GEOLOGY

Presentation for RAP3 Senior Technical Management Course

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Contents

1. Mineral Groups and Weathering
2. Rock Identification
3. Causes and Mechanism of Slope Failure

MINERAL GROUPS AND WEATHERING

Objectives

1. To identify the principal group of minerals in rock
2. To state the order of chemical stability and resistance to weathering of principal mineral group
3. To describe the relationship between rock weathering product and soil texture

Minerals

- Naturally occurring
- Inorganically formed
- With definite chemical composition
- Ordered atomic arrangement compound

Rock is an aggregate of minerals

either same types of mineral or various types of minerals

Principal Mineral Groups

- Black or coloured minerals - Hornblende
- Dark and flaky mineral or mica – Biotite
- Light coloured minerals - Calcite, Feldspar
- White flaky mineral or mica - Muscovite (platy and translucent)
- Quartz - (Sugar, translucent, milky)

Identification of Minerals

- Colour
- Streak
- Hardness
- Cleavage
- Lustre
- Specific Gravity
- Tenacity
- Fracture
- Transparency

Weathering

- Disintegration of rocks or minerals
- Physical and chemical alteration of minerals into other minerals by the action of heat, water and air

Features of Rock Weathering

- Softness - minerals can be rubbed off by hand
- Discoloration - brown colour
- Loosing grains - separation of grains
- Intact white mica - Muscovite
- Intact quartz - Quartz

Causes of Weathering

- Heat
- Air
- Water

Rate of weathering increases with increase in temperature and water content

Rock Weathering Grade

Weather Grade	Description
Grade 1: Fresh Rock	No visible sign of weathering
Grade 2: Slightly Weathered	Discoloration of all discontinuous surfaces or throughout rock
Grade 3: Moderately Weathered	Up to 50% of rock mineral decomposed and/or disintegrated into soil. Rock can be continuous mass or core stone
Grade 4: Highly Weathered	More than 50% of rock minerals decomposed or disintegrated to soil. Rock mass is discontinuous
Grade 5: Completely weathered	All rock material decomposed and/or disintegrated to soil. Original mass structure still largely intact
Grade 6: Residual soil	All rock material converted into soil. Mass structure and material fabric destroyed

Soil

- Disintegration of rock/minerals
  - Particles are much smaller
  - Clay minerals (fines) are present - new minerals
  - Derived from weathering of rock
  - Quartz and white mica remain as they are the most resistant ones to weathering (stable)

Types of Soil

- Colluvium, Alluvium, Residual and Moraine soil
- Colluvium is the product of gravity on hill slopes, angular in shape with clay
- Alluvium is the product of action of water in river, spherical in shape without clay
- Residual soil is produced by weathering of the rocks in-situ
- Moraine Soil is the product of the glacier movement, angular in shape with out the clay

IDENTIFICATION OF ROCKS

Objectives

- To give knowledge of types of rock in nature
- To demonstrate the appearance of the principal rock types of the Sub - Himalaya, Lesser ,Higher Himalaya and Tibetan Himalaya
- To identify rocks with the help of diagnostic properties

Rock Classification

Rock	Description
Igneous rock (Primary rock)	A rock that has solidified from molten or partly molten material originating from Magma. E.g. basalt, granite
Sedimentary rock	A rock resulting from consolidation of loose sediments or from chemical precipitation from solution at or near the earth's surface. E.g. limestone, sandstone
Metamorphic rock	Any rock derived from pre-existing rock by mineralogical, chemical or structural change, especially in the solid state, in response to marked changes in temperature, pressure and chemical environment E.g gneiss, schist

Igneous Rock

Common igneous rocks				
Plutonic or intrusive igneous rocks	GRANITE	PEGAMATITE	SYENITE	GABBRO
				
Volcanic or extrusive igneous rocks	VOLCANIC SCORIA	PUMICE	OBSIDIAN	BASALT
				

Diagnostic Properties of Igneous Rock

- Granite : Granular texture, mixture of minerals of quartz, feldspar, muscovite and biotite; no cementing material

- Basalt : Fine texture, minerals are not identified by naked eyes, only the vesicular structures which may be filled or open

