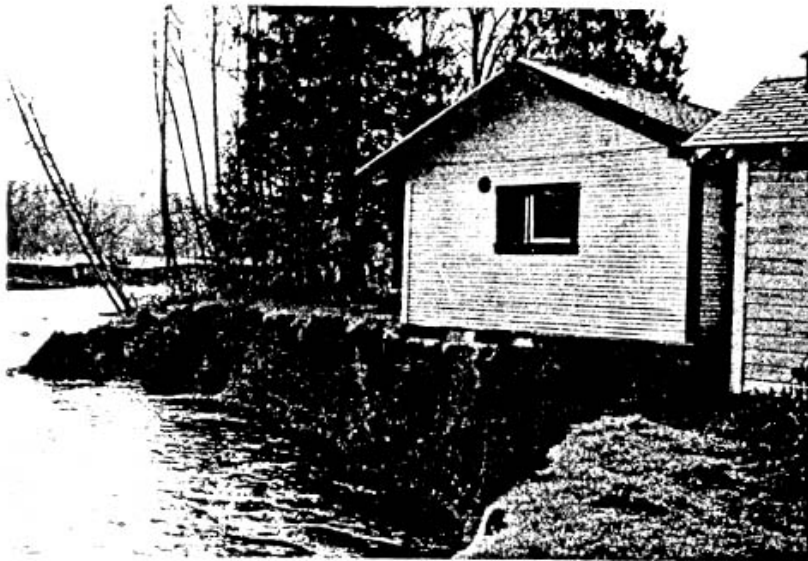
Figure 16.23
Development of river meanders and point bars by erosion and deposition.

Meandro: velocidad menor, sedimentación fuerte



**Ejemplo de erosión de la
parte externa de una
curva de un río
meandriforme**

Enero 1965



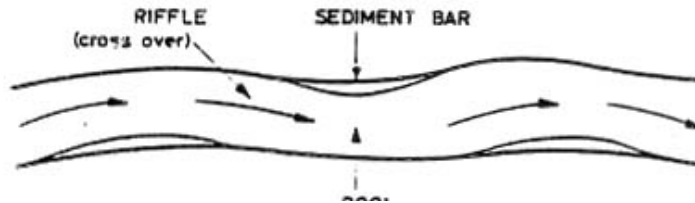
Marzo 1965

Figure 16.22

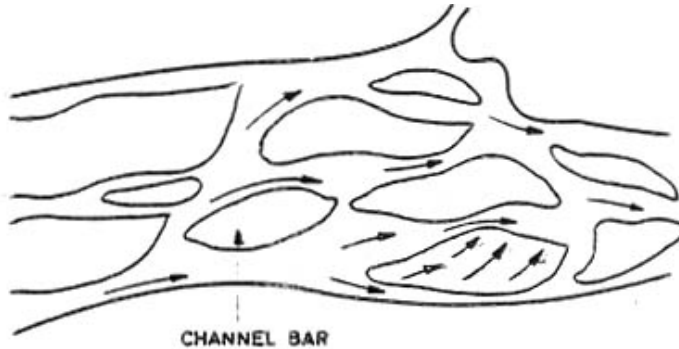
River erosion on the outside of a curve, Nwaukum River,
Washington. Pictures were taken in January and March 1965.
Photos by P. A. Glancy, U.S. Geological Survey.

Cambios en un sistema meandriforme

rectilíneo



anastomosado



meandriforme

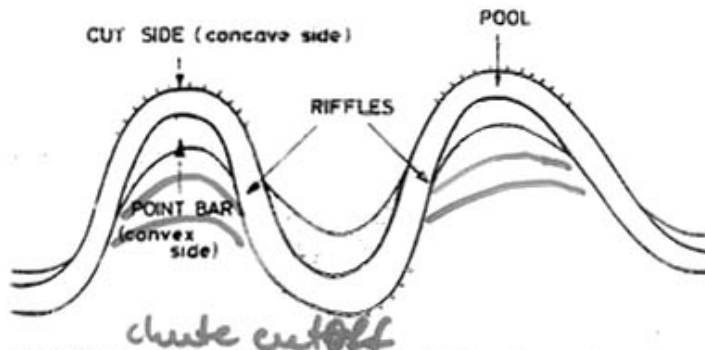


Fig. 372. Straight, braided, and meandering channel patterns



coalescencia, estragulamamiento y acortamiento

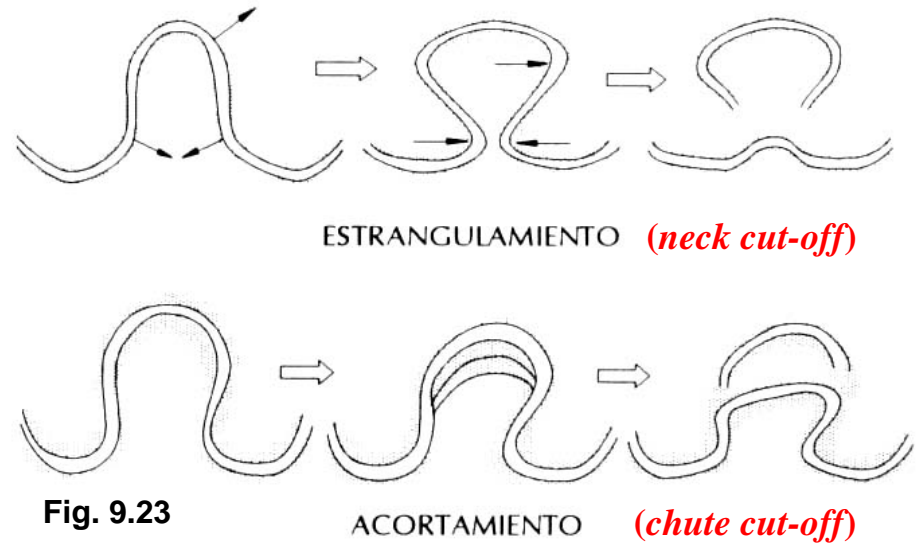
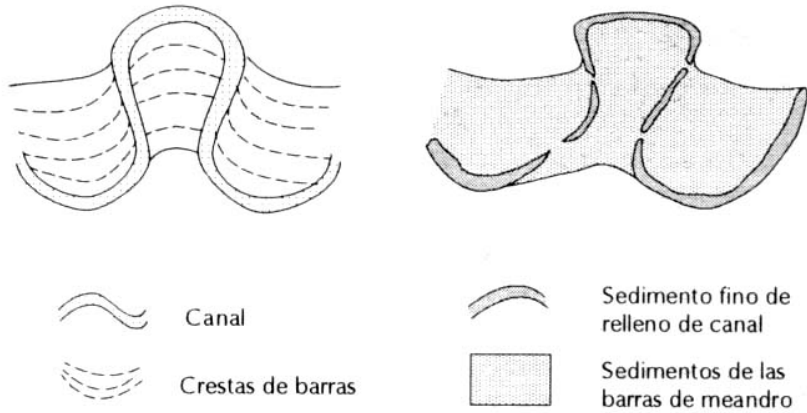


