CE- 203

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DEFINITION OF GEOMORPHOLOGY:

The study of the landforms of the earth including their history and process of origin. This is the systematic examination of the landforms and their interpretation as records of the past history.

The information is utilized by members of the different groups of sciences such as those related to geography, geology, geophysics in addition to geomorphology.

- Actually interest of different groups overlap
- No clear line of distinction among these groups.

ASPECTS OF GEOMORPHOLOGY

- It establishes relation between the land forms and the underlying rocks and is concerned with the interaction between the denundational process and rock forming.

> Denundation is a useful term for the total action of all processes by which the exposed rocks of the continents are worn away and the resulting sediments are transported to the sea by the fluid agents. **Denundation is an overall lowering of the land surface**.

- It studies the evolution of landscape, which is often called the "Denundational chronology".

- It studies the actual process of erosion which give rise of land forms.

PRINCIPAL ZONES OF EARTH

Atmosphere: It is the gaseous envelop encircling the earth. Distribution of heat, pressure and water vapor content within this envelope gives rise to the global weather and climate.

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Hydrosphere: This is the water envelope on solid earth. Elements of this zone are river, lake ocean etc.

Lithosphere or Geosphere: This is the solid earth. It has three distinct divisions, which are as follows: (Fig.21.8 Strahlar p. 143)
A thin outer shell or ***crust*** (16~ 40 km thick)
An inner zone called ***mantle*** (2900km thick)
Core: this is divided into two distinct parts:
Liquid outer core nickel iron (2200 km thick)
A solid zone called core (1300 km radius)
[Radius of the earth is about 6400 km = 3960 miles)

Biosphere: The life zone of earth. This is the zone of influence upon the geomorphic processes. From the small plankton to man is included in it.

Any form of plant or animal life that drift in or float on water bodies

Geomorphic agents and processes:

Those physical and chemical processes which effect a modification of the earth's surficial form.
A geomorphic agent is any natural medium, which is capable of securing and transporting earth materials. Thus running water including both concentrated and unconcentrated run-off, groundwater, glaciers, wind and movements within bodies of standing water including waves, currents and tides fall in this group.

IS GRAVITY A GEOMORPHIC AGENT?

Most of the geomorphic agents originate within the earth's atmosphere. And are also directed by the force of gravity. Gravity is not a geomorphic agent because it can not secure and carry away materials. It is better thought of as a directional force.

AN OUTLINE OF THE GEOMORPHIC PROCESSES:

Geomorphic processes are primarily classified into three categories depending on the origin. Those are

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Epigene or exogenetic
Hypogene or endogenetic and
Extraterrestrial

The geomorphic processes which originate outside the earth's crust are called ***exogenetic*** and others originating within the earth's crust are designated as ***endogenetic***.

The topographic effects of the impact of meteorites *(piece of rock or metal that has reached the earth's surface from outer space)* do not fall within either of the above classes and are termed extraterrestrial, which means from beyond the limits of the earth's domain.

GEOMORPHIC PROCESSES:

A. Epigene or exogenetic processes

I. Gradation

a) Degradation

i) weathering
ii) mass wasting or gravitative transfer
iii) Erosion (including transportation) by
1. running water
2. ground water
3. waves currents, tides and tsunami
4. wind
5. glaciers

b) Aggradation by

1. running water
2. ground water
3. waves, currents, tides
4. wind
5. glaciers.

c) work of organisms including man

B. Hypogene or endogenetic processes

1. Diastrophism

All actual movements of the earth's solid crust of any kind or degree. The crust movement falls in two categories.
1. Slow movements, 2. Sudden movements (eg., earthquake)

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2. Vulcanism

> Includes all sorts of volcanic activities together with the movement of the molten rock or magma into or towards the earth surface.

C. Extraterrestrial processes:
Fall of meteorites

NOTES ON DIFFERENT GEOMORPHIC PROCESSES:

a) Gradation

It includes all those processes that tend to bring the surface of the lithosphere (the rocky crust of the earth) to a common level. Gradation process belongs to two categories

1. Degradation → Level down
2. Aggradation → Level up

b) Weathering

This may be defined as the changes that take place in the minerals and rocks at or near the surface of the earth in response to the atmosphere, to water and to plant and animal life. *This is a **static process** and **does not involve** the removal or seizure of materials by **a transporting agency***.

c) Mass wasting

Involve the bulk transfer of the masses of rock debris down slopes under the direct influence of gravity. *Mass wasting is usually aided by the presence of water but the water is not in such an amount so that it can be considered as a transporting medium*. (We can think that the process is initiated by the action of water but the material is actually carried by the action of gravity)

d) Impact of meteorites:

The uniqueness of the process lies in the fact that they were produced by the extraterrestrial agents although earth's gravitational attraction was responsible for the fall of meteorites.

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e) Topographic effects of organisms:

Man made road cuts and fills and many other kinds of excavations profoundly modify the earth's surface. Explosives (bombs) may become a distinctive and prevalent type of land form if modern welfare continues.

RELATION BETWEEN WEATHERING AND EROSION:

Weathering	Erosion
Production of rock waste in place under virtually static condition	Transportation of rock waste from the site of its formation
Both the processes are parts of a single process called Denundation → lowering of the surface of the earth.	
Weathering erosion by weakening and disintegrating rocks	Erosion in turn aids weathering by removing the cover of soil and loode debris and exposing them to the weather.
Weathering can take place without subsequent erosion and erosion is possible without previous weathering. Weathering is a preparatory process but neither a prerequisite nor necessarily followed by erosion.	

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RUNOFF AND RUNOFF RELATIONS

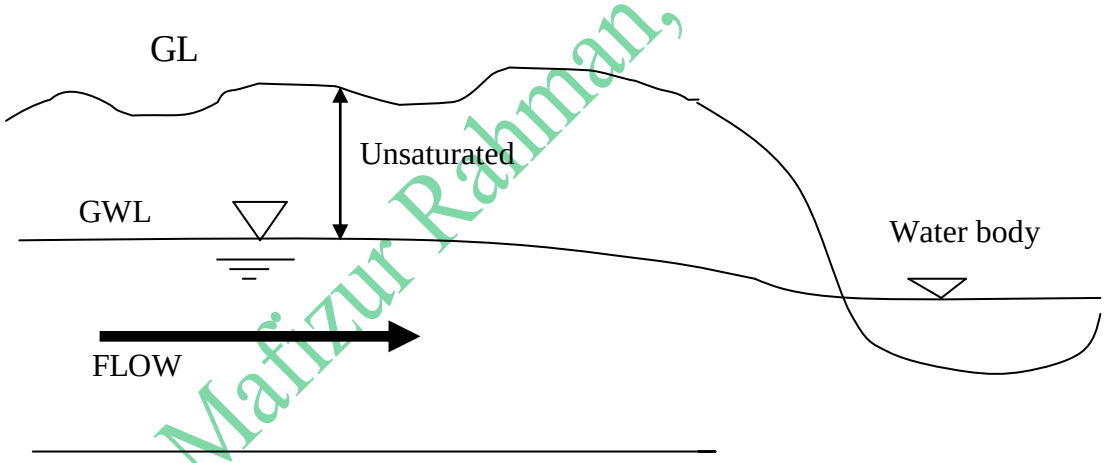
INTRODUCTION:

The water reaching the surface of the earth in the form of precipitation reaches the stream ultimately. From the point where precipitation reached the earth surface it may take different paths on it's way to the stream.

Precipitation is the general term for all forms of moisture emanating from the cloud and falling on the ground.

Some part of the water flows over the land surface and reaches the stream immediately after the precipitation. The other part of the precipitation infiltrates through the soil surface and flows through the soil surface to reach the stream.

COMPONENTS OF THE TOTAL FLOW:



Visualization of the three main routes of travel is very easy. These are

- Overland flow or surface runoff
- Interflow or subsurface run off and
- Ground water flow.

Surface runoff: It is that part of water which travels over the ground surface to the channel without infiltrating or percolating to the water table. The term channel as used here indicates all sorts of depressions which is capable of holding water for a short period of time after the rainfall.

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Sub-surface runoff: It is that portion of the total flow which after infiltrating the soil surface move laterally through the upper soil layer until it enters the channel. Subsurface runoff reaches the channel more slowly than the surface runoff and hence reaches the stream later.

Ground Water Flow: Some portion of the precipitation percolates downward until it reaches the ground water table. This ground water storage may discharge into the stream if the water table intersects the stream channels of the basin. This discharge is called the Ground Water Flow.

Runoff: Runoff is the collective term which refers to all the three components of the total flow, ie., surface runoff, sub-surface runoff and the ground water flow.

In practice it is customary to consider the total flow to be divided into two parts such as
Direct runoff and
Base flow.
Direct runoff is presumed to consist mainly of overland flow and a substantial portion of subsurface runoff whereas the base-flow is considered to be consisting of the ground water flow.

FACTORS AFFECTING RUNOFF:

1. Characteristics of precipitation:

a) ***Type of precipitation:*** Precipitation generally occurs in the form of rain or snow depending on which the runoff pattern varies. Rain produces immediate runoff whereas that in the form of snow produces runoff at a slower rate.

b) ***Rainfall intensity:*** If the rainfall intensity increases the ruoff also increases. For example if the rainfall intensity increases by four times the runoff may increase by nine times.

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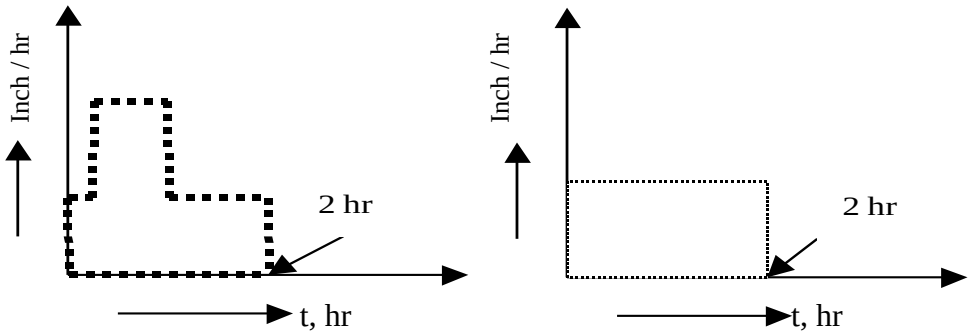


Fig. 2 (a) (b)

An intense rain as shown in Fig. 2(a) will definitely produce much more runoff than that produced by the uniform rainfall as shown in Fig.2(b) provided the infiltration capacity remains the same throughout the storm period.

c) Duration of rainfall: Duration of rainfall is important regarding the fact that the infiltration capacity of the soil goes on decreasing as the rainfall continues for longer duration. As the infiltration decreases the surface runoff increases. Thus rain of a longer duration may produce a considerable runoff even when the intensity is mild.

d) Rainfall distribution: All the above discussion is made based on the assumption that the rainfall is evenly distributed over the whole catchment area which does not happen in reality. In reality, rain falls on a small part of the whole basin. For small drainage basins the peak flow are the results of intense rain falling over the small areas whereas for the large basins the peak flows are results of storms of less intensity but covering a large area.

e) Soil Moisture deficiency: The runoff depends on the soil moisture present at the time of rainfall. If the rain occurs after a long dry spell of time, the soil is dry and it can absorb huge amount of water and thus intense rain may fail to produce appreciable runoff. On the other hand, if the rain falls after a rainy season, the soil will already be wet and there will be less infiltration and even small rainfall may cause appreciable runoff.