Sedimentary Rocks

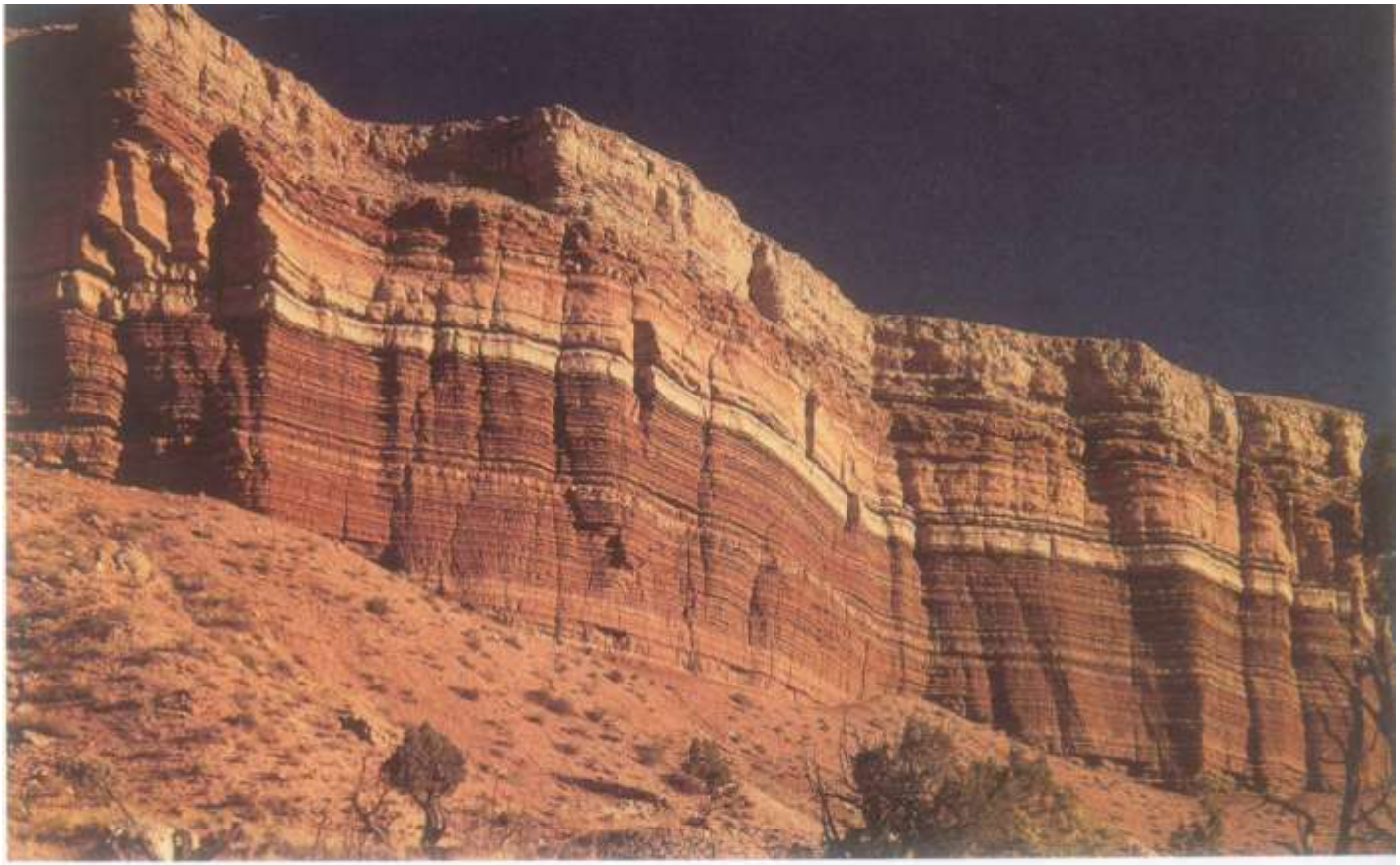


Figure 6.1 Layers of Sedimentary Rock: Bedding When you look at an outcrop of sedimentary rock, one of the first things you notice is layering, or bedding. Here, layered sedimentary rocks in Capital Reef National Park, Utah, have been exposed by erosion.

Diagnostic properties of sedimentary rocks

- Mudstone: Clay minerals, massive (no lamination), smell is like mud and is soft enough to be scratched off by fingernails
- Limestone: Mostly grey, fine to crystalline, can be scratched by a hammer or knife, effervesces strongly with dilute HCL, used for road ballast and concrete; raw material for cement
- Shale: Like mudstone, but is formed from laminated layers

- Siltstone: Silt size minerals, sharp edges, shining mica flakes
- Sandstone: Sand sized grains held together by a cementing material, scratches hammer or knife
- Conglomerate: Distinct rounded to sub-rounded fragments of grain to pebble size, held together by a cementing material
- Dolomite: Similar to limestone, powdered form effervescent (feeble)in dilute HCL, used for road ballast and concrete

Classification of Sedimentary Rocks

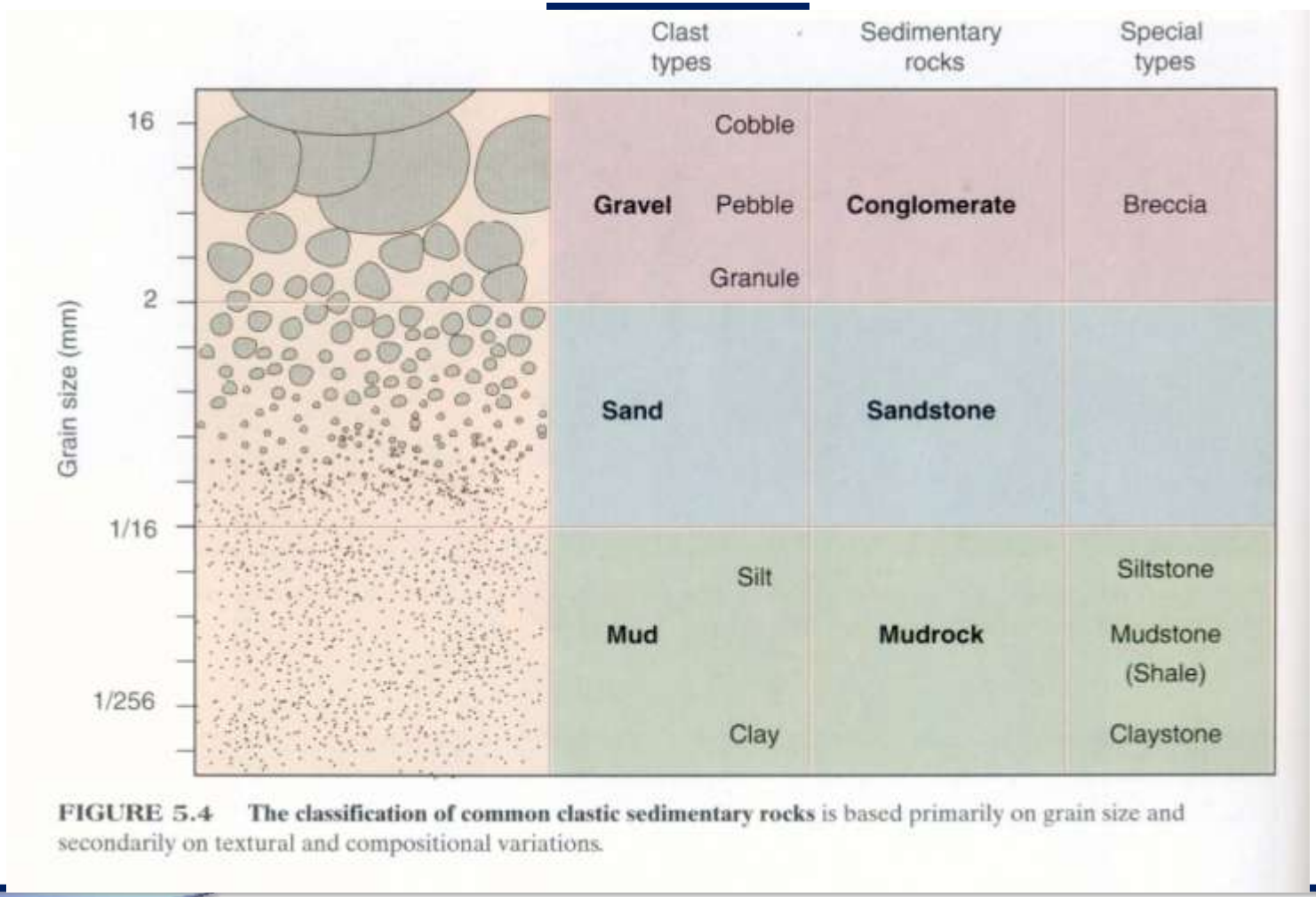
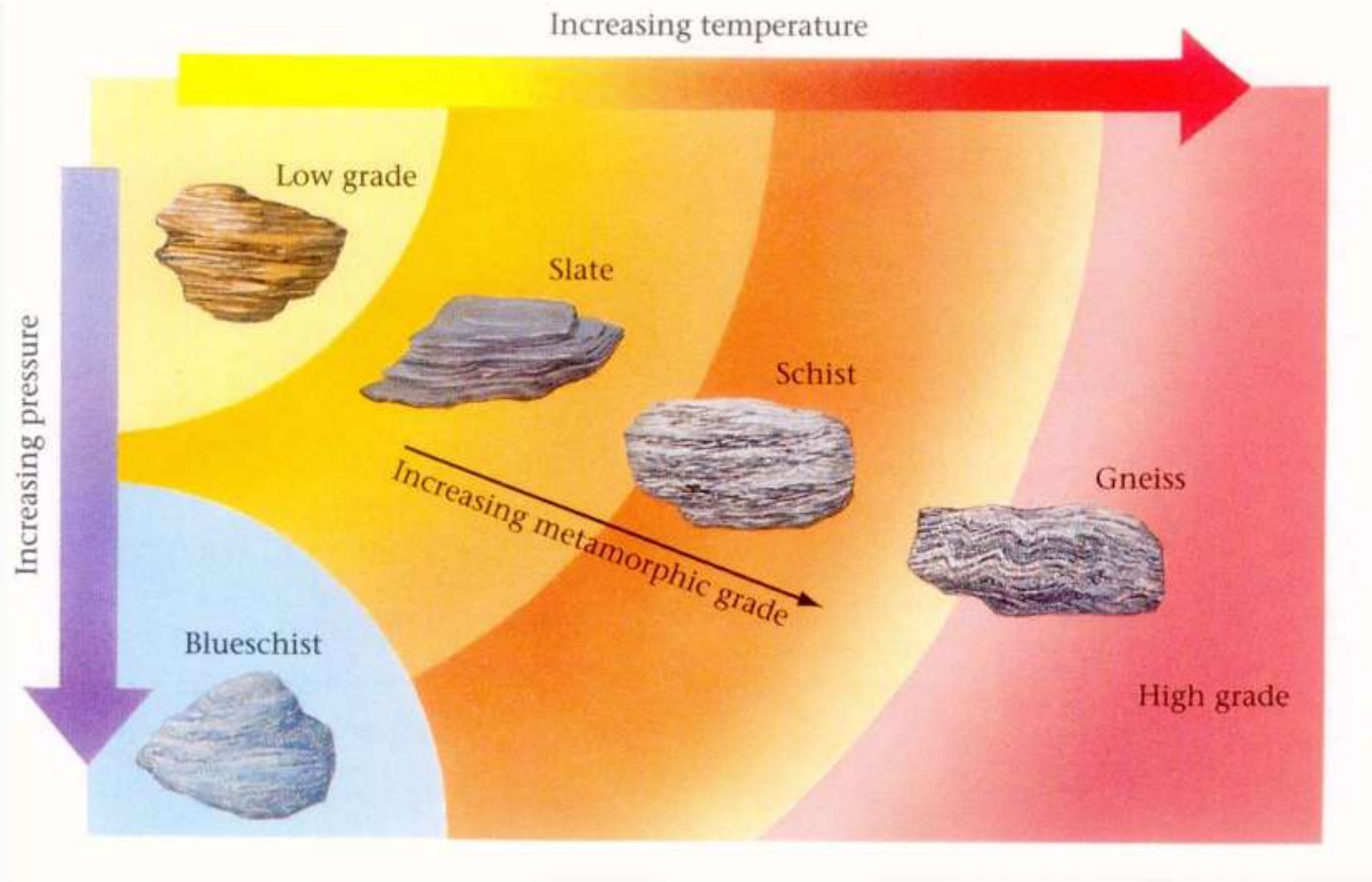