Fig. 9.23

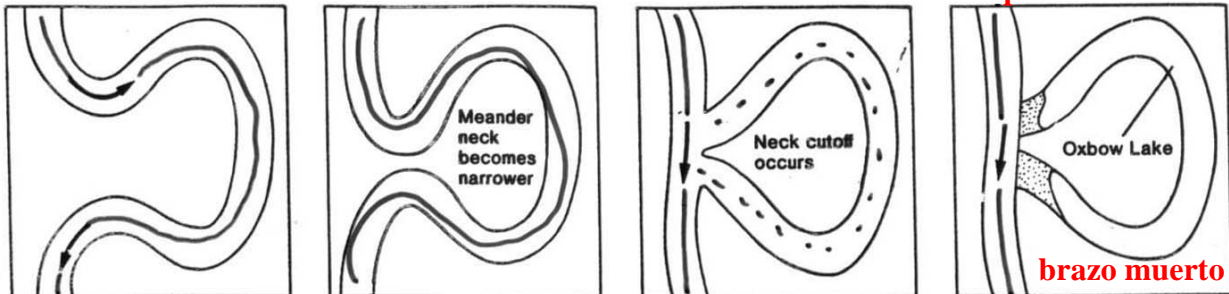


Figure 16.25

Creation of an oxbow lake by a meander neck cutoff. Old channel is separated from river by sediment deposition.

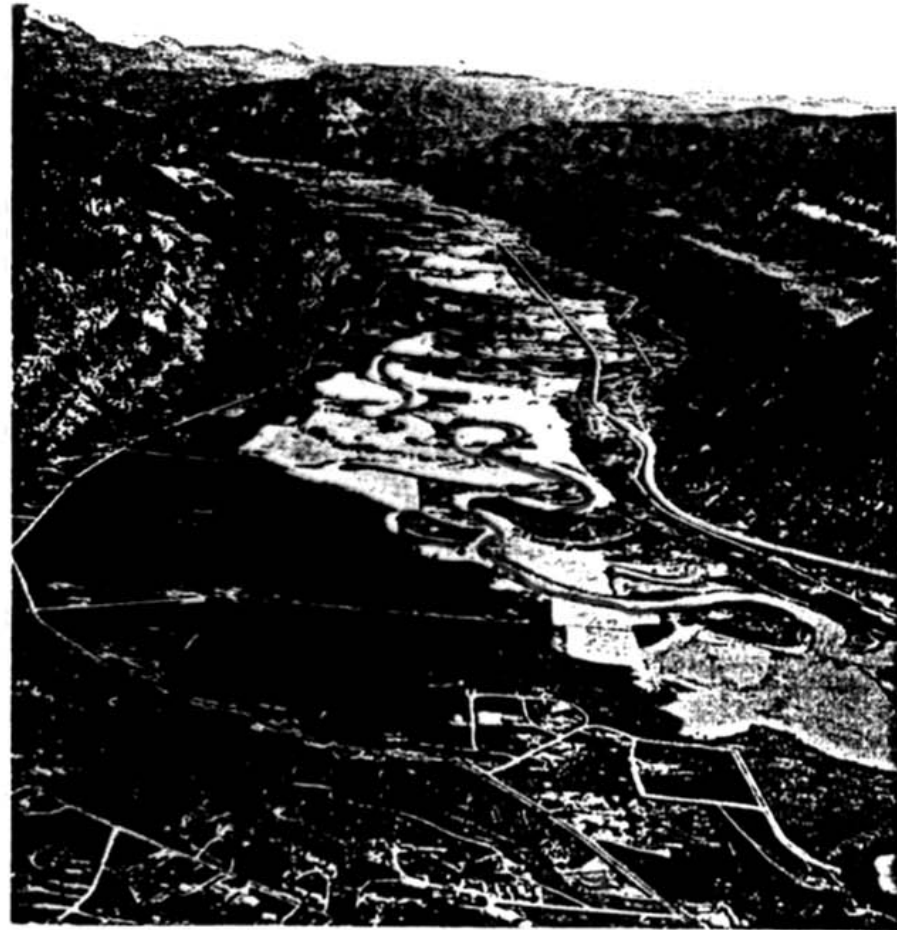
estrangulamiento

Laguna semilunar
Oxbow="collares de buey"

?



Figure 16.26
 An oxbow lake ma **Laguna semi-lunar (oxbow)**
 Sweetwater River, Wyoming.
 Photo by W. R. Hansen, U.S. Geological Survey



TIPOS DE CANALES FLUVIALES

***morfologías
relacionadas a pendientes,
velocidades y carga***

MORFOLOGÍA FLUVIAL

- Se analiza la altura y sección de un canal.
- Los tipos de canales depende directamente de:
 - 1) la cantidad de agua y,
 - 2) el régimen de flujo.
- ***LECHO FLUVIAL** (lecho de un río) :
 - 1) Lecho mayor o de inundación ocupado durante crecidas.
 - 2) Lecho ordinario: ocupado durante todo el año.
 - 3) Lecho de estiaje: ocupado sólo en los períodos de aguas más bajas.

