Cairo University
Faculty of Engineering
Public Works Department
Soil Mechanics and Foundations Research Laboratory

Engineering Geology

Lecturer:

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Acknowledgement

- Herbert Einstein
- Andy Link
- Dayanthie Weeraratne
- James M. Hayden
- Mihai Ducea
- University of Arizona, Geosciences Department, Website
- Vincent Salters
- Mustafa Hariri (KFUPM)
- Jian Zhao (EPFL)
- http://edtech.mit.edu/fcgi-bin/pgt
- Deborah Fereile (New Jersey City University)
- University of Kentucky, Department of Earth and Environmental Sciences
- Charles Smart (Kean University)

Physical Geology

Lecture 3

Geomorphology or Physical Geology

- Analysis of the various land forms of the Earth's surface in terms of their form, origin, and evolution.
- The influence of the different geologic and climatic environments upon the development of land forms.
- Agents
  - “that which acts or has the power to act”
  - Water and ice, wind
- Subsurface Modifiers
  - Tectonic compression, tension and shear
- Processes
  - “progressive steps by which an end is attained”
  - Weathering, erosion, transport, deposition

Weathering and Erosion

- **Weathering** - processes at or near Earth's surface that cause rocks and minerals to break down.

- **Erosion** - process of removing Earth materials from their original sites through weathering and transport.

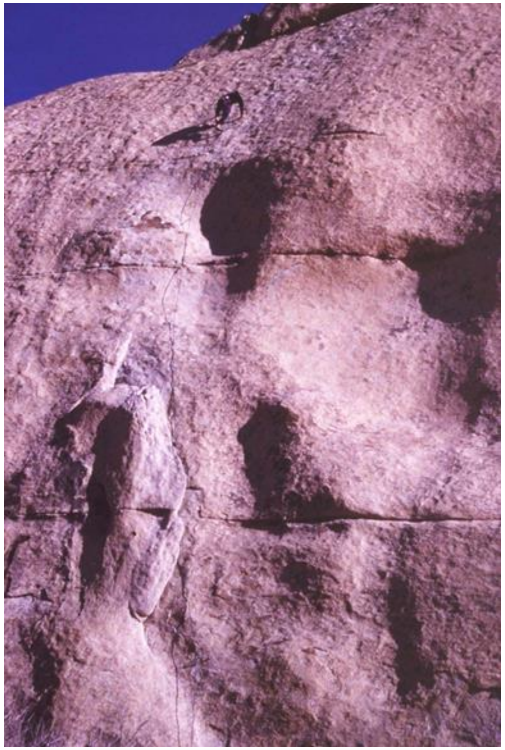
Weathering

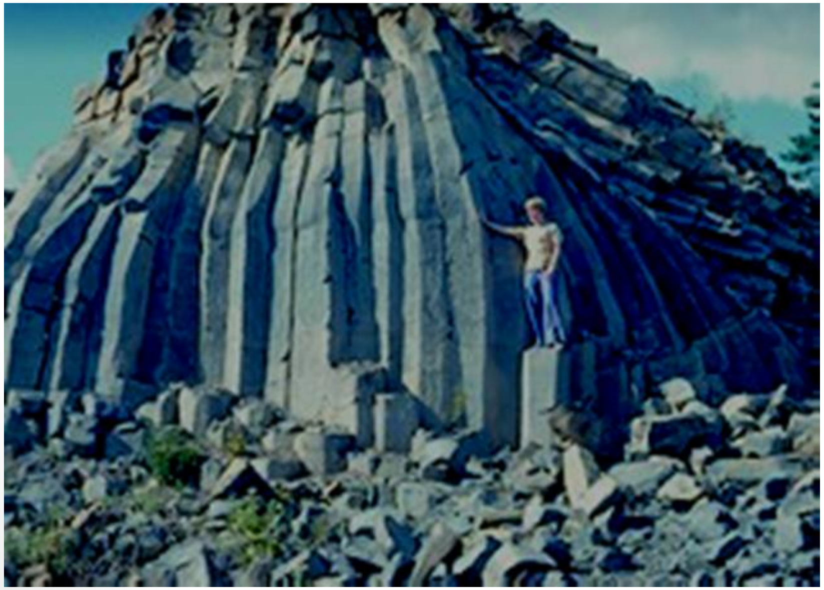
- **Mechanical Weathering** - processes that break a rock or mineral into smaller pieces without altering its composition

- **Chemical Weathering** - processes that change the chemical composition of rocks and minerals

Mechanical Weathering Causing Joints

- Unloading
- Shrinkage/ Cooling
- Differential stiffness





Unloading

- Form by unloading of bedrock through erosion.
- They form parallel to topography
- Exfoliation Joints

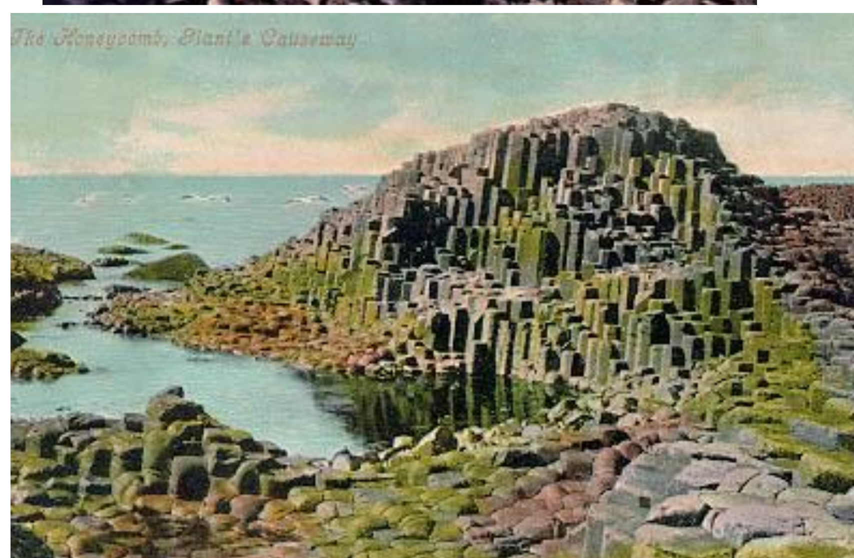
Exfoliation

- As underlying rock layers are exposed, there is less pressure on them and they expand. This causes the rigid layers to crack and sections to slide off

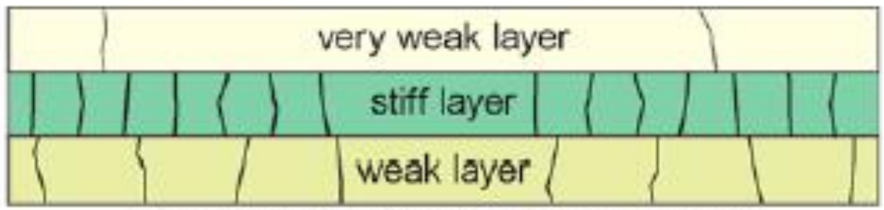
Thermal Expansion and Contraction

- repeated heating and cooling of materials cause rigid substances to crack and separate

Cooling joints: form by thermal contraction



Differential Stiffness



Spacing of bedding-parallel joints
according to competence (elastic modulus) of layers

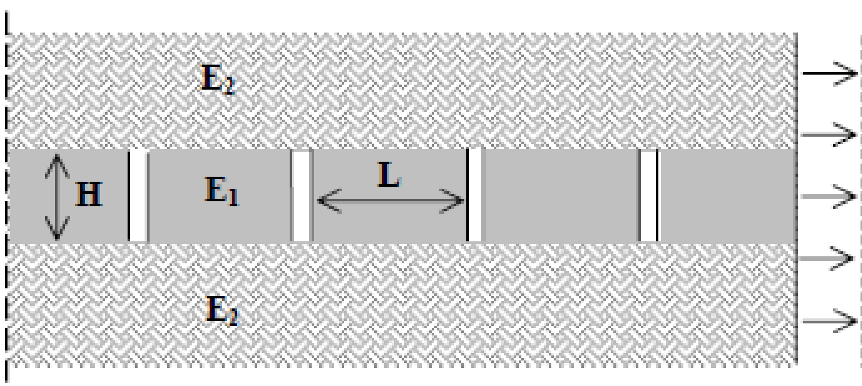
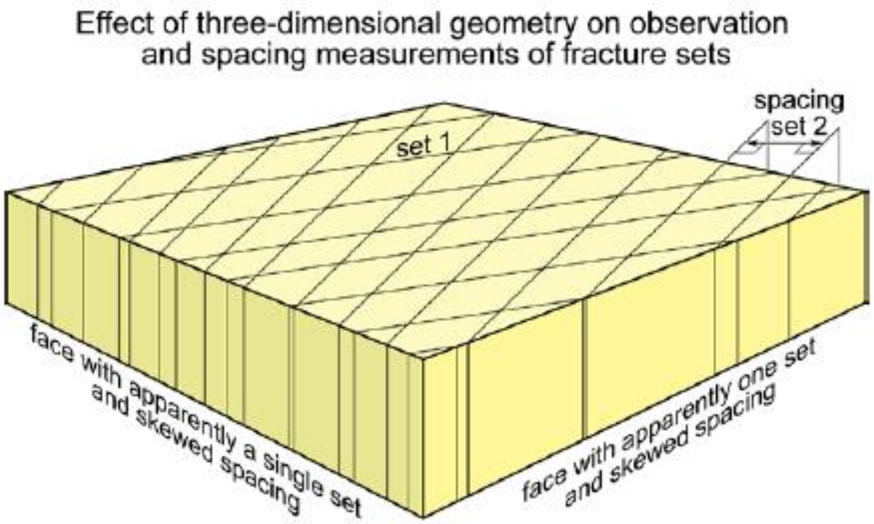