FIGURE 5.4 **The classification of common clastic sedimentary rocks** is based primarily on grain size and secondarily on textural and compositional variations.

Metamorphic rock



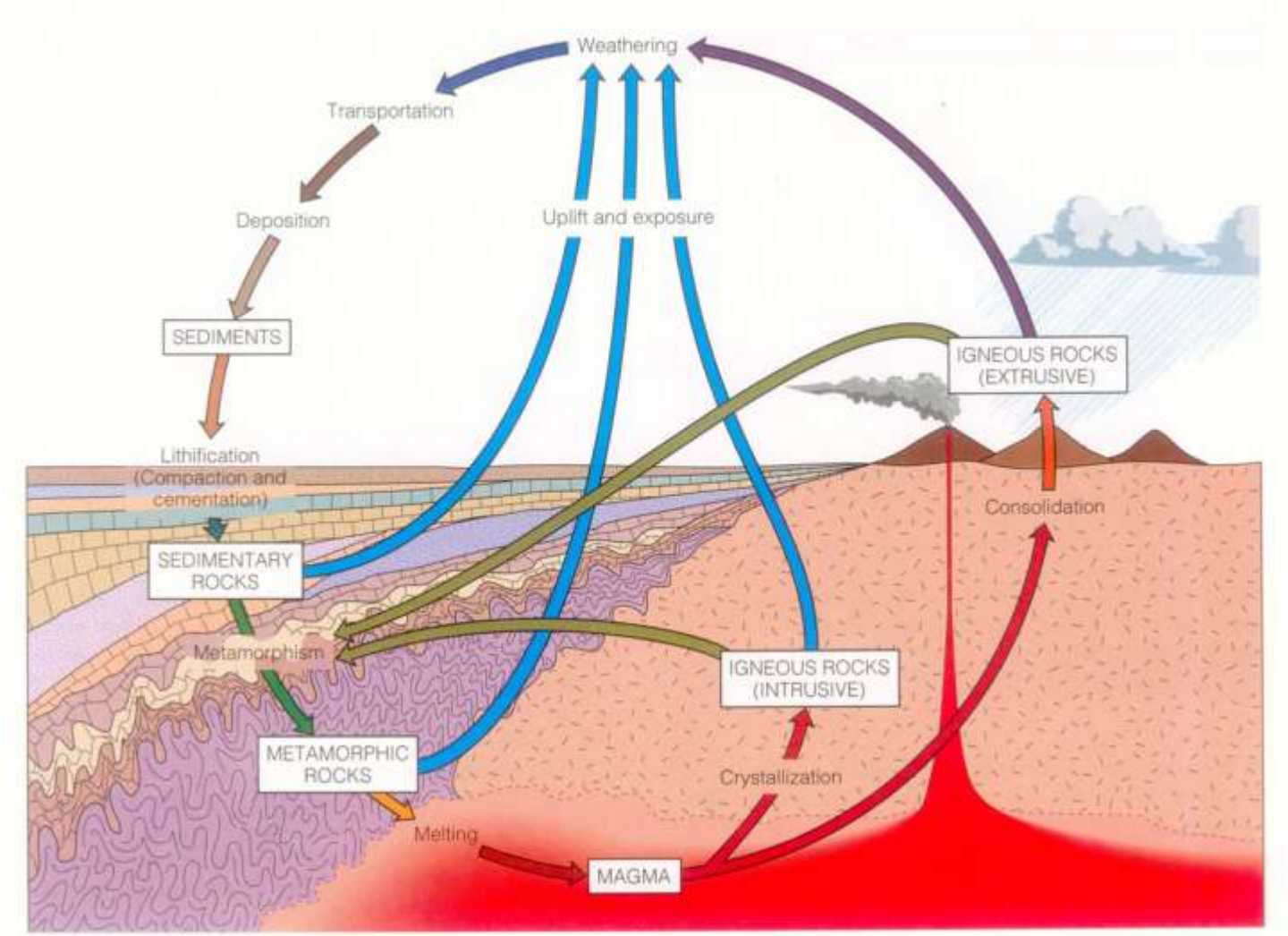
Diagnostic properties of metamorphic rocks