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f) Direction of the prevailing storm: If the direction of the storm is in the same direction as the direction of water movement in the drainage basin then the water will stay in the drainage basin for a shorter time. This is due to the fact that runoff will be more compared to that if direction of storm is opposite to that of the direction of water movement.

g) Various climatological factors such as temperature, wind, humidity, etc. affect the losses from the drainage basin. If losses are more then runoff will be less.

2.CHARACTERISTICS OF THE DRAINAGE BASIN:

a) ***Size of the basin:*** If the area of the basin is large then the total flow will take more time to pass the outlet and the peak will be reduced.

b) ***Shape of the basin:*** The shape of the drainage basin also governs the rate at which water enters the stream. "Form Factor" and "Compactness Coefficient" generally express the shape of the basin.

$$\text{Form factor} = \frac{\text{average width of the basin}}{\text{Axial length of the basin}} = \frac{B}{L}$$

The axial length (L) is the distance between the outlet and the most remote point on the basin and the average width (B) is obtained by dividing the total area (A) by the axial length. So,

$$\text{Form factor} = \frac{B}{L} = \frac{A/L}{L} = \frac{A}{L^2}$$

Compactness coefficient is defined as

$$\text{Compactness coefficient} = \frac{P}{C}$$

Where, P = perimeter of the basin

C = Circumference of the circle whose area is the same as the area of the basin.

If A is the area of the basin and r is the radius of the equivalent circle then

$A = \pi r^2 \quad \Rightarrow r = \sqrt{A/\pi}$

⇨ Circumference $= 2\pi r = 2\pi\sqrt{A/\pi} = 2\sqrt{A\pi}$

⇨ Compactness coefficient $= P/(2\sqrt{A\pi})$

Where P= perimeter of the basin, A = area of the basin

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COMPUTATION OF RUNOFF:

RATIONAL METHOD

Introduction:

The Rational Method is an intensity based rainfall method, meaning that it can be used to predict peak flows based on the characteristics of the catchment area and a rainfall event. This makes the Rational Method a popular choice for storm sewer analyses.

Objectives of Rational Method:

Many hydrologic design problems require simply an estimation of the peak flow rate generated by a river system under specified conditions. In such problems, the general shape of the flood hydrograph and the time of occurrence of the peak flow rate are no special significance and need not be taken into account. In such cases the Rational Method can be applied to estimate the peak flow rate.
Also when adequate data are not available this method can be applied.

Assumptions:
#The rainfall is uniform both spatially and temporally.
#The drainage area is small.
#The duration of the rainfall is equal to the catchment's time of concentrations.
#Peak flow occurs when the entire catchment area is contributing.
The recurrence interval of the peak discharge is equal to that of the rainfall intensity.

Rational Formula:

Peak discharge, **Q= kICA**

Where, Q= Peak discharge in m^3/s or ft^3/s
A=Area of the catchment (acres or hectares)
I = Rainfall intensity with the selected recurrence interval, T years and duration equal to the catchment's time of concentration.
k= a factor of proportionality

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= 0.278 when A in Km^2 and I in mm/hr.
= 0.00278 when A in hectares and I in mm/hr.
= 1.0 when A in m^2 and I in m/s.

C= Co-efficient of run-off which depends on the type of area, soil condition, Soil covers, storage, depressions etc.

Area type	Description	C values
Business	Downtown Neighborhood	.07-.095 .50-0.70
Residential	Single Family Multiunit Detached Multiunit Attached Suburban resident Apartment 1.2 acre lots or more	.30-.50 .40-.60 .60-.75 .25-.40 .50-.70 .30-.45
Lawns,Heavy soils	Flat 2% Average, 2-7% Steep>7%	.13-.17 .18-.22 .25-.35
Industrial	Light Heavy	.50-.80 .60-.90
Lawns,Sandy soils	Flat, 2% Average, 2-7% Steep>7%	.05-.10 .10-.15 .15-.20
Pavement	Asphalt/Concrete Brick Drives and walks	.70-.95 .70-.85 .75-.85

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THE NATURE OF A RIVER VALLEY

Valley: elongated lowland between ranges of mountains, hills, or other uplands, often having a river or stream running along the bottom.

The river development may be divided into two parts.
The development of the feature of an individual valley, and

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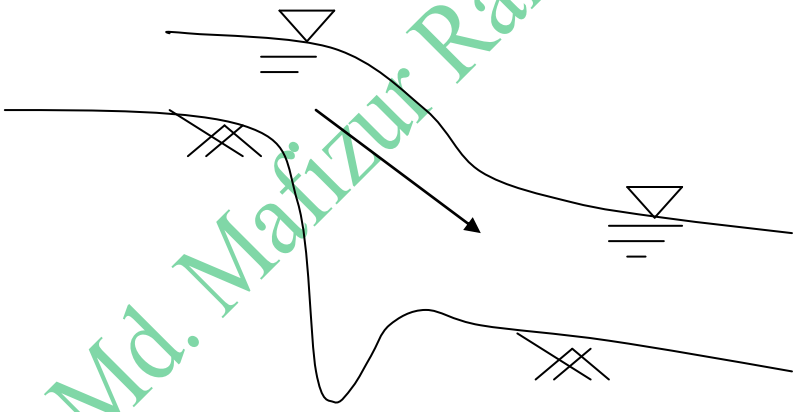
The development of a system of drainage, composed of many individual valleys.

Valley development: A valley takes the form through the operation of three simultaneous processes. These are :
1)Valley deepening, 2) Valley widening, and 3) Valley lengthening.

1) **VALLEY DEEPENING:** is effected by the following factors:

a)Hydraulic Action: The impact or pressure of running water, under certain circumstances, may cause a considerable amount of erosion even without the aid of other tools. Thus a stream flowing through relatively loose or soft materials may, by this process, cut back it's bank or push off materials from the bottom of the channel. The agent is the running water.

b)Corrosion or abrasion of the floor of the valley: It refers to the mechanical wearing away of rocks by the rubbing, grinding and bumping action of rock fragments.
c) Pothole drilling along the valley floor and the base of water falls: A pothole is a deep, round hole worn in rock by loose stones whirling in strong rapids or waterfalls.



c) ***Corrosion or solution:*** Many rocks and minerals are soluble in water and their solubility is increased by the presence of small amounts carbonic acid gas and oxygen which are found in all water in nature. Solution of bed rock material into the stream water deepens the valley.

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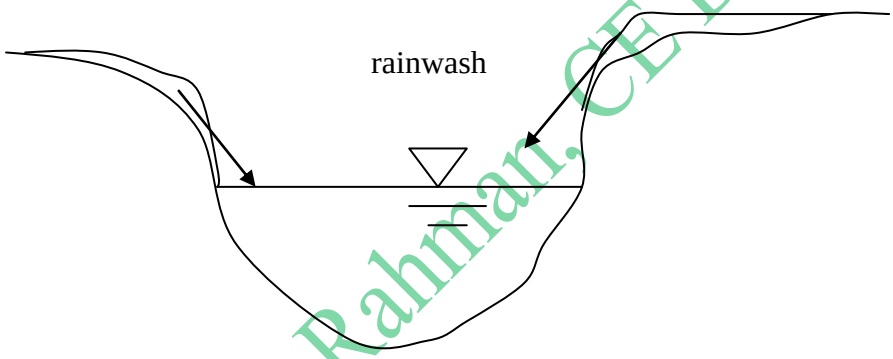
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2) **VALLEY WIDENING:** Valley width is the linear distance between the two sides of it. This is expressed along with the different locations of the valley reach.

Valley widening may be accomplished in the following ways:

a) Lateral erosion: Storm in a valley may remove materials from the base of the valley side through hydraulic and corrosive action. This results in the oversteepening of the valley floor which favors slumping of the materials into the stream.

b) Rainwash or sheetwash: Contributes in an important way in valley widening. Loose weathered materials are washed down the valley side by rain.



c) Gulleying on valley sides:



Gullies are mini streams which with every fresh supply of water, become deeper, longer and wider. After a time gullies are large enough to be called valleys.

d) ***Weathering and mass wasting:*** Weathering may loosen material which moves directly downslope into the stream channel by different types of mass wasting.

e) ***Incoming tributaries*** contribute to the valley widening even though they are nothing more than the overgrown gullies.

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3) **VALLEY LENGTHENING:** May take place in three ways. These are:

- By the process of headward erosion
- Through increase in size of their meanders
- Valley also may lengthen at their termini. Uplift of the land or lowering of the lake level will result in extension of the valley form across the newly exposed land.

CLASSIFICATION OF VALLEYS:

A. According to the stage in the geomorphic cycle valleys are classified as:

1. Young
2. Mature, and
3. Old.

This classification is rather based on the characteristics developed at different stages in their evolution.

A ***young valley*** is narrower, and steep sided because down-cutting had greatly been predominant over the process of valley widening till this age.

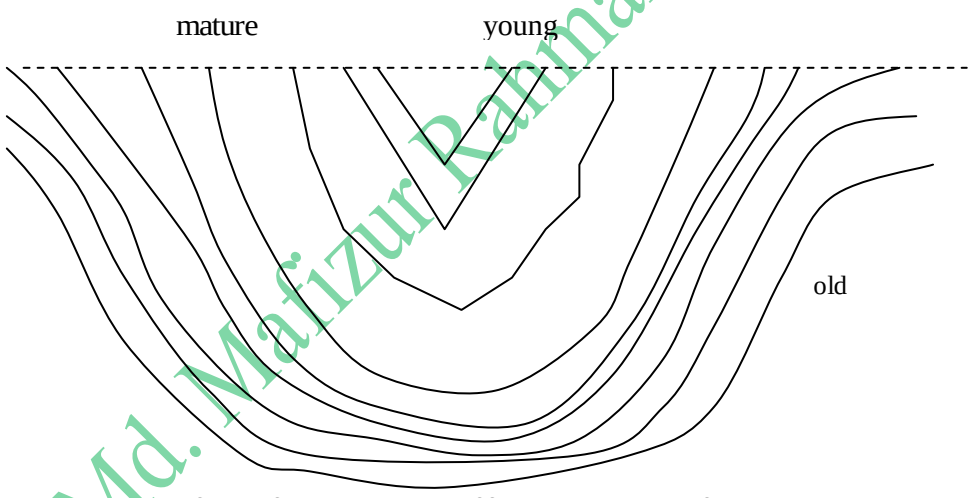


Fig. Cross profile of valleys at different stages of development

A ***mature valley*** is wider, less steep sided and usually deeper than a young valley. It generally has numerous, relatively large, well-developed tributaries.

