ELEMENTS OF PHOTO-INTERPRETATION

OR

PHOTO-INTERPRETATION KEYS

Elements of Aerial Photo-Interpretation

Photo-Geology

Technique of aerial photo-interpretation for deciphering geology of an area

- Recording of the observed data: Collecting qualitative and quantitative information
- Understanding the significance of the data: Interpreting geology of the area

Elements of Aerial Photo-Interpretation

During the process of interpretation, the aerial photo interpreters usually make use of following tasks

Detection: Selectively picking out objects

Recognition and identification: Naming objects or areas

Analysis and deduction: Detect the spatial order of the objects and predict the occurrence of certain relationships

Classification: To arrange the objects and elements identified into an orderly system

Accuracy determination: Field to confirm the interpretation

Elements of Aerial Photo-Interpretation

Kinds and amounts of information that could be obtained from aerial photographs depend primarily on

1) Type of terrain
2) Climatic environment
3) Stage of the geomorphic cycle.

Elements of Aerial Photo-Interpretation

Use of aerial photographs in geology

- Outline the structure and stratigraphic succession in an area
- Preparation of a geologic map
- Measurements of stratigraphic sections
- Inferences about rock types present in the area.

Elements of Aerial Photo-Interpretation

Factors affecting the photographic appearance of rocks

- Climate, Vegetation or Soil cover
- Absolute and relative rate of erosion
- Colour and reflectivity
- Composition and physical characteristics
- Depth of weathering

Elements of Aerial Photo-Interpretation

Photo-Interpretation Keys

- Photographic Tone
- Photographic Texture
- Shape of the objects
- Size of the objects
- Pattern
- Scale of photographs
- Vertical Exaggeration

Elements of Aerial Photo-Interpretation

Photographic Tone

- Measure of relative amount of light reflected by an objects and recorded on the photograph
- It refers to the relative brightness or colour of objects on an image.

Elements of Aerial Photo-Interpretation

Photographic tone influenced by

- Reflectivity of an object
- Angle of the reflected light
- Geographic latitude
- Type of photography and film sensitivity
- Light transmission of filters
- Photographic processing

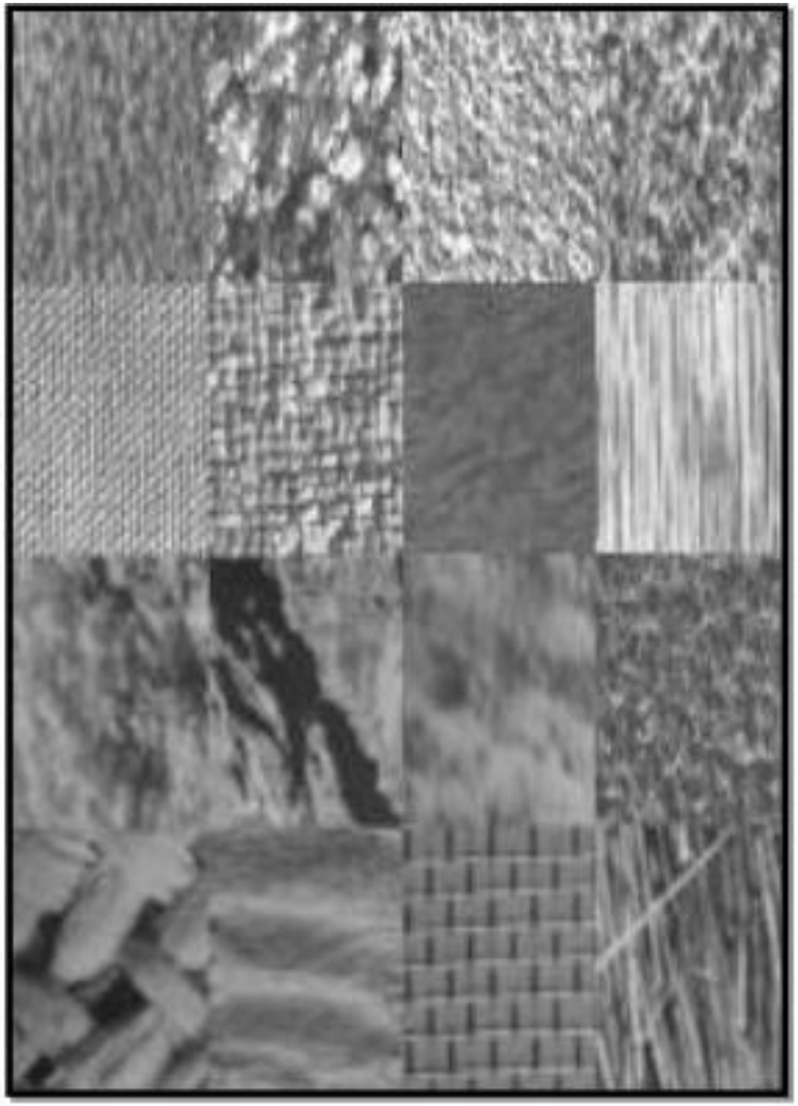
Elements of Aerial Photo-Interpretation

Photographic Texture

- Signifies the frequency of change and arrangement of tones in a photographic image
- Texture is produced by an aggregation of unit features
- It determines the overall visual “smoothness” or “coarseness”

Elements of Aerial Photo-Interpretation

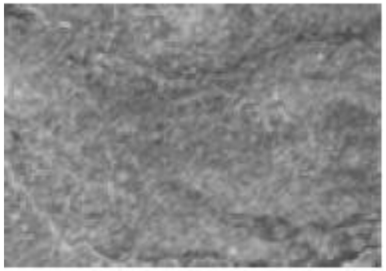
- Texture distinguish two objects with same tone.
- Texture is dependent on the scale of aerial photograph. As the scale is reduced the texture progressively becomes finer and ultimately disappears



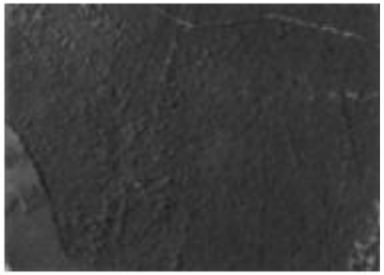
Elements of Aerial Photo-Interpretation

Coarse texture: Clustered objects with rounded crowns

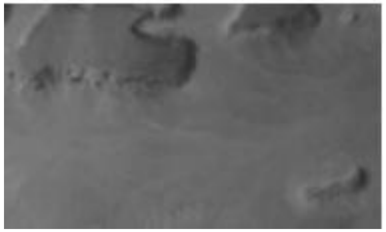
Medium texture: Scattered objects



Fine Texture: Thick object density with small crown

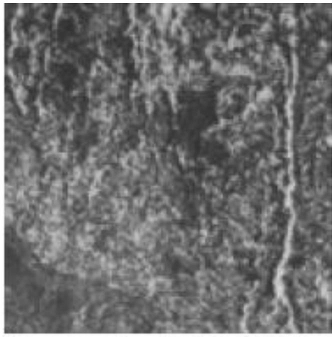


Smooth Texture: Regular dispersion of uniform objects

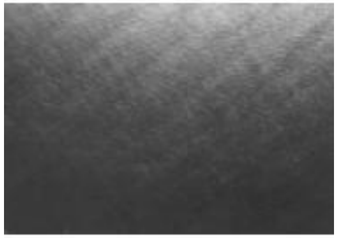


Elements of Aerial Photo-Interpretation

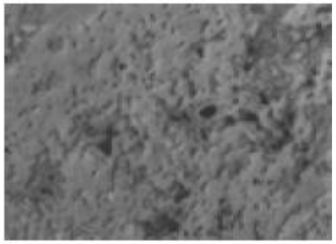
Rough Texture: Irregularly dissipated object



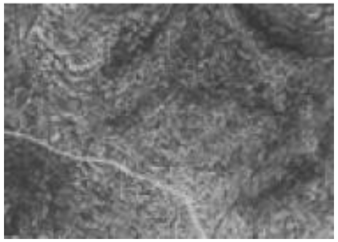
Rippled Texture: Develop due to water wave over shallow water surface



Mottled Texture: Pitted outwash plain



Granular Texture: Poor and loosely scattered objects



Elements of Aerial Photo-Interpretation

Shape of object

- Qualitative statement referring to the general form, configuration or outline of an object
- Certain geomorphic features are identified directly based on their shape of not much eroded
- Eg. Folds, Linear intrusives, Massive intrusives

Elements of Aerial Photo-Interpretation

Size of object

- Size of an object is a function of photo scale, and considered in combination of size and shape of object.
- The sizes can be estimated by comparing them with objects whose sizes are known.
- Eg. Small storage shed vs Mine pit

Elements of Aerial Photo-Interpretation

Pattern

- Pattern is the spatial arrangement of objects and gives genetic relation.
- The orderly repetition of aggregate features in certain geometric or planimentric arrangements.
- Ex. Fold pattern, drainage pattern, outcrop and lithological pattern.

Elements of Aerial Photo-Interpretation

Miscellaneous keys

Association

- The occurrence of certain features in relation to others.
- Eg. River and drainage, buildings and roads, open cast mine and trenches

Elements of Aerial Photo-Interpretation

Site

- Statement of an object's position in relation to others in its vicinity and usually aids in its identification
- Eg. certain vegetations or tree species are expected to occur on well drained uplands or in certain countries).

Elements of Aerial Photo-Interpretation

Shadow

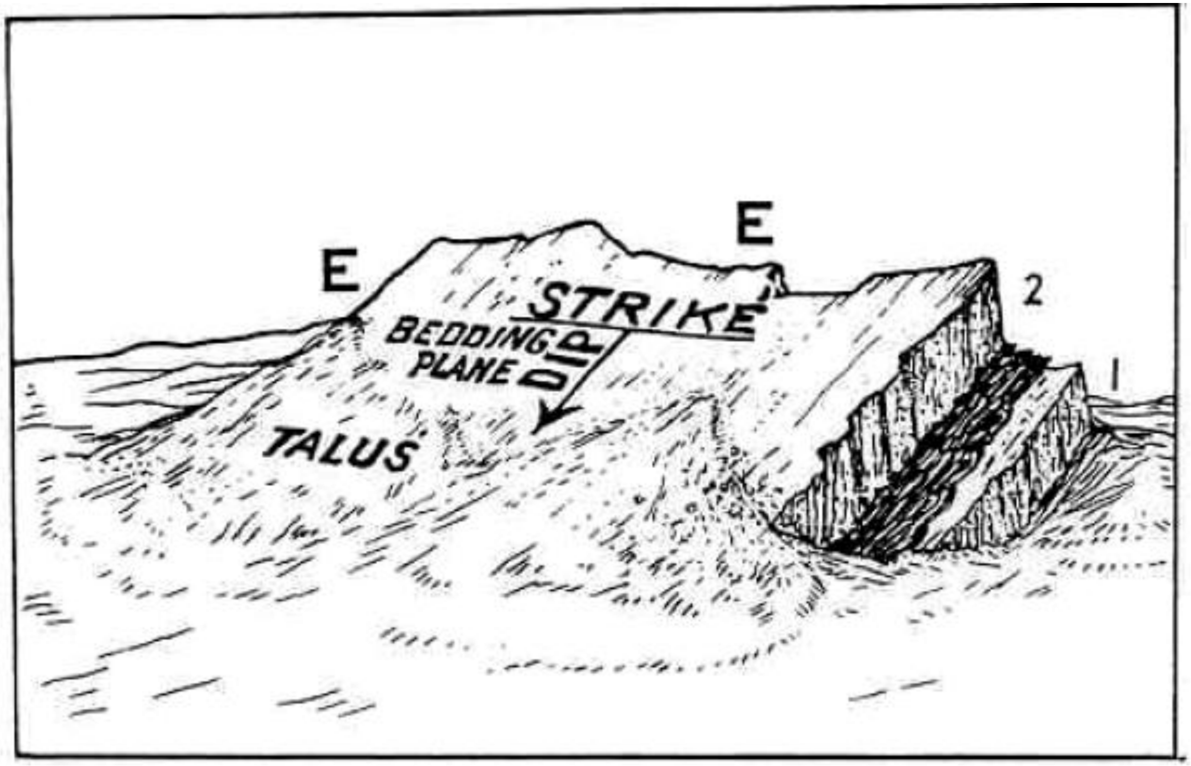
- Shadows of objects aid in their identification.
- The shape or outline of shadow affords an impression of the profile view of objects (which aids in interpretation)

AERIAL PHOTO-INTERPRETATION IN STRUCTURAL GEOLOGY

Structural Attributes

Bedding attitude

- Bed
- Bedding plane
- Dip
- Azimuth
- Strike
- Talus



Relation between strike-dip-bedding plane and talus

Beds on aerial photographs

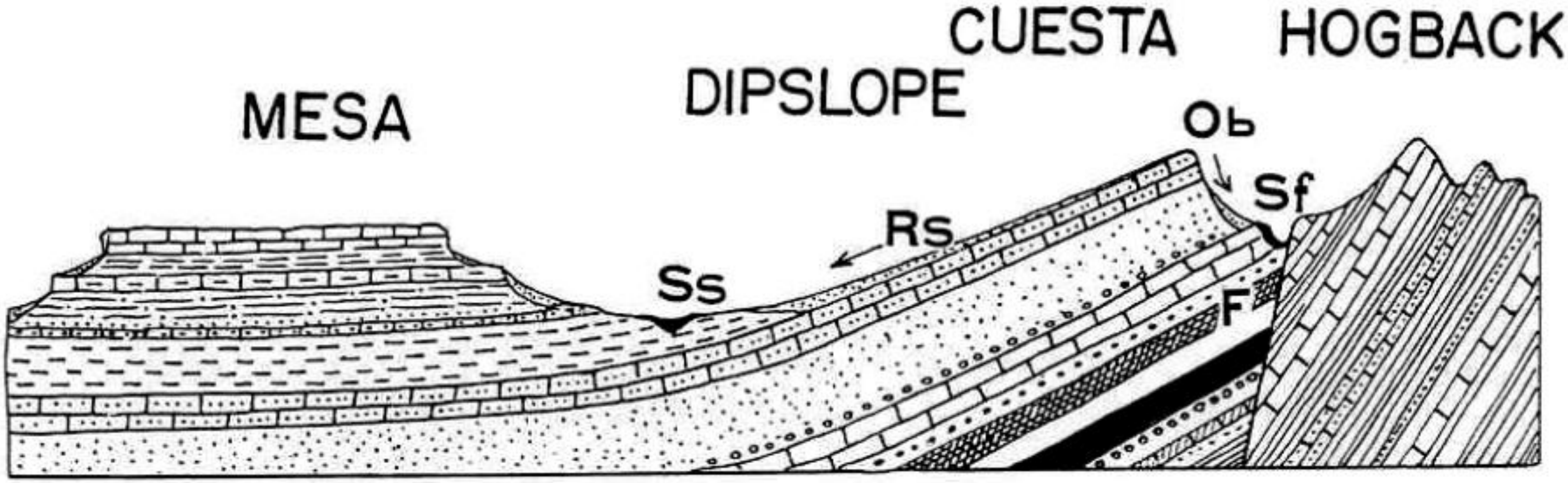
1. Beds appear as linear feature on aerial photographs
2. Occur in form of group of persistent linear ridges
3. Follow parallelism
4. Abrupt termination is indicative of fault

Structural Attributes: Bedding

In the aspect of photo-interpretation, the beds can be classified into three groups on the basis of dip amount:

1. Horizontal and gentle dipping beds
2. Medium dipping beds
3. Steep and vertical dipping beds.

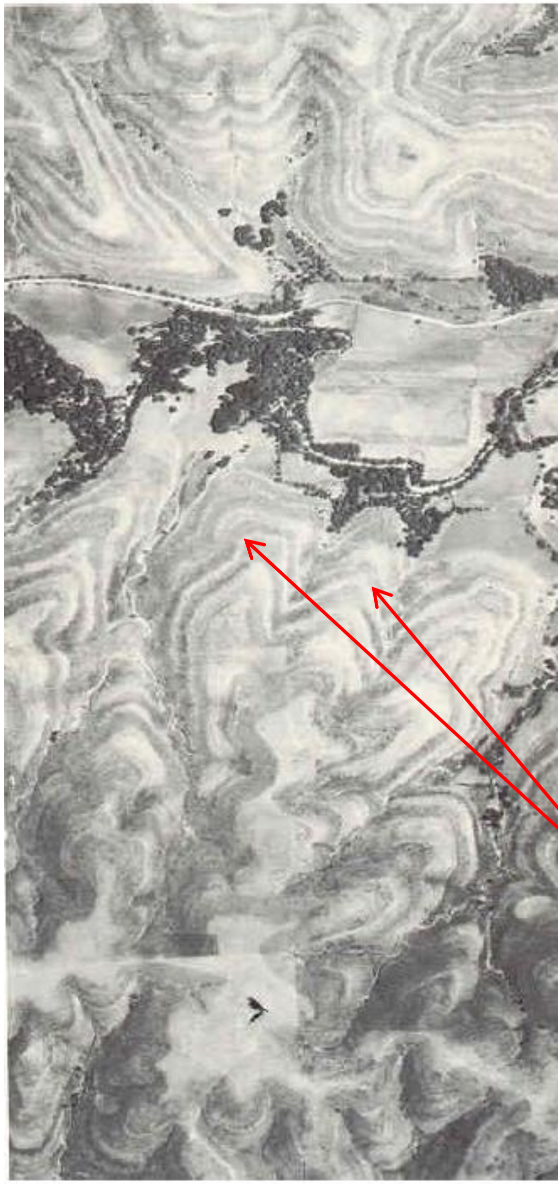
CANYON-MESA type topography



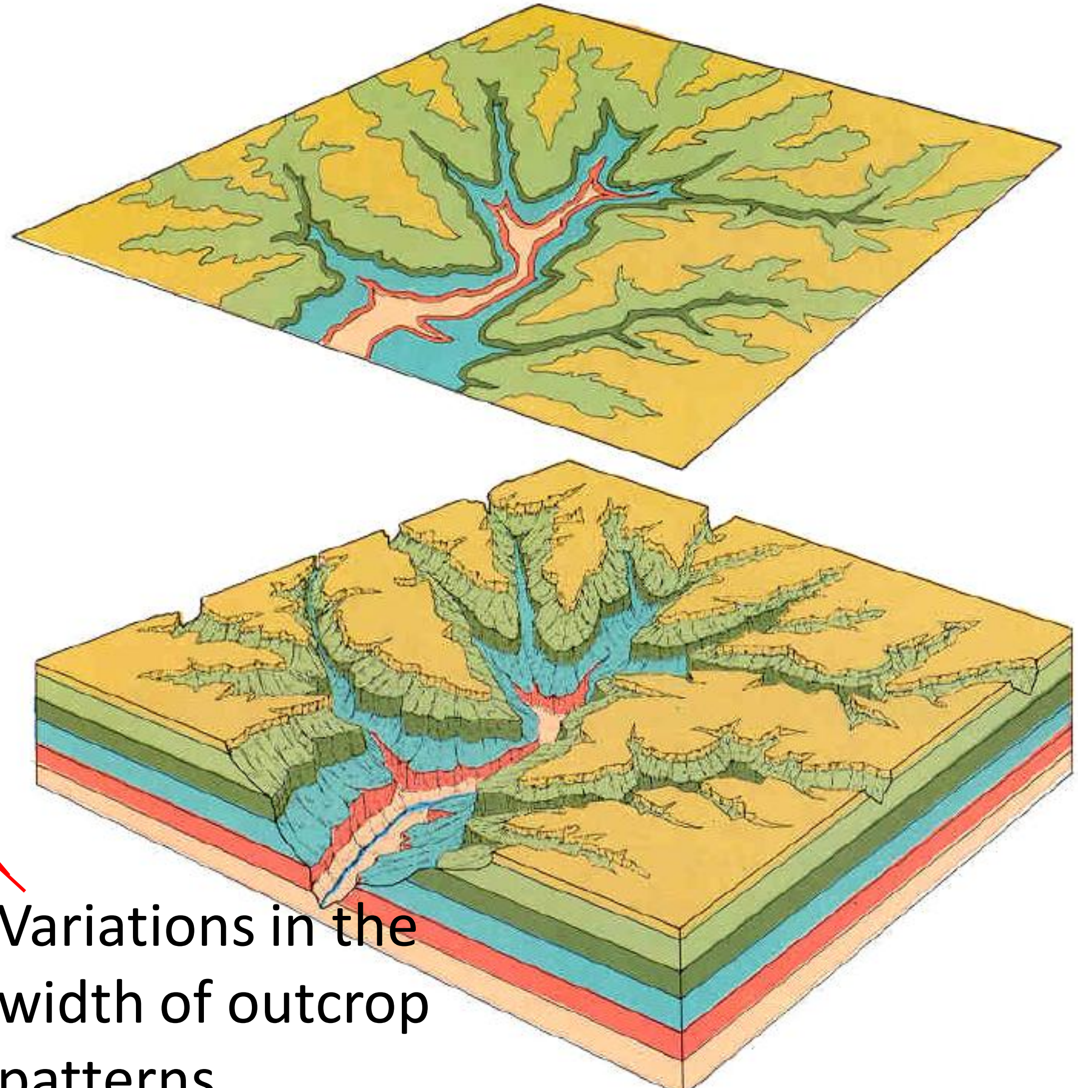
The appearance of a landscape with horizontal and low dipping beds is that of a CANYON-MESA type

Photographic characteristics of horizontal beds

1. The beds are distinguished by tonal contrast and different resistance to erosion
2. The bands are parallel to the topographic contours with loop-like shaped
3. The drainage pattern is generally dendritic
4. Bed can be observed unless beds are obliterated by talus