Características de un lecho fluvial

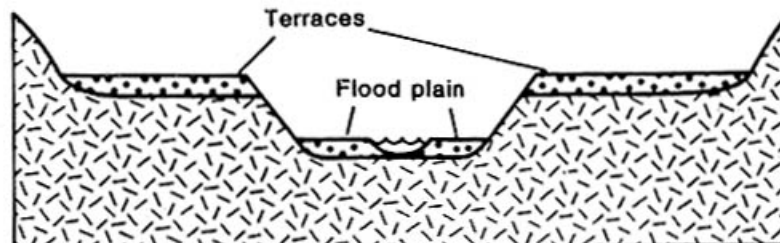
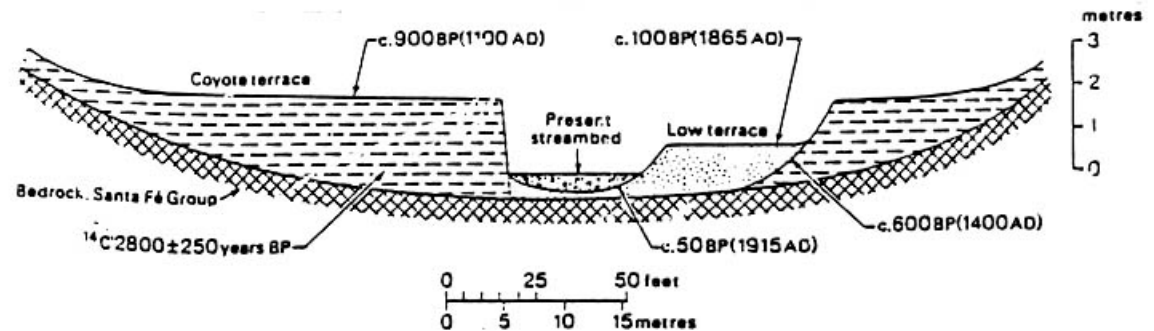
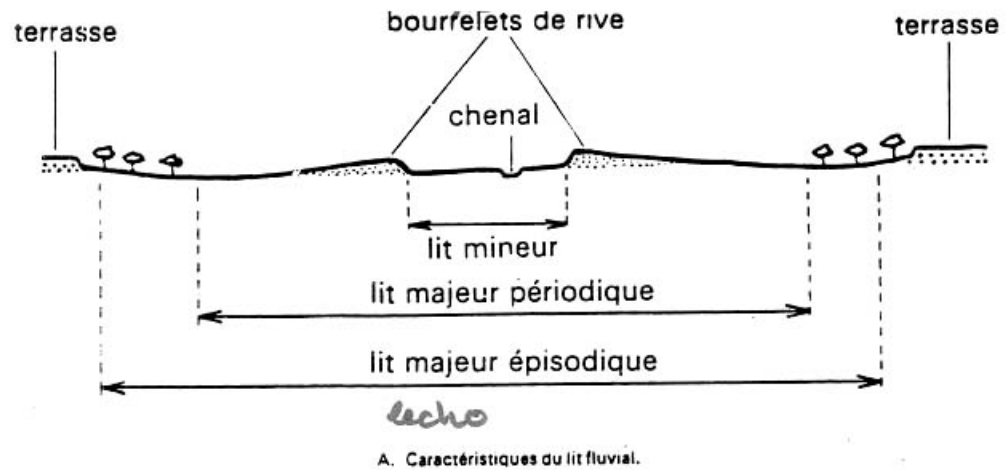


Figure 16.51
Paired terraces may be erosional benches cut in rock.

TIPOS DE RÍOS SEGÚN SINUOSIDAD y *BRAIDING*

- **SINUOSIDAD** (Si)

Si= L. del *talweg* (línea que une los puntos más bajos del canal)

Longitud del valle (distancia que separa el punto inicial del final)

- Si < 1.05 rectilíneo
- Si 1.05 a 1.5 sinuoso
- Si > 1.5 meandriforme

- ***BRAIDING***

- **BRAIDED**: Canal ordinario. Canal de estiaje no es único, son varios entretejidos separados por islas de sedimentos (muy común en Chile). Ángulos agudos entre barras y mayor velocidad que en canal sinuoso.

- **ANASTOMOSADO** : ángulos entre canales de estiaje son más abiertos. Gran cantidad de carga en suspensión. Velocidad muy baja (< que braided) y variación de velocidad escasa. Menor velocidad que el meandriforme.

Tipos de corrientes fluviales

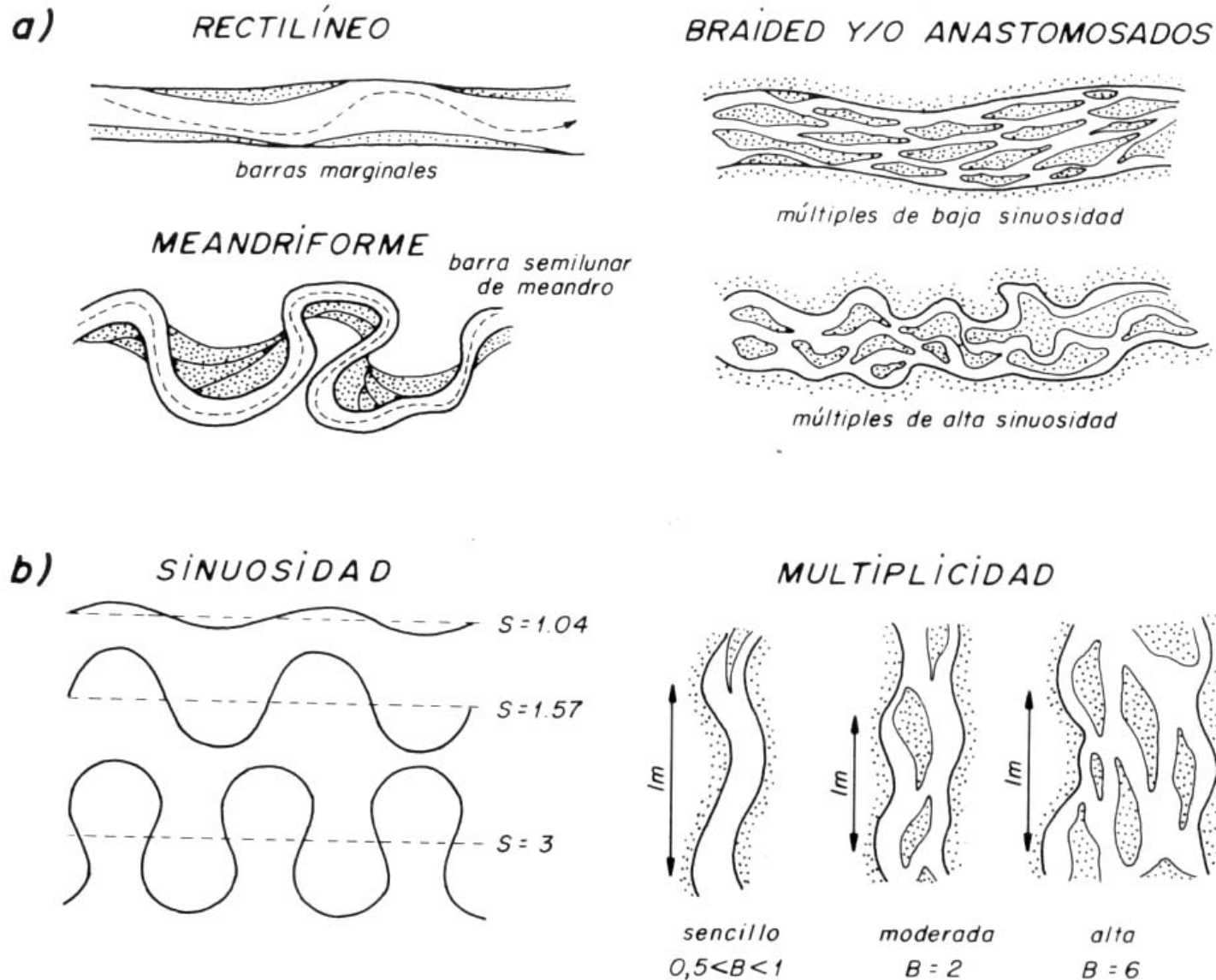


Fig. 9.14. A) Corrientes fluviales según su trazado en planta: tipologías básicas (“tipos de ríos”). B) Valores que adoptan los parámetros de sinuosidad (S) y multiplicidad (*braiding* o B) en un lazo de meandro (l_m) para varias corrientes.