An ***old valley*** shows gently sloping sides, moderate to shallow depth and fewer tributaries than the mature valley.

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B. Genetic Classification:

1. Consequent valley
2. Subsequent Valley
3. Insequent valley
4. Resequent valey
5. Obsequent Valley

A ***consequent valley*** is one whose course was supposedly determined by the initial slope of the land and natural irregularities of the surface.

Subsequent valleys are those whose courses have been shifted from the original consequent ones to belts of more rapidly erosive rocks. These streams develop independently of the original (initial) topography and are determined and regulated by erosion proceeding differently upon the bedrock formations according to the differences in hardness, structure and resistance to erosion of the formations.

Insequent valley are those which show no apparent adjustment to lithological control. These streams do not appear to depend upon either initial depressions or weaknesses in the rock. There might be two possibilities in this regard:
Either the streams owe their courses completely to chance, or
They are guided by lithological difference too small to be detected by man.

Valleys which presumably drain in direction opposite to that of the original consequent valleys are defined as ***obsequent***. Now a days they are defined as streams which flow in a direction opposite to that of the geological dip of the beds.

C. Based on controlling structures:
It is possible to classify the valleys on the basis of the geological structures, which have controlled their development. Based on this classification we have:

1. Homoclinal valleys
2. Anticlinal valleys

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3. Synclinal valleys
4. Fault valleys
5. Fault line valleys
6. Joint valleys

1. **Homoclinal valleys:** This type of valleys were known as the monoclinal valleys in the earlier times. These are strike valleys which follow the beds of weaker rock along the flanks of folds.

2. **Anticlinal valleys:** If the valleys follow the axes of breached anticlines.

3. **Synclinal valleys:** These follow the axes of the breached synclines.

4. **Fault valleys:** Valleys whose positions are determined by the faults may be of two types. One of these is a fault valley in cases when the streams follow depressions consequent upon faulting. The other type is the fault line valleys.

5. **Fault line valleys:** If the subsequent valleys follow a fault line.

6. **Joint valleys:** Some valley courses or portion of the valley courses are controlled by the major joint systems and are classes as the joint valleys.

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RIVER TRANSPORTATION

Activities of running water: The water that flows along the river does the following works:

- It transports the debris
- It erodes the river channel deeper into the land
- It deposits sediments at various points along the valley or delivers them to lakes or oceans

River transportation: River transportation is the ability of the river to carry along the particles that a stream picks up directly from it's own channel or that is supplied to it by slope wash, tributaries or mass movement.

Factors affecting the transportation power of river:

- Size of particle to be carried
- Volume of total load
- Velocity of river

Some important definitions:

Load: The amount of material that a river carries at any time is called its load.

Capacity: The total **amount of material** a river is **capable of carrying** under any given set of conditions is called the capacity of the river.

Capacity of a river varies approximately with the third power of the velocity if a fair proportion of all grain sizes are available, with a higher power if all the materials are fine grained and with a lower power if the material is coarse. The capacity is a function of discharge and velocity.

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Competence: The maximum size of particle that a river can carry is called its competence. The competence of a river is a statement of its ability to move materials in terms of material size. Competence is a function of velocity only. The diameter of a particle that a river can move varies approximately with the square of the stream velocity.

CLASSIFICATION OF LOAD

- Load carried in solution
- Load carried mechanically as sediment

Dissolved load: These are the **soluble materials** and are **carried in solution** in the form of ions. The amount of dissolved load depends upon 1) Climate, 2) Season, and 3) Geologic setting.

Suspended load: This is the load carried mechanically as sediment. These are the particles of solid matter that are swept along in the turbulent current of the stream and **remain in suspension**. The amount of this load depends upon 1) intensity of turbulence of water, and 2) terminal velocity of each individual particle.

Bed Load: These are solid particles, which **move along the riverbed**. Bed load mainly consists of gravel and sand.

MOVEMENT OF BED LOAD:

Particles in the bed load move in three ways:

1. By saltation,
2. By rolling , and
3. By sliding.

1) Saltation: A particle moving by saltation jumps from one point of the stream to another. First, it is picked up by a current of turbulent water and flung upwards and if it is too heavy to remain in suspension, it drops to the stream floor again at some spot downstream.

2) Rolling and sliding: Some particles are too large and too heavy to be picked up by the water current. But they may be pushed along the streambed and depending upon their shape, they move forward either by rolling or by sliding.

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CHANNEL CHANGES IN THE FLOOD:

We think the flood as the change in the height of water surface and subsequent inundation but apart from that change occurs in the stream bed which we can not see because of the turbidity of water flowing through the stream.

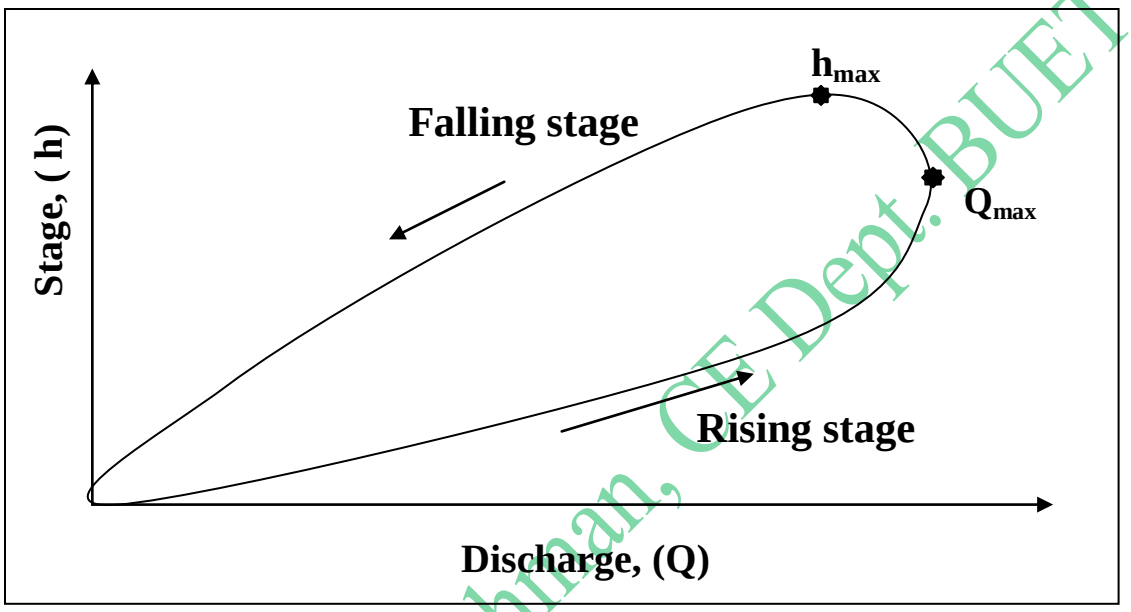


Fig: Stage discharge behavior in unsteady flow condition

The figure above, represents the unsteady behavior of stage-discharge relationship at a location of the stream. The maximum stage and the maximum discharge occur at different times. The changes of the channel bed form that take place during the flood need a clear understanding of this unsteady behavioral pattern.

River channel changes in configuration with this rising and falling stage.

- At first the **bed** may be **built up** by large amounts of bed load supplied in the stream during the first phase of heavy runoff. [Observe the **elevated bed** level as result of it] . This stage disappears soon.

- The bed is actively deepened by scour as the stream stage rises. This is quite interesting to mark the **lowest elevation of the bed level at the highest stage**.

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- In the next stage which can be identified by the falling stage of the stage discharge curve, the stage starts to fall and the bed is built back up by the deposition of the bed load.

In the example shown in the figure, about 10ft of thickness of alluvium was **reworked**, that is, moved about in the complete cycle of rising and falling stage.

When the flood crest has passed after the **decrease in the discharge**, the capacity of the stream **transport load also declines**. Some of the **particles** that are in **motion come to rest** on the on the bed in the form of sand and gravel bars. First he largest boulders and cobblestones will cease (stop) rolling, then the pebbles and gravels and then the sand. When restored to low stage, the water may become quite clear with only a few grains of sand rolling along the bed where the current is still fast enough.

CONCEPT OF EQUILIBRIUM AND GRADED STREAM:

As an idealized concept, "an equilibrium condition" means the supply of load to a stream from its drainage basin such that it exactly matches the capacity of stream to transport. In this type of stream the hydraulic factors are changing continuously to bring about a state of equilibrium. This sort of stream is called the **graded stream**.
Based on the concept of Mackin, a geomorphologist:

A graded stream is one which the **slope** is delicately adjusted over a period of years **to provide,** alongwith the available discharge and prevailing channel characteristics, just the velocity required for the transportation of the load supplied to it by the drainage basin.

FACTORS CONTROLLING EQUILIBRIUM OF THE STREAM:

a) **Stream Discharge (Q):** Usually measured in ft^3/sec or m^3/s. Dependent mainly on climate. The relationship $Q=A * V_m$ is important.
   V_m= mean velocity of the section
   A = Area of the section perpendicular to the direction of flow.

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b) **Sediment discharge and the size of sediment:** Climate, weathering and all processes delivering sediment to the stream determine the quantity of sediment discharge (tons/day) and the size of sediment. The size of grains and the structure of the original rock material are also important criterion.

c) **Slope:** The slope adjusts automatically to provide the velocity necessary for transporting the amount and size of the material being delivered to the stream. If the slope is too low for transporting the sediment load, deposition occurs until the slope is sufficient for transporting. If the slope is so steep that it provides a velocity greater than that necessary to transport the load, erosion reduces the slope. This new slope will provide the velocity needed to transport the sediment load.

d) **Channel Shape:** The ratio of width to depth is used to describe the channel shape. The interaction of discharge, amount of sediment, slope and local factors such as bank erodability and channel alignment determine channel shape.

$Q = A * V_m$

Channel slope is important in determining stream velocity and so sediment transport. Generally, as the channel becomes narrower, sediment transport becomes more efficient. When narrowing of a channel occurs because of deposition on the bank, erosion of bed is likely to result. Again, when the deposition of the channel bed occurs, the erosive forces on the bank increases resulting widening of the stream.

LONGITUDINAL PROFILE OF A STREAM:

The longitudinal profile of a stream is a graphic outline of the stream's gradient along it's course. It provides information of the elevation of the streambed (Fig as shown below) at any location, the elevation being measured with respect to some fixed datum (may be w.r.t. MSL).

The longitudinal profile is a function of the following variables:
Discharge, Load delivered to the channel, Size of debris, Velocity of flow, Flow resistance, depth of flow, width of the channel, Slope of the channel.