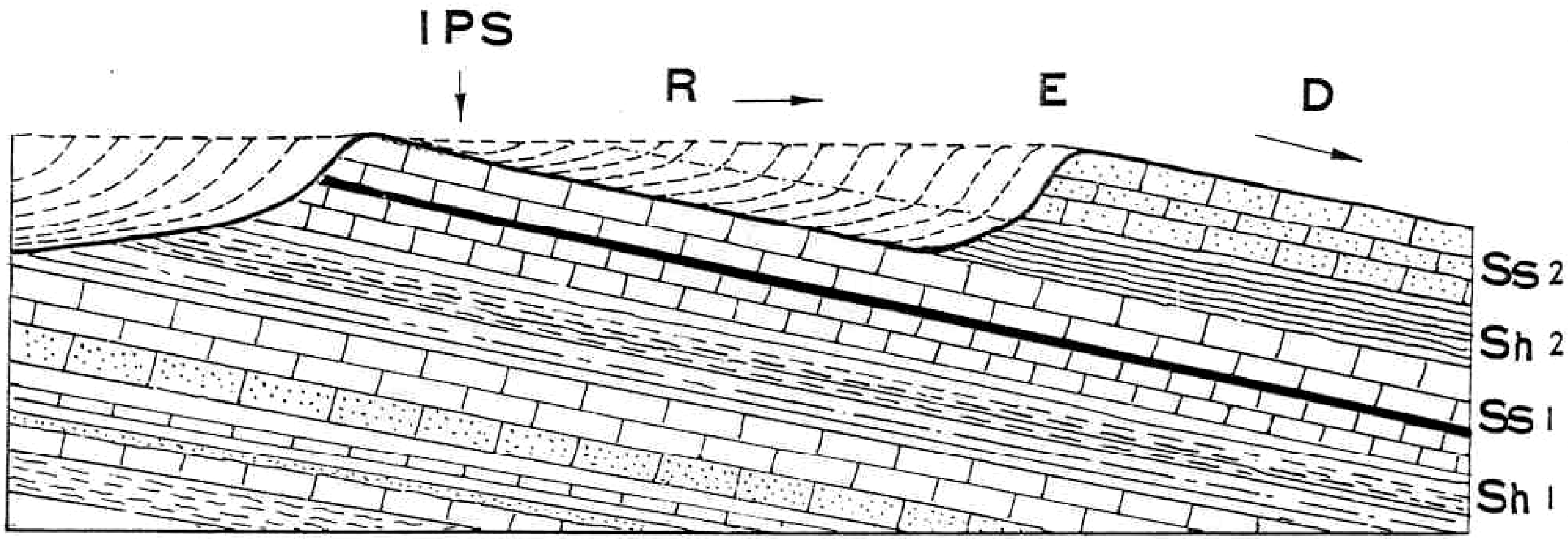
Variations in the width of outcrop patterns



Horizontal beds on aerial photograph

Dendritic drainage pattern on horizontal strata

DIP SLOPE or CUESTA type topography



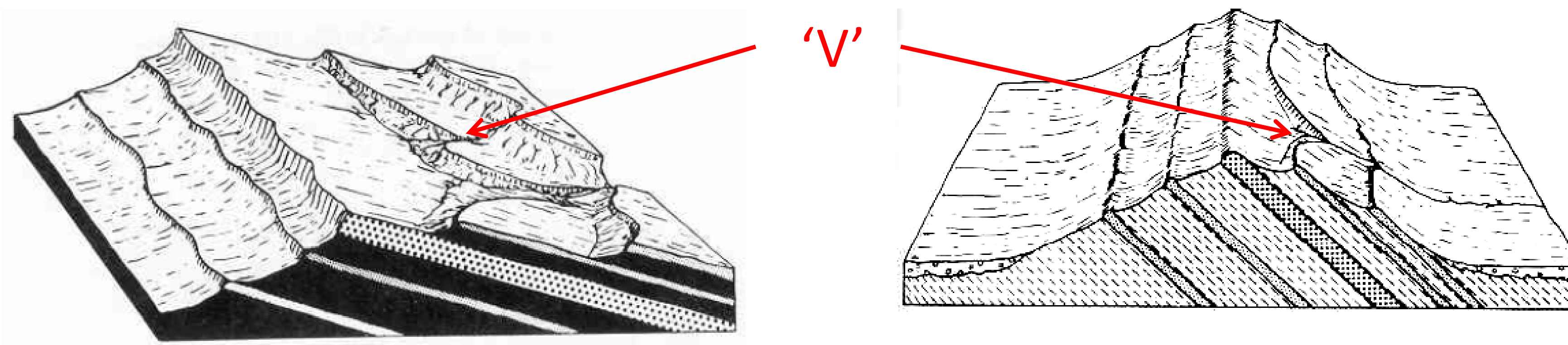
The dip-slope or Cuesta is an asymmetric ridge

The longer, gentle slope is called the face slope and the other is the steep slope

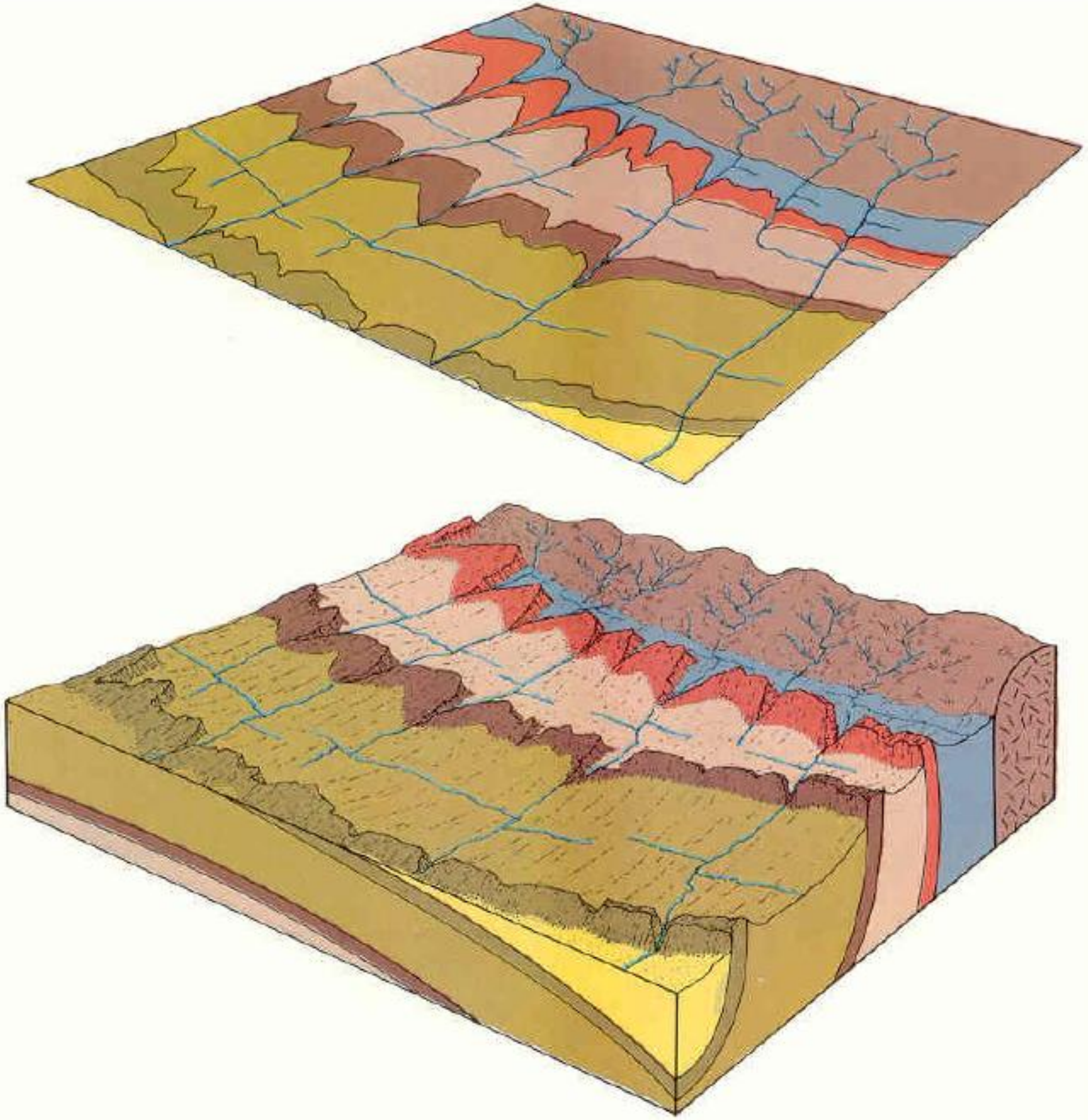
Photographic characteristics of medium dipping beds

1. Bedding is expressed by bands of differing photographic tone or by topographic breaks in slope due to the resistance of beds
2. Resistant beds appear thin as compare to less-resistant beds
3. Allow to determine dip amount, dip direction and the strike of the beds.

The rule of ‘V's may be applied to determine the direction of dip where a stream valley intersects the trace of a bed, a ‘V’ in the outcrop pattern will point the direction of dip



Reverse case: But if the direction of dip and direction of stream flow are the same



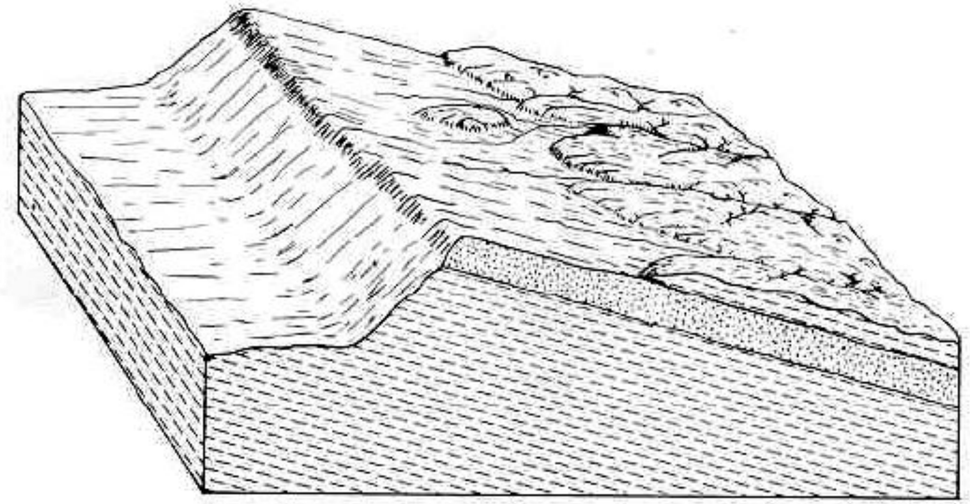
The size of the outcrop pattern is inversely proportion al to the magnitude of dip

Photographic characteristics of steeply dipping beds

1. The diagnostic landshape is **Hogback (**sharp, straight or slightly curved ridges with same high dipping opposing .
2. Often covered by talus on both sides of a hogback ridges.
3. The long axis is parallel to the strike of the bedding.
4. The true thickness of vertical or nearly vertical bed can be easily measured

Criteria to determination of the direction of dip

Able to determine only where topographic surfaces coincide with bedding surfaces



1. ‘V’ Rule

2. Drainage characteristics

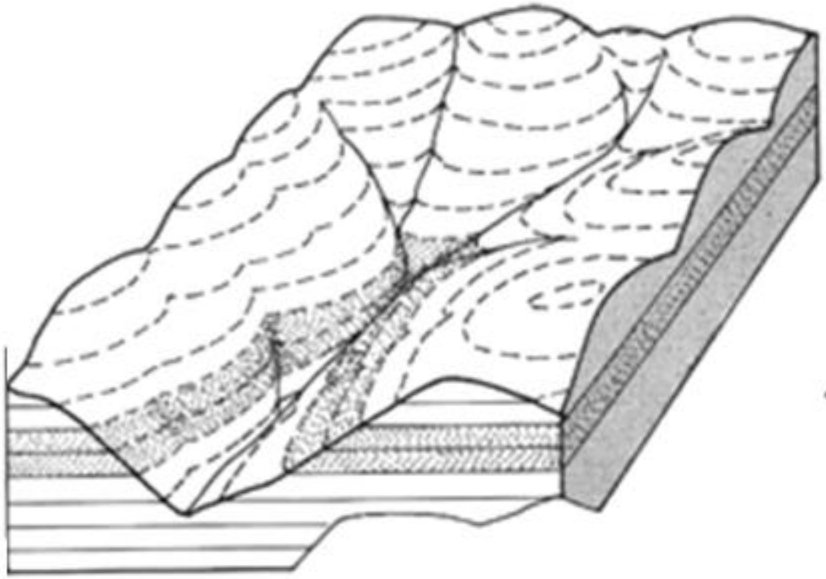
‘V’ Rule

The apex of V always points the dip direction.

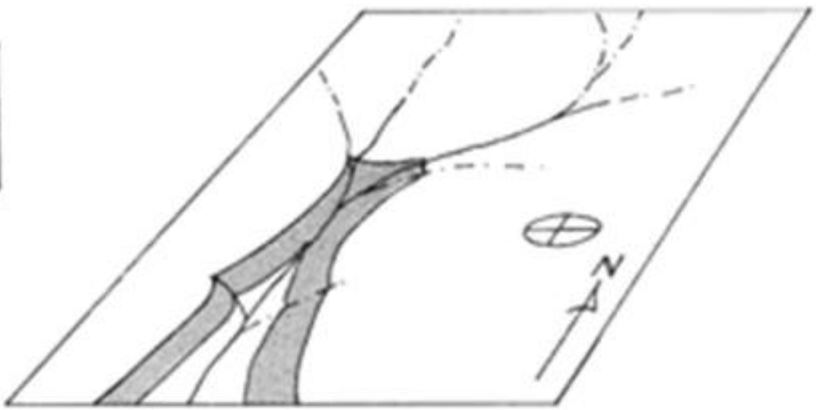
The long and narrow V shape shows less dip amount or gently dipping beds

Short and wide V shape refers medium and steep dipping beds

BLOCK DIAGRAM

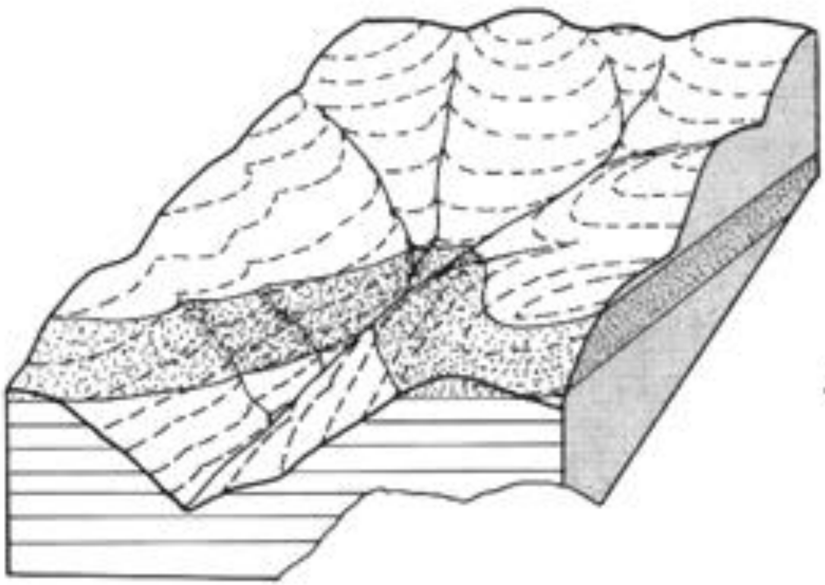


GEOLOGICAL MAP

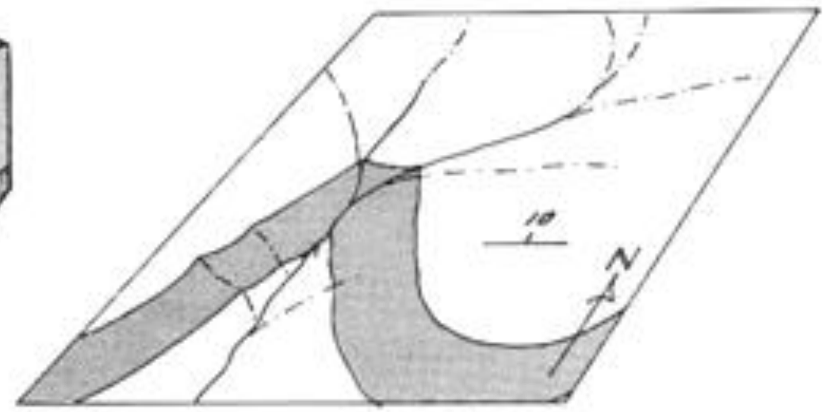


Outcrop pattern of horizontal bed: ‘V’ pointed deep inside valley toward upstream direction