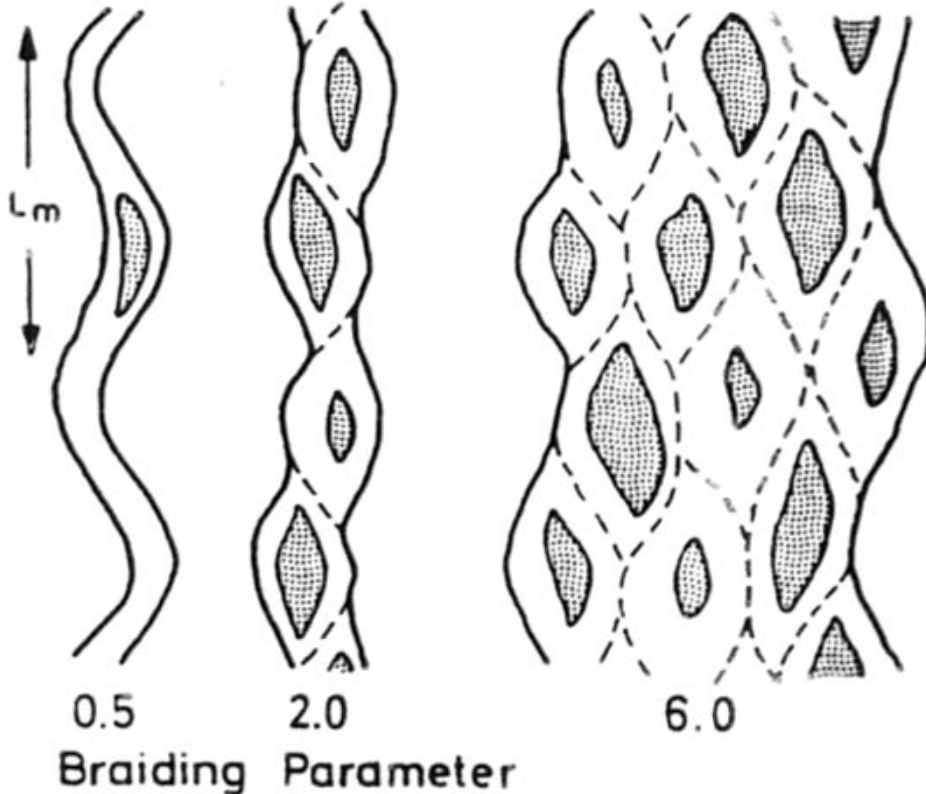
Tipos de ríos (parámetro de *braiding*)

SINGLE -
CHANNEL

MULTI- CHANNEL

Moderately
braided

Highly
braided



Cuadro 9.2. Tipos de ríos (según Rust, 1978).

Sinuosidad \ Multiplicidad	Canal sencillo (parámetro de <i>braiding</i> < 1)	Canal múltiple (parámetro de <i>braiding</i> > 1)
	RECTILÍNEO	<i>BRAIDED</i>
Baja < 1,5		
Alta > 1,5	MEANDRIFORME	ANASTOMOSADO

Fig. 371. Schematic diagram showing single-channel and multi-channel (moderately and highly braided) streams. (After Rust 1978a)

braided - anastomosado

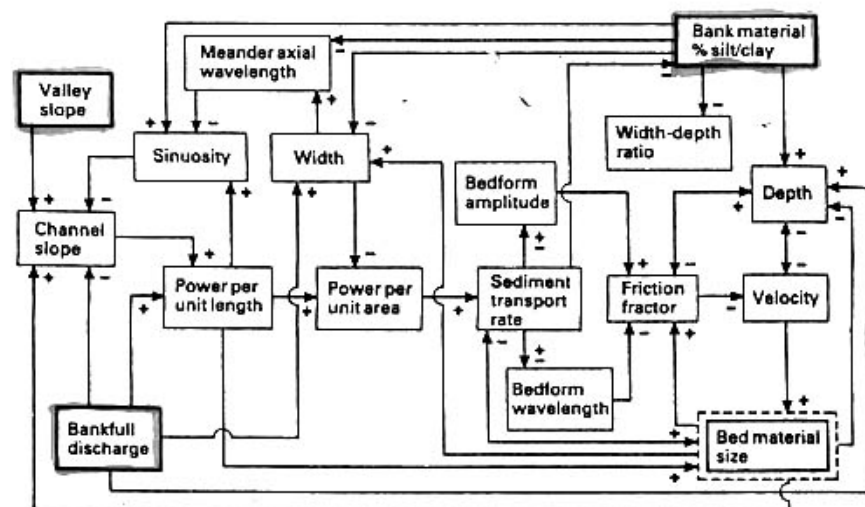


Fig. 9.17 The alluvial channel system. Independent variables are indicated by a bold outline. Direct relationships are shown by + and inverse relationships by -. Indeterminate relationships are indicated by double-headed arrows. (After K. Richards (1982) *Rivers: Form and Process in Alluvial Channels*. Methuen, London, Fig. 1.8, p. 26.)

Table 9.2 Classification of stable alluvial channels

TYPE OF CHANNEL	BED LOAD AS % OF TOTAL LOAD	CHANNEL CHARACTERISTICS
<i>ej.</i> 3a Suspended load	<3 m	Width-depth ratio <10; sinuosity usually >2.0; relatively gentle gradient
3b Mixed load	3-11 ms-a	Width-depth ratio 10-40; sinuosity usually 1.3-2.0; moderate gradient
4 Bed load	>11 b	Width-depth ratio >40; sinuosity usually <1.3; relatively steep gradient

Source: Modified from S. A. Schumm (1977), *The Fluvial System*. Wiley, New York, Table 5-4. p. 156.

sinuosidad = $\text{Largo canal} / \text{Largo valle}$
 $s=1 \Rightarrow$ canal rectilíneo, $s>1.5 \Rightarrow$ meandro