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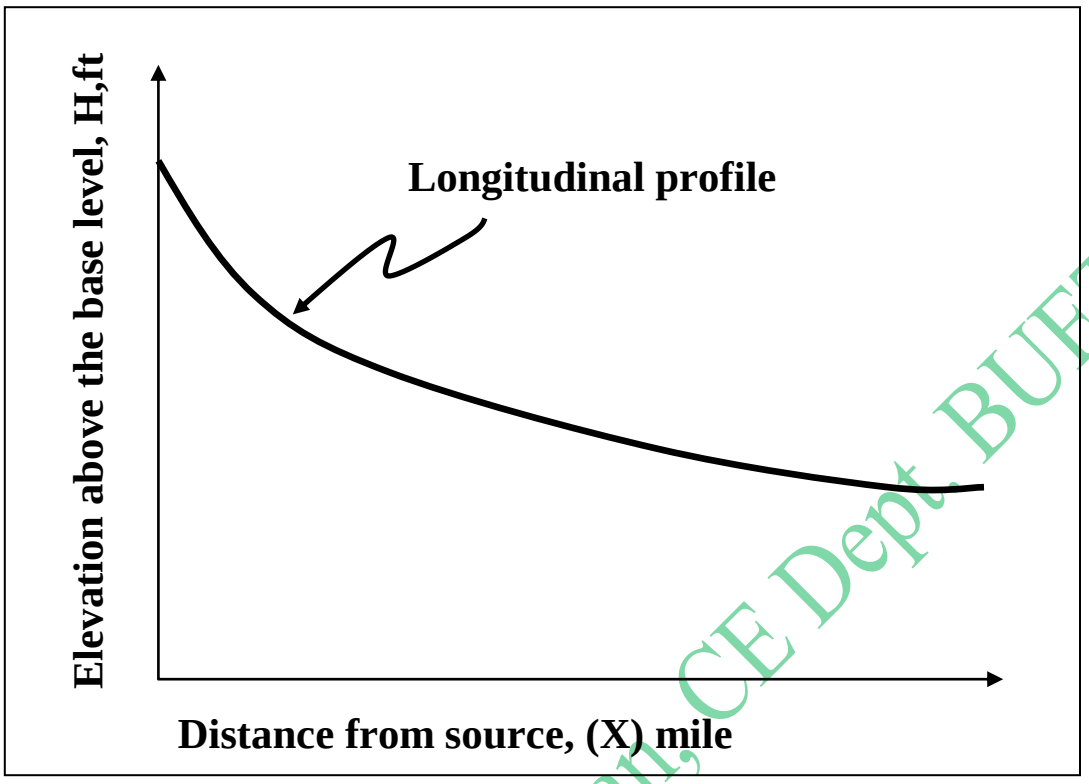


Fig. **Schematic diagram of longitudinal profile of a stream**

EQUATION OF LONGITUDINAL PROFILE:

Assumption: The tendency of a stream to erode at any particular point along its profile is directly proportional to the height of the stream above the base level.

If,
H = Elevation above base level or MSL in feet
X = Distance downstream from source in mile

Then based on the assumption:

$$\frac{dH}{dX} \alpha - H$$

or, $$\frac{dH}{dX} = -bH$$

or, $$\frac{dH}{H} = -bdX$$

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or, $\log_e H = - bX + \log_e C$

or, $\log_e H - \log_e C = - bX$

or, $\log_e (H/C) = -bX$

or, $H/C = e^{-bX}$

is the equation of the longitudinal bed profile.

READJUSTMENT OF THE STREAM GRADE:

A graded stream delicately adjusted to its environment of supply of water and rock waste from the upstream sources is highly sensitive to changes in those controls. Changes in climate and in land surface of the water shade bring changes in discharge and load at downstream points and these changes in turn require channel readjustment.

Effect of increase in bed load:
[Increase of bed load beyond stream capacity → acumulation of coarse sediment on the stream bed → elevation of stream bed **]** ➔ Aggradation

As consequence of aggradation

In the upstream direction: Reduces the channel slope in the u/s direction → reduction of stream capacity in the reach → accumulation of the bed materials in the u/s direction

In the downstream direction: The channel slope is increased → velocity increases → more bed materials gragged downstream

Aggradation ***changes the channel cross section*** from a narrow and deep form to a wide and shallow one. Formation of bars continuously → Division of flow into multiple directions → Braided channel.

Effect of decrease in bed load: This change can come along in a number of ways:

- Reforestation of an abandoned farmland
- Building of dam, trapping sediment in the upstream reservoir

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Due to the decrease of the bed load a channel preciously graded is no longer in equilibrium. As result: [Scour of stream → trenching into the alluvium and lowering of the stream profile.] → Degradation {also referred to as ***channel trenching***}. As result of this the channel takes a narrow cross section and develops steep, wall-like banks of alluvium. After this channel trenching, the former floodplain is free from annual flooding and becomes a ***stream terrace***.

After degradation has taken place, the stream will normally attain a new and lower profile of equilibrium. When the new equilibrium is established the stream will usually develop meanders and will shift laterally to form a new floodplain.

In many cases alternate cycles of aggradation and degradation produce a very complex series of terraces. These reflect the changing response of the stream to climatic changes.

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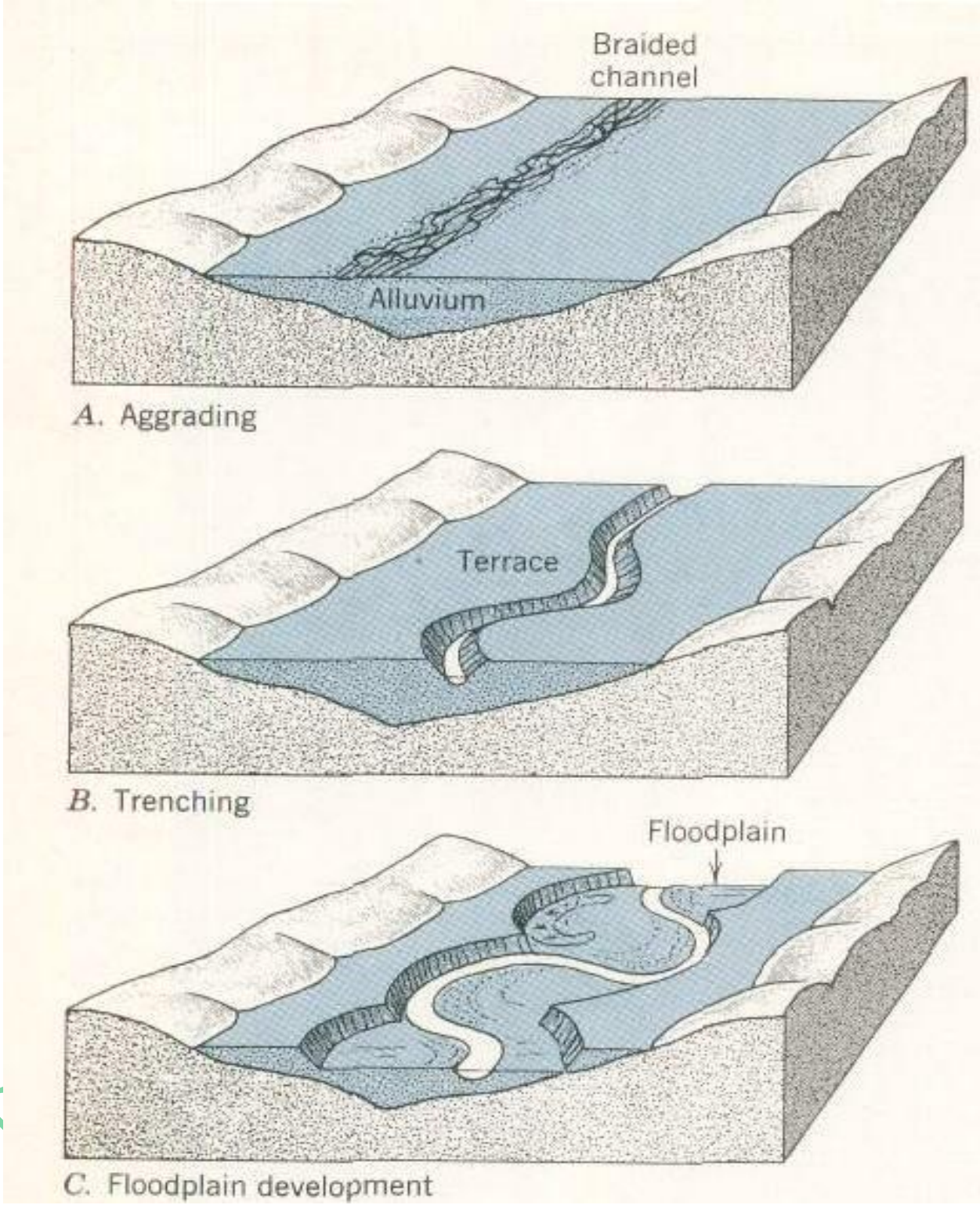


Figure 32.5 **Stages in stream trenching and terrace formation**. (A) Aggradation by a braided stream has partly filled a valley with alluvium. (B) Trenching leaves a wide alluvial terrace. (C) The graded stream forms a new floodplain by undercutting the terrace.

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DRAINAGE PATTERN:

Definition:

Distribution of stream courses and their spatial relationship to one other

Types:

1. Dendritic
2. Trellis
3. Rectangular
4. Radial
5. Annular
6. Parallel
7. Irregular

1. Dendritic:

- Irregular branching of tributary streams in many directions at almost any angle (Usually less than or at right angle)
- Most likely to be found upon horizontal rocks or in areas of massive igneous/metamorphic rocks
- Looks similar to that of the roots of trees

2. Trellis:

- These are formed in places where the bands of rock resistant to weathering alternate with bands(of rock) that erode more rapidly
- The main streams frequently make nearly right angled bends to cross or pass between aligned ridges
- Primary tributary streams are usually at right angles to the main stream and are joined at right angles by the secondary tributaries whose courses are commonly parallel to the main stream
- This is a special variety of the rectangular pattern

3. Rectangular:

- Characterized by the bends in both the tributaries and the master streams
- Generally right angle joints

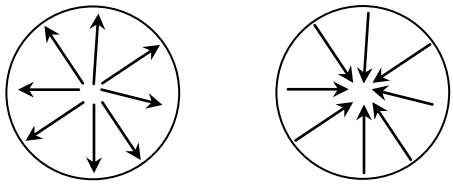
4. Radial:

- In the ***radial outward*** pattern the drainage lines radiate outward from a common center. This center is located at an elevated location.

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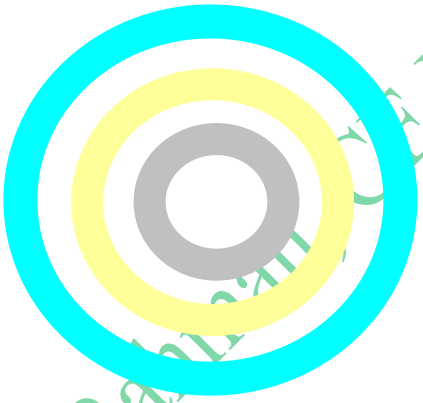
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- In the ***centripetal or radial inward*** type the streams flow into a common center from the circular basin walls.