BLOCK DIAGRAM

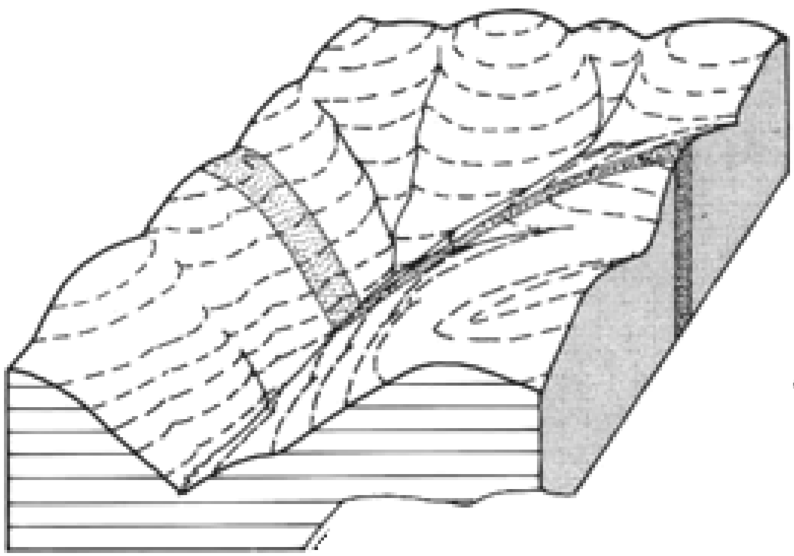


GEOLOGICAL MAP

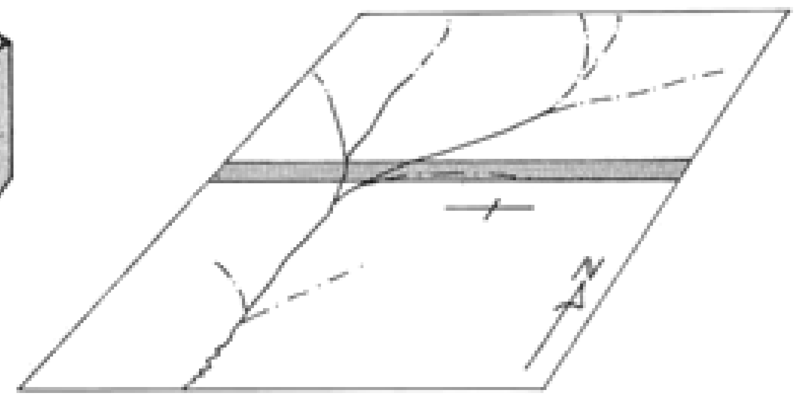


Outcrop pattern of bed dipping north at a low angle. 'V' pointed upstream

BLOCK DIAGRAM

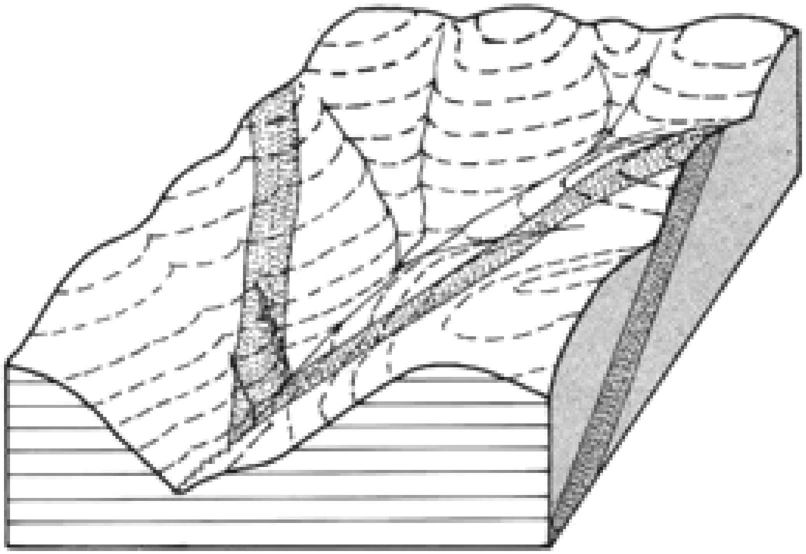


GEOLOGICAL MAP

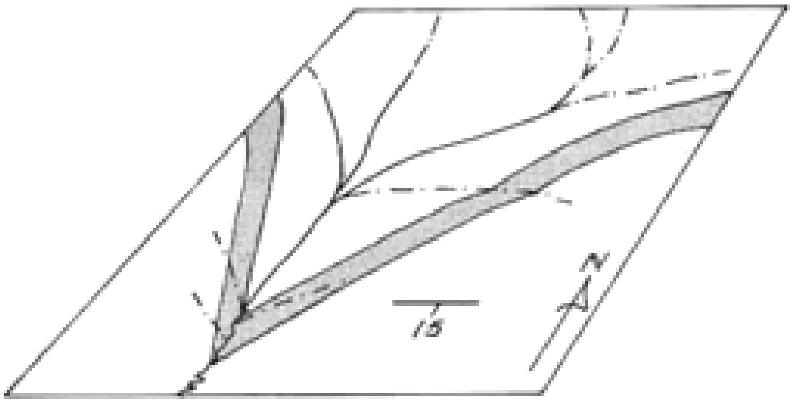


Outcrop pattern of vertical dipping bed

BLOCK DIAGRAM



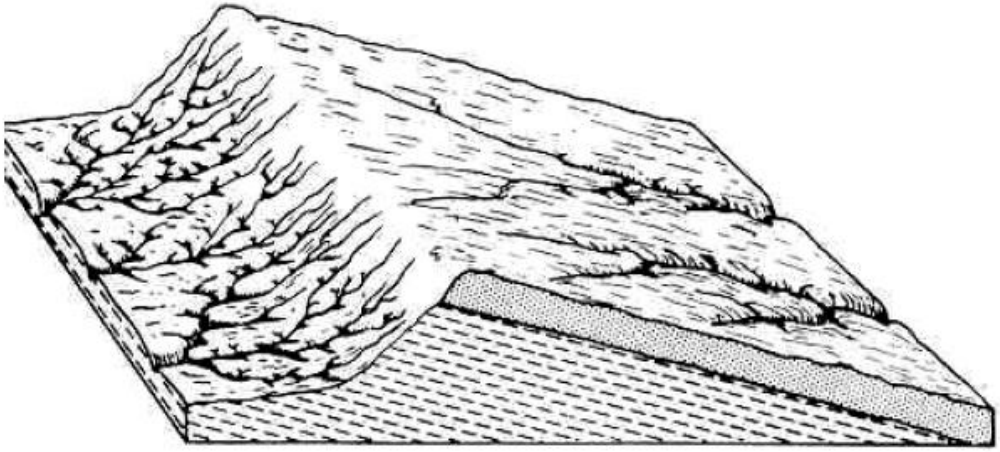
GEOLOGICAL MAP



Outcrop pattern of bed dipping south at a low angle. ‘V’ pointed downstream

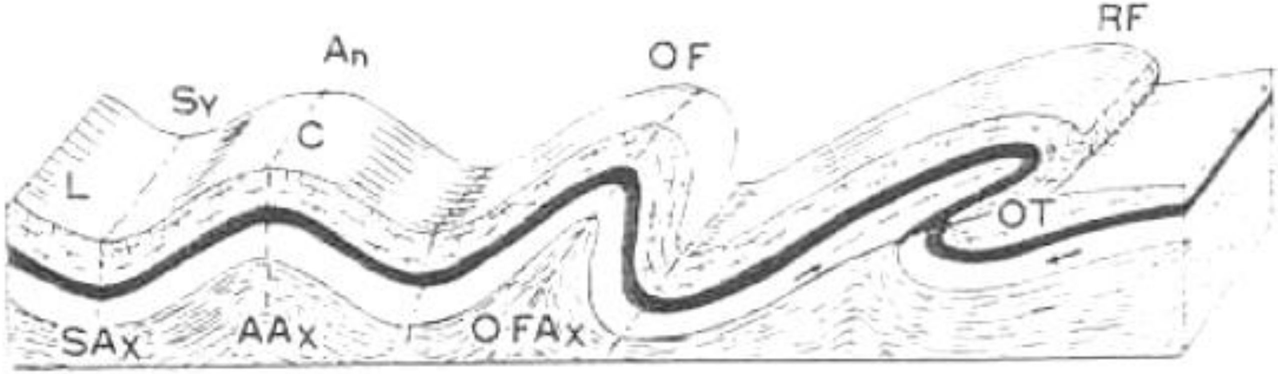
Drainage characteristics

- Dips could be gentle, if the relatively long tributary systems commonly flow down the face slopes



- Short tributary systems will characterized back slopes.
- High drainage density correspond to steep dip

Folded structures (Plunging)

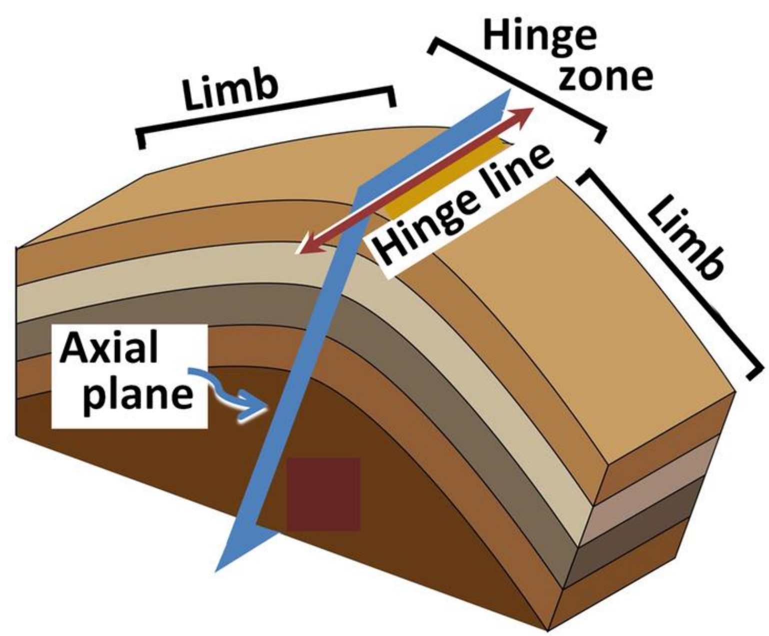


Hinge, Limb, Axis, Axial Plane

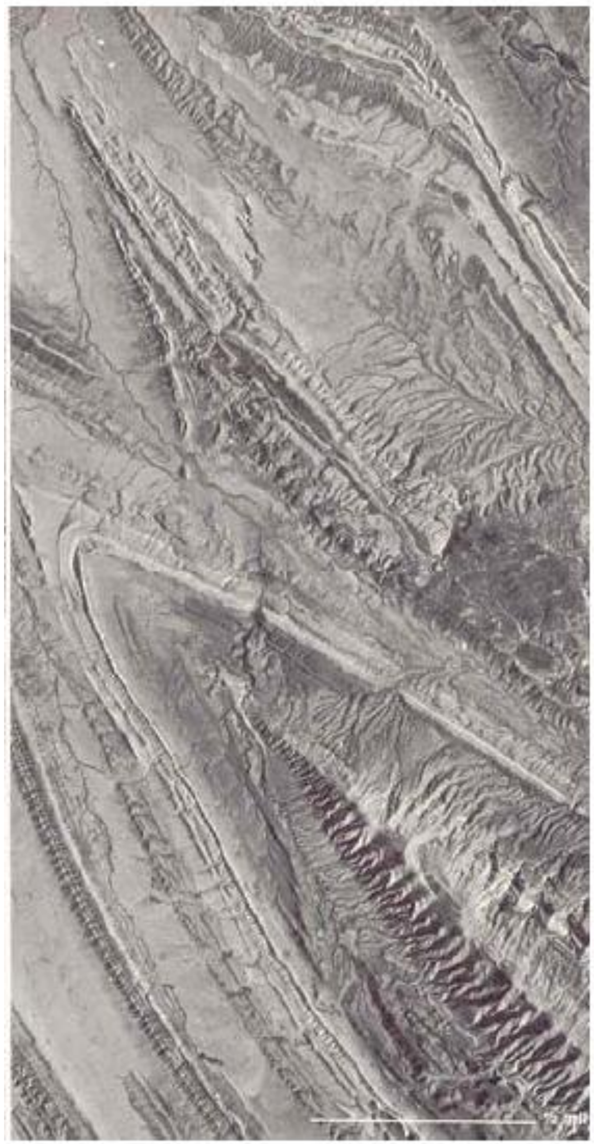
Type of fold

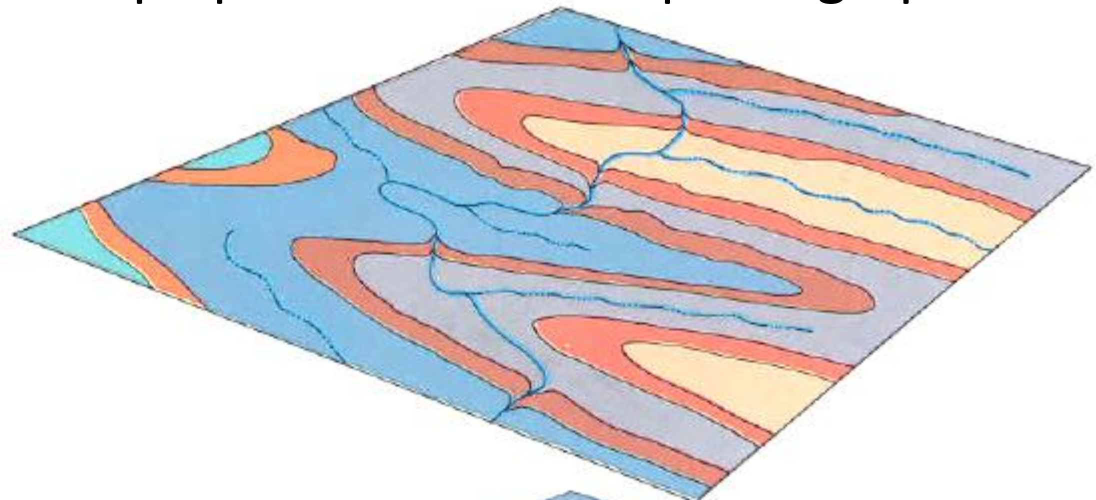
Anticline – Syncline

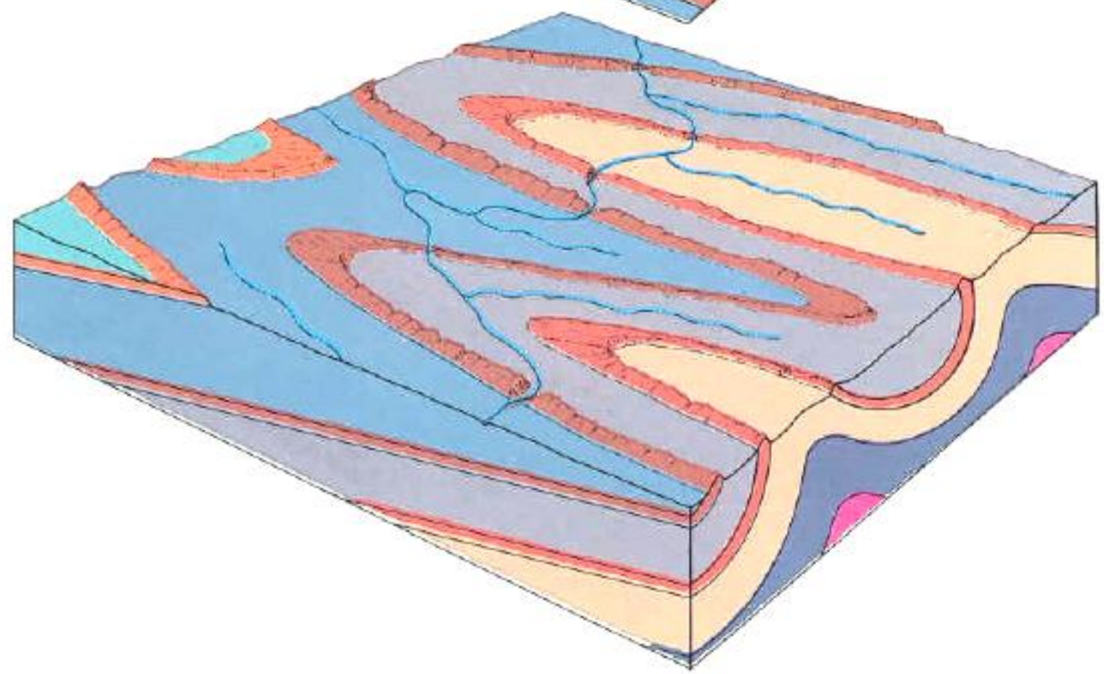
Plunge



Form zig-zag shape or ‘V’ shape pattern on aerial photograph





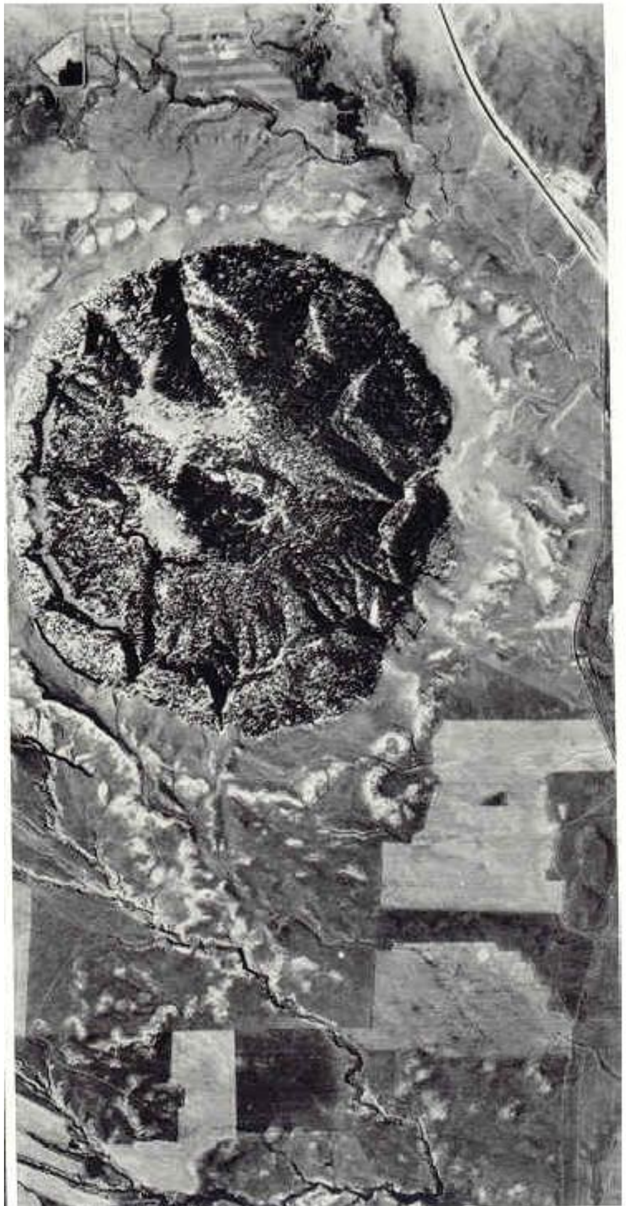


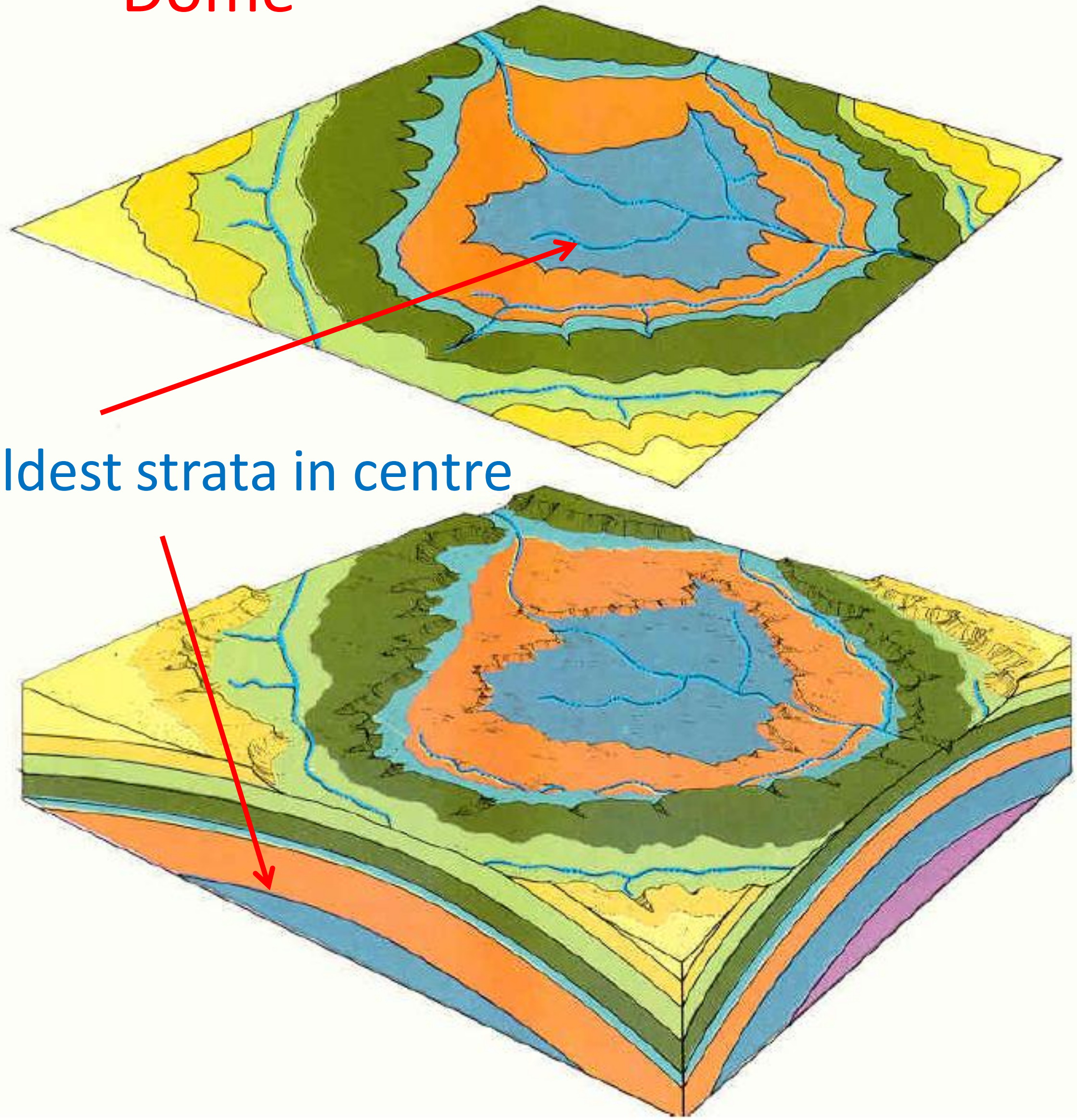
Recognizable only when fold is plunging

Criteria to demarcate plunging anticline or syncline

- A plunging anticline forms a V –shaped outcrop pattern with the apex (or nose) pointing in the direction of the plunge.
- Plunging synclines form a similar pattern, but the limbs of the fold open in the direction of plunge.