Fig. 4.11. Multilayer of stiff (E_1) and softer layer (E_2) under uniform lateral extension. Extension causing tension fractures in the stiffer bed:

$E_2 < E_1$

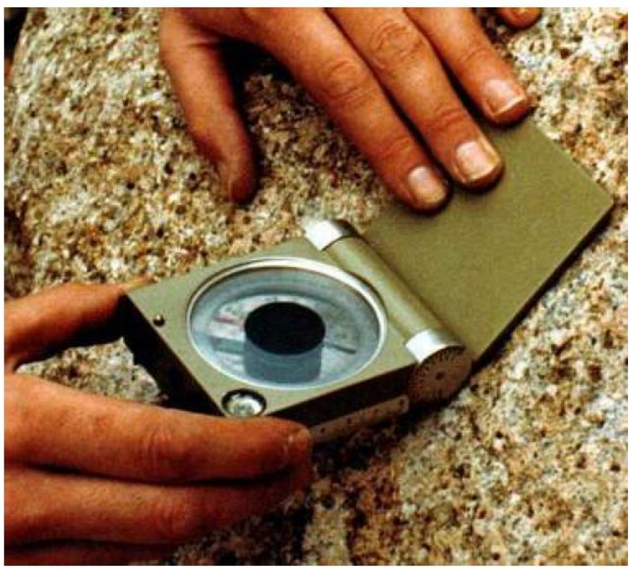
Joint Sets and Systems

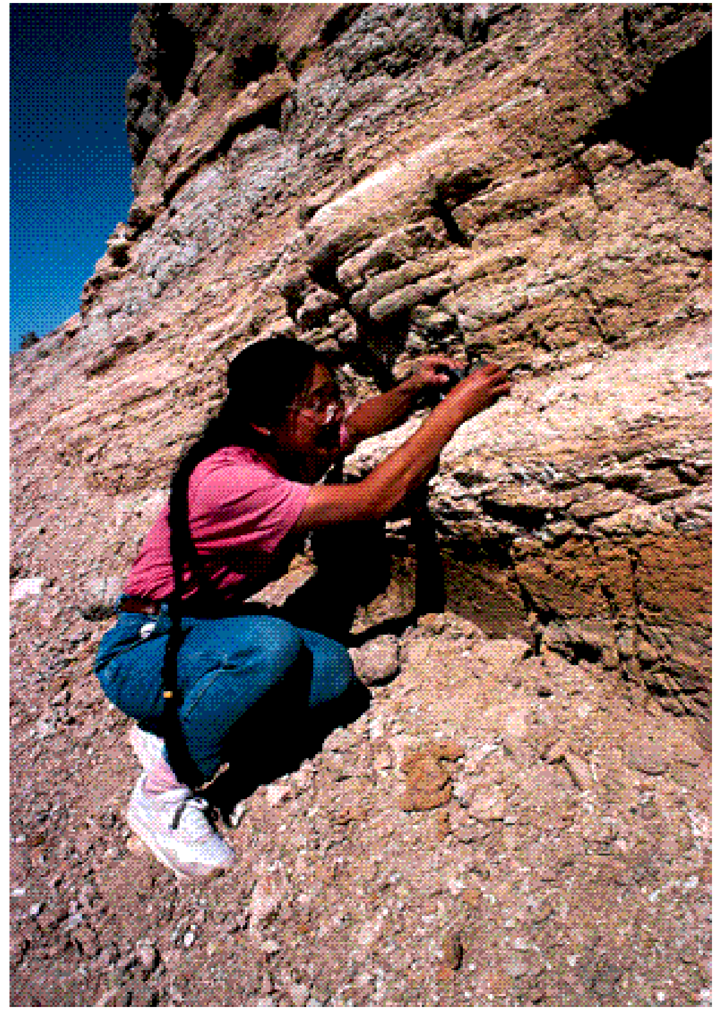
- Orientation/ Attitude
- Spacing
- Aperture
- Persistence
- Roughness/Waviness