5. Annular:

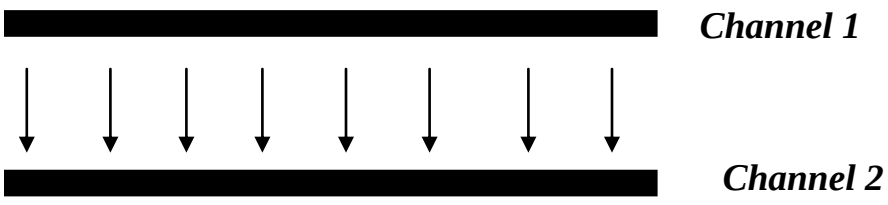
- May be found around maturely dissected domes which have alternating belts of strong and weak rocks encircling them



- As breaching proceeds the initial radial drains completely disappear, influence of slope control ceases and concentric arrangements of streams (the annular pattern) on the least resistant formations will develop if other factors are negligible

6. Parallel:

- It consists of parallel master and tributary streams
- Pronounced regional slopes, parallel faults and parallel topographic features are the controlling factors in the formation of this type of drainage pattern



7. Irregular:

- Guess what!!

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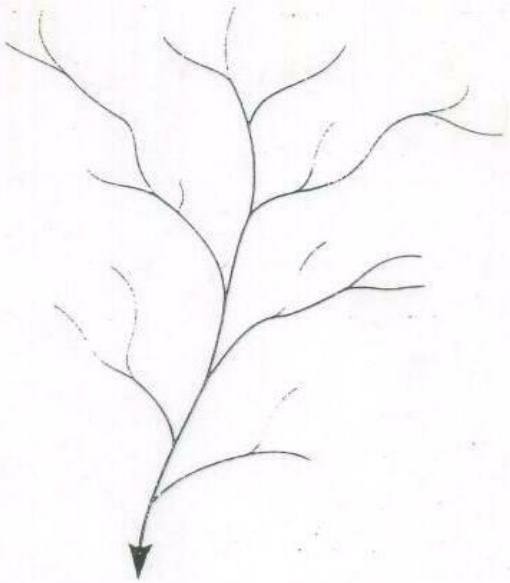


Figure 9-39
Typical dendritic drainage pattern, characterized by a branching pattern similar to that of the limbs or roots of trees.

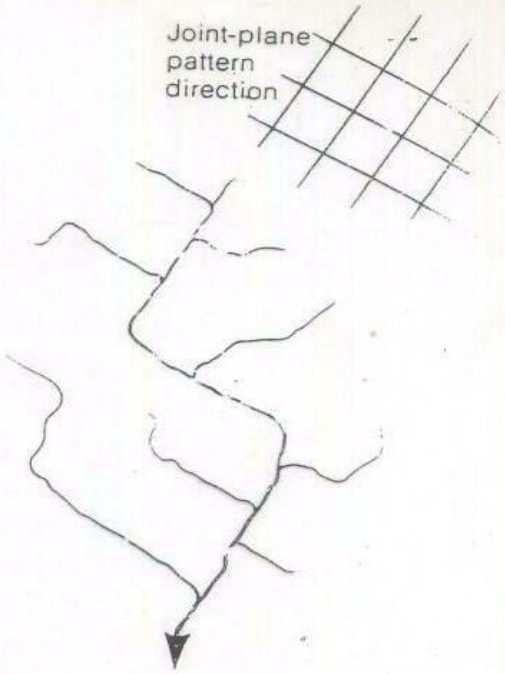


Figure 9-40
Typical rectangular drainage pattern developed on a strongly jointed rocky terrain. Drainage tends to follow the joint pattern.

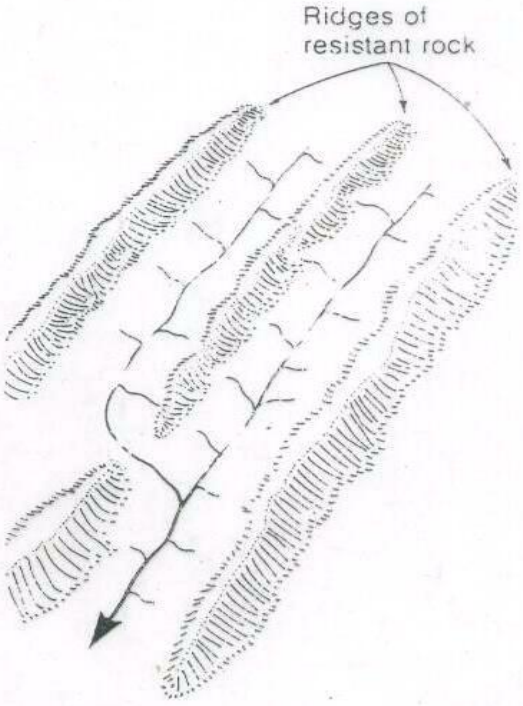
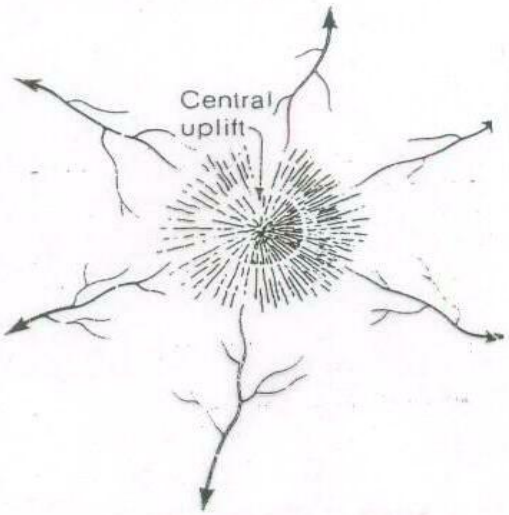


Figure 9-41
Typical trellis drainage developed in valley and ridge terrain, in which rocks of varying resistance to erosion are folded into anticlines and synclines.

Figure 9-42
Typical radial drainage pattern developed on a large single peak, such as a large dormant volcano or a domal uplift.



QUANTITATIVE ANALYSIS OF STREAM NETWORK

STREAM ORDER:

Stream order is a measure of the position of a stream in the hierarchy of tributaries (Branches of stream).

PURPOSE OF MAKING STREAM ORDER:

- To make comparison between different drainage basins
- To help making relationship between different aspects of drainage pattern of the same basin to be formulated as general laws.
- To define certain useful properties of drainage basin in numerical terms

HORTON'S SYSTEM OF STREAM RANKING:

According to this system of stream ranking- a stream which has no tributaries is a stream of *1st order*.
A stream which has tributaries of order 1, is a *second order* stream.
A stream which has first and second order tributaries, is a stream of *third order*.

BIFURCATION RATIO:

The ratio between (Mean ratio) the number of streams of one order to the number of streams of next higher order is a constant and is called bifurcation ratio (B.R.).

For the stream network shown above:

Stream order	No of streams	B.R.	Average B.R.
1st	18	18/6 = 3	$\frac{3+2+3}{3}$
2nd	6	6/3 = 2	$= \frac{8}{3} = 2.667$
3rd	3	3/1 = 3	
4th	1		

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Length Ratio(L.R.) :

The ratio between the mean length of stream of an order to the mean length of streams of the next lower order is a constant and is called length ratio (L.R.)

Stream order	Mean length (Miles)	L.R.	Average L.R.
1st	5.3	24.8/ 5.3 = 4.7	$\frac{4.7+2.83+2.14}{3}$ = 3.218
2nd	24.8	70.2/ 24.8 = 2.83	
3rd	70.2	150.5/ 70.2 = 2.14	
4th	150.5		

CONSTANT OF CHANNEL MAINTENANCE:

It is the drainage area required to be sustained by unit length of the channel.

Length of channel (L) is given by the empirical formula: $\mathbf{L = 1.4\ A_d^{0.6}}$

L = Mean length of the channel (mi), A_d = the area of the drainage basin (mi^2)

The value of A_d for L =1 unit, is the constant of channel maintenance.

Drainage density:

Drainage density = $\frac{\sum Length}{\sum Area_d} = \frac{L}{A_d}$; Unit is '1/ mile'

Length of overland flow:

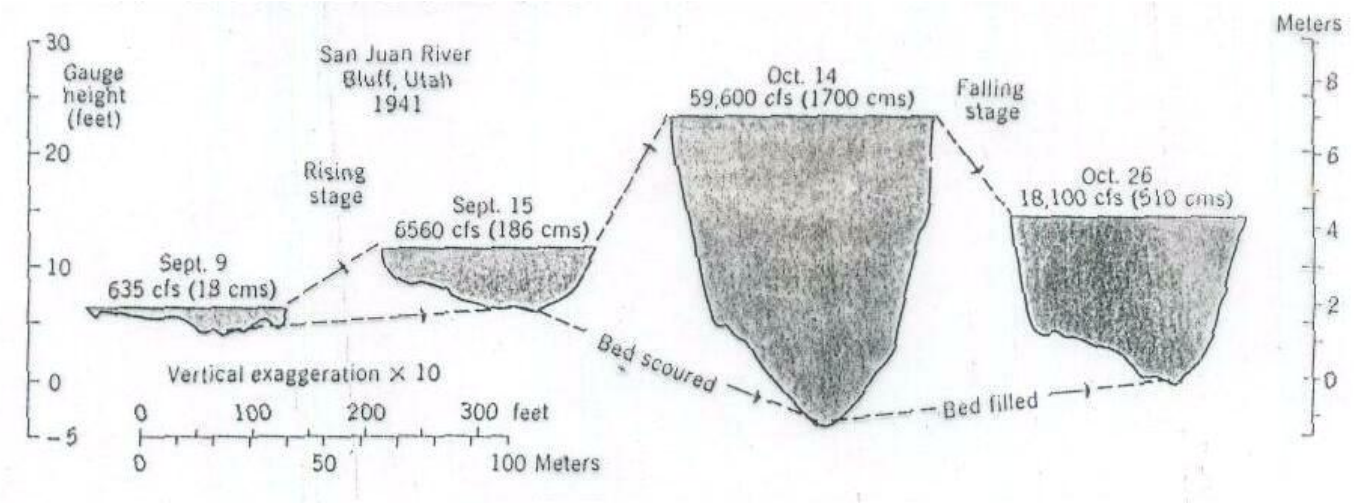
Length of overland flow = ½ x $\frac{1}{DrainageDensity} = \frac{\sum A_d}{2\sum L}$; Unit is mile

Stream Frequency: Stream Frequency = $\frac{\text{No of streams in a network}}{\text{Total area of drainage basin}}$

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Figure 32.2 Changes in channel from of the San Juan River near Bluff, Utha,during the progress of a flood. (Based on data of L.B. Leopold and T. Maddock, 1953, U.S. Geological Survey, Professional Paper 252, p. 32, Figure 22).