- Slate: Dark grey, thin foliation (splits easily), used for roofing, formerly for writing
- Phyllite: Foliated (less perfectly split than slate) light grey, clear joint set, small secondary quartz grain, dark minerals
- Schist: Schistosity (foliation), undulating or bulging surface due to mineralisation, coarser grain size than phyllite

Contd..

- Gneiss: Alternate bands of light (quartz, feldspar) and darker minerals, fairly coarse grain, highly foliated; used as grinding stone in water mills
- Quartzite: Banded, hard (Scratches hammer or knife)mostly consisting of mineral quartz, metallic sound, no cementing material, used for slabs
- Marble: Crystalline (sugary texture), effervescences highly in dilute HCL, used as facing stone

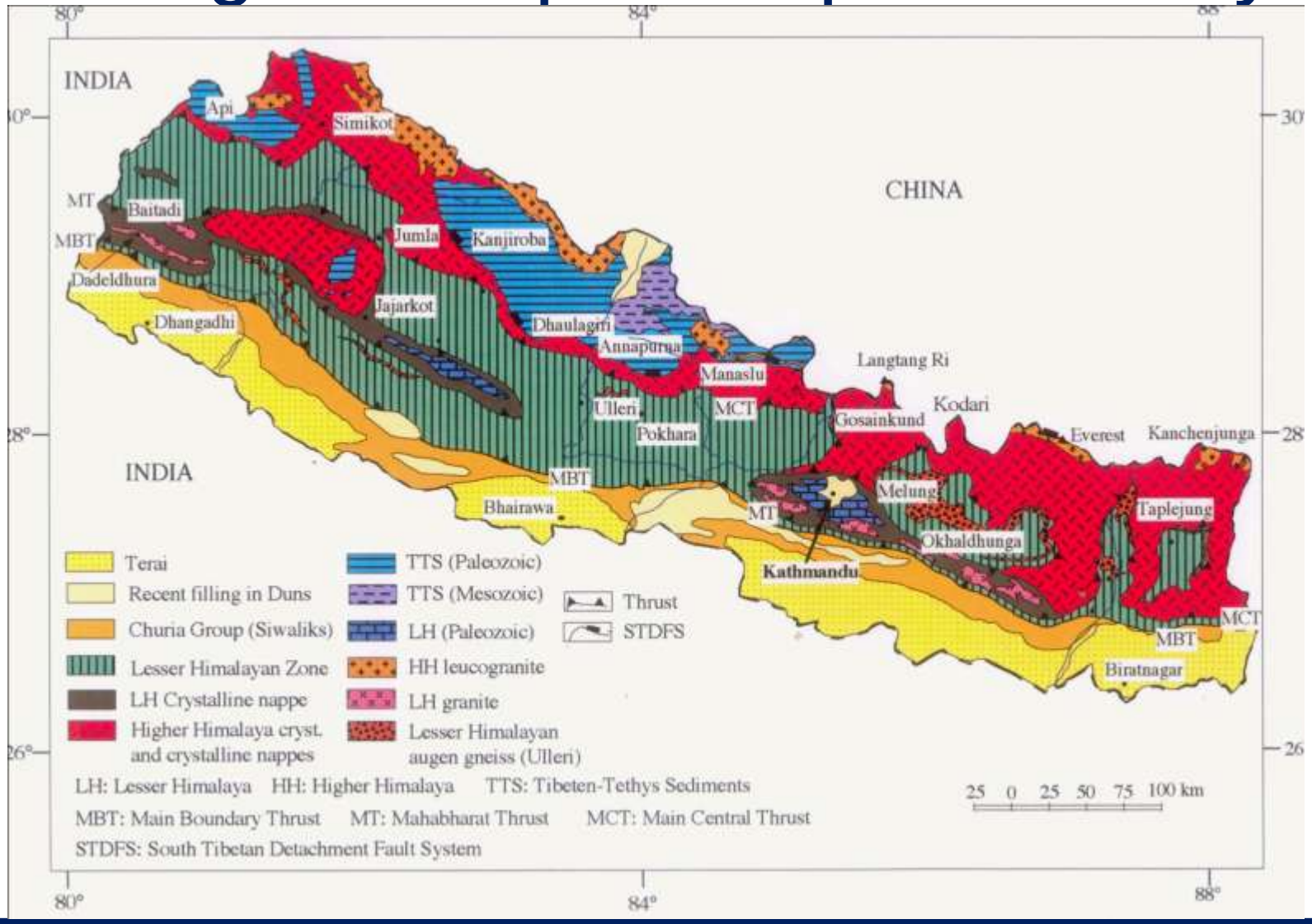
Rock Cycle


Weathering
Transportation
Deposition
Uplift and exposure
SEDIMENTS
Lithification
(Compaction and
cementation)
SEDIMENTARY
ROCKS
Metamorphism
METAMORPHIC
ROCKS
Melting
MAGMA
IGNEOUS ROCKS
(EXTRUSIVE)
Consolidation
IGNEOUS ROCKS
(INTRUSIVE)
Crystallization