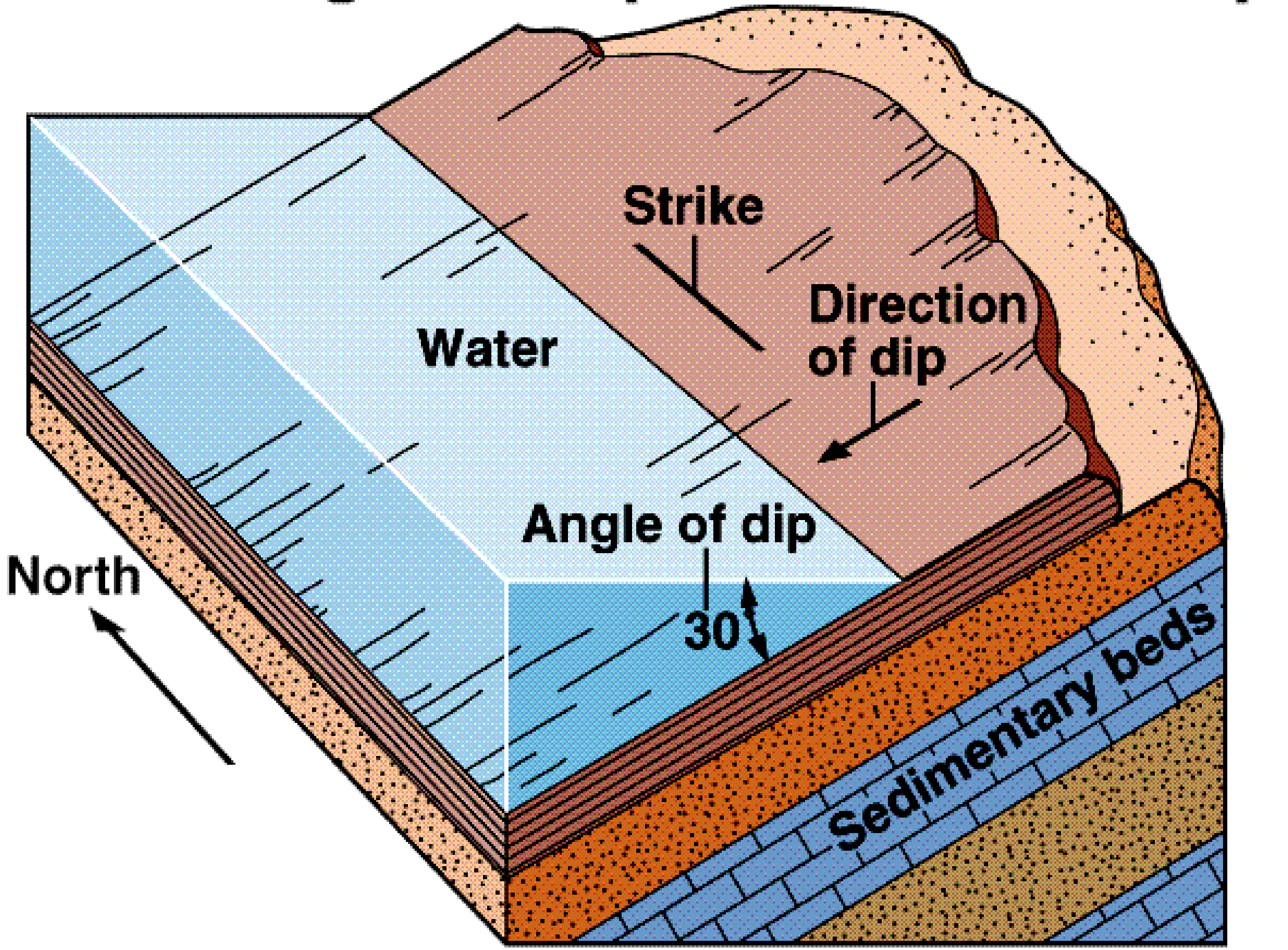
Orientation

Geologist Determines Strike and Dip

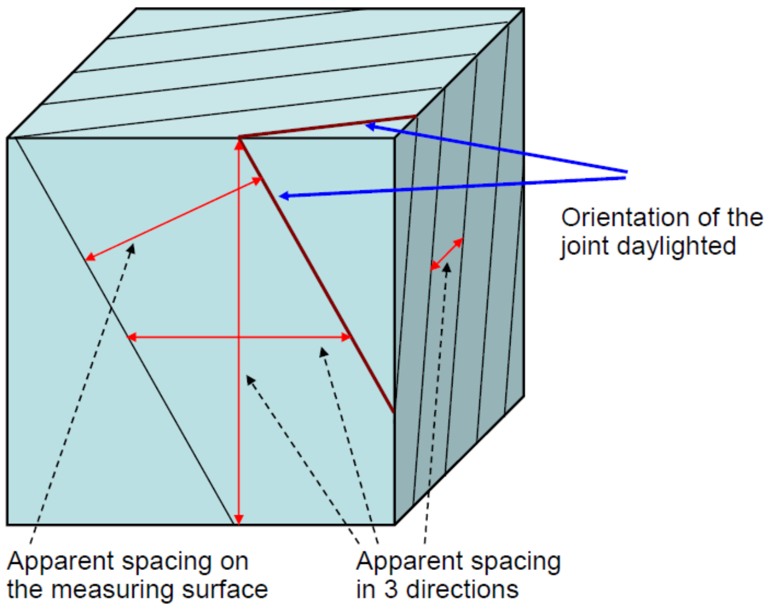




Strike; Angle of Dip; Direction of Dip



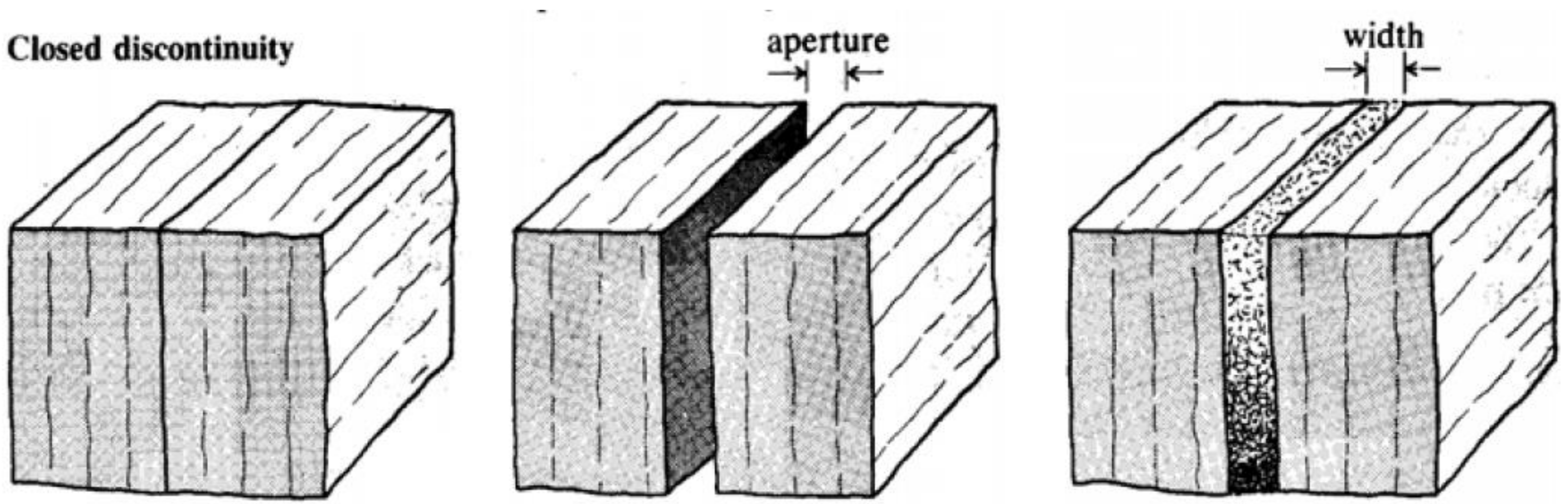
Spacing



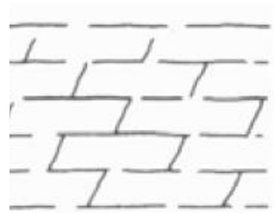
Description	Joint Spacing (m)
Extremely close spacing	< 0.02
Very close spacing	0.02 – 0.06
Close spacing	0.06 – 0.2
Moderate spacing	0.2 – 0.6
Wide spacing	0.6 – 2
Very wide spacing	2 – 6
Extremely wide spacing	> 6

Aperture

Aperture	Description	
< 0.1 mm	Very tight	
0.1 ~ 0.25 mm	Tight	"Closed feature"
0.25 ~ 0.5 mm	Partly open	
0.5 ~ 2.5 mm	Open	"Gapped feature"
2.5 ~ 10 mm	Widely open	
1 ~ 10 cm	Very widely open	
10 ~ 100 cm	Extremely widely open	"Open feature"
> 1 m	Cavernous	



Persistence



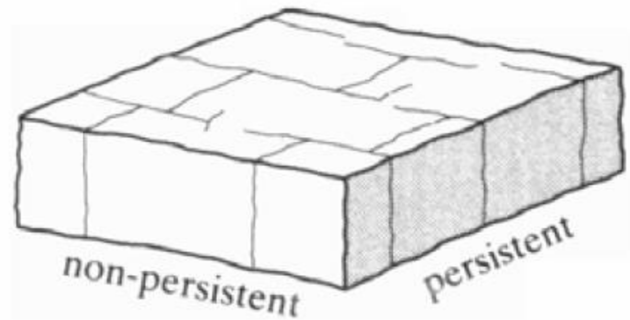
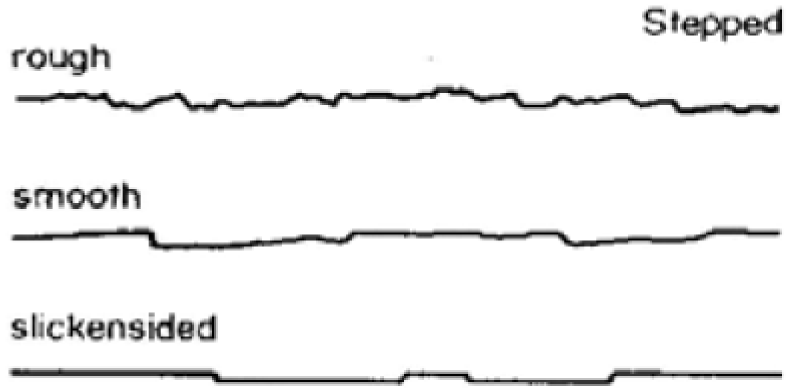


Table 5.1.1b ISRM classification of discontinuity persistence

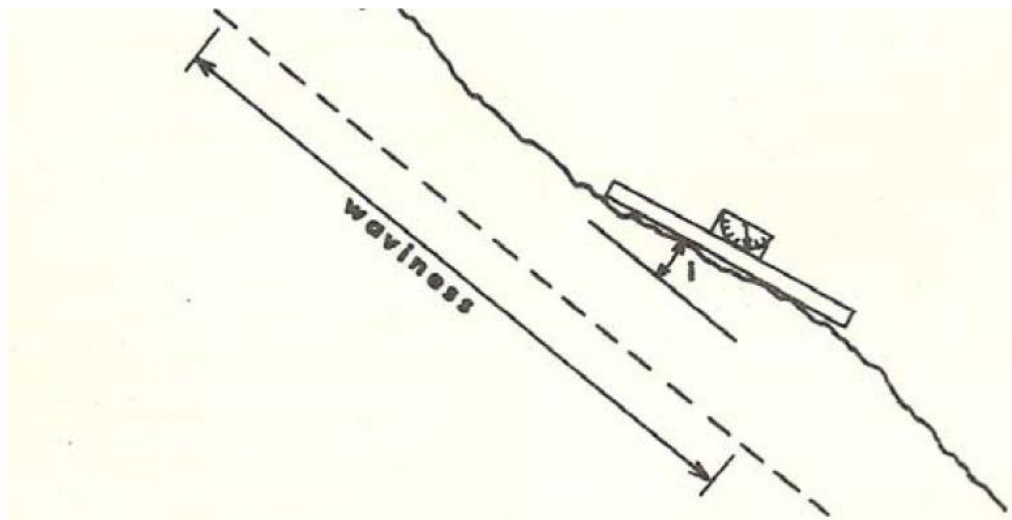
Description	Surface Trace Length (m)
Very low persistence	< 1
Low persistence	1 – 3
Medium persistence	3 – 10
High persistence	10 – 20
Very high persistence	> 20

Roughness and Waviness

Small Aperture <5mm



Larger Aperture >5mm

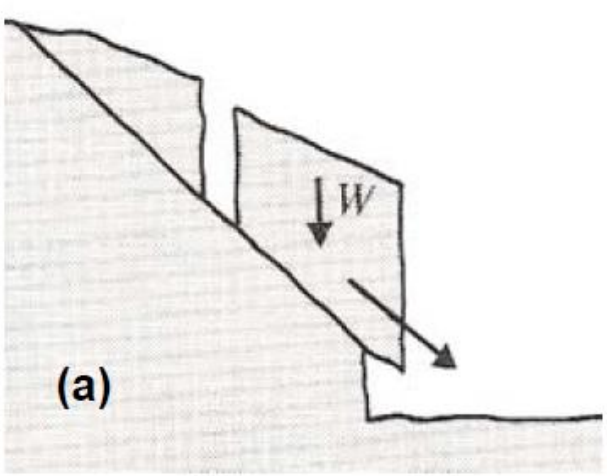


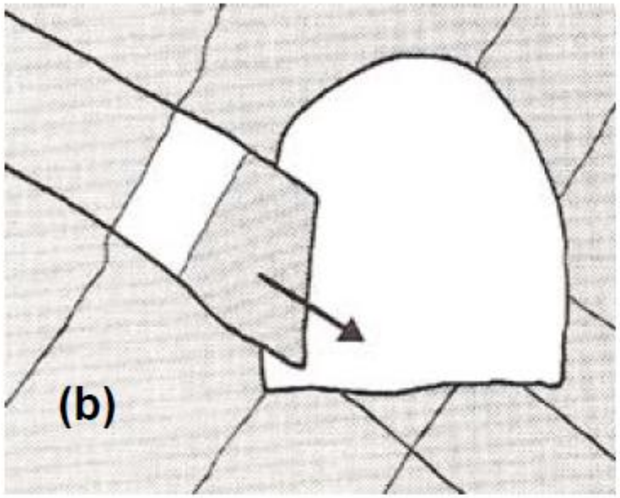
Effect of joint Characteristics on Engineering Properties

- Permeability
- Deformability
- Strength

Fillings:

- Air
- Water
- Sediments washed in or out
- Weathered Material
- Precipitated Material



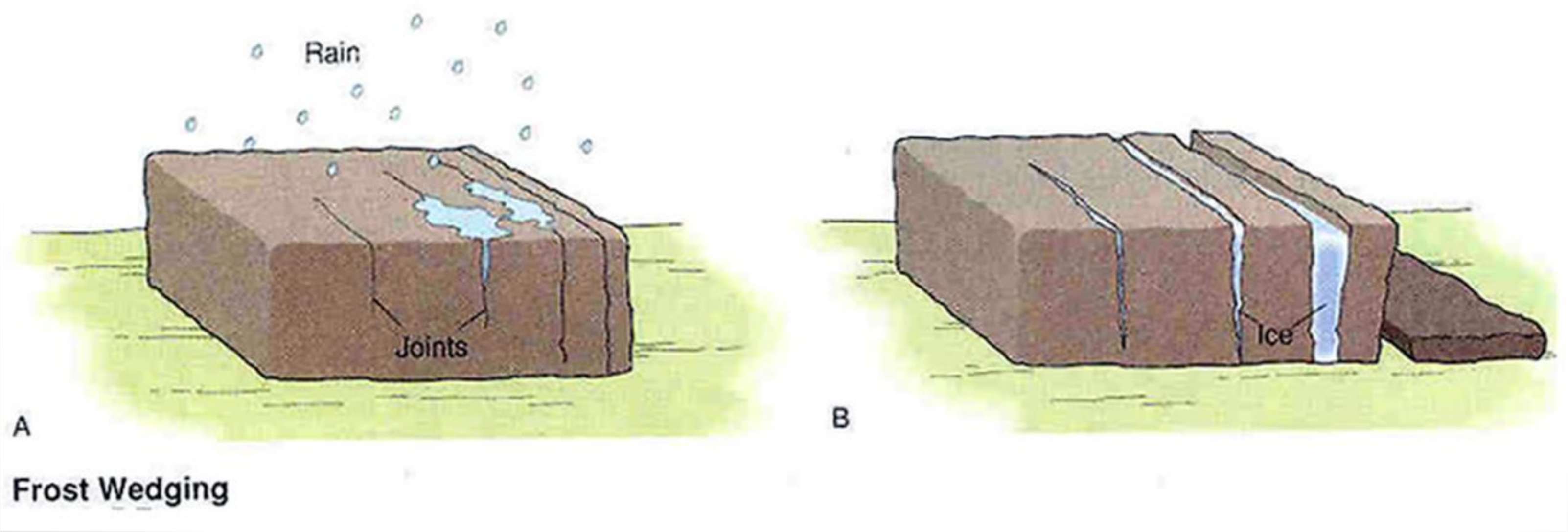


Effect of joint Characteristics on Engineering Properties

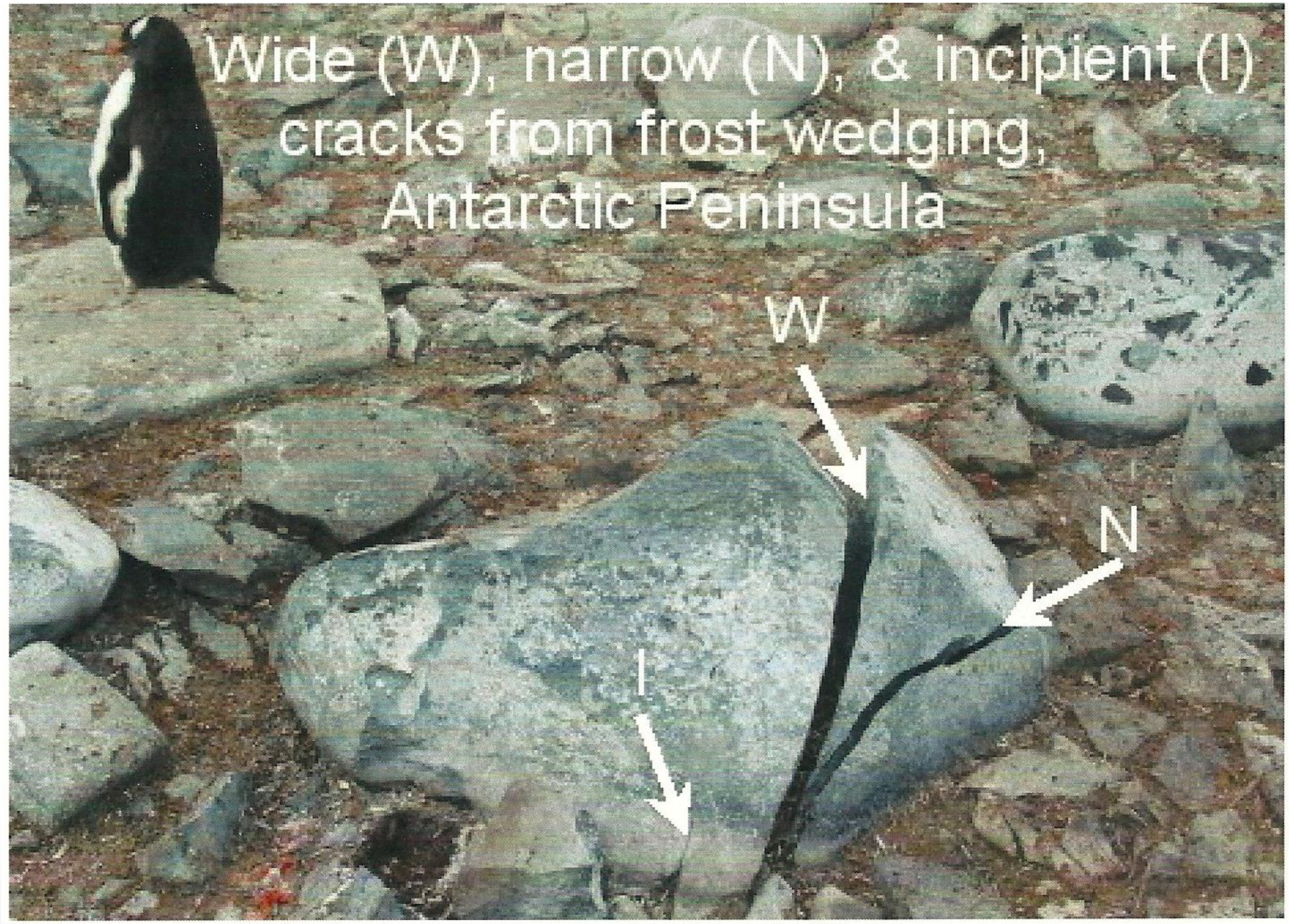
Characteristic	Permeability k	Deformability E	Shear Strength S
Attitude	k greatest parallel to joint direction	E smallest perpendicular to joint direction	S smallest parallel to joint direction; randomly jointed rock mass behaves as cohesionless, interlocking aggregate
Spacing	Smaller the spacing, larger the k	Smaller the spacing, smaller the E	Often only one joint of a set needed for sliding to occur
Aperture	Smaller the width, smaller the k. As width approaches zero, k approaches the value for intact rock	Greater the width, smaller the E	---
Persistence	k approaches the value for intact rock if joints are not continuous	---	S reduced more by continuous joints than by joints that are not continuous
Regularity	---	---	Work of dilatancy depends on planeness; coefficient of friction depends on roughness
Joint filling	k is small if filling is clayey, and approaches k of intact rock if joint is filled with mineral precipitate	E depends on deformability of joint filling; may approach E of intact rock if joint is filled with mineral precipitate	S along joint is that of joint filling; may be small if joint filling is clayey

Other Mechanical Weathering Forms: Frost Wedging

Frost Wedging – cracking of rock mass by the expansion of water as it freezes in crevices and cracks