Dome



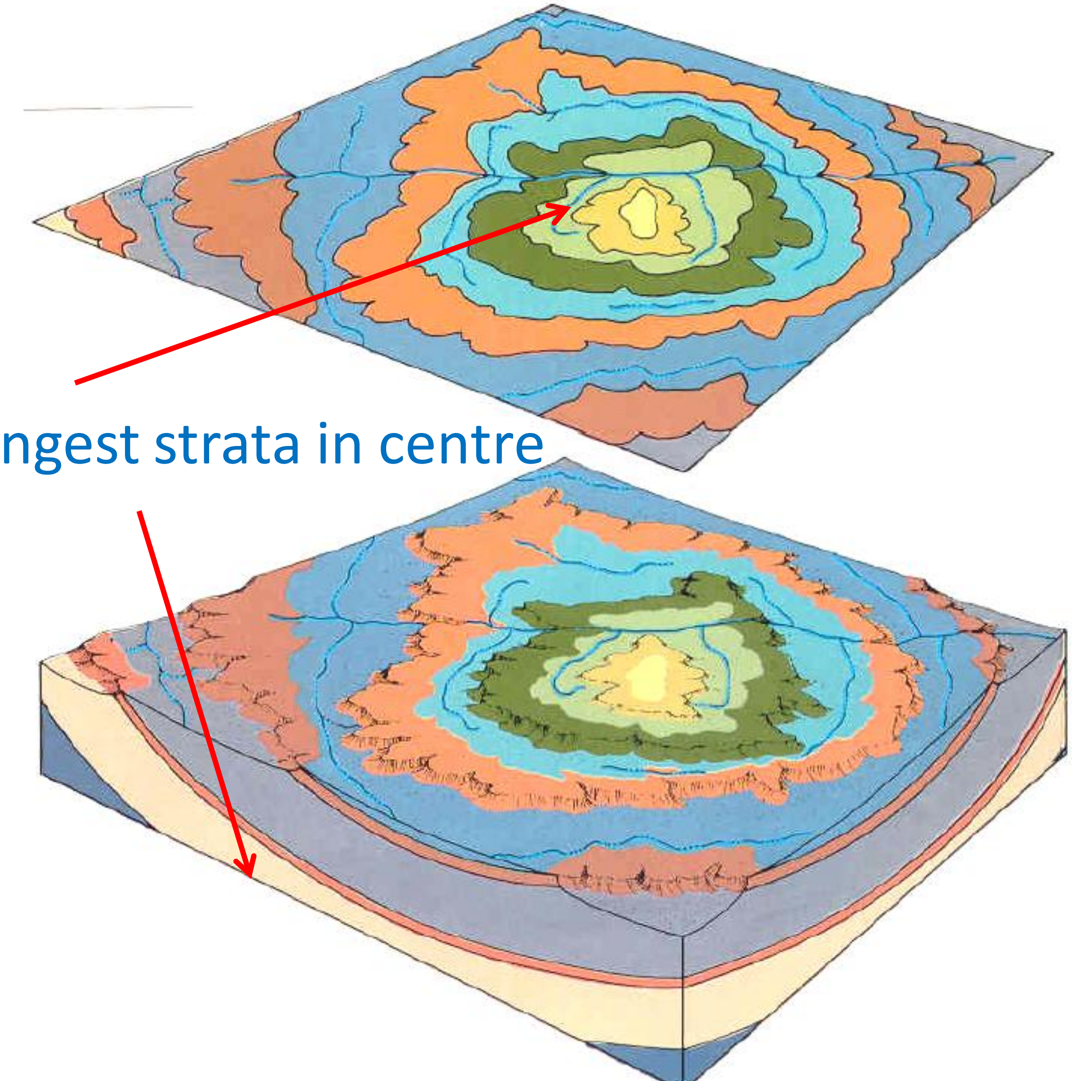


Oldest strata in centre

Dome-shaped structures

- Roughly circular to elliptical outcrop
- Beds dipping away from a central area
- Eroded dome is made up of the oldest bed at the centre with progressively younger rock units located outward
- Form a radial pattern
- If the structure has been dissected by stream erosion, the V in the outcrop points outward from the centre of a basin

Basin



Basin-shaped structures

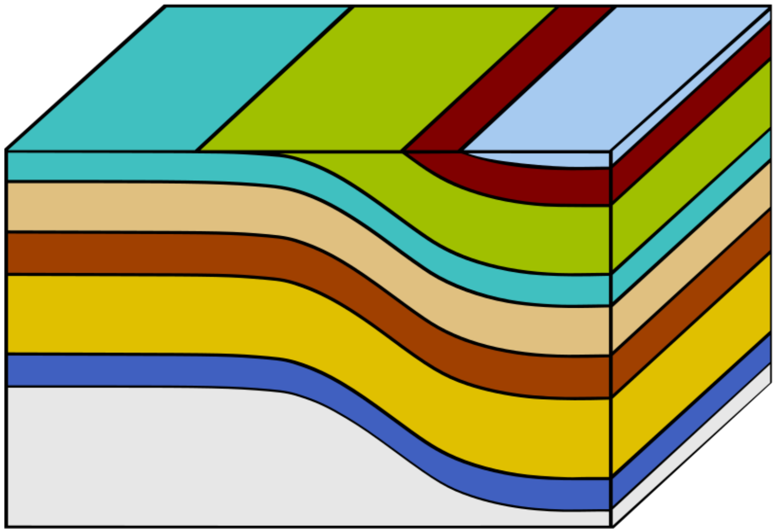
- Elliptical or circular outcrop pattern
- Beds dipping toward the central area
- Younger rocks at the centre of a basin
- If the structure has been dissected by stream erosion, the V in the outcrop points toward the centre of a basin

Structural Landforms (non-plunging)

Tectonic terrace

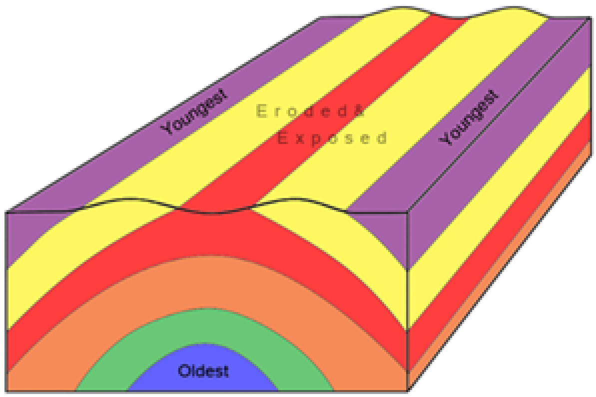
Monocline: Local steepening of an otherwise horizontal sequence of strata (could be sub-cylindrical fold with only one inclined limb)

Homocline: Structures that have the same attitude

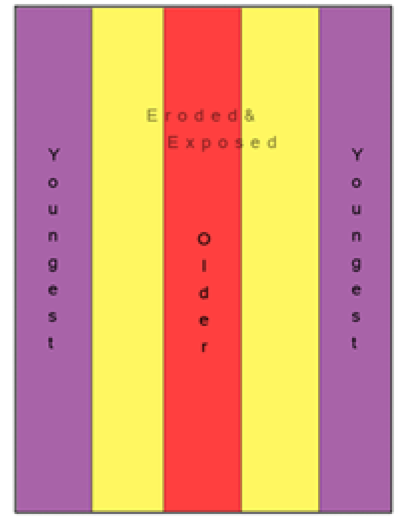


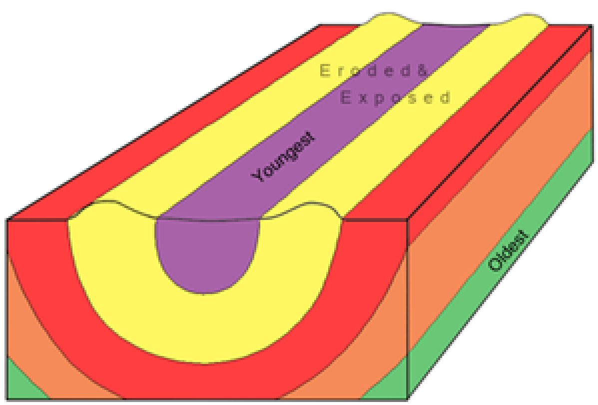
Monocline

Planer view of Non-Plunging Structural Landforms

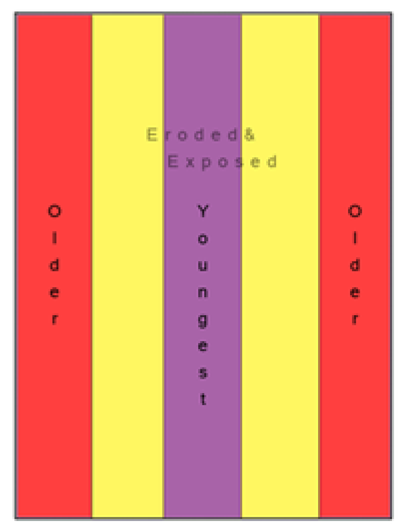


Anticline

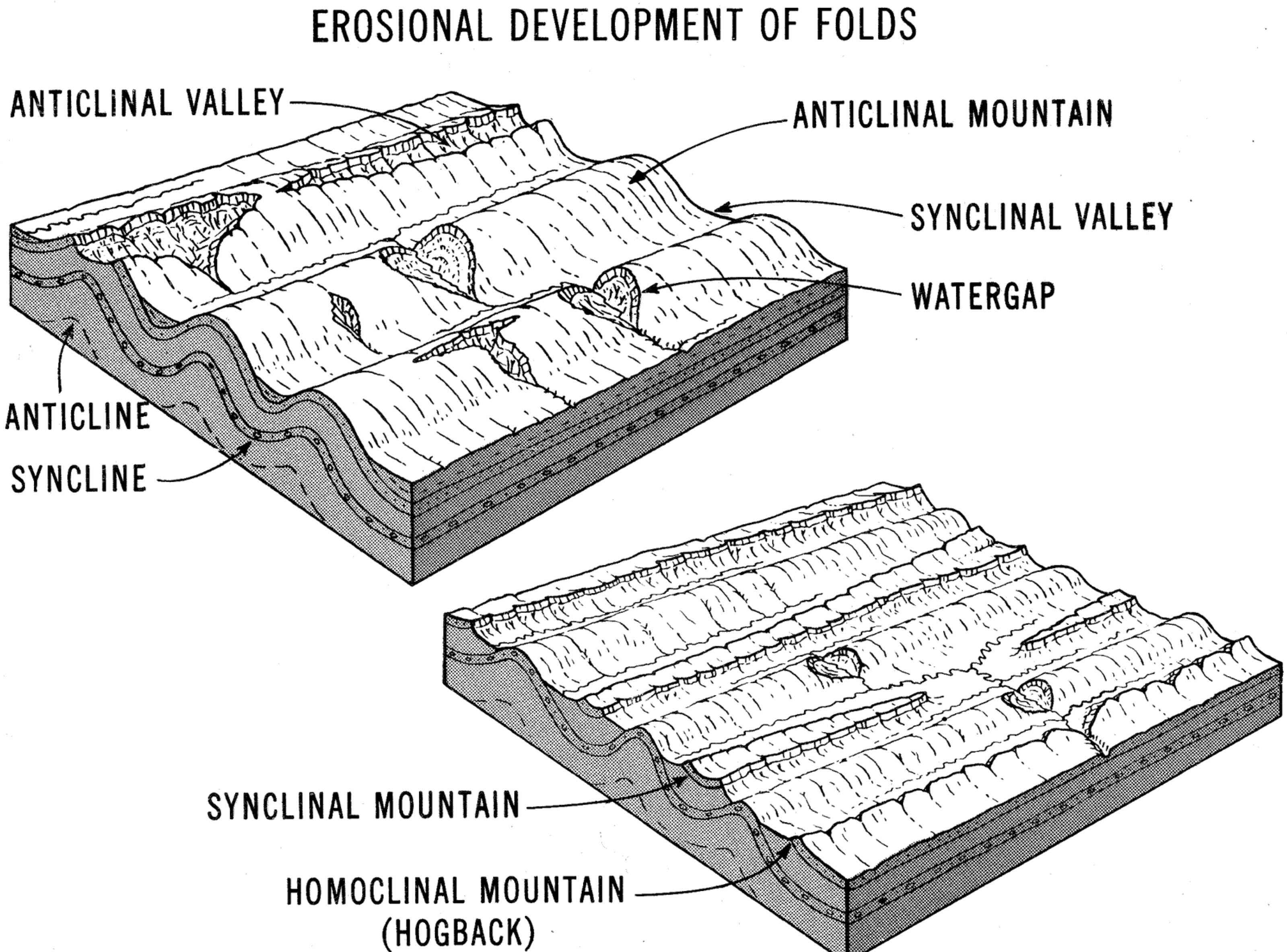




Syncline



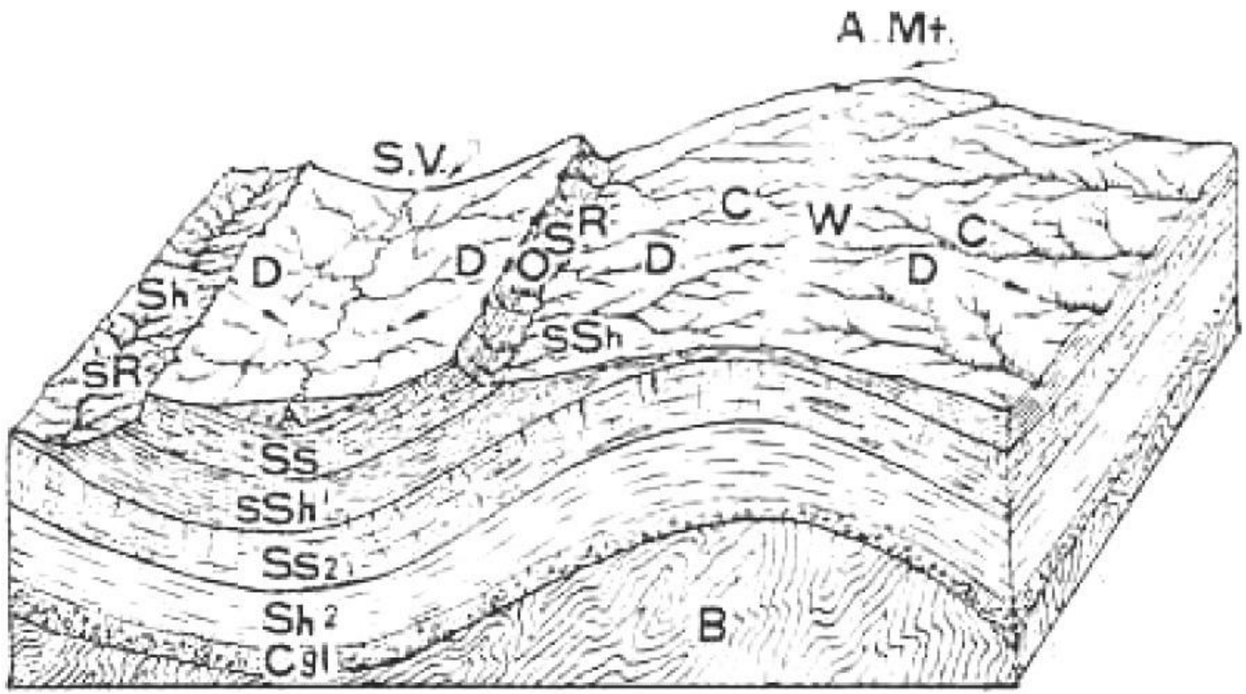
Structural Landforms



Structural Landforms

The axial part can be built up by a younger, resistant formation.

Erosion causes older beds crop out. The core part will, therefore, form an **anticlinal mountain**

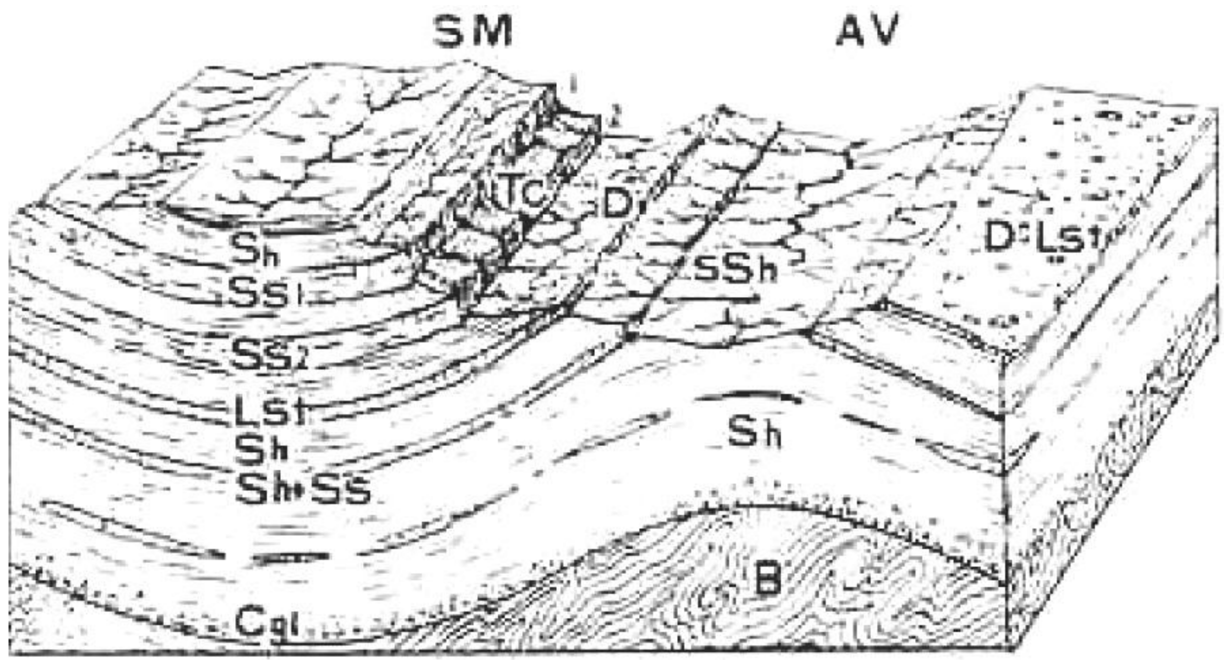


Anticlinal mountain and Synclinal valley

Structural Landforms

Less frequent and occur when an outcrop have alternate resistant and non-resistant units

The beds are gentle sloping, along the flanks are weak and removed by erosion



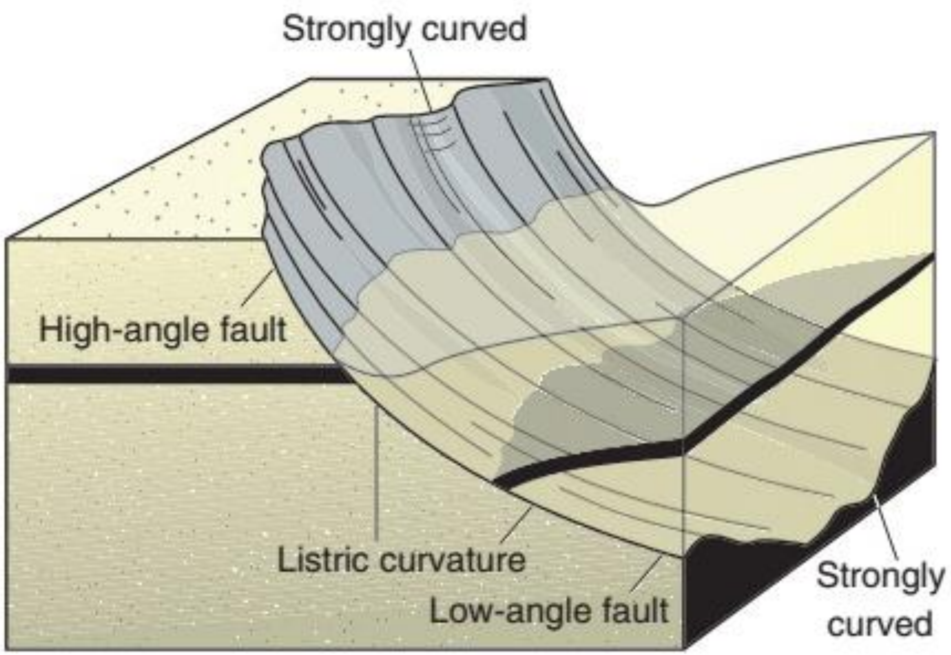
Synclinal mountain and Anticlinal valley

Fractures

Fault

On AP, fault are always straight, or slightly curved.

The relative straightness of a fault indication is based on the straightness of the fault plane.

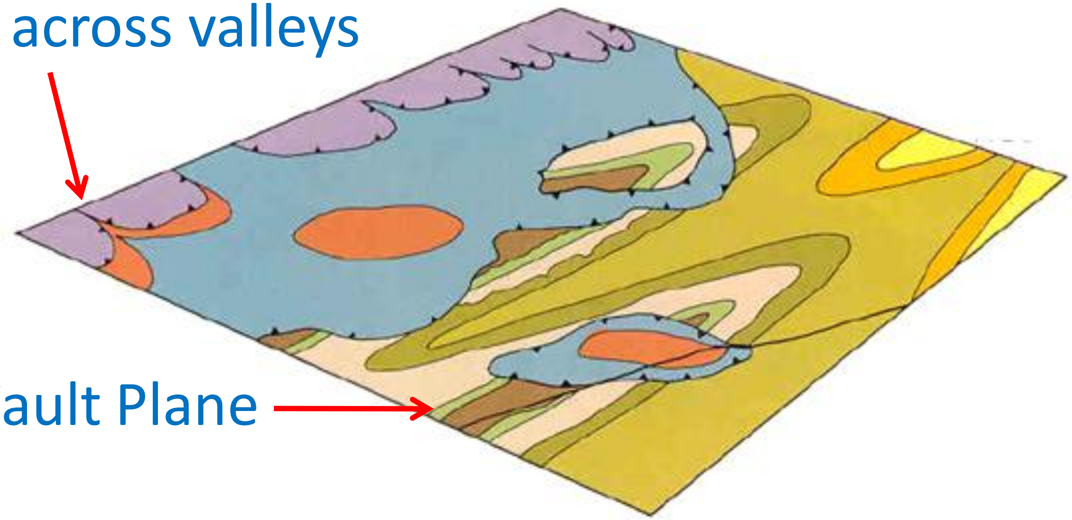


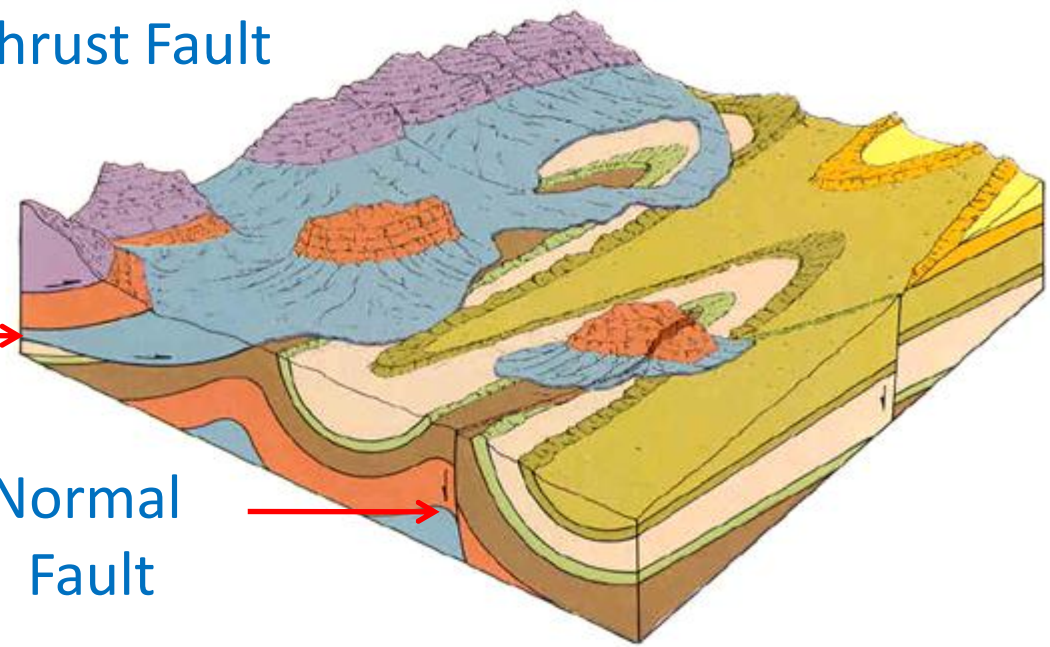
This plane is irregular or slightly curved.