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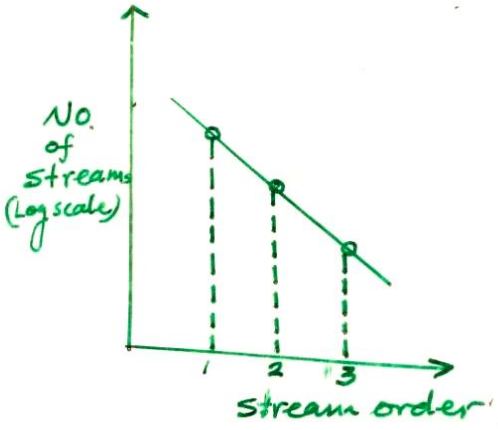
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Hints: Try to trace orders from the lowest (ie, 1st order) to the higher ones:

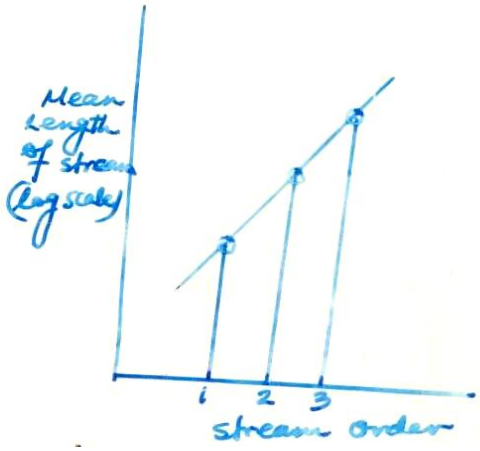


Fig: Stream Network

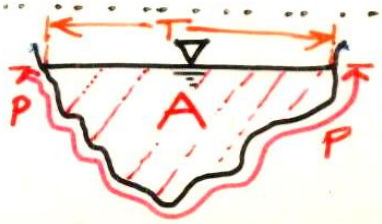
Law of stream number:



Law of stream length:



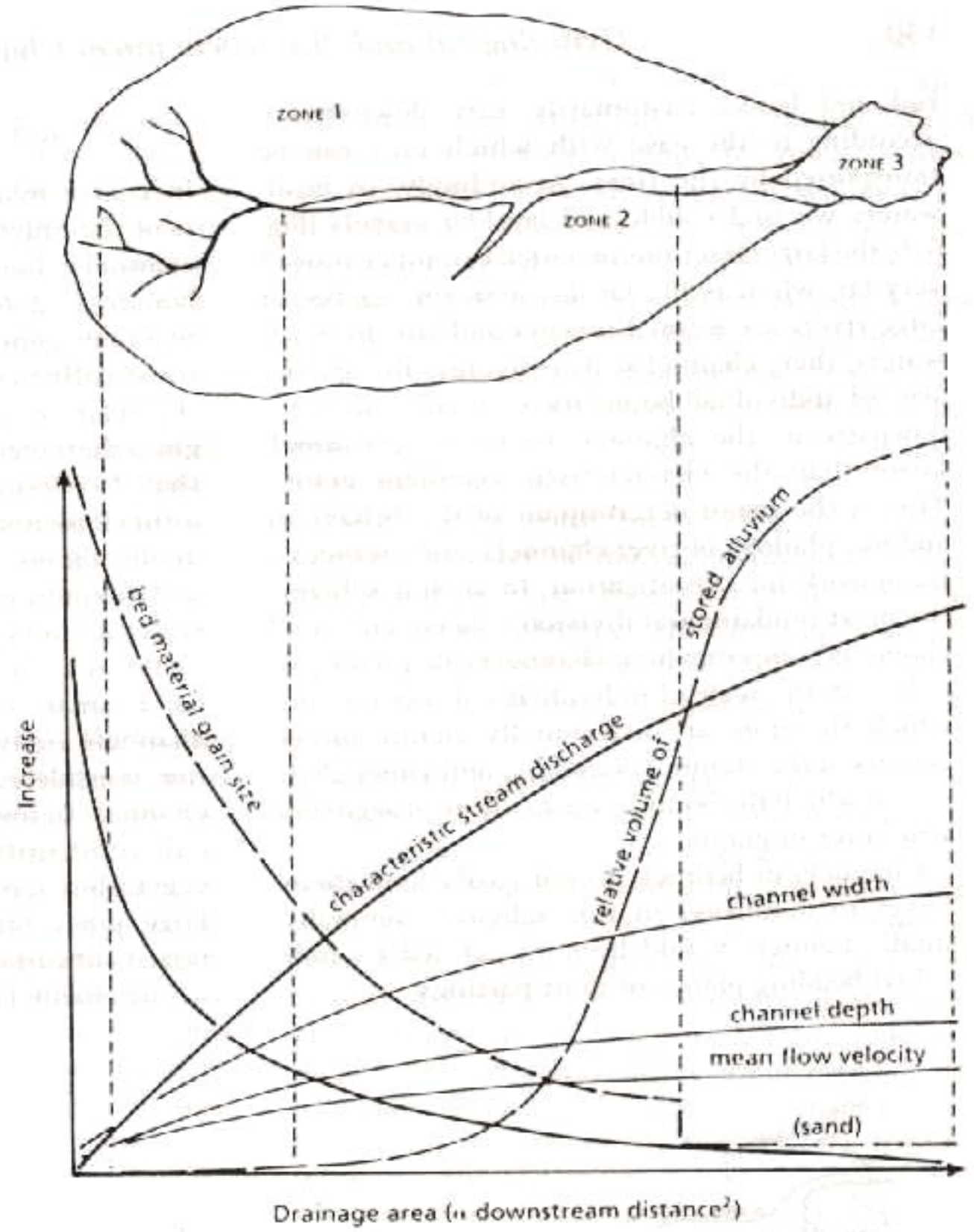
Channel sectional properties:-



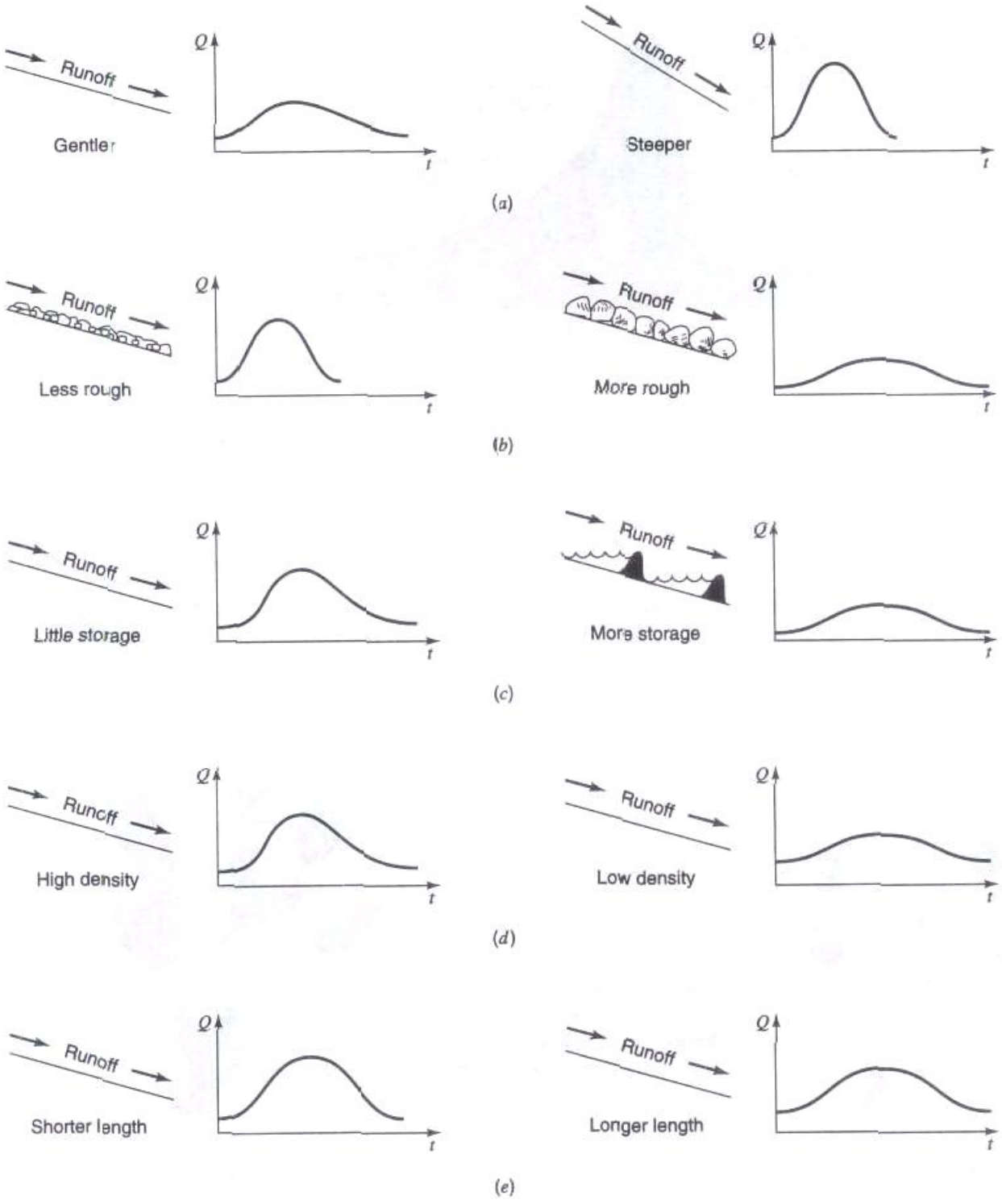
$$\frac{\text{wetted area } (A)}{\text{wetted perimeter } (P)} = \text{hydraulic radius } (R)$$

$$\frac{\text{Wetted area } (A)}{\text{Top width } (T)} = \text{hydraulic depth } (D)$$

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Effects of basin characteristics on the flood hydrograph.

(a) Relationship of slope to peak discharge; *(b)* Relationship of hydraulic roughness to runoff. (c) Relationship of storage to runoff. *(d)* Relationship of drainage density to runoff. *(e)* Relationship of channel length to runoff (from Masch (1984)).