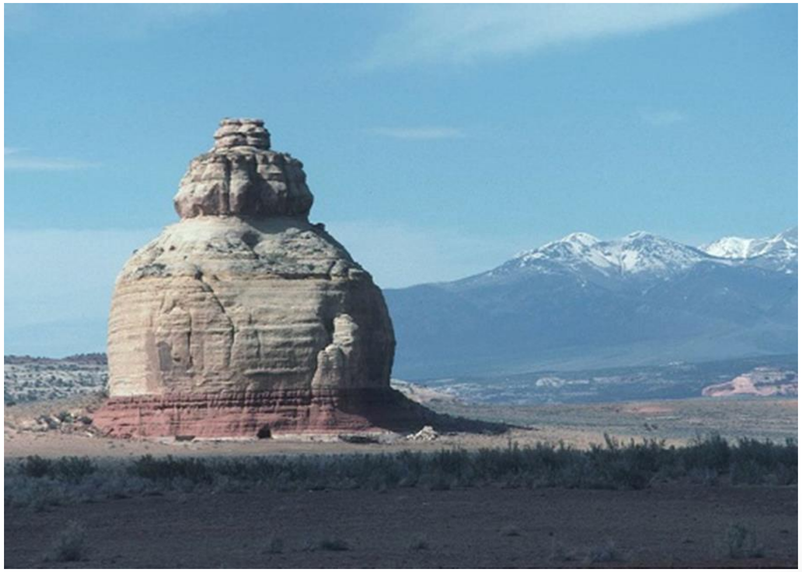


Frost Wedging



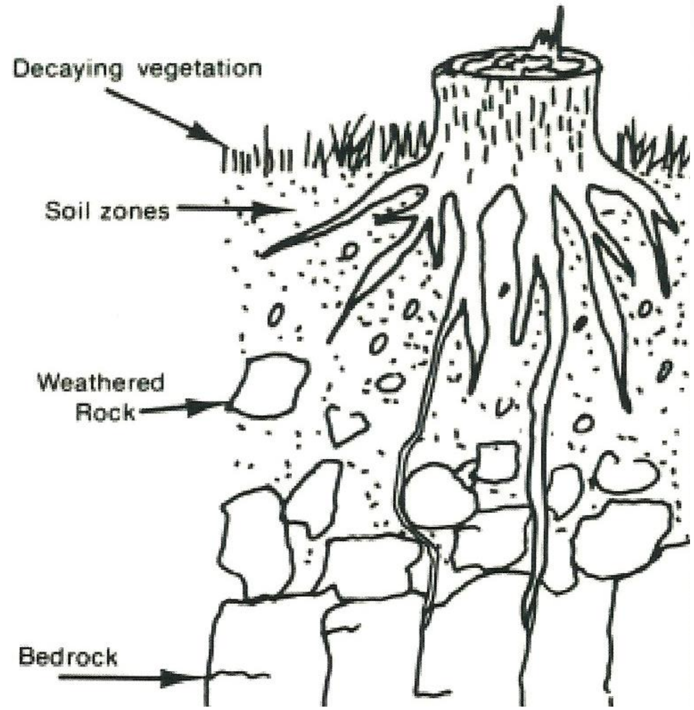
Abrasion

- Moving sediments or rock sections can break off pieces from a rock surface they strike. The sediments can be moved by wind or water and the large rock sections by gravity.



Plant Growth

- As plants such as trees send out root systems, the fine roots find their way into cracks in the rocks. As the roots increase in size, they force the rock sections apart, increasing the separation and weathering.



Chemical Weathering: Dissolution

- Water, often containing acid from dissolved carbon dioxide, will dissolve minerals from a rock body leaving cavities in the rock. These cavities may generate sinkholes or cave features.

Stalactites in Carlsbad Caverns, New Mexico
Original picture by Jennie Hango
Massachusetts Institute of Technology

Chemical Weathering: Altered Minerals

- Minerals may combine with oxygen (oxidation) or water (Hydrolysis) to form new minerals that are not as hard.

http://www.mii.org/Minerals/Minpics1/Plagioclase%20feldspar.jpg

http://www.uwm.edu/Course/422-100/Mineral_Rocks/kaolinite1.jpg

Feldspar → Kaolinite (clay)

Engineering Significance

- Variable Depth
- Restrictions on groundwater movement
- Chemical Weathering can cause clay seems and week layers or even subterranean caves.
- Chemical weathering products can be buried under later sediments or deposits.
- Seasonal Rainfall can wash away finer products of weathering.

Classification

Term	Description	Symbols
Fresh	No visible sign of rock material weathering; perhaps slight discolouration on major discontinuity surfaces	W_1
Slightly weathered	Discolouration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker than its fresh condition.	W_2
Moderately weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.	W_3
Highly weathered	More than a half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.	W_4
Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	W_5

IAEG2006 Paper number 260

Overview of the evaluation of the state of rock weathering by visual inspection
ANTÓNIO PINHO1, JOSÉ ALCINO RODRIGUES-CARVALHO2, CELSO GOMES3 & ISABEL MARIA DUARTE4

Classification

Table 3. *Weathering grades of weak and weathered rock (modified from Dearman, 1976; and Geological Society, 1995).*

Weathering Grade	General Description	Specific Description: Weathered Materials*	Specific Description: Weak Rock Materials†
VI — Residual soil	The rock is completely changed to a soil in which the original rock texture has been completely destroyed.	Soil derived by *in situ* weathering but retaining none of the original texture or fabric.	Residual or reworked. Matrix with occasional altered random or "apparent" lithorelics, bedding destroyed.
V — Completely decomposed	The rock is changed to soil in which the original rock texture is (mainly) preserved.	Considerably weakened, slakes, and the original texture is apparent.	Destructured. Greatly weakened, mottled, ordered lithorelicts in matrix becoming weakened and disordered, bedding disturbed.
IV — Highly decomposed	50–100 percent soil from decomposition of the rock mass.	Large pieces can be broken by hand; does not readily slake when dry sample immersed in water.	Partially or distinctly weathered. Weakened, close fracture spacing, weathering penetrating in from fractures, brown oxidation.
III — Moderately decomposed	Up to 50 percent soil from decomposition of the rock mass.	Considerably weakened, penetrative discoloring; large pieces cannot by broken by hand.	Unweathered. Original strength, color, and fracture spacing.
II — Slightly decomposed	100 percent rock; discontinuity surfaces or rock material may be discolored.	Slight discoloration and slight weakening.	—
I — Fresh	100 percent rock; no discoloration, decomposition, or other change.	Unchanged from original state.	—

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Field Methods for Characterizing Weak Rock for Engineering

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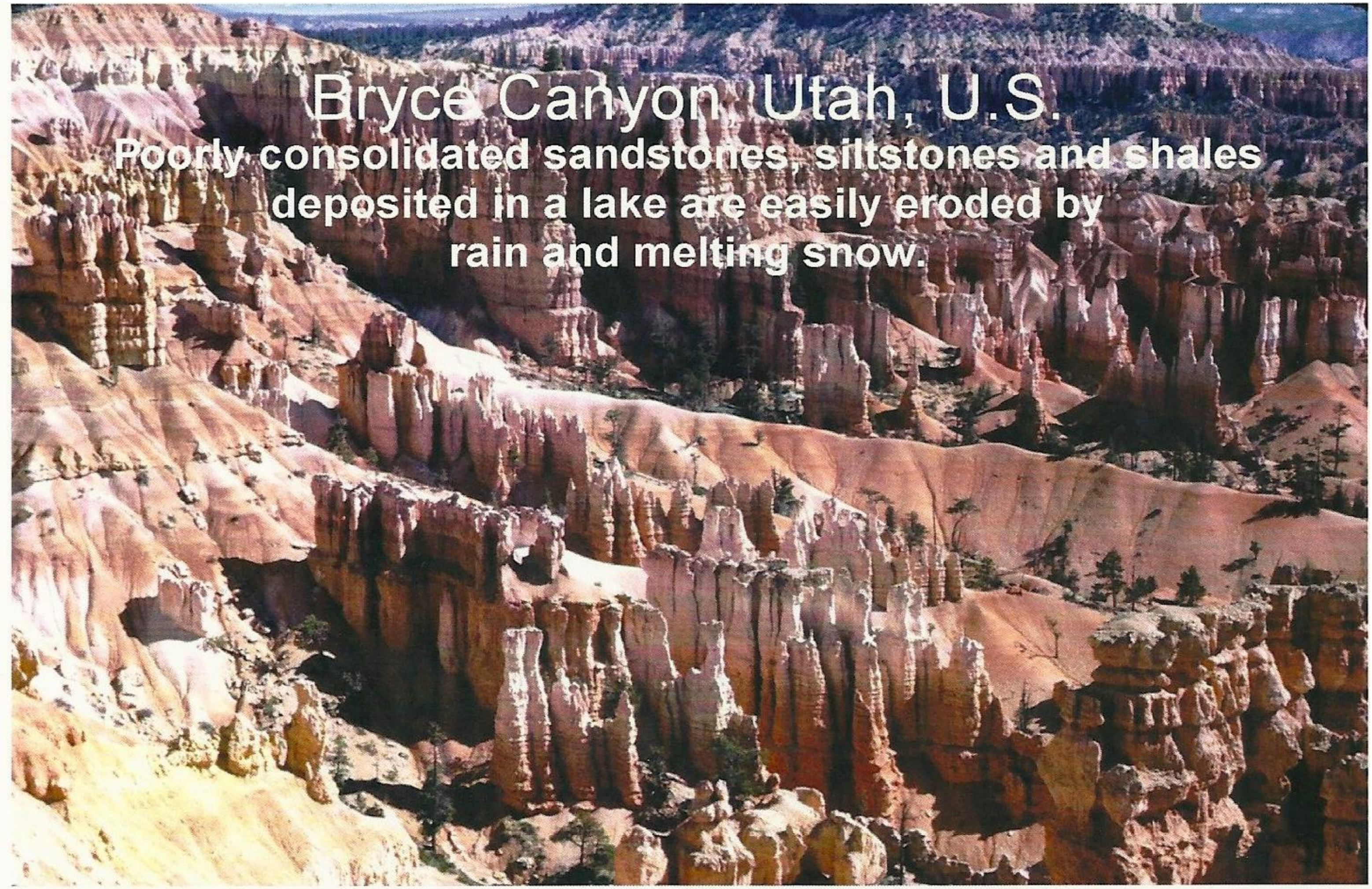
Erosion and Transport

- Water
  - rain
  - streams and rivers
  - ocean dynamics
  - ice in glaciers
- Wind
- Gravity