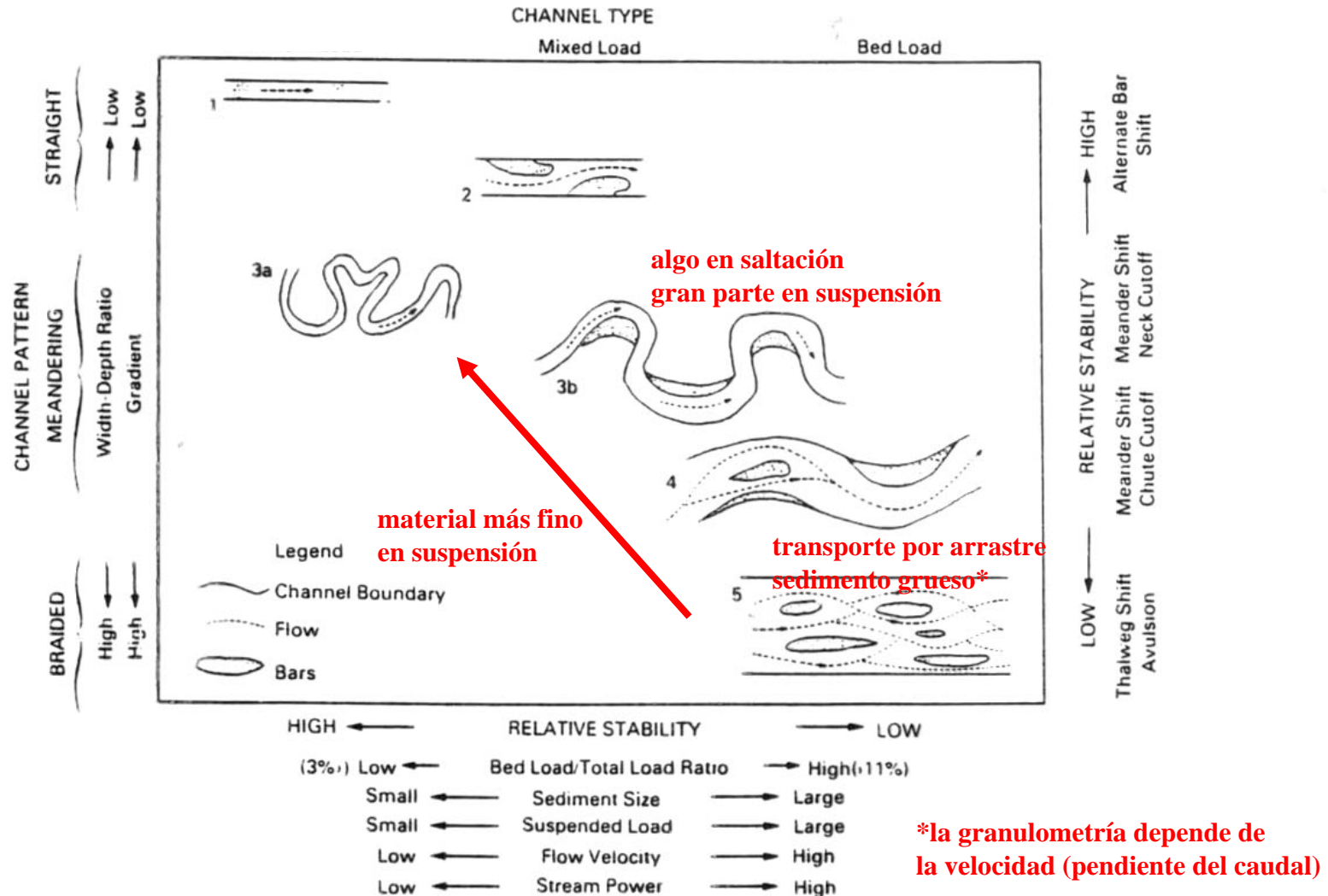
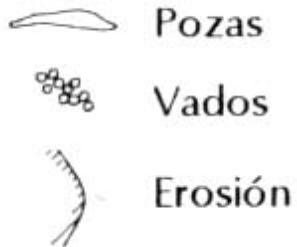
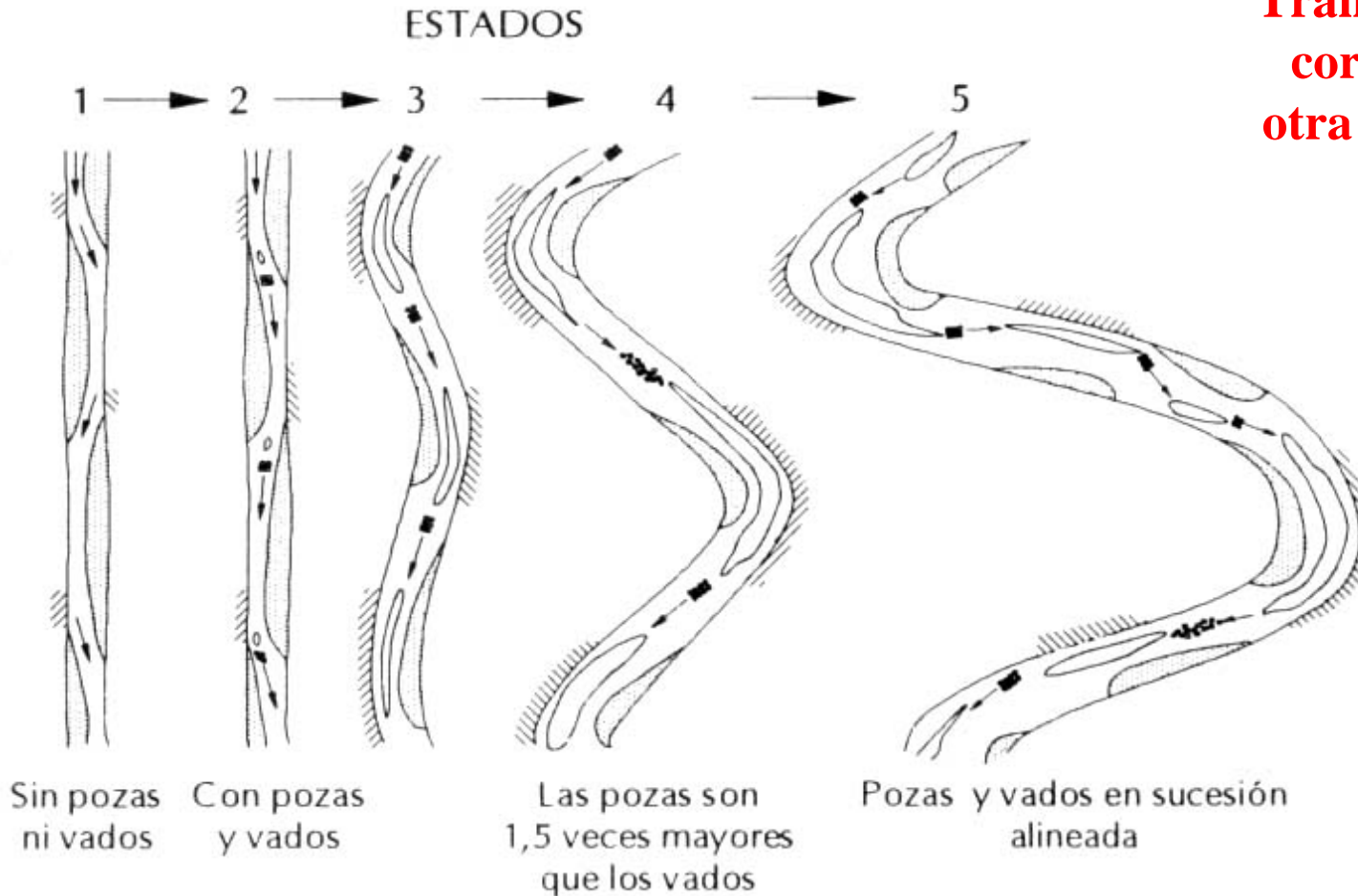