Outcrop patterns of faults

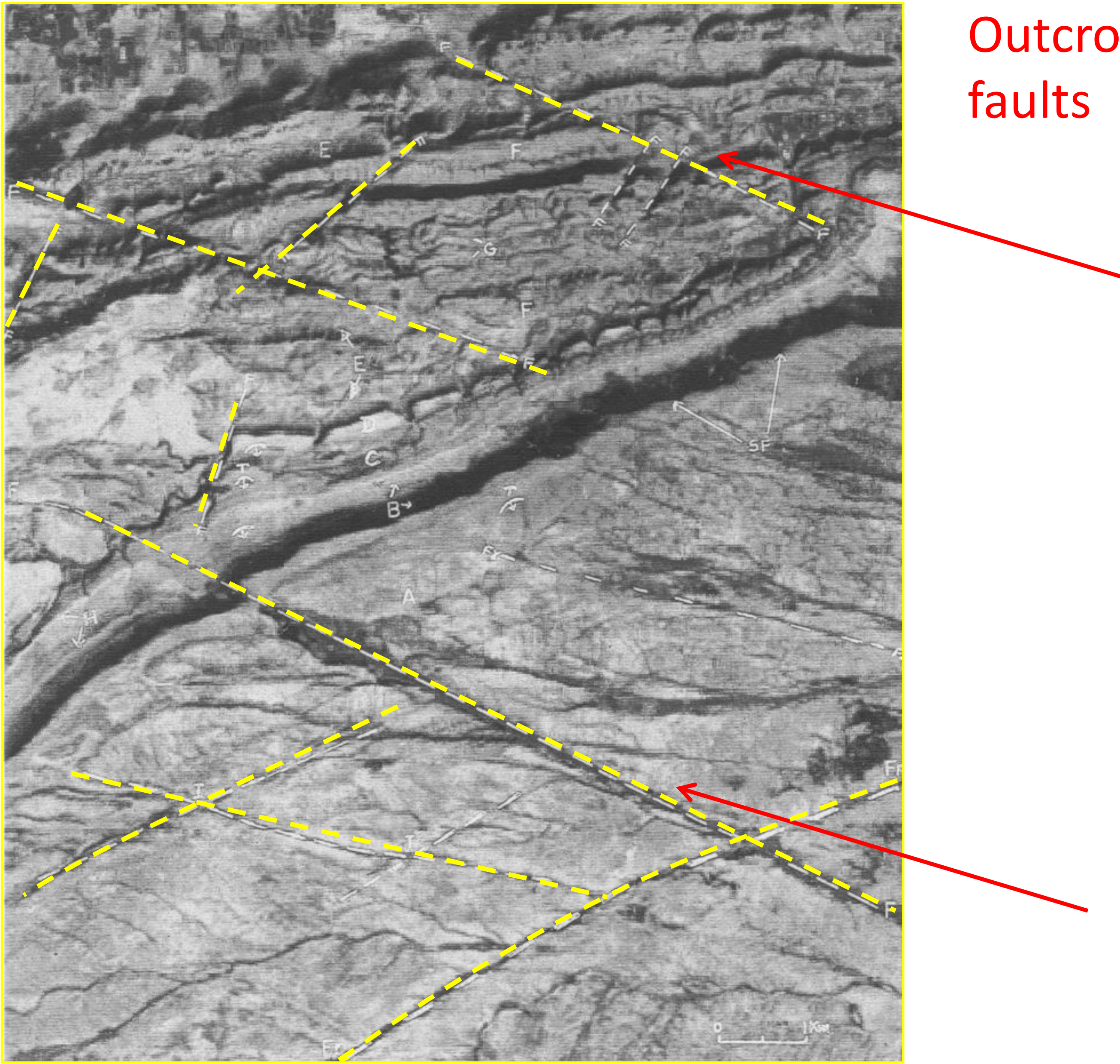
Fault patterns appear as lines or zones of displacement that abruptly offset structures and terminate contacts between formations.

Thrust faults generally dip at a low angle and appear as zig-zag irregular trace

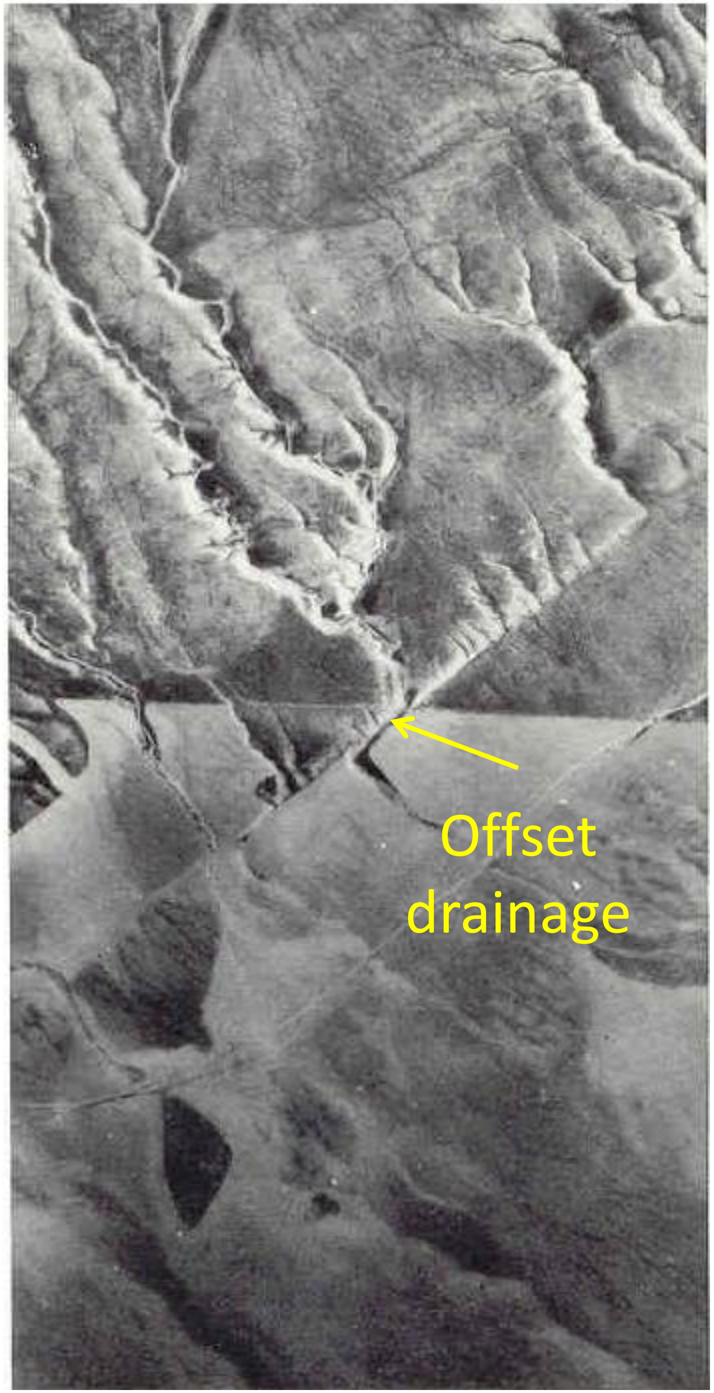


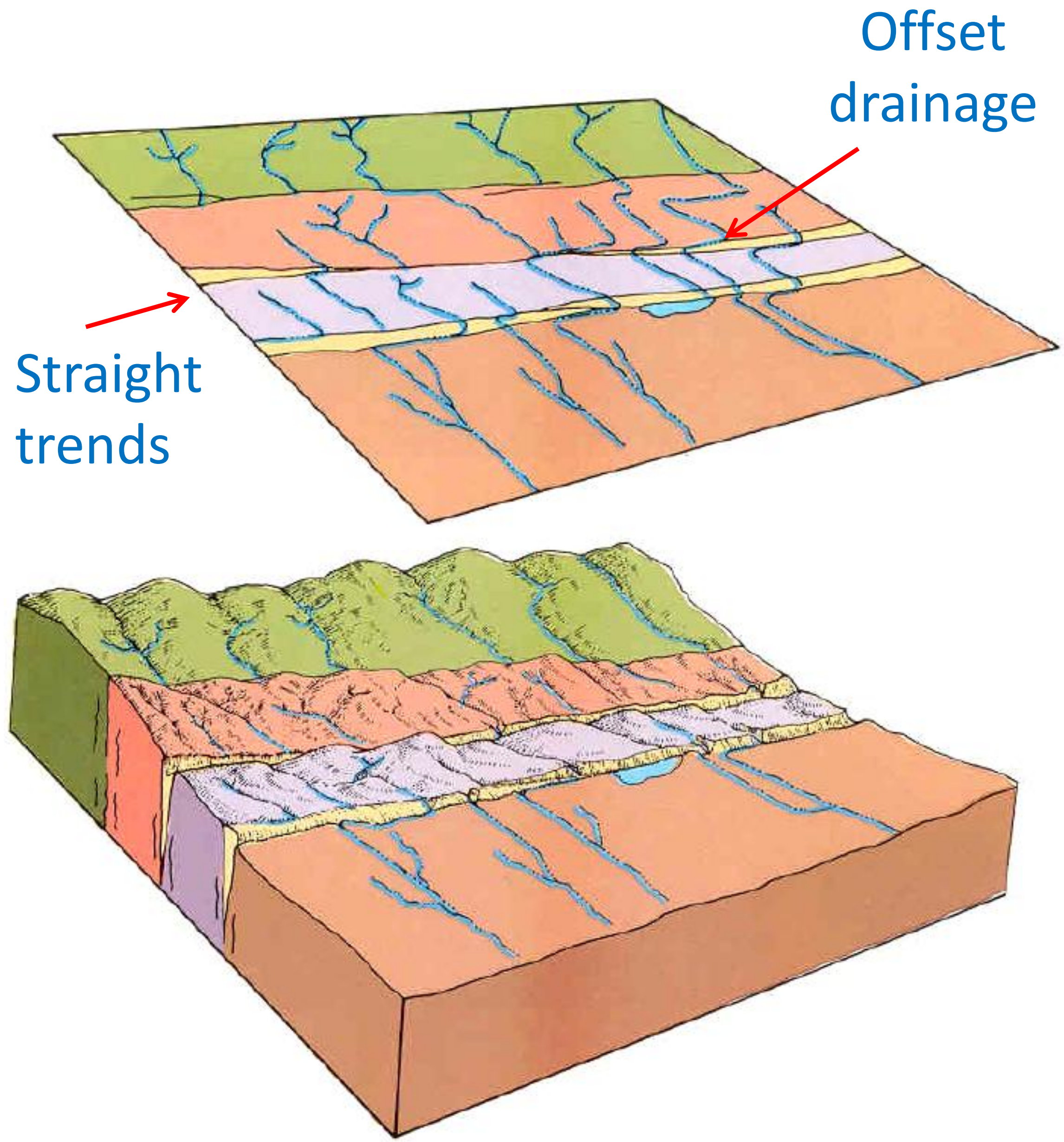


Outcrop patterns of faults



Outcrop patterns of strike-slip faults

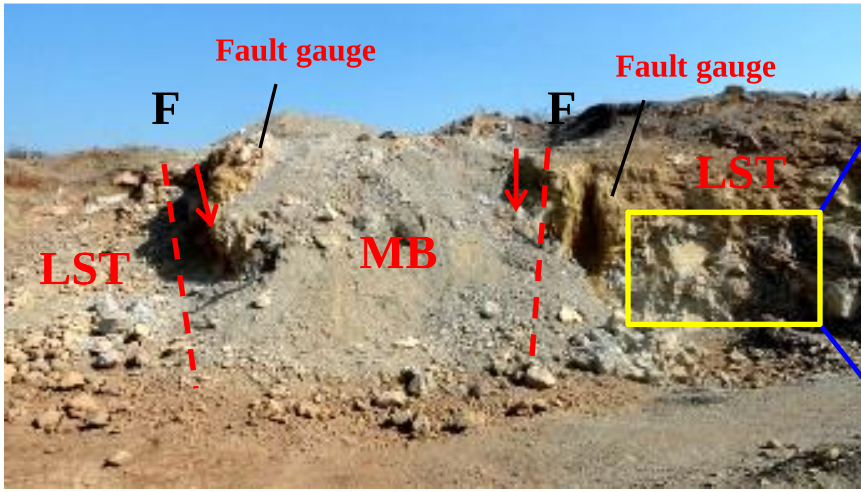




Outcrop patterns of strike-slip faults

- The lateral displacement does not produce high scarps.
- The fault line is marked by structural and topographic discontinuities, linear ridges and rivers, and offset drainage patterns.
- The offset drainage indicates the direction of displacement.

Determine the faults on aerial photographs



Graben structure in Limestone (LST) showing the central block of Meta-basalt (MB)

Dragging of Limestone beds (LST) along the fault plane

Fault gauge

Scarps

Drainage Offsets

Dragging of beds

Igneous Intrusives

Lineaments

Abrupt changes of dip on monoclines

Trenches

Landform Truncation

Lineaments

Lineaments are large scale linear features, which are the topographic expression of underlying structural features:

- Fault-controlled valley
- Joint controlled valleys or streams
- Mountain Fronts
- Lines of isolated hills
- Linear igneous intrusions and fissures

Joints

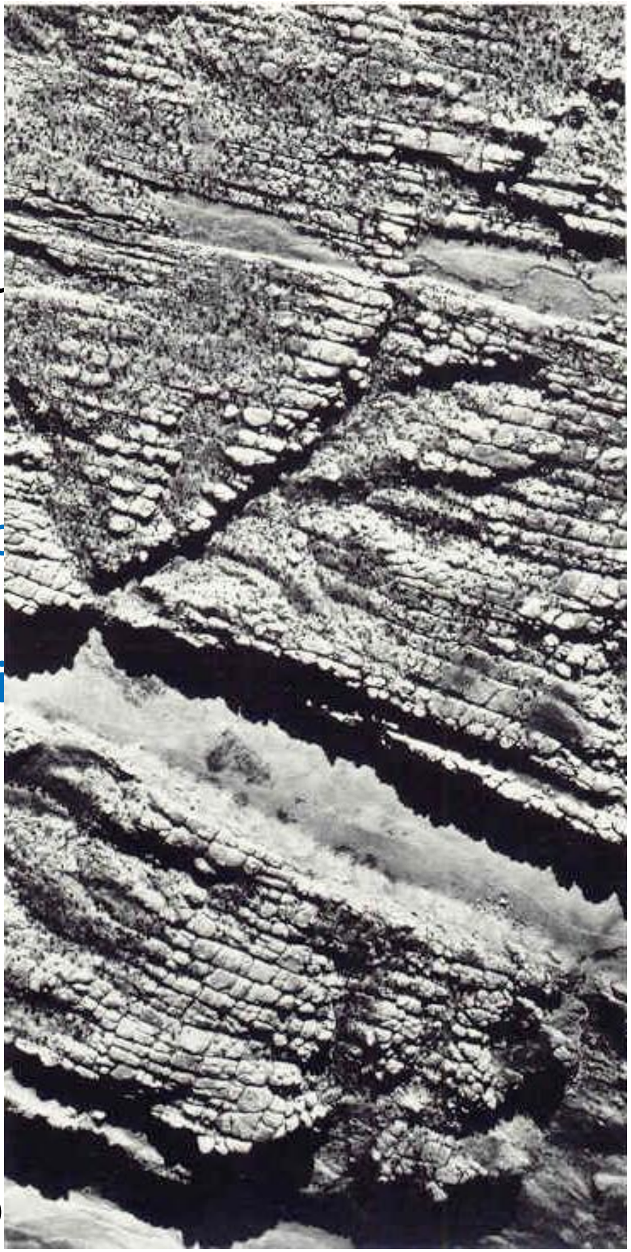
Joints are also expressed as linear featu

on aerial photographs

- There is no displacement along the jo
- The lengths and the spaces of the li by the joints are less than that of fau

Joints in sedimentary rocks develop parallel sets with equal separation .

In igneous rocks, criss-cross pattern of jo

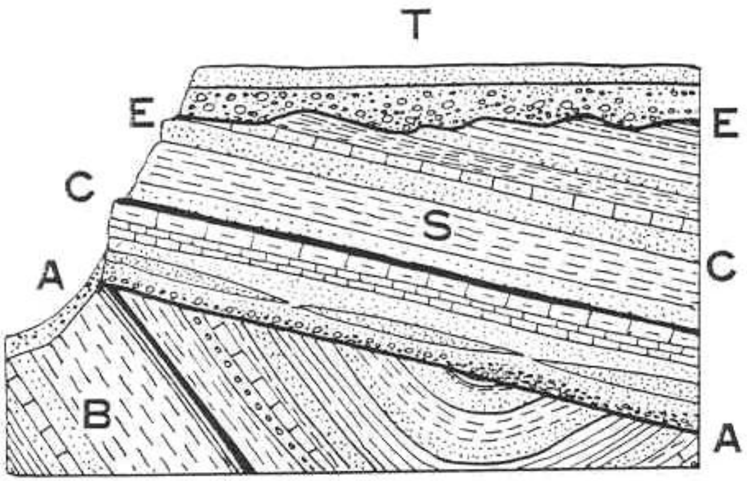


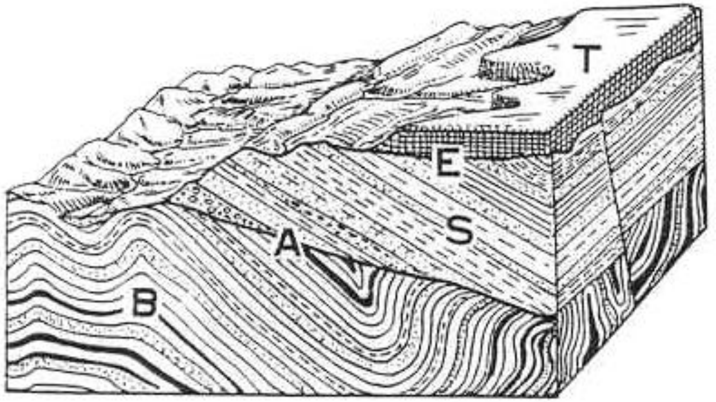
Unconformity

Unconformity occur if the deposition of sediments is interrupted

The relationship between the old and the new deposit cycle is called Unconformity

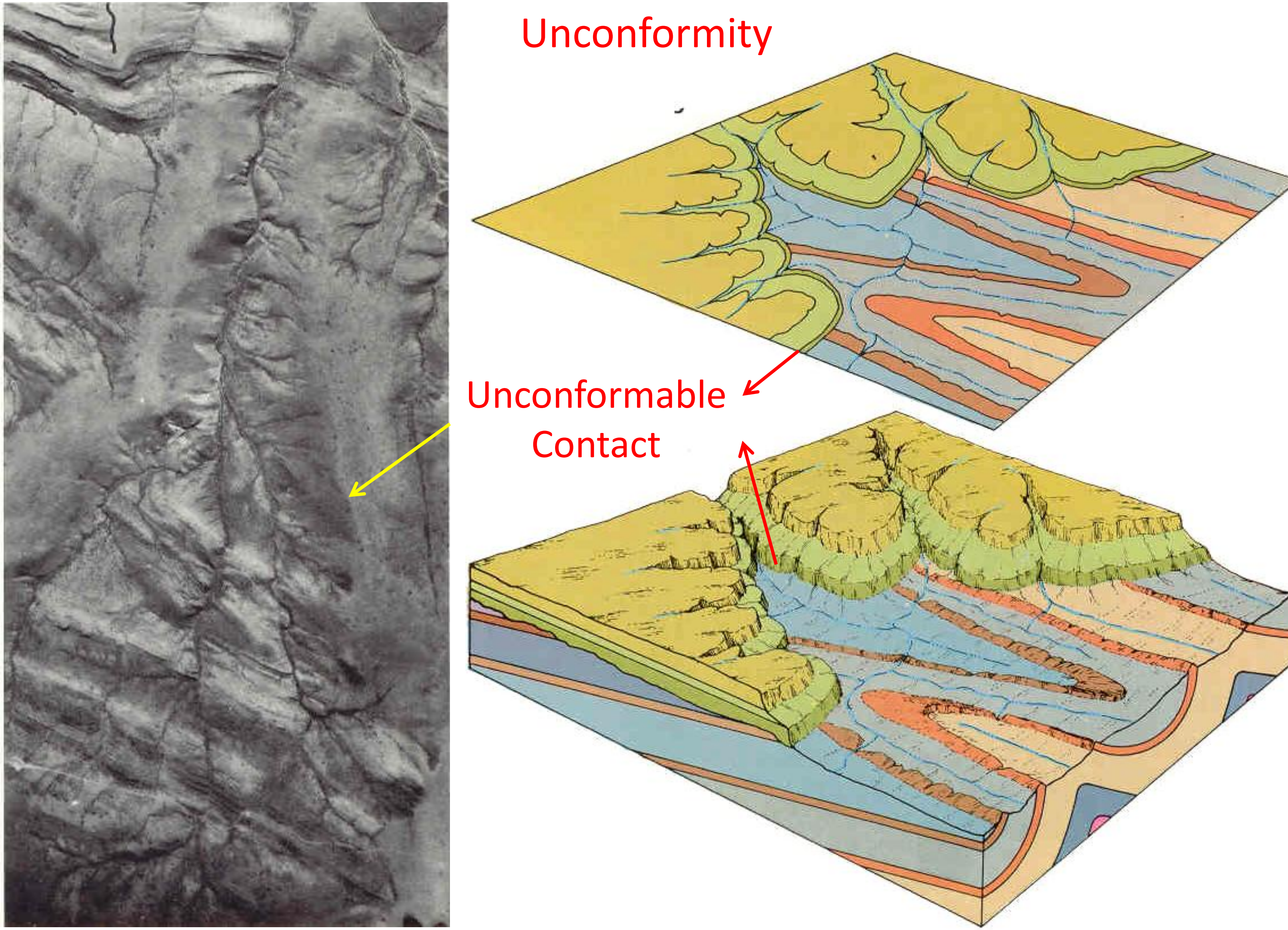
Angular relation between the two sedimentary groups is called an Angular unconformity





Unconformity

Unconformity



Unconformity

- Angular unconformities can be recognized on geologic features by interruptions, or discontinuities, in the outcrop patterns.
- The contacts of the older structures will terminate abruptly against the patterns of the overlying younger beds.
- A second period of erosion has partly removed the younger strata and exposed segments of the older folds.
- The angular unconformity is located at the base of the sequence of younger strata.