The work of Rains



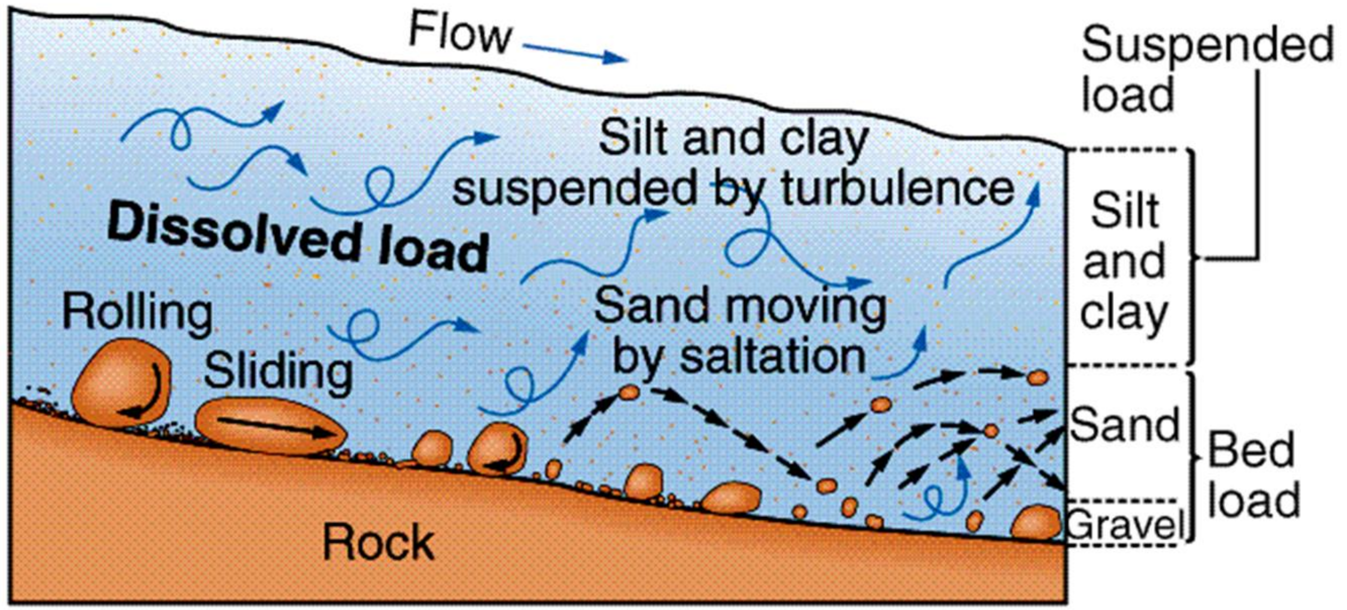
Alluvial Fans

- Localized areas of enhanced sedimentation downstream of points where laterally confined flows expand