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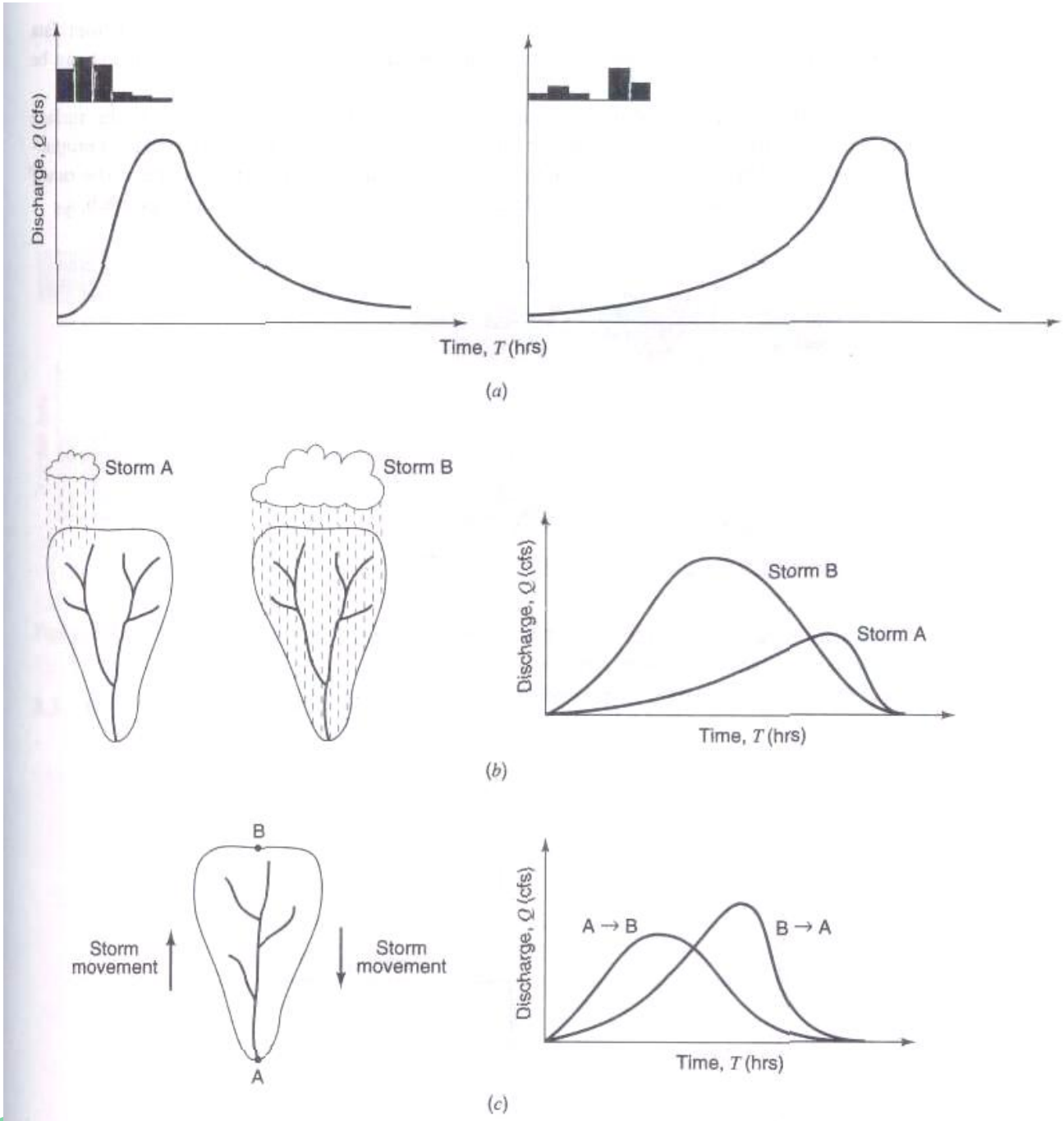
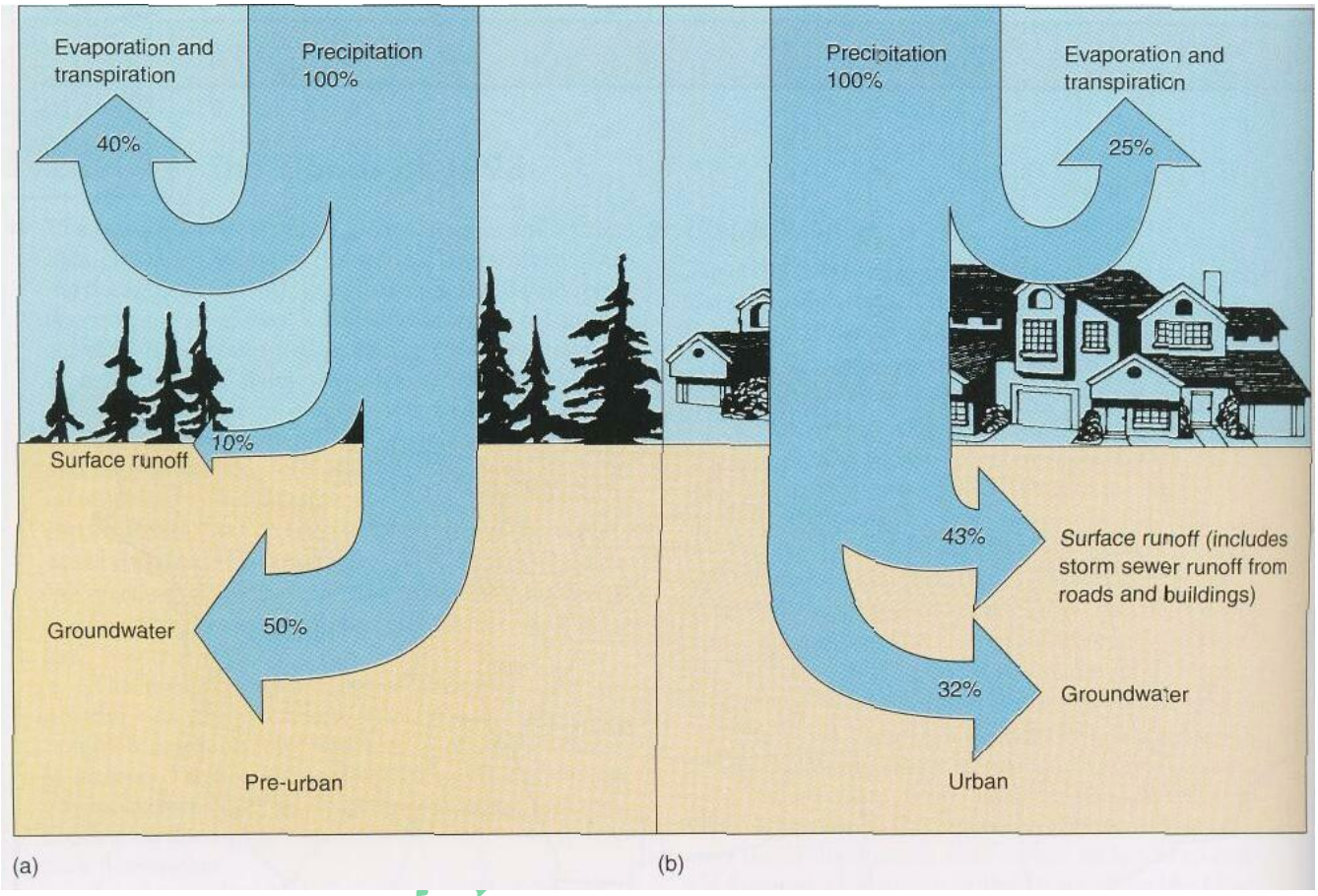


Figure **8.1.5 Effects of storm shape, size, and movement on surface runoff**. (a) Effect of time variation of rainfall intensity on the surface runoff; *(b)* Effect of storm size on surface runoff. (c) Effect of storm movement on surface runoff (from Masch 1984)).

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The development of an area changes the natural flow of water. The fate of precipitation in Ontario, Canada (a) before and (b) after urbanization. After Ontario was developed, runoff increased substantially, from 10 percent to 43 percent.

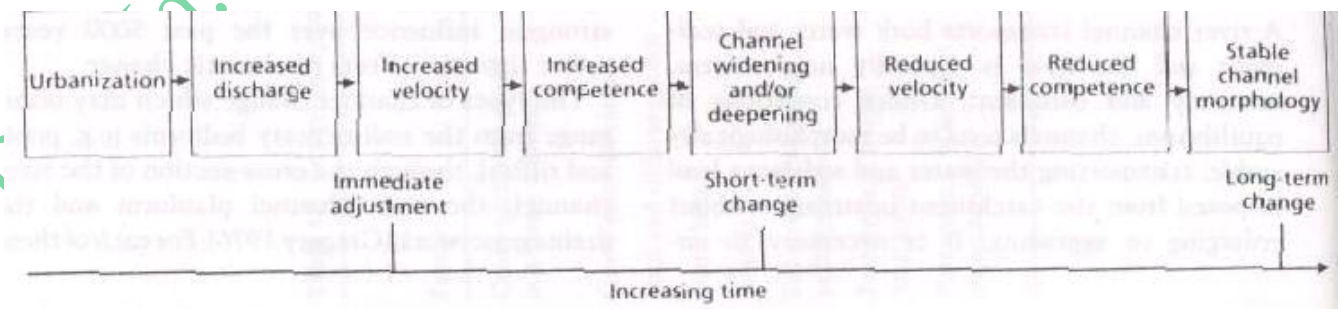


Fig. 4.2 Impact of urbanization (after Murisawa 1985).

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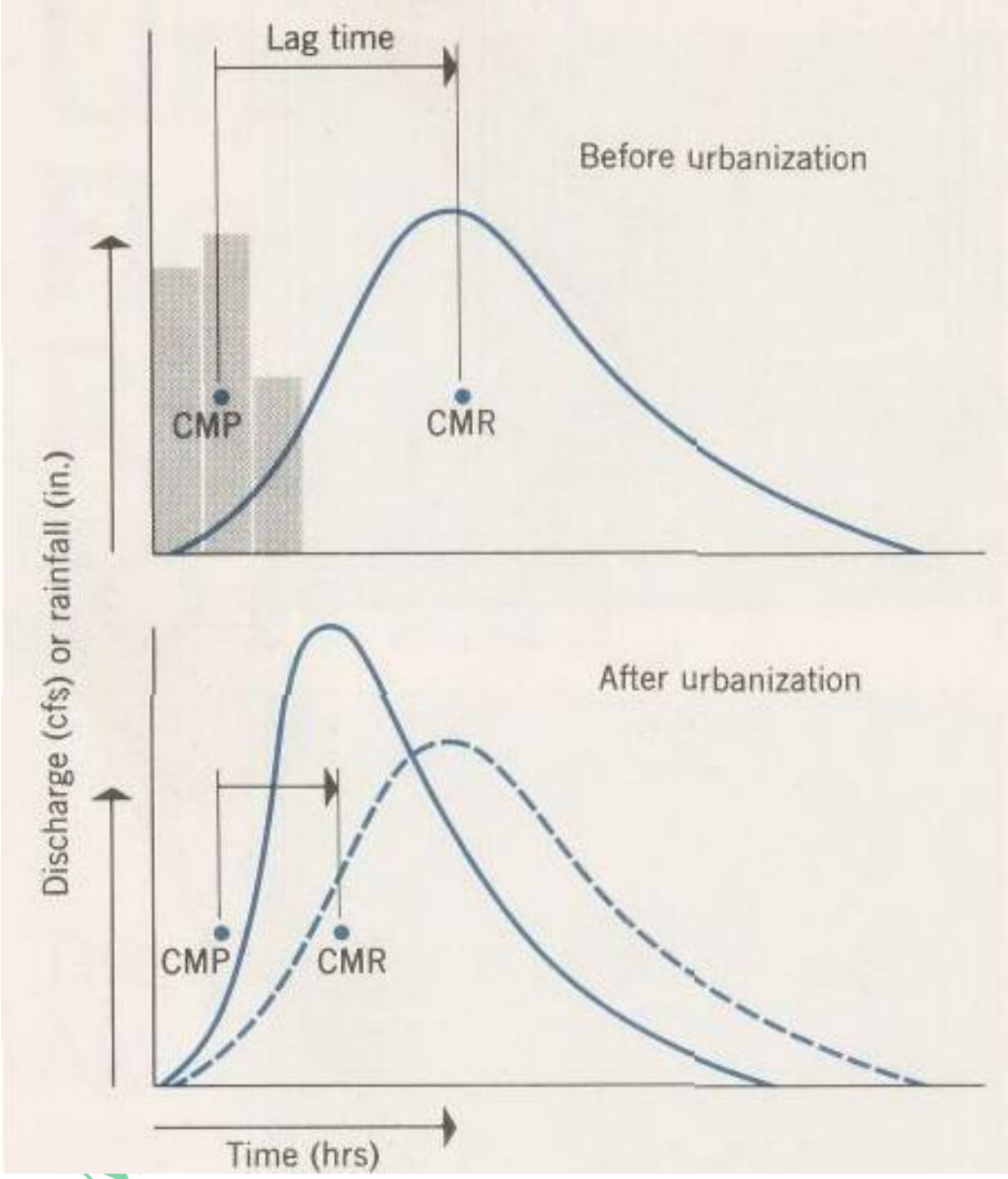


Figure 28.7 **Schematic hydrographs showing effect of urbanization** as reducing lag time and increasing peak discharge. Points CMP and CMR are centers of mass of rainfall and runoff, respectively, as in Figure 28.3. (After L. B. Leopold [1968] U.S. Geological Survey, Circular 554.)