Figure 11.13 Channel classification based on pattern and type of sediment load, showing types of channels, their relative stability, and some associated variables (after Schumm 1985).

Transformación de una corriente rectilínea en otra meandríforme por pérdida de energía



En un computo global, los ríos rectilíneos aparecen como los más inestables, con alta energía y capacidad para la excavación; por ello su permanencia es escasa.

Una pérdida energética, normalmente hace que comiencen a desarrollar sinuosidades ajustando su dinámica a un proceso mixto erosivo-sedimentario.

OTRA CLASIFICACIÓN DE LOS RÍOS

Según sinuosidad y relaciones de carga de fondo/carga total

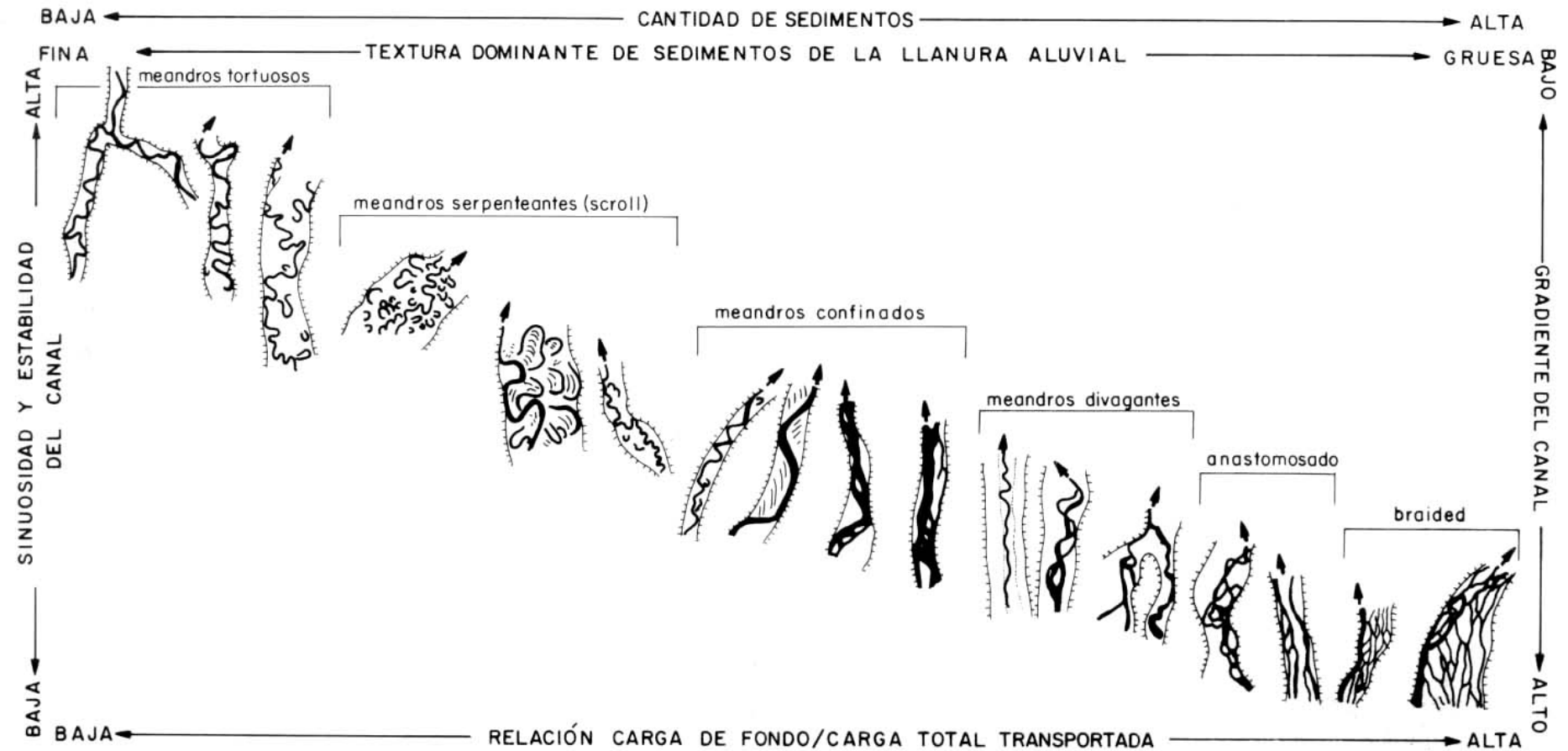


Fig. 9.25. Relación entre las diferentes modalidades de corrientes (en planta) con la carga, estabilidad y gradiente del canal (según Mollard, 1973). Obsérvese que las corrientes multimeandriiformes son consideradas por este autor como anastomosadas.



tren de meandros, **con desplazamiento**,
restos de canales abandonados por acortamiento
y estragulación



río confinado en un cañon fluvio-cárstico
meandriforme, **con poco desplazamiento**.
La extensión de los arcos deja colgados algunos
afluentes