AERIAL PHOTO-INTERPRETATION IN LITHOLOGICAL DISCRIMINATION

Lithology Identification

Photographic appearance of a particular rock type

1. Climate
2. Amount of relief

Criteria for rock types identification would not be applicable to everywhere

Criteria to follow for lithology identification

- Determine the climatic environment (e.g. desert, arid, semi-arid, humid, temperate, tropical) and associate type of erosional environment
- Recognize and mark the bedding traces of the sediments or mark the outline of outcrop
- Recognize and mark the areas of superficial cover that do not indicate bedding, fold and determine the position of the axial traces
- Study the lineaments to determine whether they represent faults, dykes or joints

IGNEOUS ROCK

Formed by consolidation of magma

GENETIC CLASSIFICATION

- Intrusive igneous rocks
- Extrusive igneous rocks

CHEMICAL CLASSIFICATION

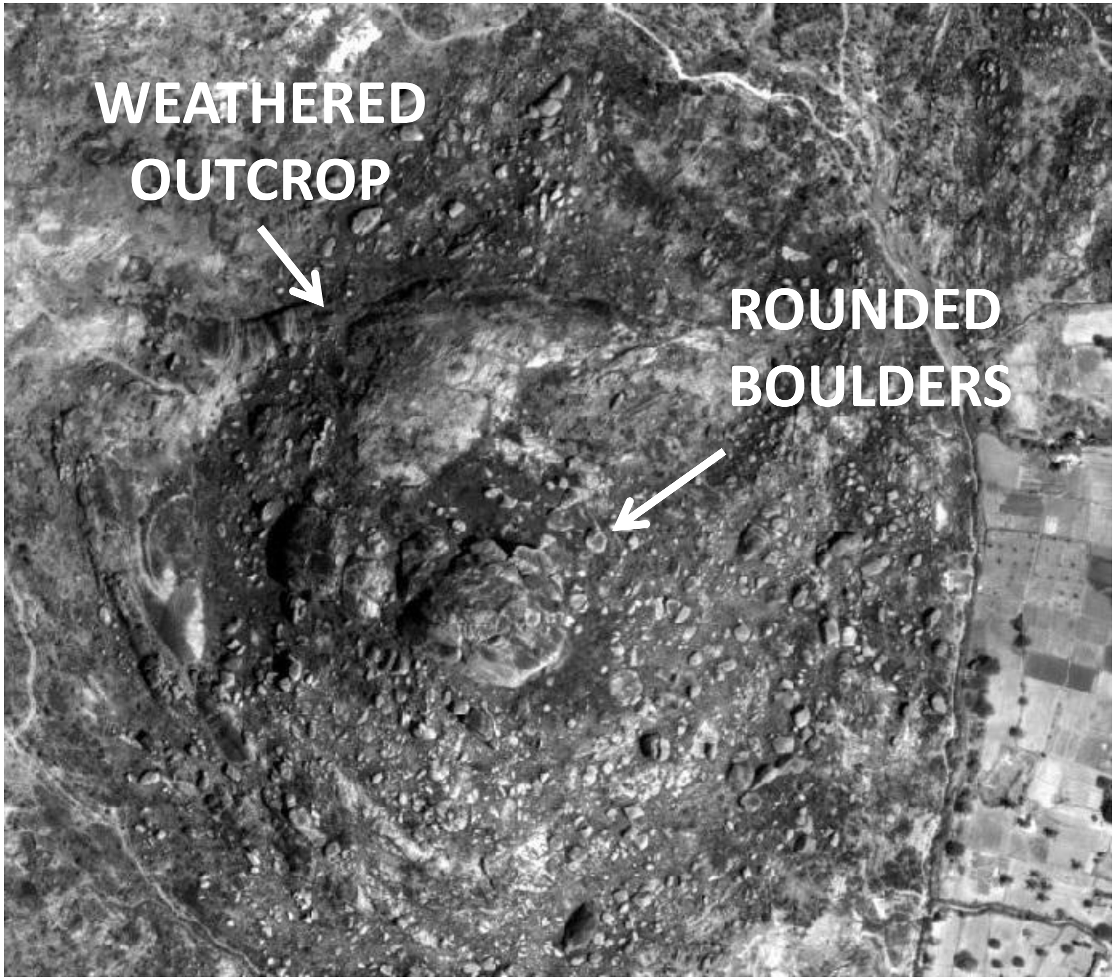
- Acidic (Granite, Ryholite)
- Intermediate (Diorite, Andesite)
- Basic (Gabbro, Basalt)
- Ultrabasic (Preridotite, Komateite)

GENERAL CHARACTERIZATION OF INTRUSIVE IGNEOUS ROCKS

- Massive, isotropic, homogeneous and cross-cutting relations with country rocks
- Different shapes and dimensions (e.g. batholiths, laccoliths, dykes, sills etc).
- Hummocky or rounded dome like topography (in humid region);
- Unless fracture controlled, dendritic drainage pattern or radial-annular drainage patterns occur.

CONTINUED…..

- Criss-cross relationship by forming a narrow ridge (e.g. Quartz reef).
- More or less uniform vegetation
- Uniform appearance
- Rectilinear or dendretic drainage
- Light and uniform tone for acidic intrusives
- Dark to black for basic intrusives



RESIDUAL GRANITIC HILL

RESIDUAL GRANITIC HILL

(TUMKUR , KARNATAKA)

ACID OR BASIC INTRUSIVE IGNEOUS ROCK

Topography

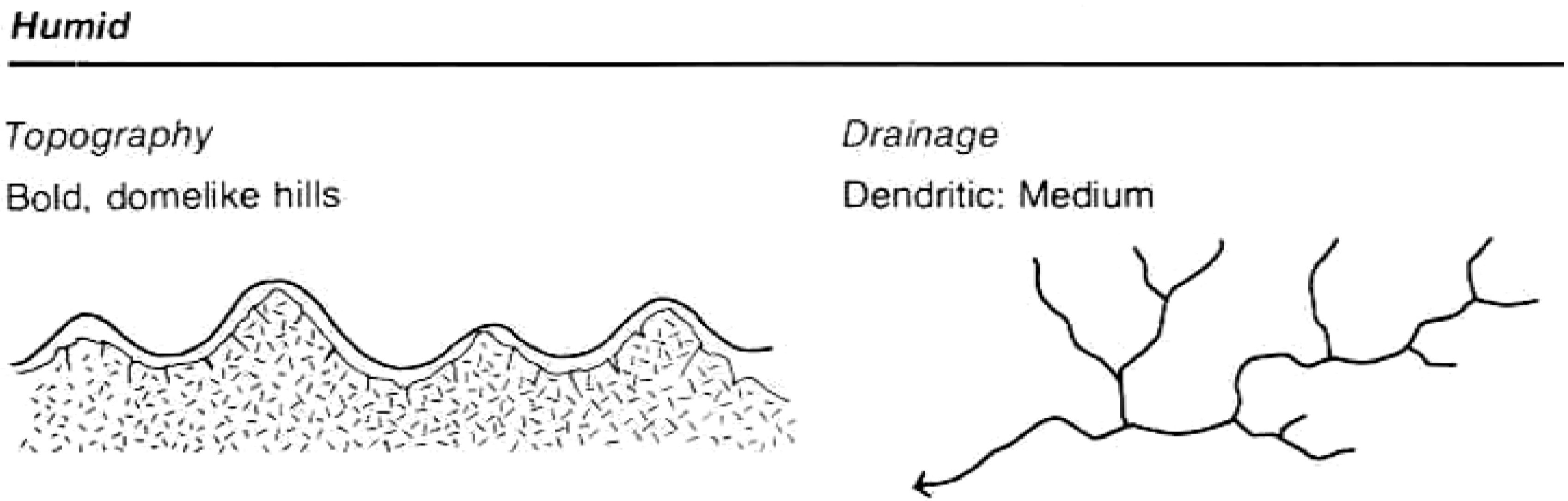
Straight, narrow ridges

Drainage

None

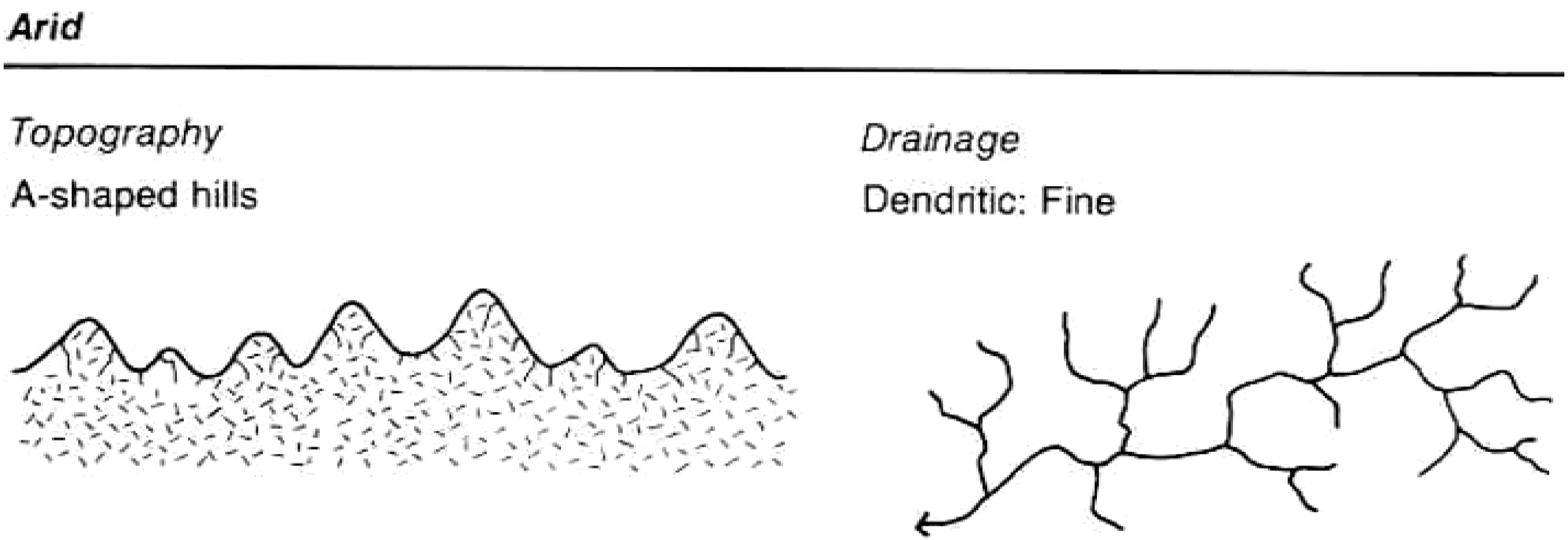
- Narrow linear ridges in case of acidic intrusion
- Basic intrusion results in linear depression
- Form is too small to developed any drainage

ACID OR BASIC INTRUSIVE IGNEOUS ROCK



- Large, massive, rounded dome like hills are weathered to accumulates in drainage course
- Dendritic drainage with medium texture
- Rounded hills cause curvilinear alignment of the tributaries

ACID OR BASIC INTRUSIVE IGNEOUS ROCK



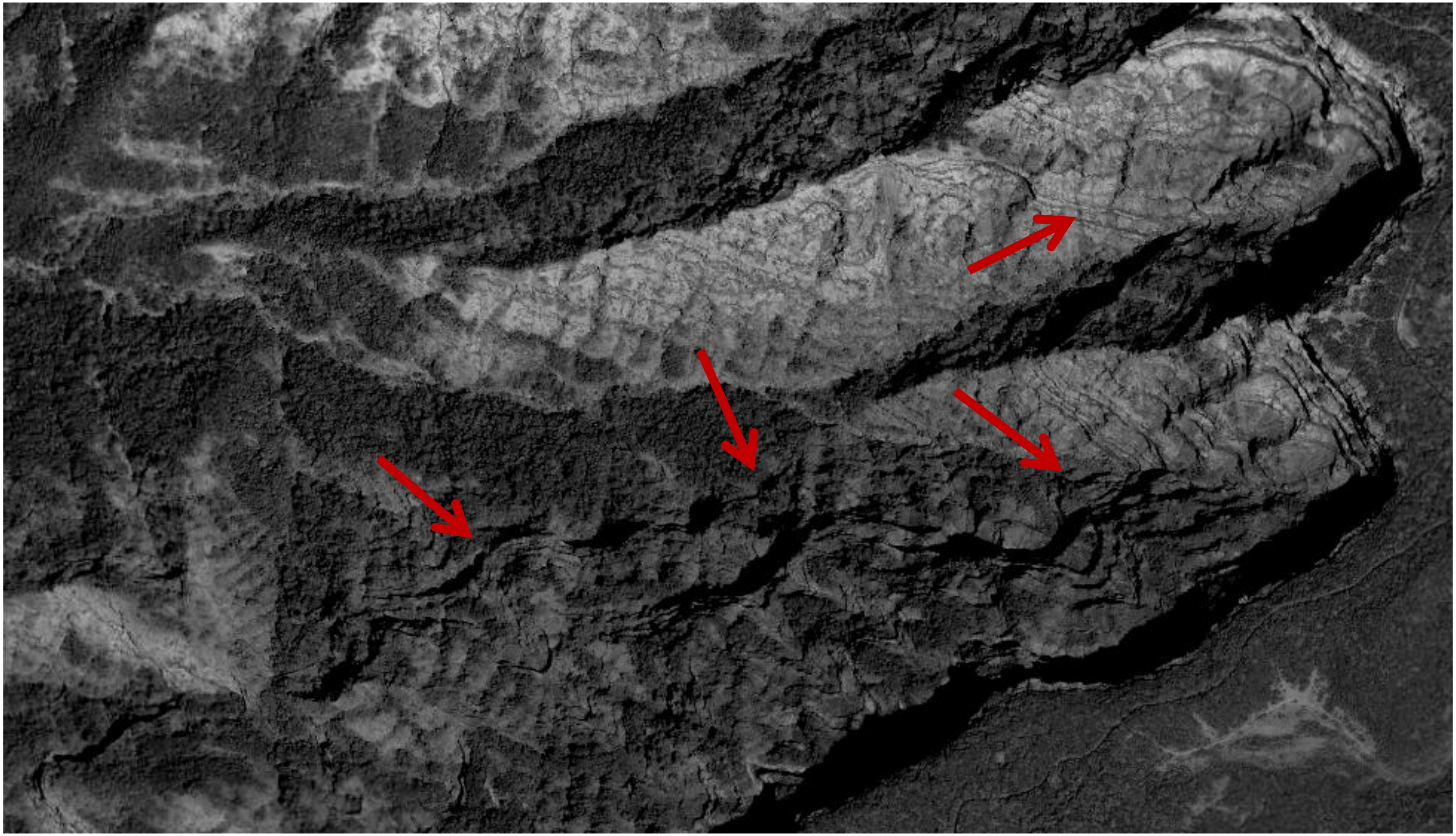
- Bold, Large, massive dome like hills
- Area is highly dissected by wind erosion forming 'A' shaped hills with steep sides
- Dendritic drainage with fine texture

GENERAL CHARACTERIZATION OF EXTRUSIVE IGNEOUS ROCKS

- Associated volcanic landforms, lavaflows, cones, craters, plug, volcanic necks, flat topped plateaus etc.
- Successive flow structure
- Rough and irregular terrace surfaces
- Lobate patterns of vegetation (sparse in arid region and luxuriant in humid region) and topography
- Dendretic or radial drainage

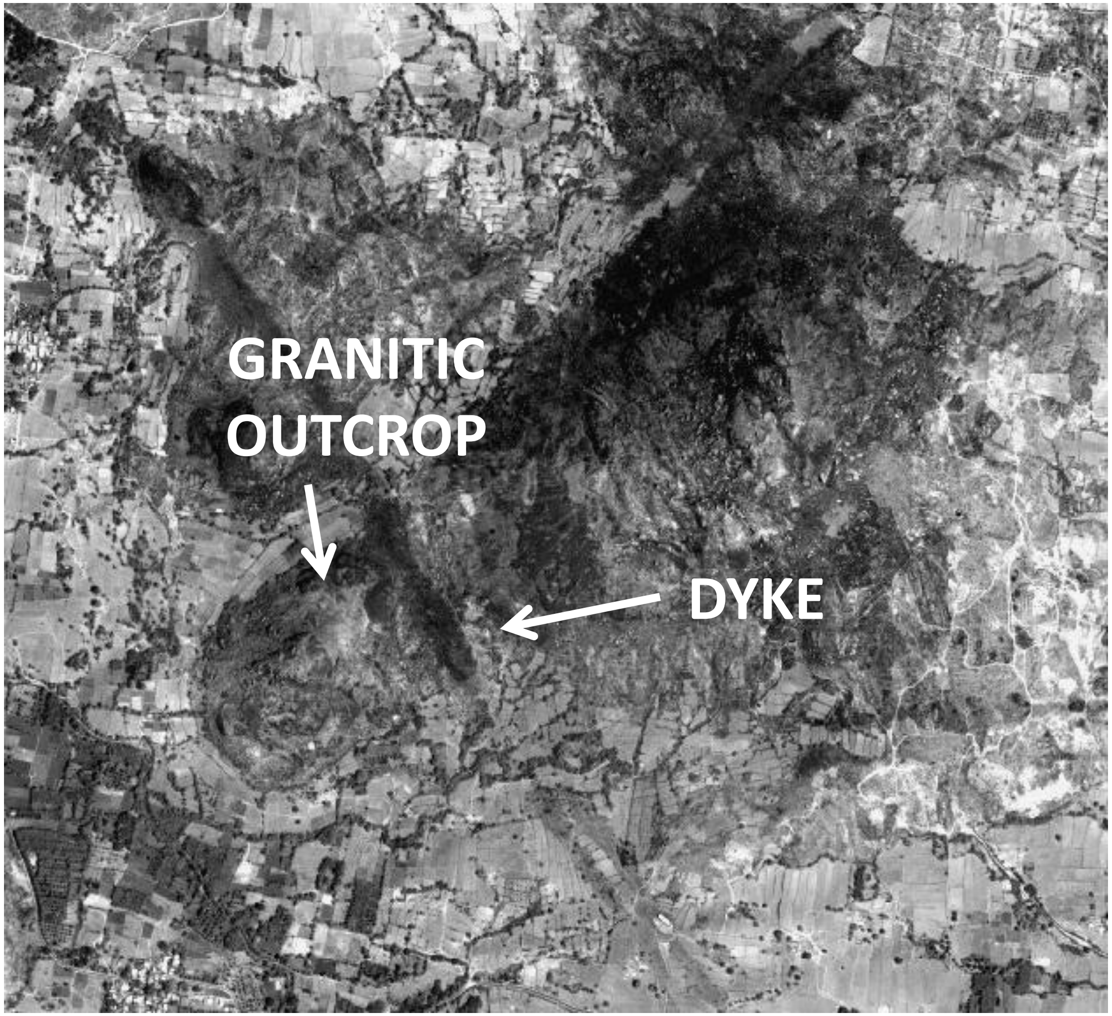
CONTINUED….