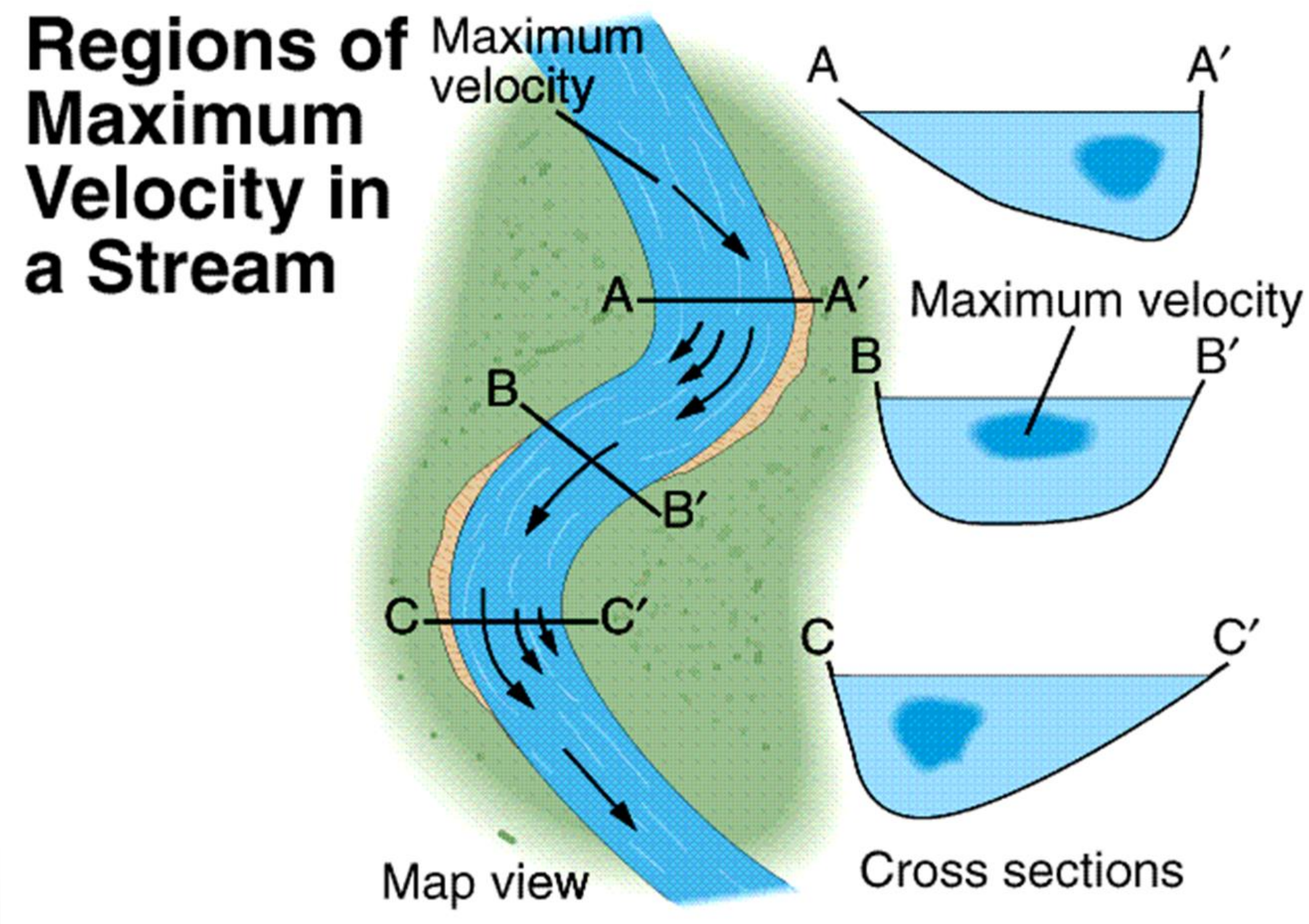
The work of Rivers

Transportation

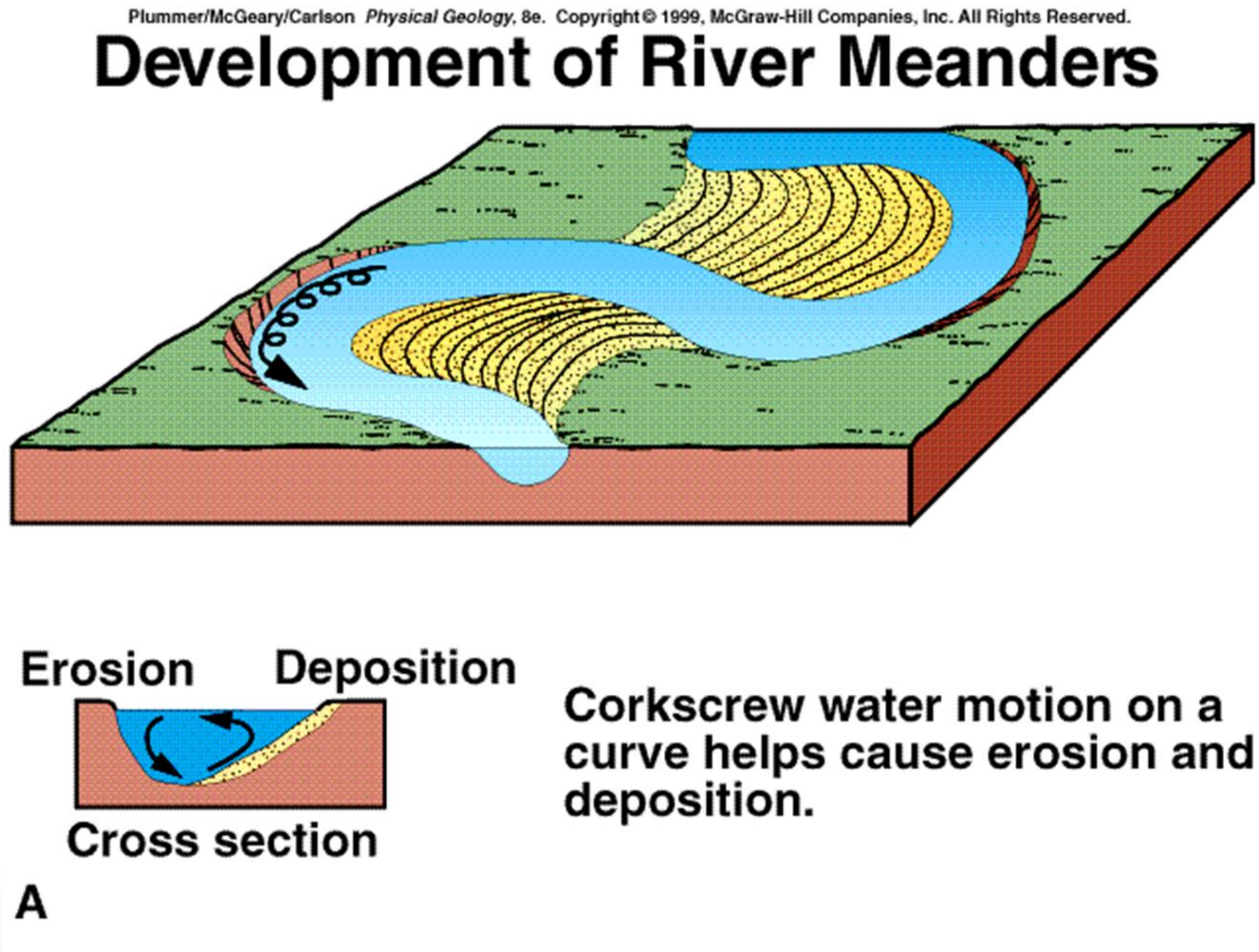
Contents of a Stream Bed



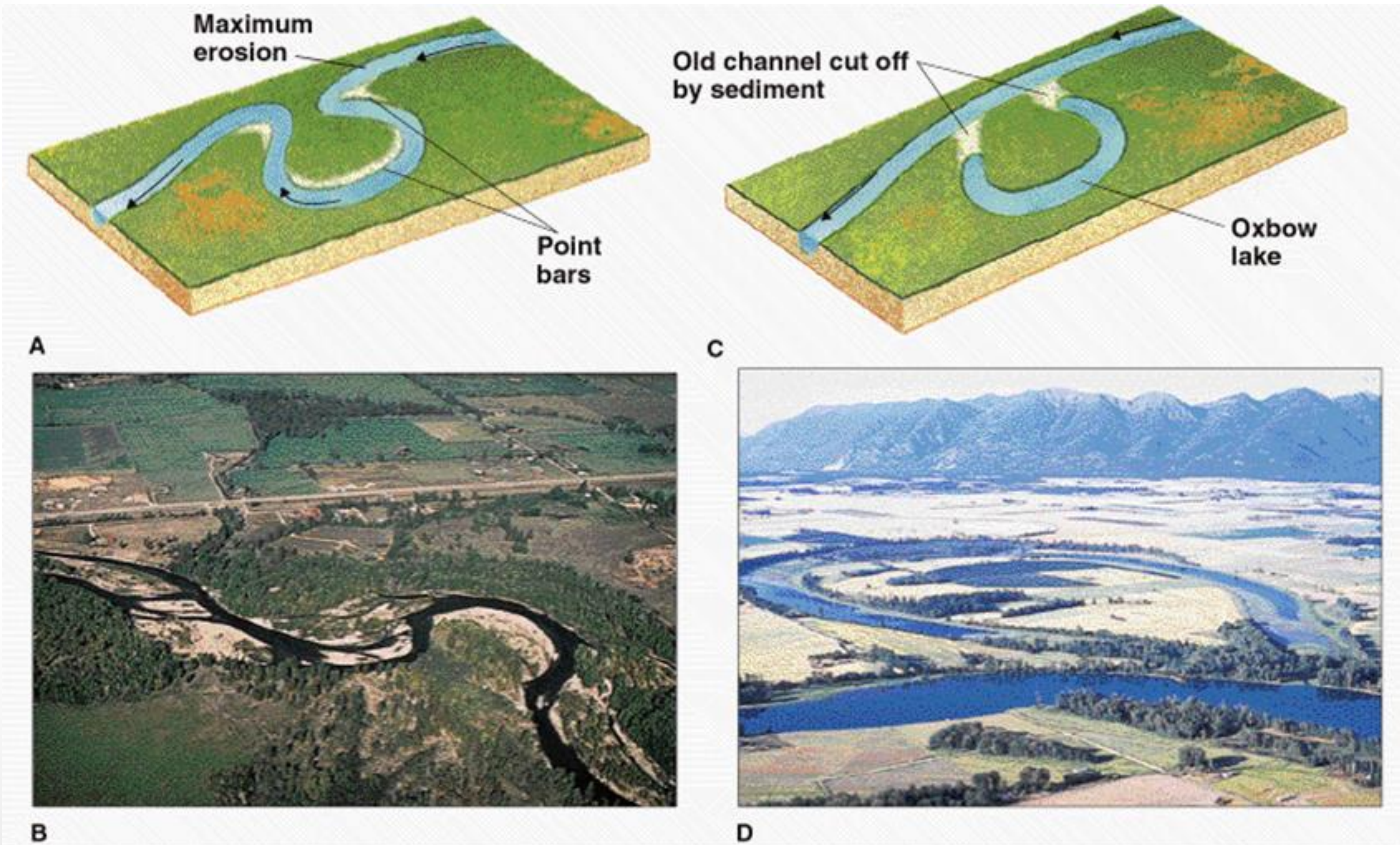
Flow Velocity



Fluvial Deposits in Meandering River

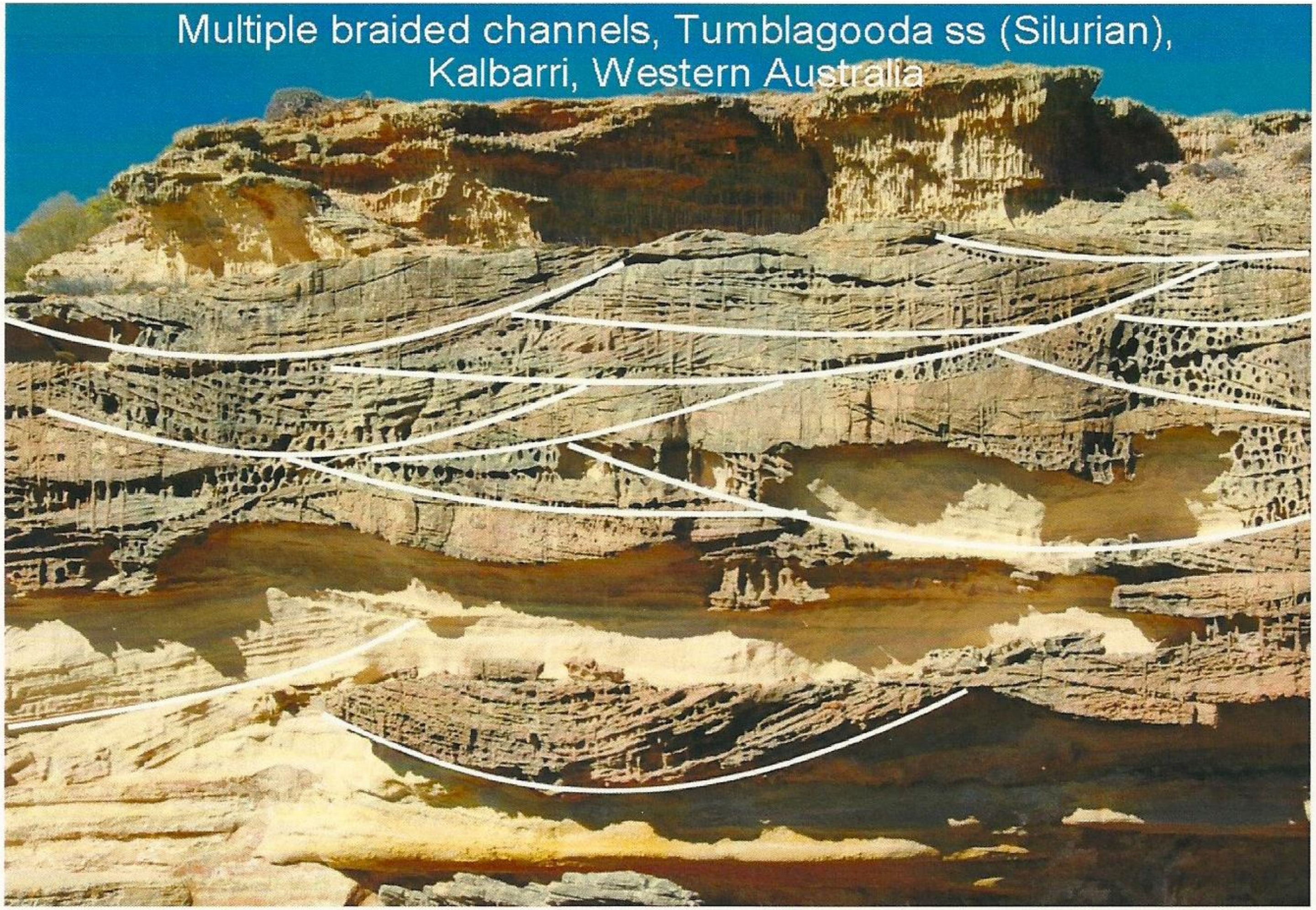


Ox Bow Lake

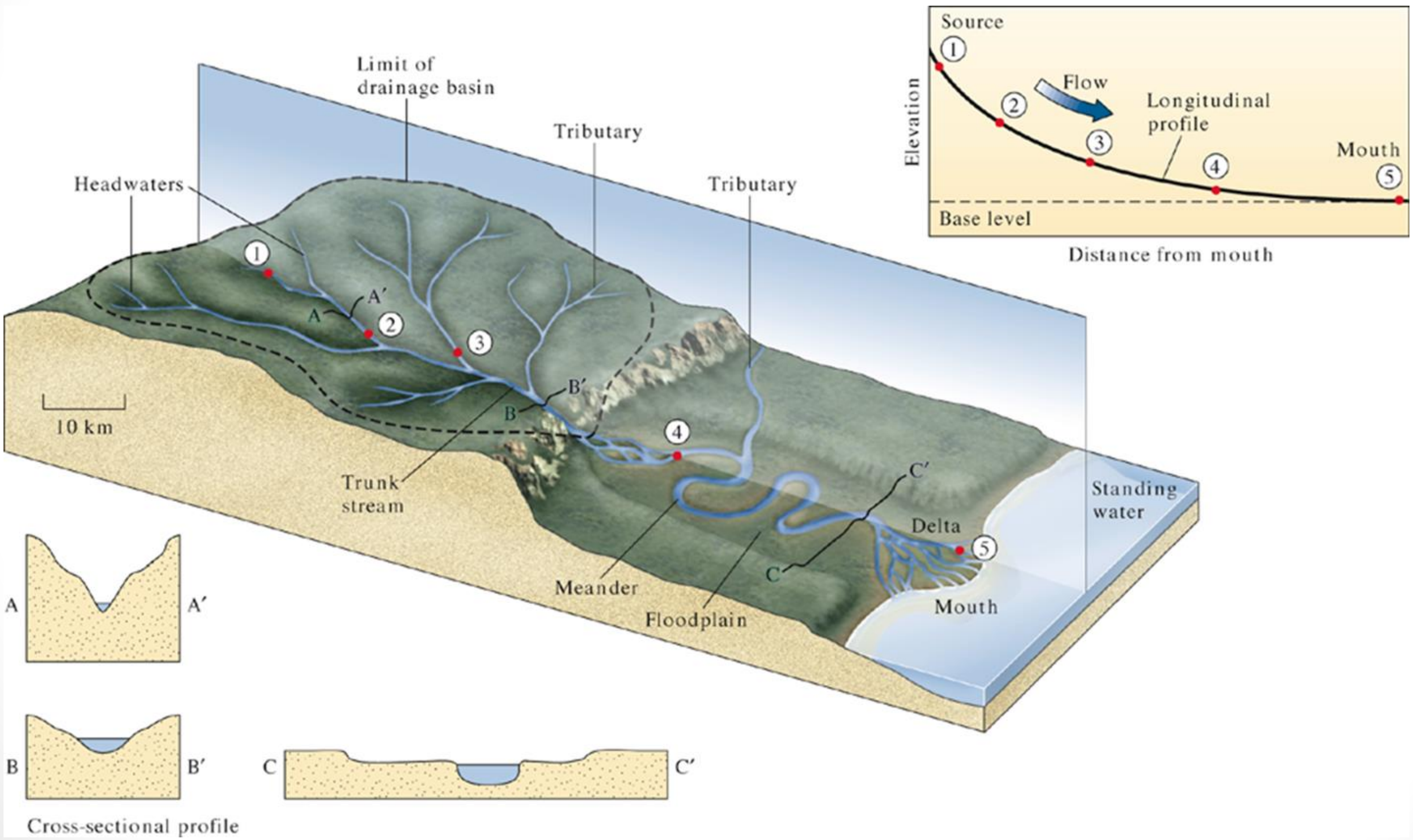

Maximum erosion
Point bars
A
Old channel cut off by sediment
Oxbow lake
C
B
D

Fluvial Deposits in Braided River

Signs of Old Braided Rivers

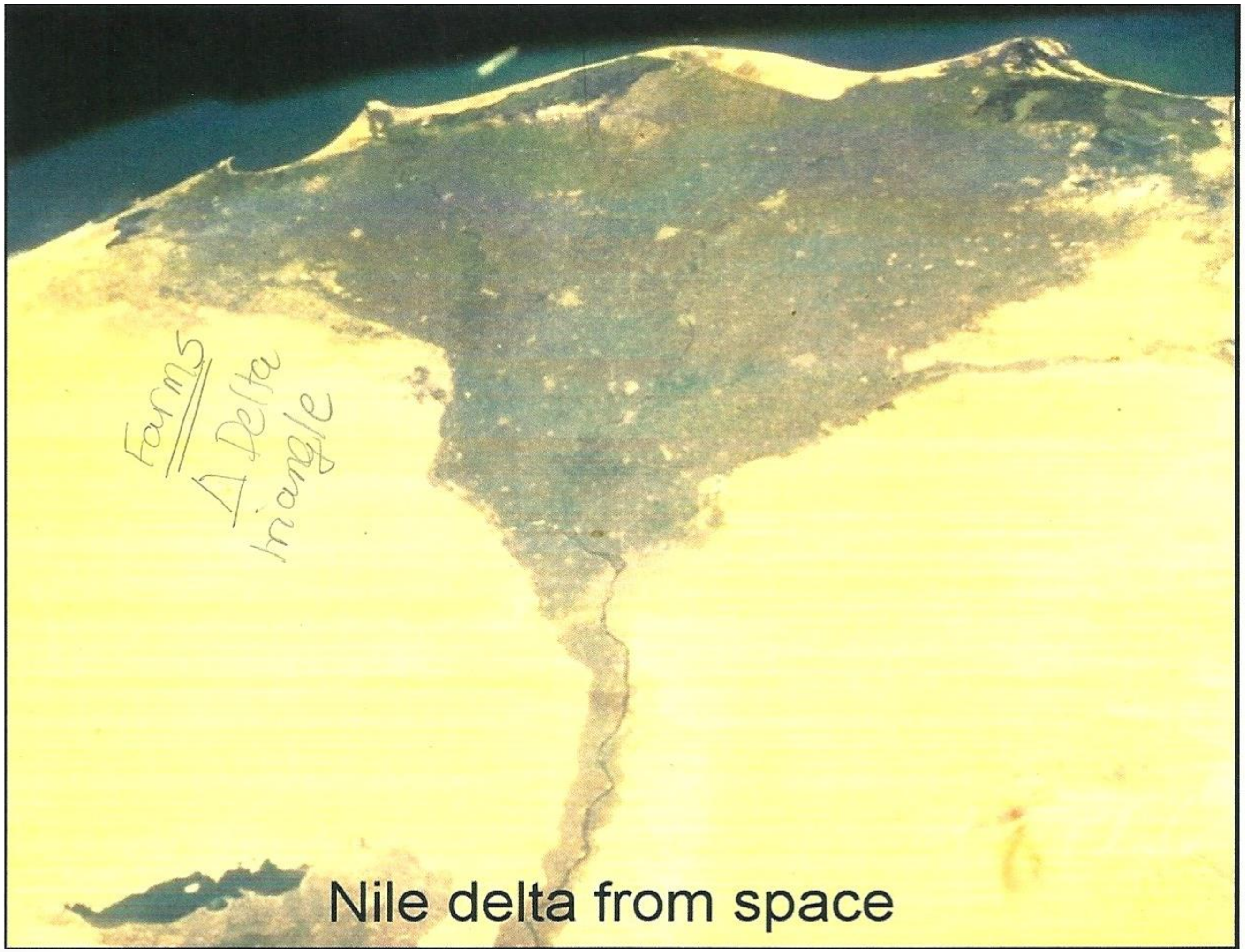


Deltas



Source
Elevation
Flow
Longitudinal profile
Mouth
Base level
Distance from mouth
Limit of drainage basin
Tributary
Headwaters
Tributary
A′
A
B′
B
10 km
Trunk stream
C′
Standing water