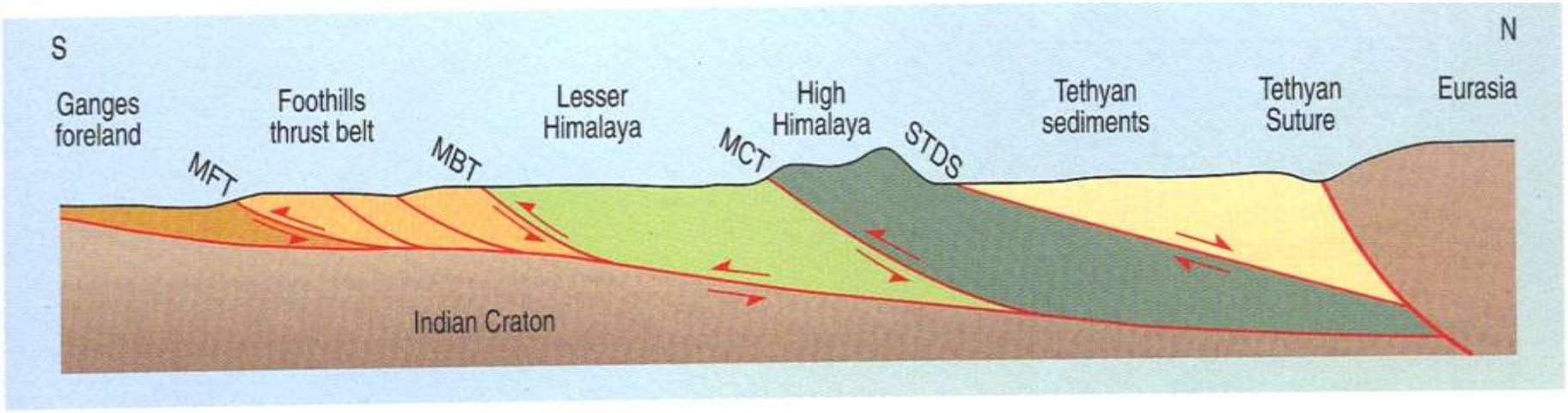
Sedimentary to metamorphic rock

- Clay-Mudstone(Shale)-slate-phyllite-schist-gneiss----------Magma
- Limestone-marble
- Sandstone-quartzite
- Dolomite-marble

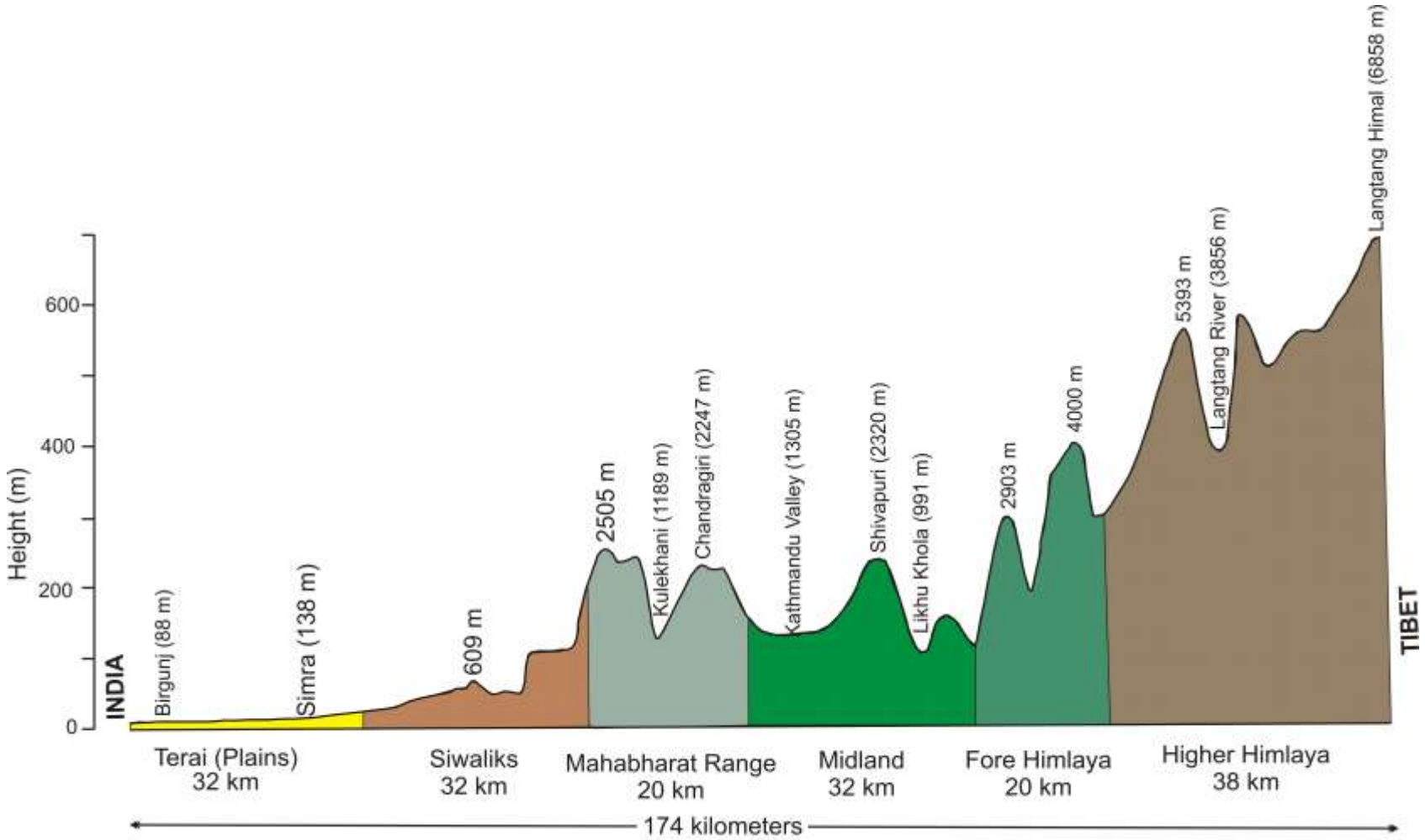
Geological Map of Nepal Himalaya



Cross section from South to North of Nepal Himalayas



Geomorphic X-section of Nepal Himalaya




Higher Himalaya
Lesser Himalaya
Siwalik

Rock types found in Nepal

- Principal rocks in the Sub Himalaya (Siwalik)
  - Sedimentary - Mudstone, shale, sandstone, siltstone, conglomerate
- Principal rocks in the Lesser Himalaya
  - Sedimentary to metamorphic - limestone, dolomite, slate, phyllite, quartzite, marble, granite
- Principle rocks in the Higher Himalaya
  - Metamorphic - Schist, Gneiss
- Principal rocks in the Tethys Himalaya
  - Sedimentary - limestone, sandstone and shale,