- Light and uniform tone for acidic extrusives
- Dark to black for basic extrusives
- Active rate of erosion
- Columnar joints



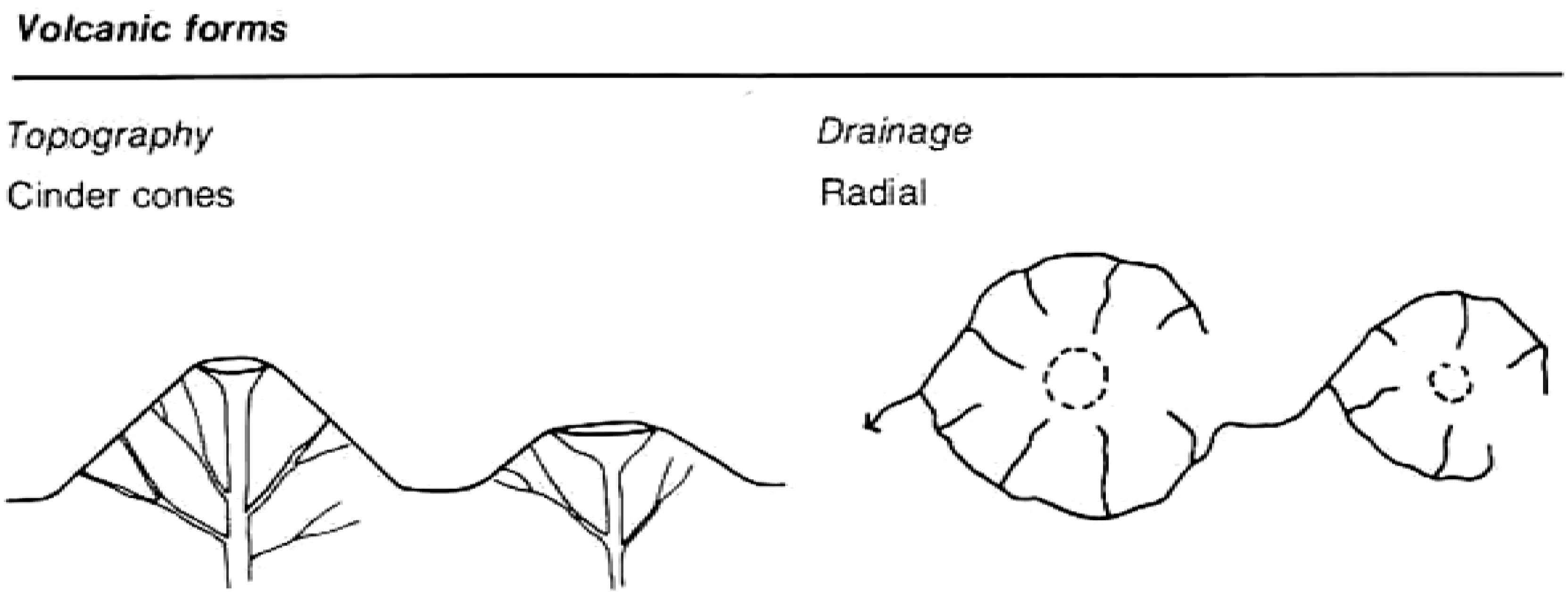
SUCCESSIVE LAVA FLOW STRUCTURE

(NEAR MAHABALESHWAR, MAHARASHTRA)



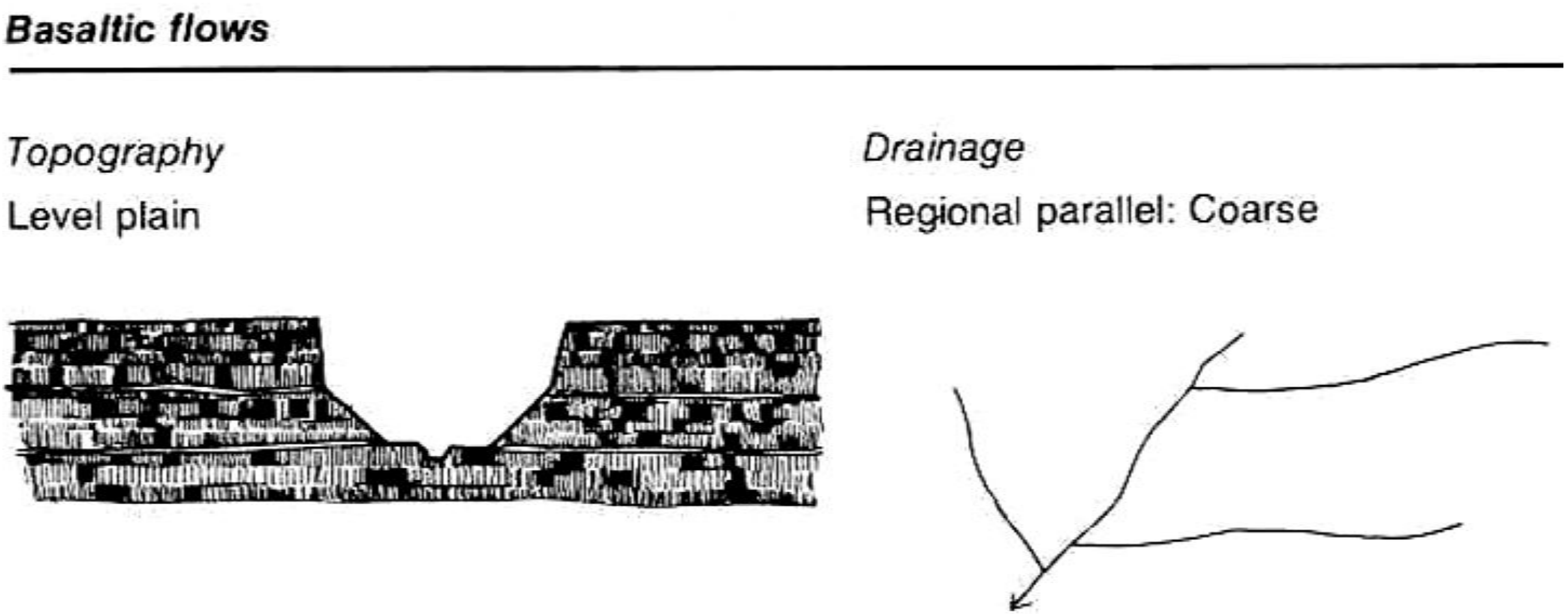
CROSS-CUTTING RELATIONSHIP OF DYKE WITH GRANITIC OUTCROP

EXTRUSIVE IGNEOUS ROCK



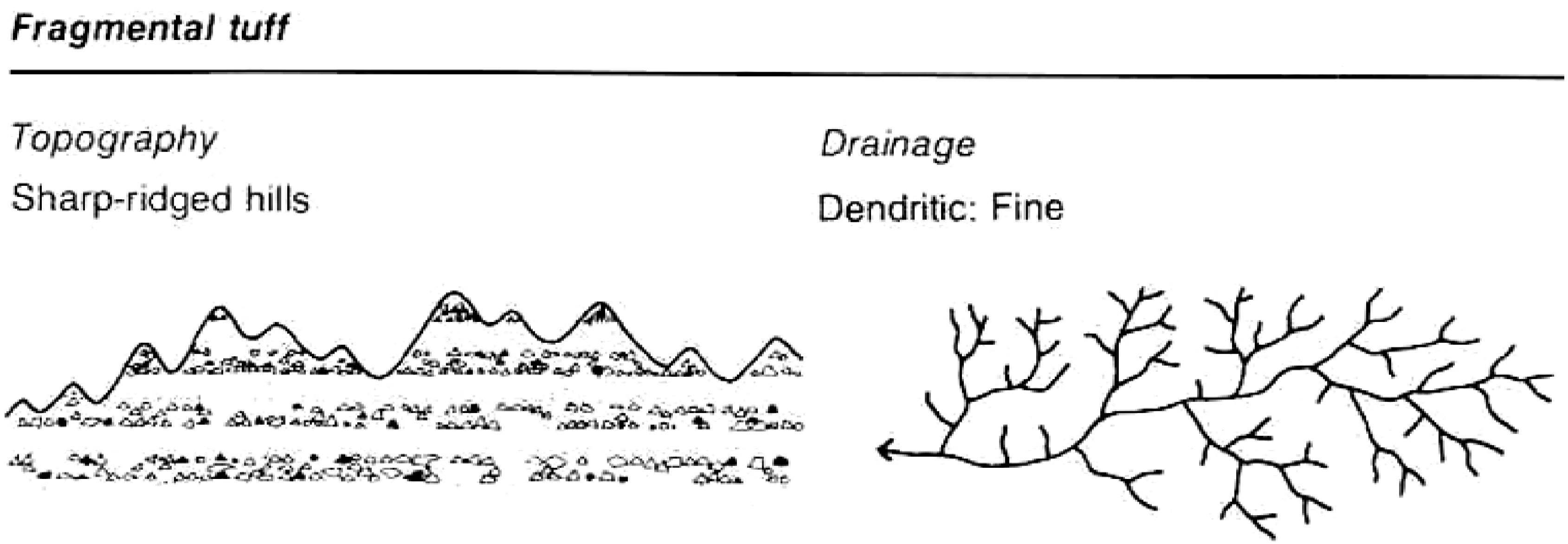
- Round cones with radiating dykes
- Radiating drainage
- Tributaries along the slope are parallel

EXTRUSIVE IGNEOUS ROCK



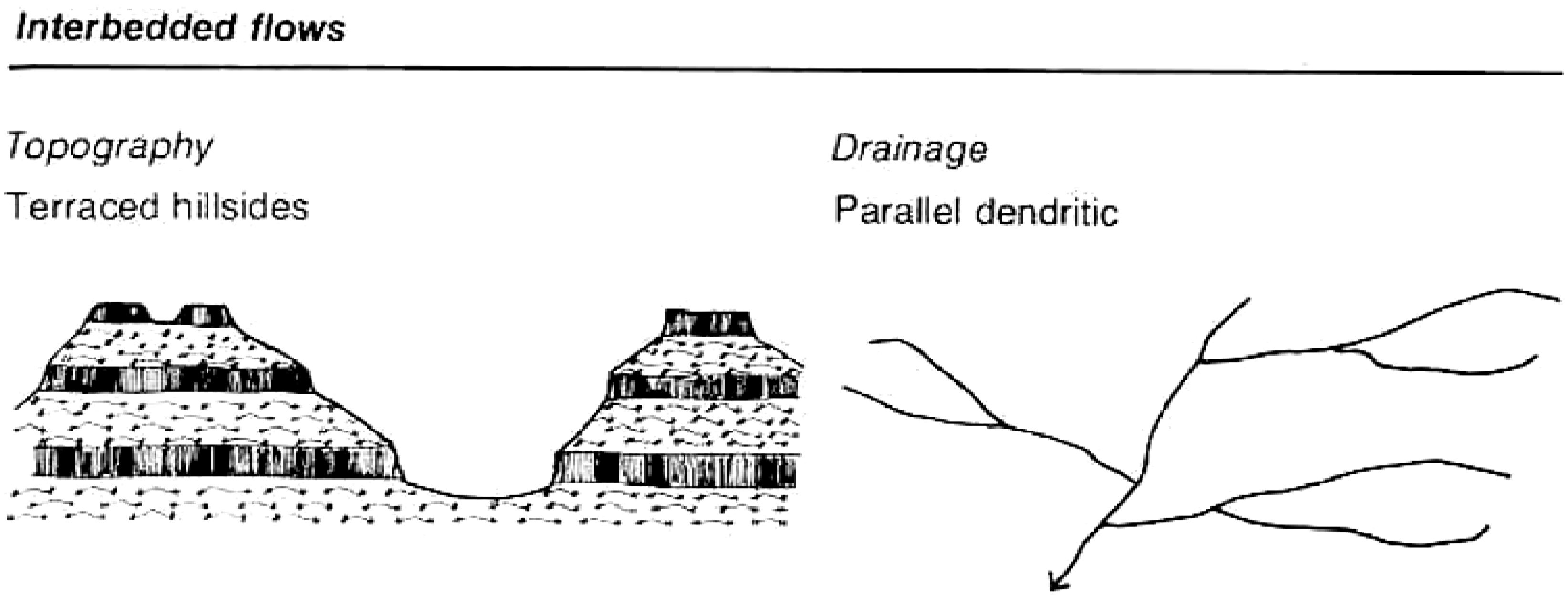
- Gently uniform sloping broad plains
- Vertical escarpments with parallel joints
- Regional parallel drainage with coarse texture

VOLCANIC ASHES



- Sharp knife edge type linear ridges with highly dissected topography
- Steep uniform slope
- Extremely fine dendritic drainage

INTERBEDDED FLOW



- Dissected topography exposed stratified layers
- Parallel ridges with convex sideslopes
- Dendretic drainage with parallel tributories

PHOTO INTERPRETATION OF COMMON IGNEOUS ROCKS

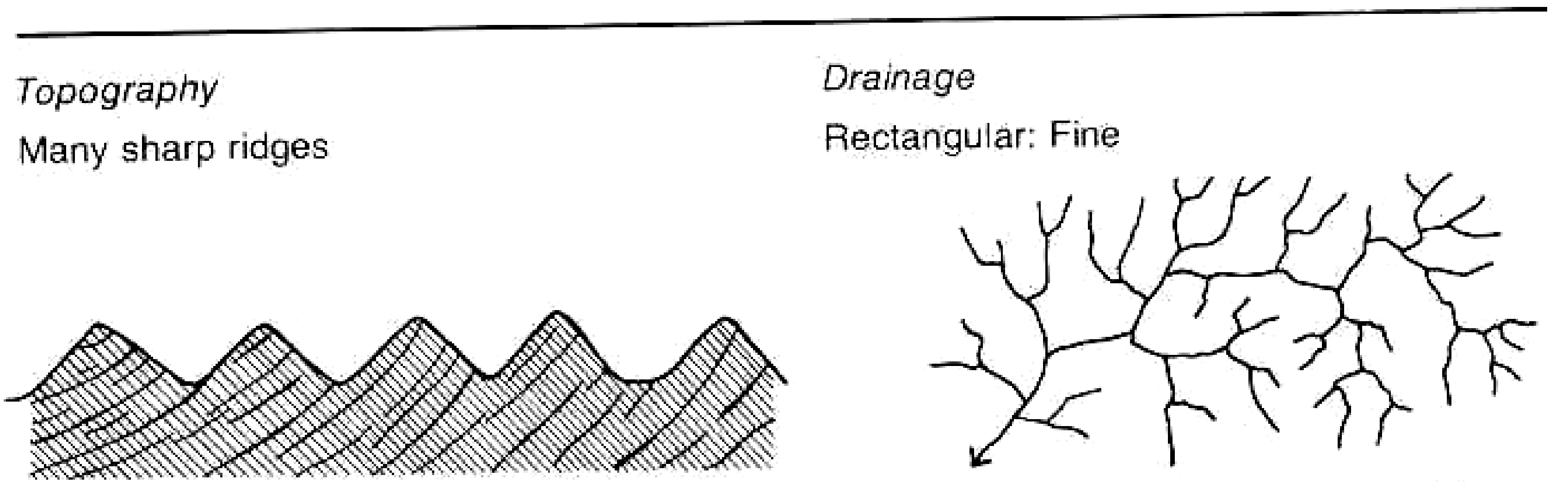
Rock	Composition	Weathering	Tone	Landforms	Drainage	Topography	Vegetation	Joints
Granite	Acidic intrusives	Variable	Bright	Rounded outcrops or residual hills	Low to medium density dendritic	Low lying	Variable	Three or four set
Rhyolite/ Pumice/ Obsidian	Acidic extrusive	Highly susceptible	Bright	Oblate in outline, Volcanic landform	Radial drainage	Rough and irregular	Poor	Faintly developed
Dolerite	Basic intrusive	Basic dykes are susceptible	Dark	Appear as wall or Trench. Sills are like sheets	None	Linear ridge or depression	Absent	Present
Basalt	Basic extrusive	Highly susceptible	Dark	Flow structure with oblate outline	Fine dendretic drainage	Flat and rough topography	Sparse	Columnar
Gabbro/ Peridotite	Basic and ultrabasic intrusives	Highly susceptible	Dark	Small dimension plugs and domes	Coarse dendritic/ Fine dendritic/ Radial drainage	Undulating rolling or rough and jagged	Scanty	Well developed

METAMORPHIC ROCK

Difficult to identify metamorphic rocks from aerial photographs

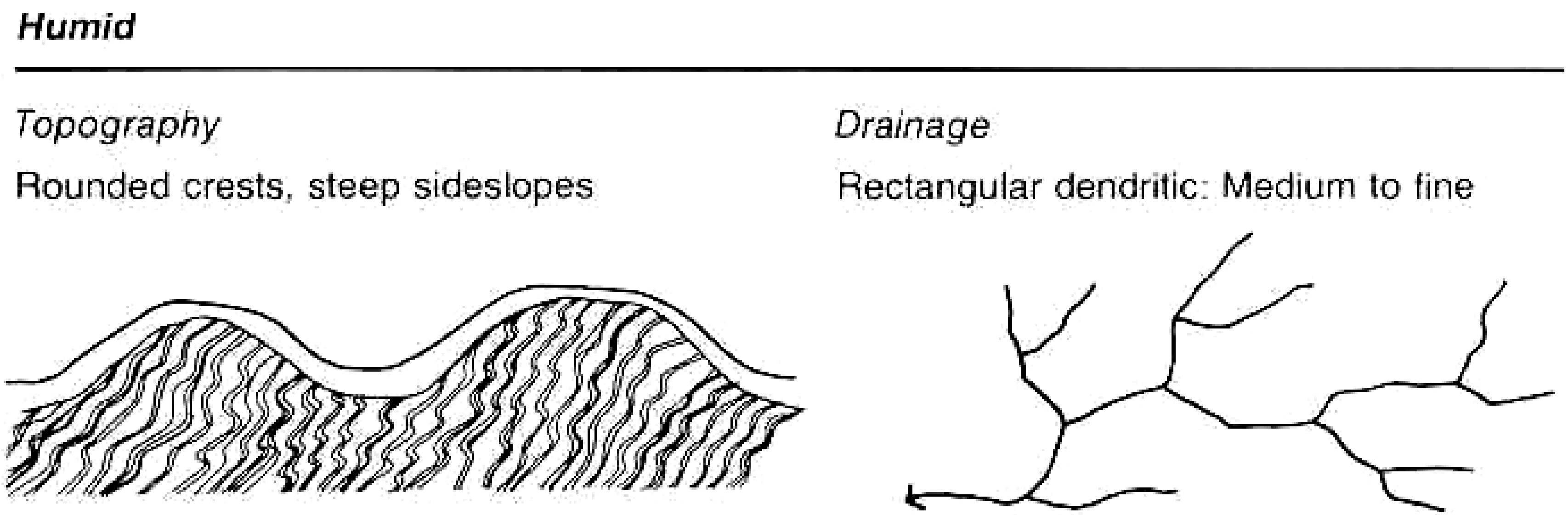
- Small-scale distinguishing characteristics
- Physical changes in the rock units due to high pressure and/or high temperatures of the metamorphism.
- Structural trends are foliations rather than bedding.
- Parallel alignments of ridges may reflect regional cleavage, foliation or fold axis and may suggest metamorphic rocks.
- The lineations represent regional cross-joints and may be reflected in abrupt deflections of drainage along straight stream segments

SLATE



- Rugged topography with sharp ridges and steep hillsides due to gully erosion
- Fine rectangular dendretic drainage pattern

SCHIST



- Rounded hills with steep sideslopes, parallel gullies
- Medium structurally controlled rectangular dendretic drainage pattern

SCHIST

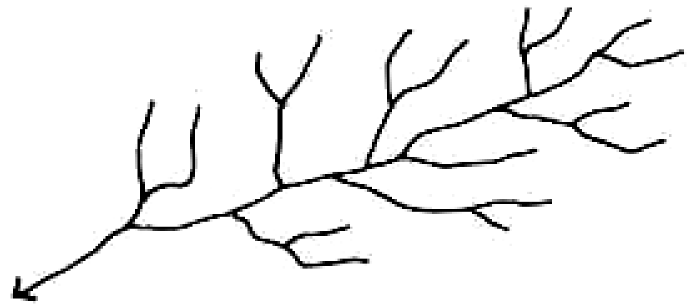
Arid

Topography

Parallel laminations

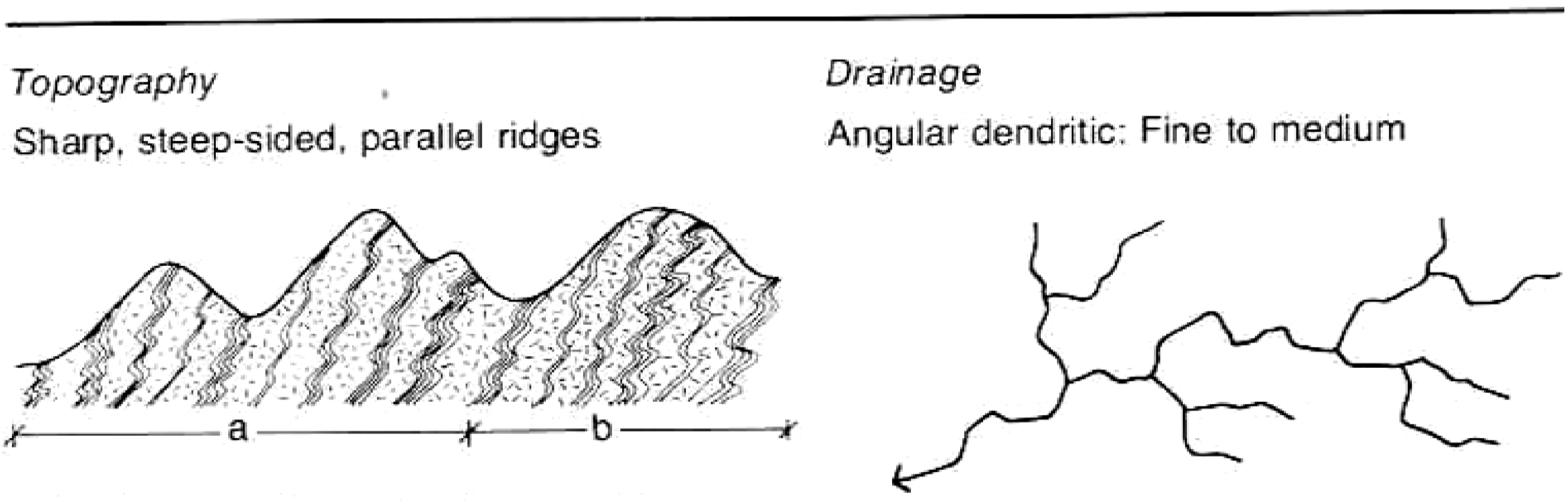
Drainage

Rectangular dendritic: Fine



- Rugged topography controlled by obvious foliation, parallel gullies
- Fine structurally controlled rectangular dendretic drainage pattern

GNEISS



- Parallel sharp ridges and steep hillsides results from differential weathering
- Medium angular dendretic drainage pattern

SEDIMENTARY ROCK: Consolidated Sediments

- The most prominent feature of sedimentary rocks is **bedding**.