TERRAZAS FLUVIALES

procesos de alzamiento

Fuerza erosiva de un río

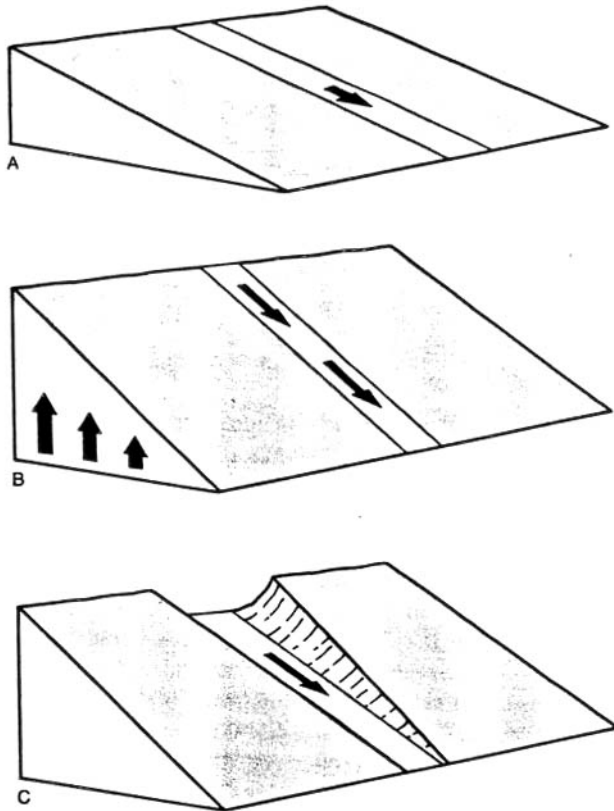


Figure 16.8

Uplift of the land can increase the rate of erosion. (A) River flows slowly on a gentle gradient, with little erosion. (B) Differential uplift increases the gradient, which increases the river's velocity. (C) The valley is deepened by rapid erosion resulting from the increase in velocity.

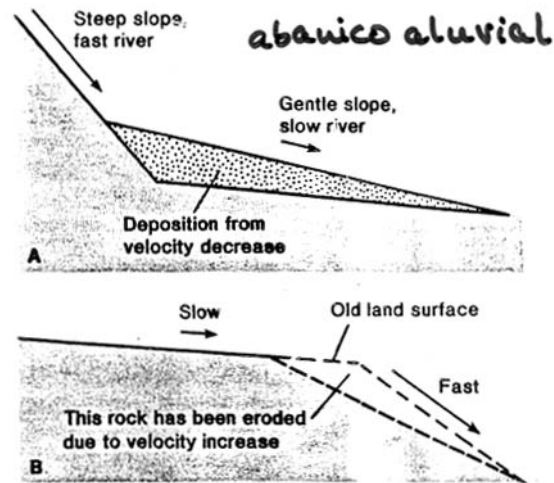
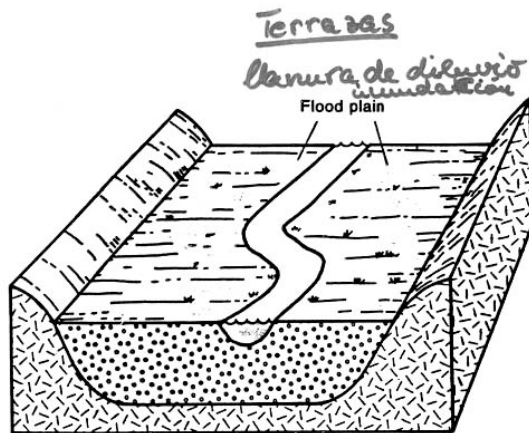
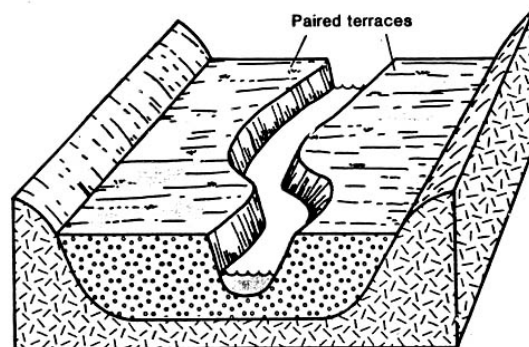


Figure 16.7

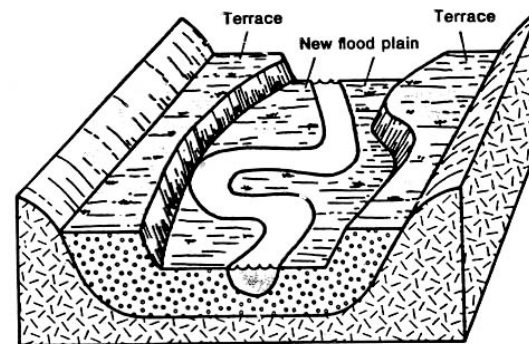
Changes in gradient can cause deposition and erosion.



A



B

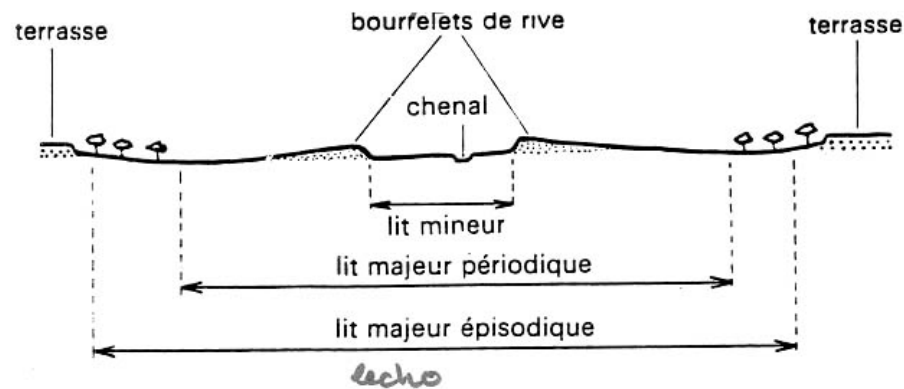


C

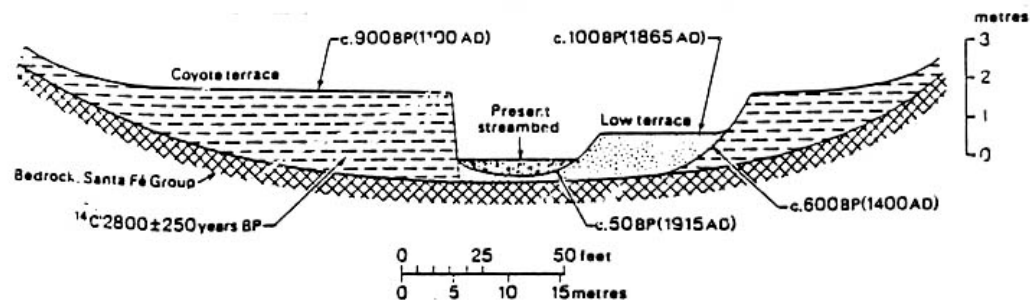
terrazas pares

Figure 16.50

Paired terraces formed by a river cutting downward into its own flood-plain deposits. (A) River deposits thick, coarse, flood-plain deposits. (B) River erodes its flood plain by downcutting. Old flood-plain surface forms paired terraces. (C) Lateral erosion forms new flood plain below terraces.