CAUSES AND MECHANISMS OF SLOPE FAILURE

Objective

To understand

- Causes and condition leading to slope failure
- Failure mechanism

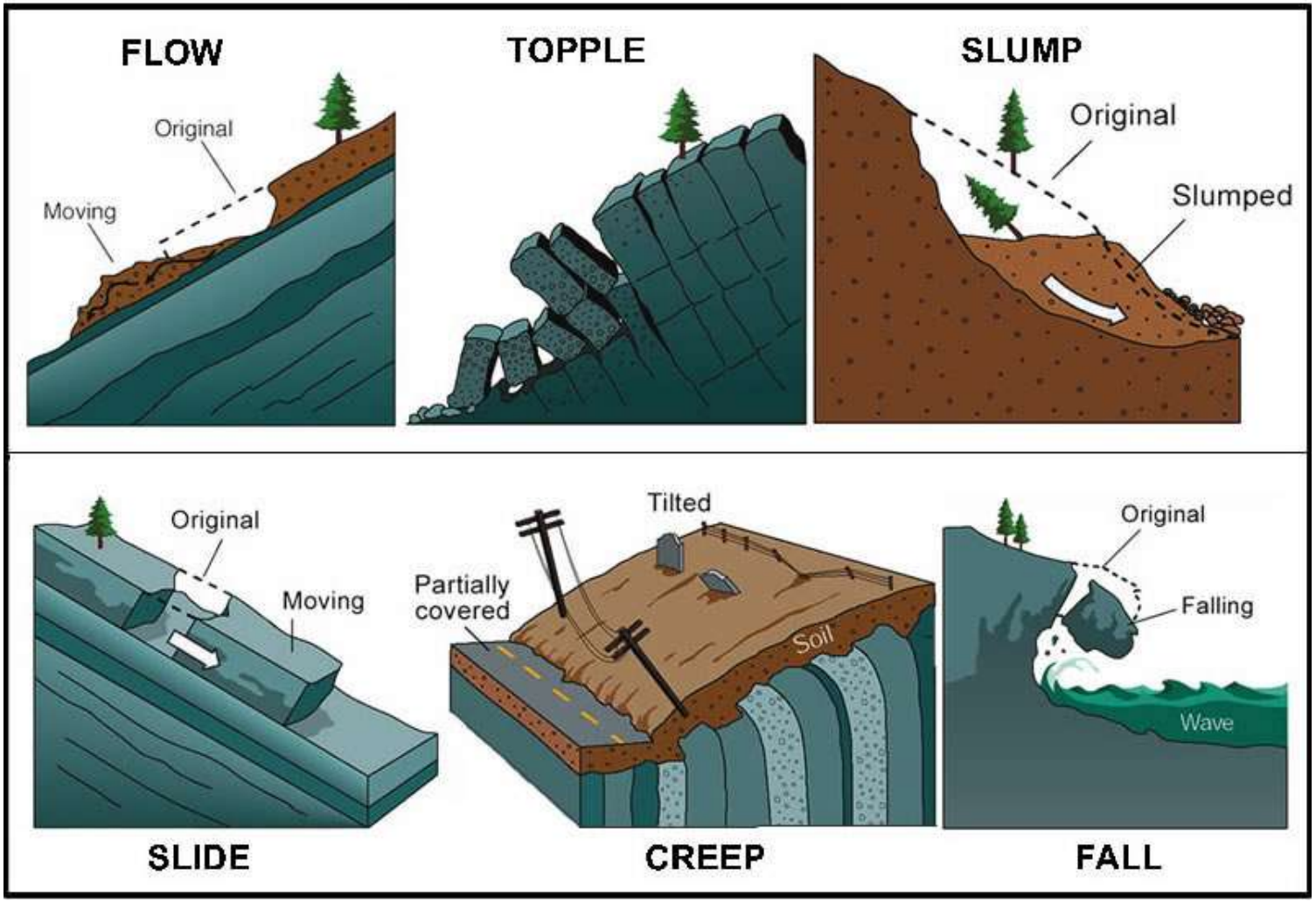
Landslide

- Downward and outward movement of slope - forming material along surfaces of separate either slowly or quickly from one place to another moved by the forces of gravity

Classification of Mass movement

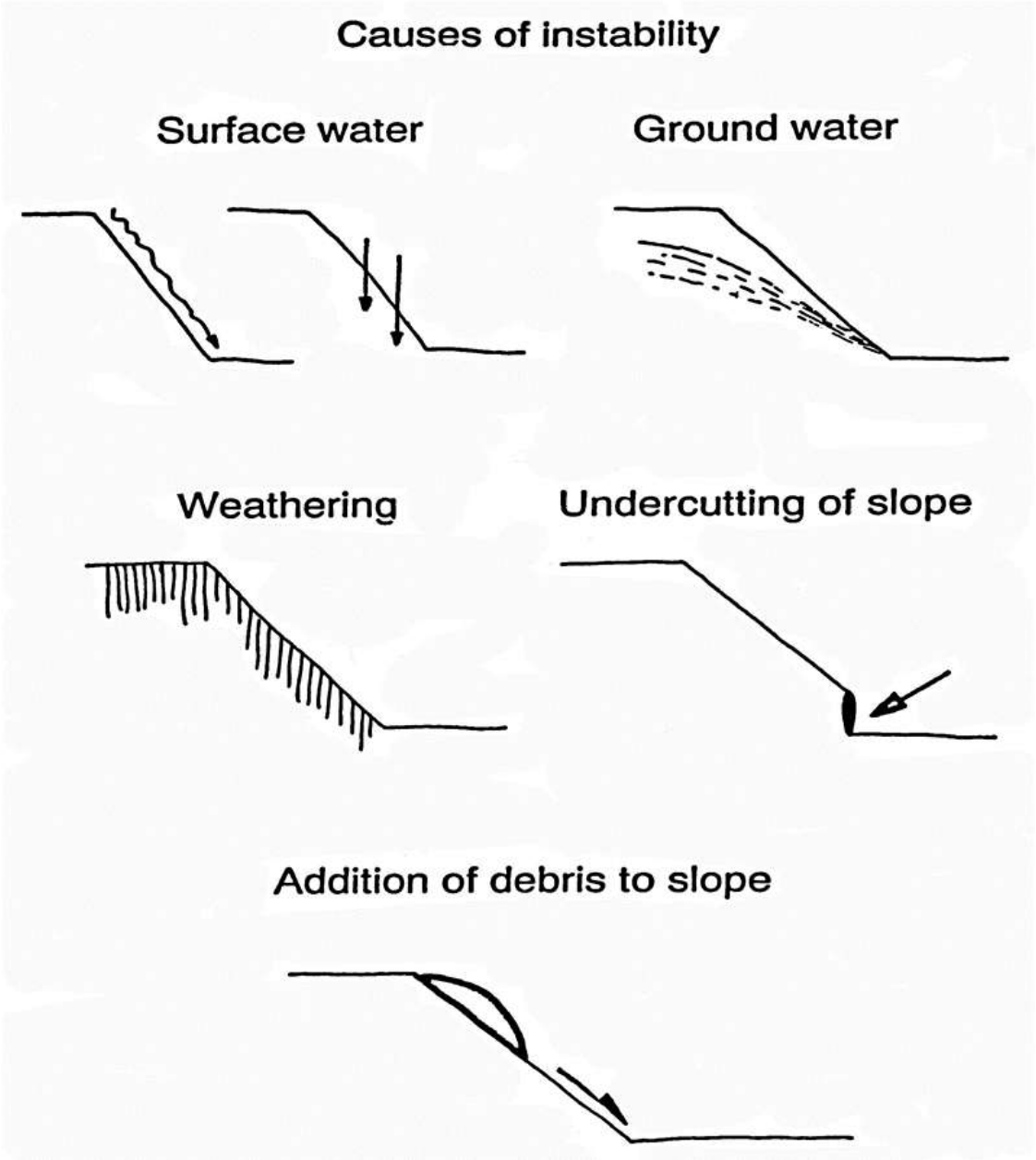
Types of Movement	Bed Rock	Types of Material / Engineering Soil	
Falls	Rock fall	Predominantly coarse debris fall	Predominantly fine earth fall
Topples	Rock topples	Debris topples	Earth topples
Slides a) Rotation (Few units)	Rock slump	Debris slump	Earth slump
b) Translation (many units)	Rock block slide; rock slide;	Debris block slump; debris slide;	Earth block slide Earth slide
Lateral Spread	Rock spread	Debris spread	Earth spread
Flows	Rock flow (Deep creep)	Debris flow	Earth flow
Complex	Combination of two or more principal types of movement		