Delta
C
Meander
Floodplain
Mouth
A
A′
B
B′
C
C′
Cross-sectional profile

The Nile



Nile delta from space

The work of the wind

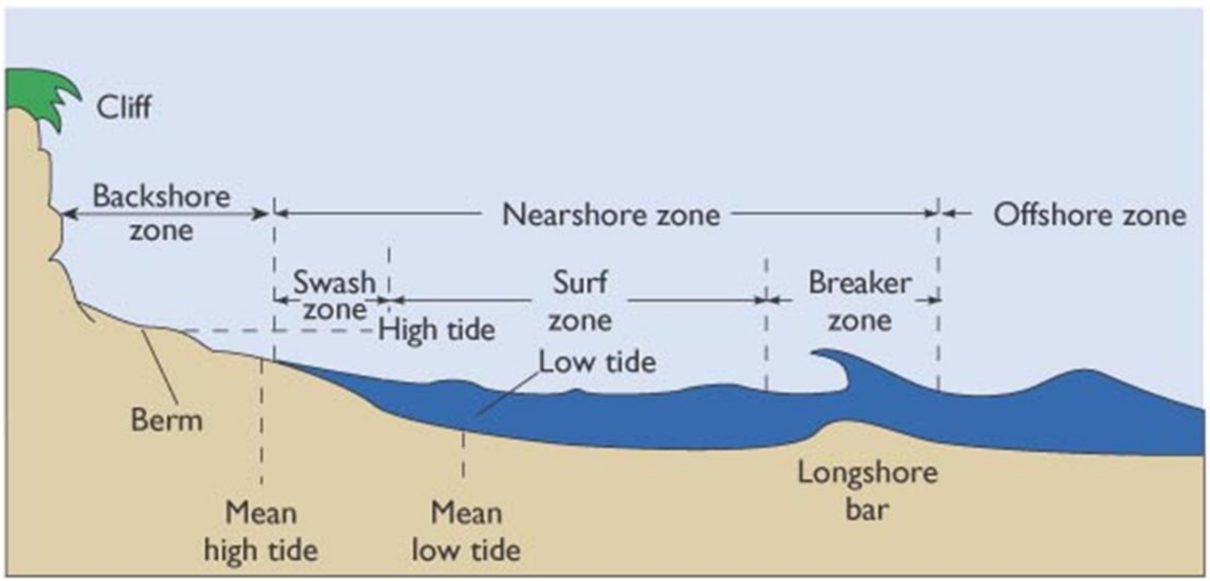
- well sorted since fines were winnowed away
- as wind V increases, λ lengthens (smear out)
- as grain size increases, height goes up (piles up)

Sand Dunes

The work of the sea

- The profile of many beaches vary seasonally as a result of wave processes and sediment transport
- Summer beaches exhibit gently sloping profiles with offshore sand bars
- During winter larger more powerful waves redistribute offshore sand and erode the beach producing a steeper profile

Deposits at the Beach



The coastal zone.

Figure 11.2

THANK YOU