A. Caractéristiques du lit fluvial.



Arroyo de Los Frijoles (Nuevo México) (Leopold, 1966)

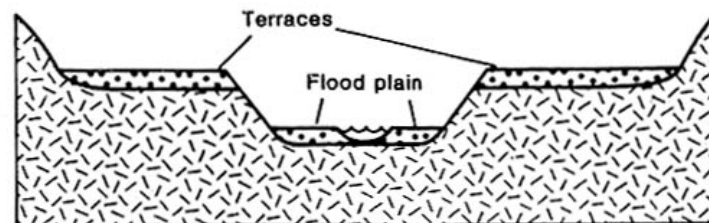
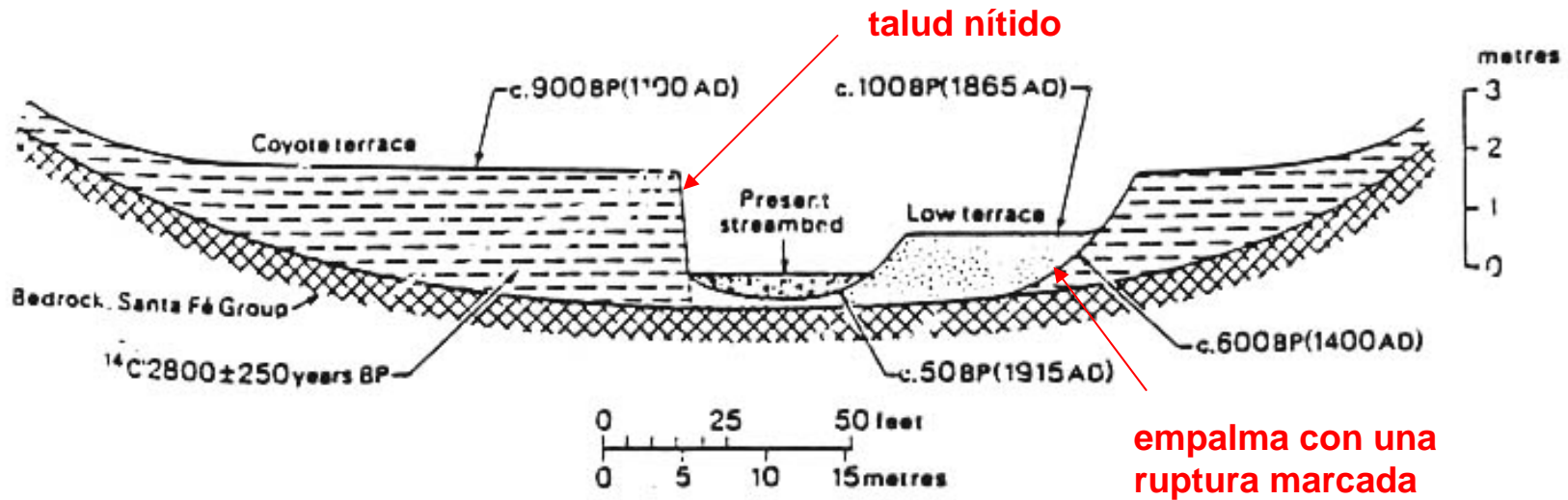


Figure 16.51

Paired terraces may be erosional benches cut in rock.

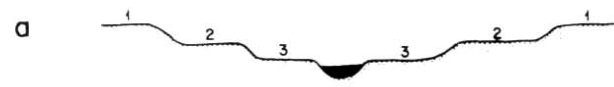


Los cambios del sistema indican un desequilibrio debido a efectos antrópicos, agricultura por ejemplo. Los sedimentos que rellenan el valle no cortan la cuenca.

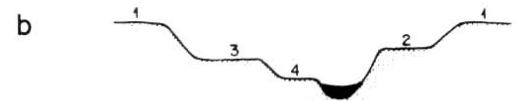
Evolución:

- 1º) Se rellenó el valle al menos hasta el nivel de 2 m.
- 2º) Fase de desequilibrio, mayor energía => erosión del substrato, formándose la primera terraza aluvial.
- 3º) Venía más material que el que podía ser transportado => sedimentación.
- 4º) Segunda fase de disección, reexcavación del valle.
- 5º) Sedimentación de gravas.

apareadas



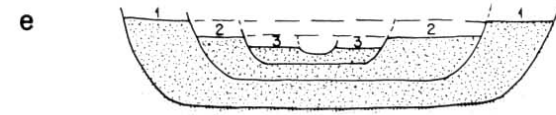
No apareadas



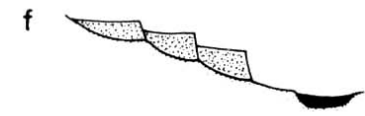
simétricas



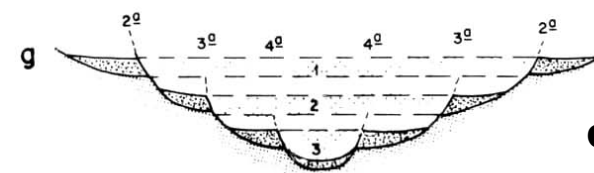
asimétricas



Superpuestas o encajadas



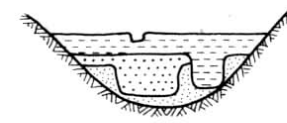
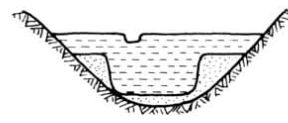
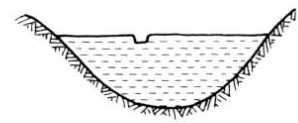
escalonadas



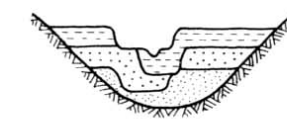
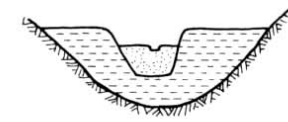
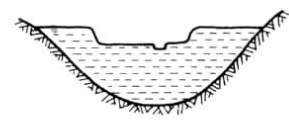
combinaciones

(4g) actual

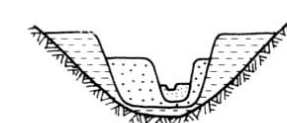
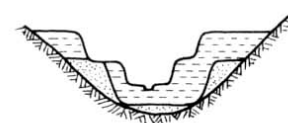
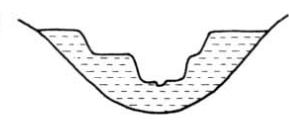
h₁) Sin terraza



h₂) Una terraza



h₃) Dos terrazas



1

2

3

Una fase de aluvionamiento

Dos fases de aluvionamiento

Tres fases de aluvionamiento

Fig. 9.30. Tipologías más frecuentes de terrazas según sus perfiles transversales (secciones):