Types of Landslide



Causes of Instability

a. Geological
b. Intense Rainfall
c. Surface water
d. Ground water
e. Added weight
f. Anthropogenic


Causes of instability
Surface water
Ground water
Weathering
Undercutting of slope
Addition of debris to slope

a)Geological

i) Weathering

- Rock shear strength is reduced by weathering as constituent minerals are broken into weathered particles and clay minerals
- Physical bond between rock constituents are weakened or broken
- Interlaying of the thin beds of the rocks
- Differential weathering also

ii) Earthquake

- Increase in pore water pressure and shear stresses in the slope causing imbalance between increasing shear forces and decreasing frictional forces.
- Rock falls, soil slides, rockslides and spreads are common during an earthquake.

b) Intense rainfall

- Small scare debris landslide when cum. precipitation is about 50-100/day and daily precipitation >50mm.
- High frequency landslide when cumulative precipitation over 2 days is about 150mm and daily precipitation about 100mm.
- Large and high frequency landslides when cumulative precipitation exceeds 250mm over 2 days and has an average intensity of >8mm per hour.

i) Under cutting

- Slope is undercut by a flowing stream or by opening up of rock cutting
- Incision (down cutting) or lateral scour most common

c) Surface water

- Shallow sliding due to erosion or soaking of surface
- Water infiltrating from surface produces hydrostatic stress in the rocks and decreases shear resistance.

Treatments (According to material type)

- Grass plantation with/without combination with jute netting and mulch for soil
- Revetment for steep toe slopes in soil and soft rock
- Surface rendering for rock slopes without noticeable ground pressure

d) Ground Water

- Causes increased pore water pressure at depth
- Failure plane is deeper than in surface failure

e) Addition of weight

- Weight added usually by dumping of spoil or landslide debris

Treatment

- Remove extra material and re-vegetate slope

f) Anthropogenic Factors

i. Deforestation

ii. Improper land use

- ❖ Agricultural practice on steep slopes
- ❖ Irrigation on steep and vulnerable slopes
- ❖ Overgrazing
- ❖ Quarrying for construction material
- ❖ Construction activities
- ❖ Others (blasting, spoil disposal, change in natural drainage system)

Failure Mechanism

1) Erosion

- Removal of particles from the surface by flowing water
- Initial removal of particles up to 25mm

2) Sheet erosion

- Water flows over surface in an even film, not in channels

3) Rill erosion and gully erosion

- Scour by water flow in channels
- Gullies begin as shallow, narrow incision in slopes (rills)
- Erosion up to 2m depth is considered gully erosion

4) Piping

- Removal of fines along an underground channel
- Percolating ground water in permeable fine soil of low plasticity can remove fines along fissures to a point where underground stream is formed
- The roof of this stream cavern can enlarge upwards towards the surface and eventually collapse to create an open, elongated chasm or pit
- Stabilized by exposing underground waterways and treated as gullies

5) Disintegration:

- Tensile failure occurs in very soft rock or consolidated soil.
- Saturation and weathering cause rocks to fail by planar or arc-like shearing throughout the mass.
- Sometimes partly controlled by weakly developed joint planes
- Distinct (plane) failure characterised by fall of hard rock.
- Upon landing, the material breaks into loose debris, consisting mostly of loose rock mineral particles like sand containing few boulders of weathering grade 4/5. All traces of rock structure or stratification are destroyed in the fall.
- Typical in thick beds of soft Siwalik sandstone and terrace deposits.

Contd..