Landforms of Alluvial River Floodplains

An **alluvial river** flows on a very gentle downvalley gradient. The typical alluvial river has sinuous (snakelike) bends, called **alluvial meanders,** and occupies a floodplain. As we explained in the previous unit, the floodplain is a belt of flat land, present on one or both sides of the river channel, and subjected to inundation by overbank flooding annually or biennially.

Before launching into an investigation of the hydrology of river floods, it is helpful to know about the surface configuration and landforms of a typical alluvial river floodplain. A block diagram, Figure 29.1 shows these features in exaggerated form.

An alluvial river flows on a thick accumulation of alluvial deposits constructed by the river itself in earlier stages of its activity. These sedimentary deposits, called **alluvium,** consist of clay, silt, sand, or gravel in various layered arrangements. The floodplain is bounded on either side by rising slopes, called **bluffs.**

Dominating the floodplain are the meandering river channel itself and also the abandoned reaches of former channels. An air photograph, Figure 29.2, shows these features nicely. Meanders develop narrow necks, which are cut through, shortening the river course and leaving a meander loop abandoned. This event is called a **cutoff.** It is quickly followed by deposition of silt and sand across the ends of the abandoned channel, producing an **oxbow lake.** The oxbow lake is gradually filled with fine sediment brought in during high floods and with organic matter produced by aquatic plants. Eventually the oxbows are converted into swamps, but they retain their identity indefinitely.

During periods of overbank flooding, when the entire floodplain is inundated, water spreads from the main channel over adjacent floodplain deposits. As the current rapidly slackens, sand and silt are deposited in a zone adjacent to the channel. The result is an accumulation known as a **natural levee.** Between the levees and the bluffs is lower ground, the **backswamp.** Because deposition is heavier closest to the channel and decreases away from the channel, the levee surface slopes away from the channel. Figure 29.3 is a profile across a river channel and its flanking levees. Figure 29.4 shows a river in flood. Notice that the higher ground of the natural levees is revealed by a line of trees on either side of the channel.

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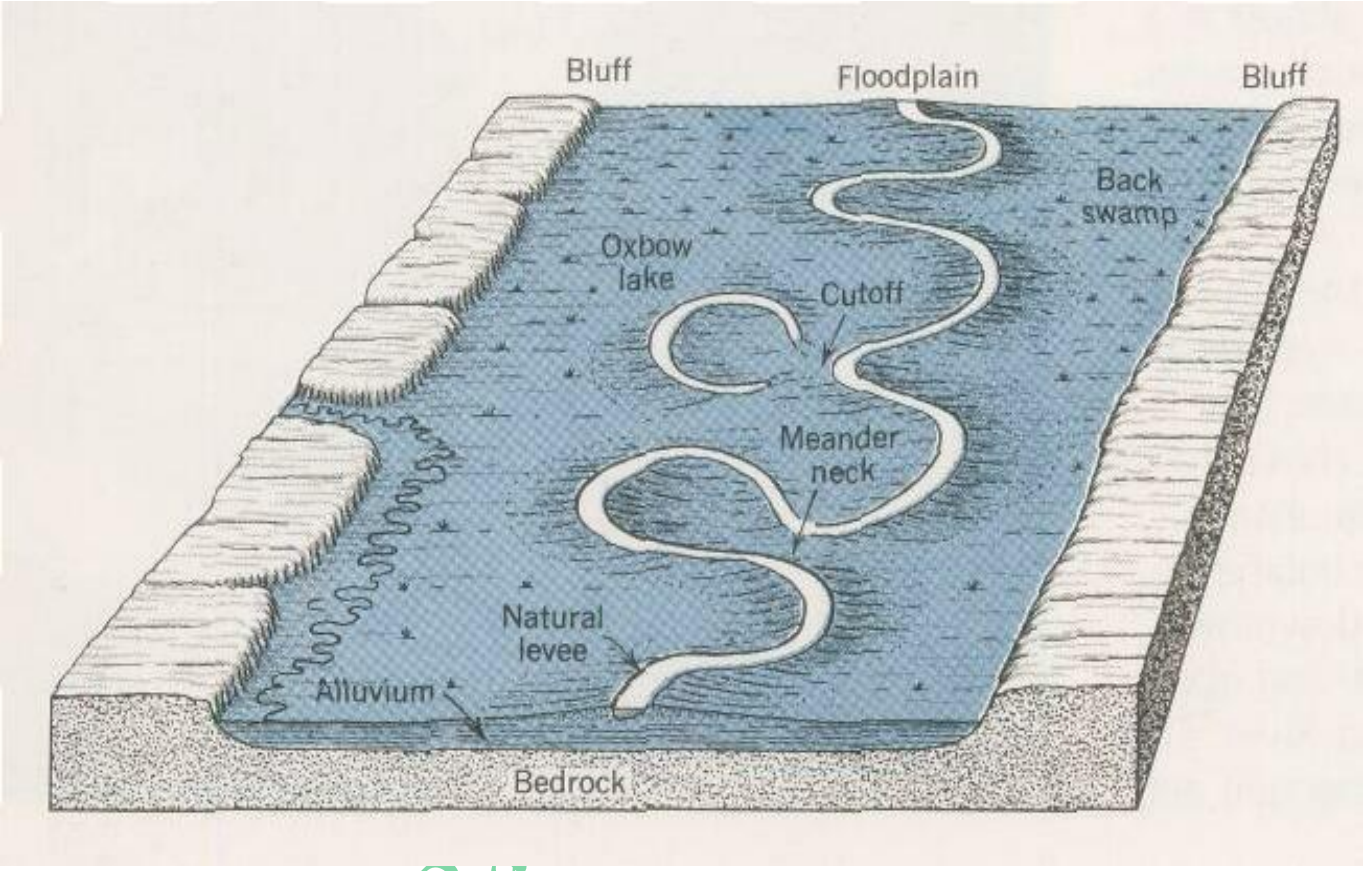


Figure 29.1 Floodplain landforms of an alluvial river.

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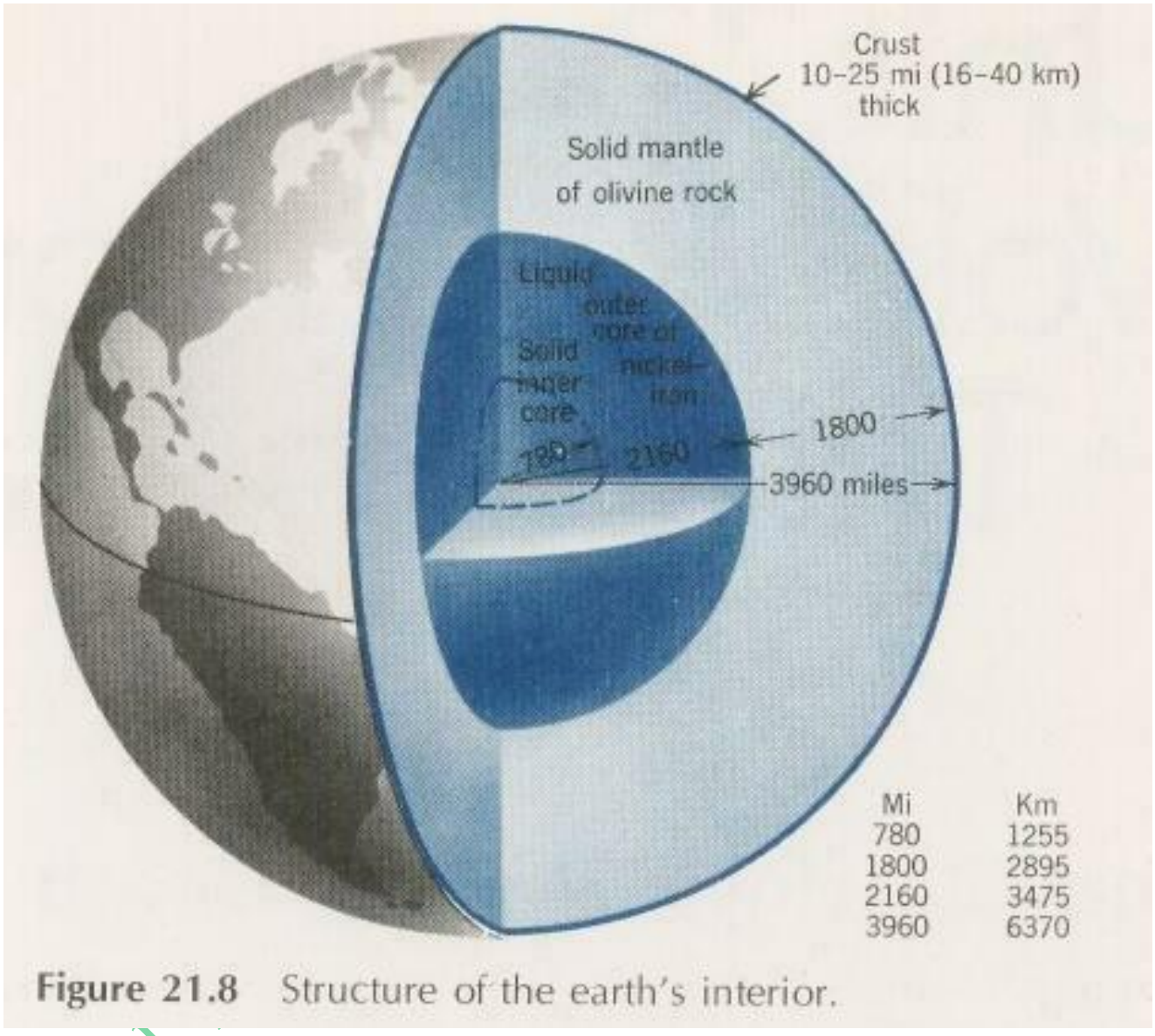


Figure 21.8 Structure of the earth's interior.

Dr. Md.

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