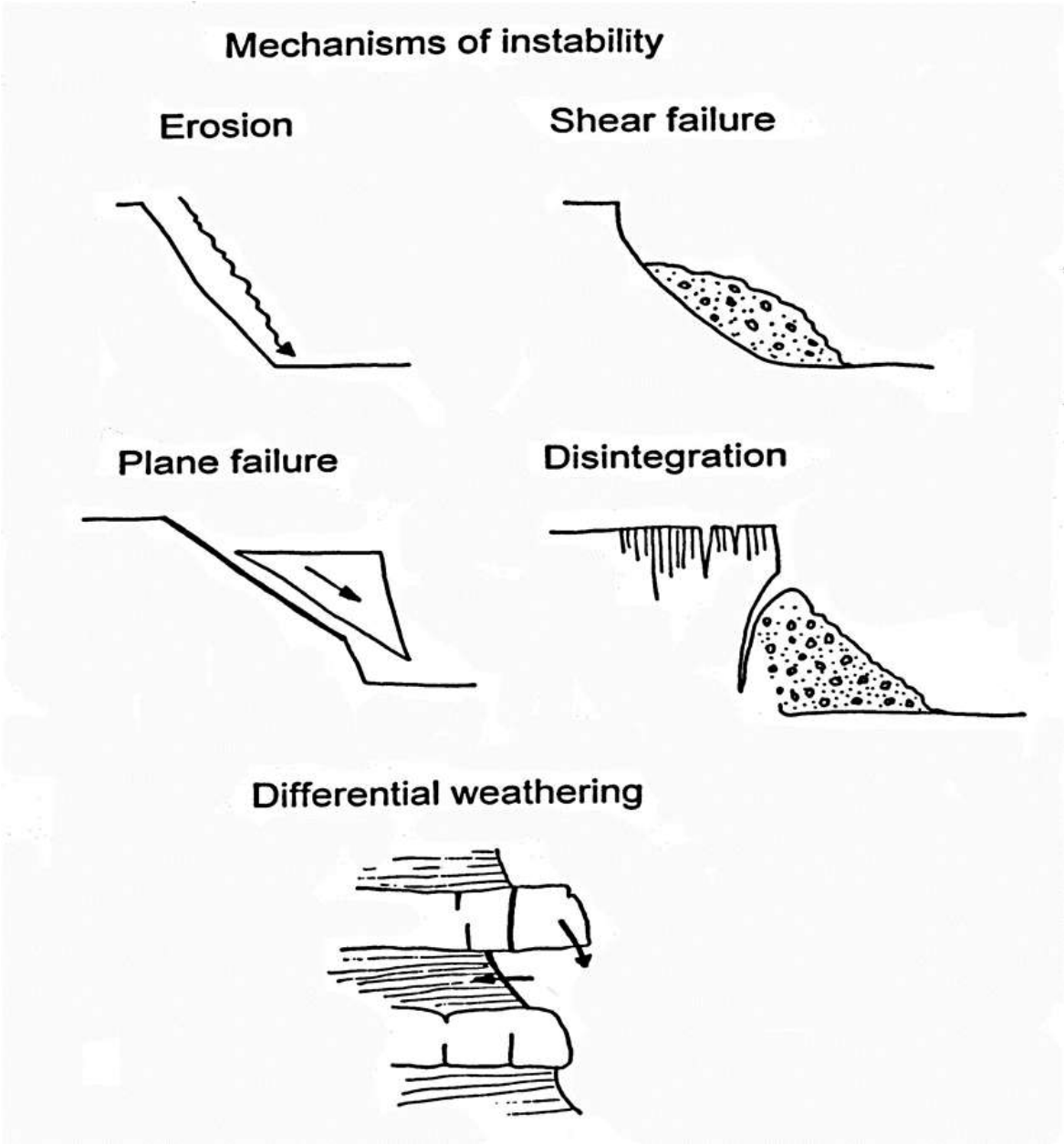
- Very difficult to stabilise- cut back to a stable angle determined by shear strength of saturated, weathered material.

6) Plane failure

- Any mass movement whose failure plane or planes is controlled principally by fracture planes in rock, and whose debris consists chiefly of rock fragments.
- Weathering grade of the rock is 1 - 4 (the rock rings when struck with a hammer). Failure types commonly include plane failure, wedge failure, and toppling (rock fall).

7) Fall

- Weathering of rock layers whose susceptibility to weathering is strongly contrasting.
- This failure occurs typically in alternating thin beds of hard and soft rock e.g. sandstone and mudstone or siltstone.
- Characteristic of the Siwalik rocks of Nepal.
- Caused by combination of **weathering** of the soft rock layers and **plane failure** of the hard rock layers. The soft rocks weather back from the face to leave the hard rocks sticking out. Eventually the hard rocks overhang so far that they break off along vertical fractures. The process then starts again and the whole face retreats.
- This mechanism is very common in Nepal


Mechanisms of instability
Erosion
Shear failure
Plane failure
Disintegration
Differential weathering

Data Collection method for instability area

ROAD INSTABILITY SURVEY

Chainage with landslide: Date:

1 LOCATION Of INSTABILITY AREA (Natural Hill slope (DD/DA):)

Along the road Above road - any distance Below road - any distance

Type of instability: Rock/Soil Slide/Erosion/fall/debris flow Deep seated / shallow slide:

2 MATERIAL FORMING ORIGINAL (FAILED) SLOPE:

Colluvium Alluvium Residual Soil Glacier till Fill material Rock

Thickness of the soil on the bed rock: **Color:**

3 ROCK WEATHERING GRADE: Completely Highly Moderately Slightly Fresh

Discontinuities (DD/DA)	**Continuity**	**Spacing**	**Waviness**	**Opening**	**Filling materials**
Bedding/Foliation:					
Joint 1					
Joint 11					
Joint 111					

4 HYDROLOGICAL CONDITIONS AND LANDUSE PATTERN:

Spring /Seepage flow/Active seepage flow Monsoon saturation/well drained. Dry/ wet

Forest Barren Wet cultivated Dry cultivated Sparsely dense forest Grassland

5 DIMENSION OF THE FAILURE (m):

Length Breadth Depth

7 GENERAL TYPE OF FAILURE: Rock/soil; Fall/topple; Rotational/translational

8 FAILURE MECHANISM: Erosion (sheet, rill, pipe) Shear failure (slide, slump, flow)
Plane failure Wedge failures in rock
9 CAUSE OF FAILURE:
Surface water. Erosion, or soaking of surface: shallow slide/flow
Ground water, causing increased pore water pressure at depth Weathering
Undercutting of slope by stream, Active/passive Addition of spoil or landslide debris Other:
10 HISTORY OF SLIDE:
Moved this year for the first time, if possible mention year: Moves every year by initial mechanism - diminishing
Moves every year by initial mechanism - constant or getting worse Reactivated
Brief history if possible:
11 LIFE PROGRESSION OF SLIDE:
Stable slope formed, or will stabilise naturally Further movement expected, by less serious mechanism
Repeated movement expected, by initial mechanism or another equally serious

12.PRESENT ENGINEERING STRUZCTURES APPLIED:										
13. MITIGATION MEASURES										
Short term:										
Long term:										
14. HAZARD										
Low		Medium		High						
15. GULLY EROSION					**RILL MARK EROSION**					
L=	B=	H=			L=	B=	H=			
16. VOLUME OF MATERIALS DEPOSITED ON ROAD										
L=	B=	H=								
17. FEATURES OF SLIDE AREA										
a. presence of drunken trees			b.Presence of tension cracks			c. Clear scarp		d. Vegetation cover		

THANK YOU