- As a result of differential erosion of sedimentary rocks, beds appear as banded patterns on aerial photographs.

- Banding due to vegetation or soil differences expressed by topographic tone can also be used to recognize and mark the beds in absence of topographic expressions.

- Bedding may be most prominent in the mature stage of geomorphic cycle.

Summary chart of sedimentary rocks (Way, 1973)

Landform	Topography	Drainage*	Tone	Gullies	Vegetation/Land Use
Sandstone					
Humid	Massive, steep slopes	Dendritic, C	Light	Few (V-shaped)	Forested
Arid	Flat table rocks	Angular dendritic, M-F	Light (banded)	Few to none	Barren
Shale					
Humid	Soft hills	Dendritic, M-F	Mottled-Dull	Soft U-shaped	Cultivated
Arid	Steep, rounded hills	Dendritic, F	Light (banded)	Steep-sided	Barren or badlands
Limestone					
Humid	Karst topography	Internal	Mottled	White-fringed	Cultivated
Arid	Flat table rocks	Angular dendritic, M-F	Light	Few to none	Barren
Tropical	Tropical karst	Internal	Uniform light	None	Barren or forested
Dolomite					
Humid**	Hill and valley	Angular dendritic, M	Light gray	Soft U-shaped	Cult. & forested
Coral					
Tropical***	Terraced or reef	Internal	White to gray	None	Barren or forested
Flat, interbedded (thick bedded)					
Humid	Terraced hillsides	Dendritic, M-C	Subdued bands	Varies	Cult. & forested
Arid	Terraced hillsides	Dendritic, M-F	Banded	Varies to few	Barren
Flat, interbedded (thin bedded)					
Humid	Uniform slopes	Dendritic, M	Med. gray	Soft U-shaped	Cult. & forested
Arid	Minor terraces	Dendritic, F	Faint, thin bands	Few to none	Barren
Tilted, interbedded					
Humid	Parallel ridges	Trellis, M	Faint banding	Varies	Forested & Cult.
Arid	Saw-toothed ridges	Trellis, F	Banded	Varies	Barren

*C, coarse; M, medium; F, fine.

**Characteristics of dolomite in arid climates appear similar to those listed for arid limestone.

***For all practical purposes coral formations are found only in tropical climates.

SEDIMENTARY ROCK: Coarse grained rocks (sandstone)

•Porosity and permeability are variable.

•The individual beds are generally thin and occur interbedded with shale. Differential erosion is an important recognition factor.

•Cross bedding features might be observed in the photographs taken in arid regions. The joints and fissures may be visible on photographs.

•In spite of their porosity and permeability they develop a drainage pattern (dendritic). It is partly an internal drainage and streams often follow lines of dislocations (angular drainage).

•Gullies are generally short, steep, V-shaped and widely spaced. The tone is usually light gray, ferruginous types may become dark. Sandstones support little or no vegetation, less dense than on shales. In humid climates sandstone-shale are usually vegetated and cultivated

Sandstone Humid & Arid (Way ,1973)

Humid

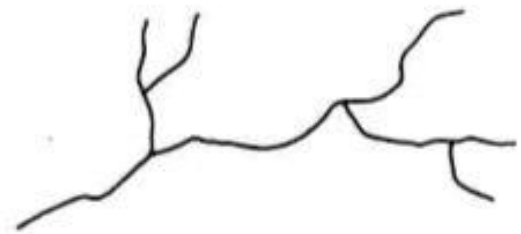
Topography

Massive, steep slopes

Sandstones tend to be relatively resistant to weathering because of the strength of their cementing agents. Therefore, in humid climates they produce a massive, bold topography with steep sideslopes. The residual soils tend to be very shallow along the ridgelines but thicker at lower elevations, owing to the accumulation of colluvium. Since sandstone is usually the most resistant sedimentary rock in humid climates, it tends to occur as an overlying cap rock. Where sandstones encounter other sedimentary rocks, there is generally a sharp boundary.

Drainage

Dendritic: Coarse



In humid climates the drainage pattern for sandstones is generally dendritic although, depending on the influence of the jointing pattern, it may also be somewhat angular or even rectangular. The drainage system texture is usually coarse but may also be medium, with minor tributaries joining the next higher stream order at right angles.

Arid

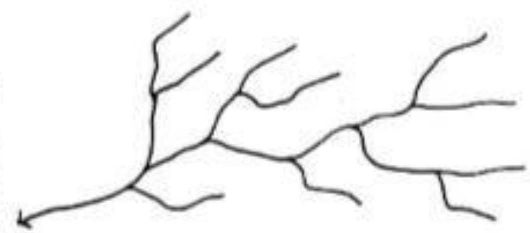
Topography

Flat table rocks

Sandstone deposits in arid climates are resistant to the forces of weathering and form dominant formations in the landscape. Fracture or joint patterns, having the appearance of rectangular blocks, can be readily observed since there is little soil cover. Cliffs may occur where sandstones overlie weaker sedimentary rocks, and wind erosion and blowing sand may modify these vertical elements, rounding and carving them into streamlined shapes. If the beds are flat, the hilltops tend to be of equal elevations.

Drainage

Angular dendritic



In arid climates the lack of residual soil cover allows the joints in sandstone to have maximum control over the drainage pattern. Thus, it is usually an angular dendritic or even rectangular pattern, medium to coarse in texture. Many streams are intermittent, so large areas of no apparent drainage may be observed.

SEDIMENTARY ROCK: Shale and Similar fine grained sedimentary rocks

•Shales are the most common and wide spread sediments. They exhibit dark tones, a fine-textured drainage, and relatively closely and regularly spaced joints.

•Dark tone of shales is due to absorbed water (but it is impervious to it). As a result of very poor permeability no internal drainage develops on shales (or unconsolidated equivalents, clays).

•Erosion is intense, typical drainage pattern is closely spaced tree-like (dendritic), and when steepsloped and silty, is dendritic-parallel. Gullies in shales are long, more open with more gentle gradient than in sandy beds.

•In most places shales are interbedded with more or less sandy beds or sandstone. Sand content influences the drainage pattern. Strike controlled subsequent pattern may form. Faulting can rarely be observed in shales, because the fissure is soon closed and joined together by clay.

Sandstone Humid & Arid (Way ,1973)

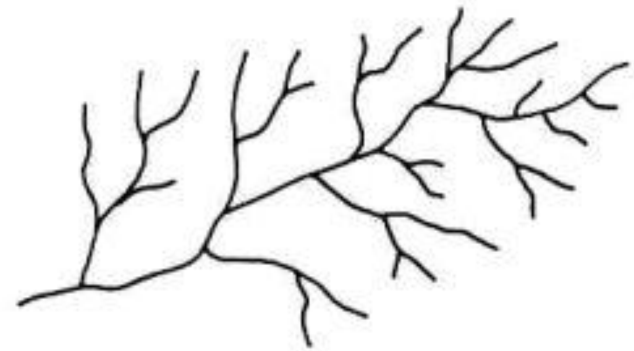
Topography

Soft Hills

A smooth, sag-and-swale topography occurs, appearing as soft hills and mounds. Sharp breaks in slopes are neither common nor stable. The attitude of the bedding layers does not affect the appearance of the topography, and it is difficult to observe bedding planes, because of the deep soil profiles found in this climatic zone.

Drainage

Dendritic: Medium to fine



The soft materials exert no control over the drainage system, allowing a medium to fine dendritic pattern to develop freely. No angularity is found, and tributaries enter streams of the next order at acute angles.

Arid

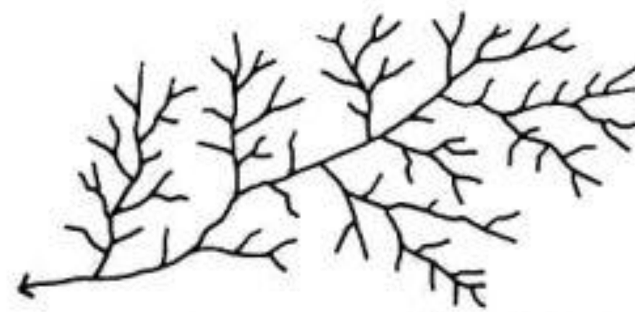
Topography

Steep sideslopes

The topography is characterized by steep sideslopes and is highly dissected, reflecting the soft nature of the rock. Ridgelines are rounded, and faint bedding planes may be observed along the sides of hills.

Drainage

Dendritic: Fine



Shale regions show a very finely dissected pattern, dendritic in nature, reflecting rapid runoff and the impervious nature of the shale.

SEDIMENTARY ROCK: Very coarse grained rocks (conglomerate and breccia)

- These seldom show a great degree of permeability. Permeability depends on the grade of cementation and the type of solubility of the matrix.

- They are usually lenticular and almost always associated with sandstones.

- It is difficult to separate conglomerates from sandstones on the basis of drainage since they differ from sandstones only in the size of fragments.

- In deserts the surface of beds are disintegrated to gravel deposits giving a rough surface and darker tone (shadow effect).

- Cataclastic breccias and conglomerates occur in crush zones.

SEDIMENTARY ROCK: Limestone

•Limestones have light tones with dissolution forms like rills, channels, trenches and sinkholes.

• Dolomite is less soluble than limestone. Different types of limestones have sinkholes different size and distribution.

•Fractures are broadened by solution.

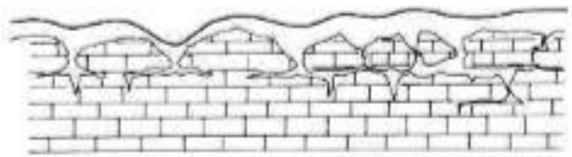
•The drainage is internal. Marls are light in tone, have drainage patterns similar to shales depending on their clay content. In tropical regions they support dense forest vegetation.

Limestone
Humid
&
Arid
(Way ,1973)

Humid

Topography

Karst



Chemical weathering dissolves the rock along jointing and bedding planes, thus developing a collapsing surface of sinkholes and depressions known as "karst topography." The ground surface is undulating and forms indistinct transitional boundaries with other, associated sedimentary rocks. Sinkholes are rounded in flat-laying beds, elongated in tilted beds.

Drainage

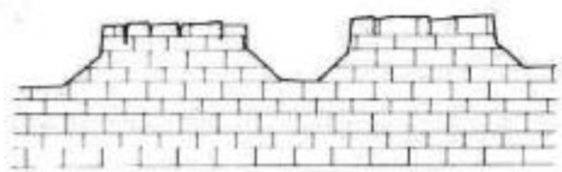
Internal

The solution cavities within the rock and the high permeability of the residual soil cause humid limestone regions to be drained internally, leaving little water to be collected in a surface water system. Major streams follow angular alignments of old jointing patterns. Typical sinkholes average 10 to 40 feet in depth and 50 to 500 feet in width.

Arid

Topography

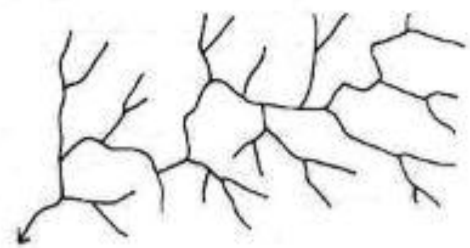
Table Rocks



Since little moisture is available for chemical weathering in arid climates, the limestones present erode very little. Pure, thick limestone deposits form cap or table rocks, developing none of the characteristics associated with karst topography.

Drainage

Angular dendritic: Medium to fine



The surface drainage system is well developed (karst topography does not exist in arid climates.) The pattern is very angular, following jointing alignments in the bedrock, and is medium to fine textured. All but major streams are intermittent.

Tropical limestone, dolomite or cherty limestone (humid and arid) (Way, 1973)

Tropical limestone

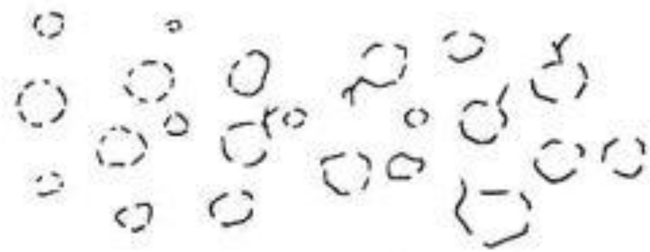
Topography

Tropical karst

A very rugged, tropical karst topography is developed with conical hills and large depressions (up to 1000 feet deep and 1 mile in diameter).

Drainage

Internal

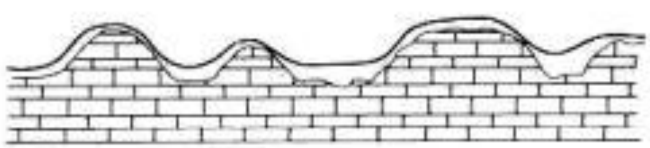


All drainage is internal through the highly permeable soil and bedrock.

Dolomitic or cherty limestone

Topography

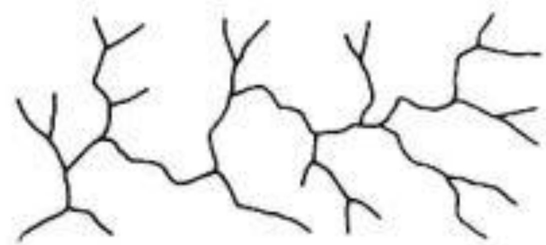
Hill and valley



These areas are similar to sandstone in appearance, with little or few solution cavities or sinkholes. Nodules of chert can be observed in open fields.

Drainage

Angular dendritic: Medium



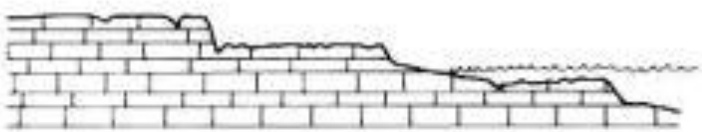
A dendritic pattern of medium texture is characteristic in humid climates, with angularity reflecting jointing control.

Tropical limestone, dolomite or cherty limestone (humid and arid) (Way, 1973)

Coral

Topography

Terraced



Elevated reefs appear flat, with a steep, jagged cliff along the seaward edge. Sea-level reefs either encircle (barrier type) or appear as a white, discontinuous fringe along the edge of an island.

Drainage

Internal

Coral is very porous and spongy and therefore does not develop either a surface drainage pattern or sinkhole topography.

Thin bedded sedimentary rocks (humid and arid) (Way, 1973)

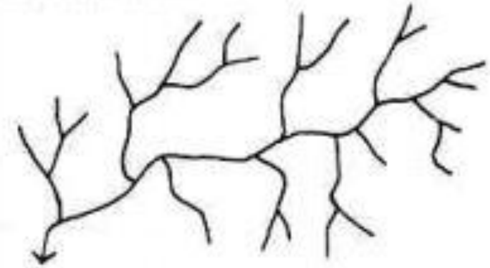
Topography

Uniform slopes

Thin, interbedded sedimentary materials do not have terraced slopes, although faint banding may be observed. Sandstones have steeper slopes than shale or limestone masses. Hilltops throughout such regions have approximately the same elevations.

Drainage

Dendritic: Medium

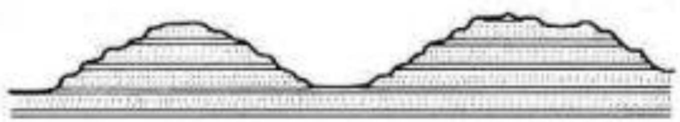


The drainage pattern in thin, interbedded sedimentary rocks is dendritic and of medium texture, similar to shale drainage in humid climates. The presence of shale in the interbedding, however, increases surface runoff, resulting in a more dissected topography.

Arid

Topography

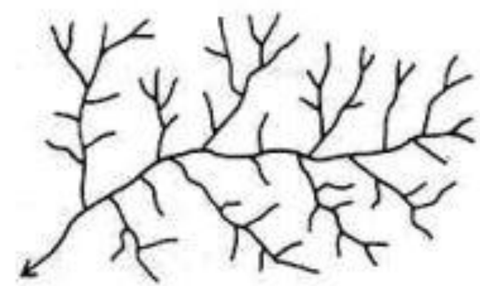
Minor terracing



The well-dissected topography shows very narrow terracing, following hillside contours. Sandstones and limestones have vertical cliffs, while shale forms more gradual slopes.

Drainage

Dendritic: Fine

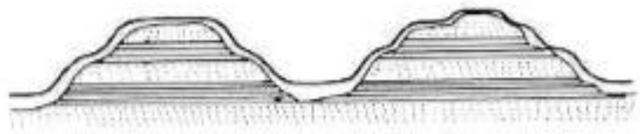


Interbedded sedimentaries in arid climates form dendritic patterns with fine textures. If shales are present, they provide impervious layers which increase surface runoff and dissection.

Thick bedded sedimentary rocks (humid and arid) (Way, 1973)

Topography

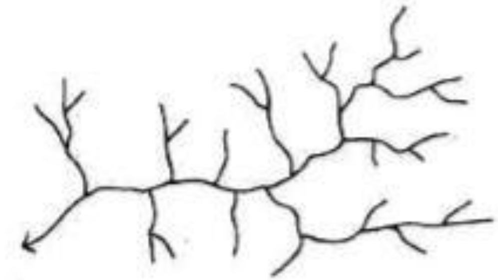
Terraced hillsides



Hillsides in thick, interbedded sedimentary rock regions appear terraced; hilltops are at the same elevations. In sandstone-shale combinations the more resistant sandstone remains as a cap rock with steep sideslopes; the underlying shale has a more gradual sideslope. In limestone-shale combinations the limestone occupies the hilltops and uplands and may have solution features.

Drainage

Dendritic: Medium to coarse



The drainage pattern is commonly a medium dendritic system and tends to be controlled by the most resistant rock in the series, commonly sandstone. Thick, limestone cap rocks may be characterized by solution sinkhole topography, with major streams following angular alignments.

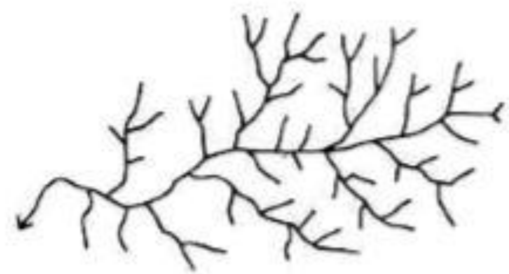
Topography

Terraced hillsides

As in humid climates, hillsides appear terraced and hilltops are at the same elevations. The more resistant rocks occupying table rock positions, such as limestone and sandstone, maintain steep escarpments. Shale, usually underlying more resistant rock, is characterized by more gradual slopes.

Drainage

Dendritic: Medium to fine

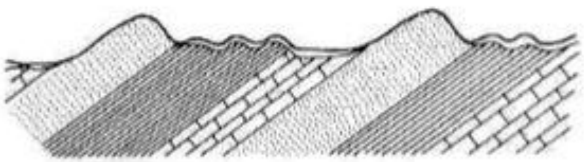


A dendritic drainage system of medium to fine texture is common, reflecting the nature of the upper strata of bedrock. Limestone does not develop solution cavities but may control su,face drainage and valley alignments through its angular jointing system.

Tilted sedimentary rocks (humid and arid)
(Way, 1973)

Topography

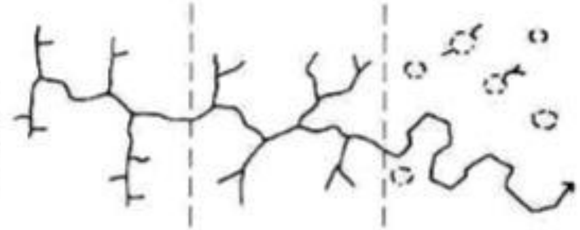
Parallel ridges



In sandstone-shale combinations sandstone forms resistant, sharp, parallel ridges; shale forms soft, rounded hills in the lowlands. Limestone-shale forms low, rounded hills in shale formations, and karst topography with rounded or oval sinkholes in limestone areas. Thin beds give the ridge topography a saw-toothed appearance.

Drainage

Trellis and dendritic

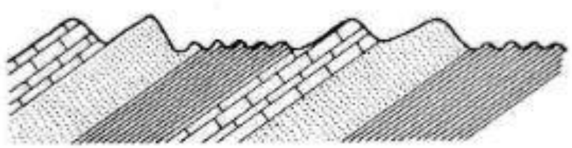


In most situations a trellis drainage pattern of medium to fine texture exists, controlled by the tilted rock structure. Interbedded limestone and shale may have a dendritic pattern and solution topography with internal drainage. Stream courses are generally located in shale lowlands; if they are located in limestone lowlands, some angularity should occur as a result of jointing influence.

Arid

Topography

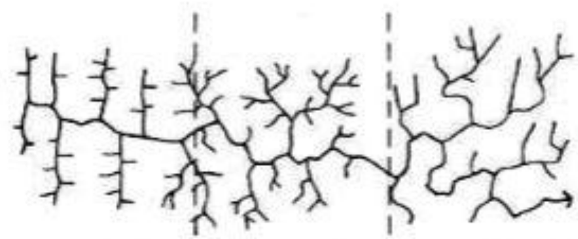
Saw-toothed ridges



Ridge crests in arid climates are much sharper, and the ridges develop a saw-toothed appearance. The V's formed between the teeth point down the dip of the rock strata. Sandstone and limestone both form resistant ridges; shale forms conical lowland hills. Thin beds give the ridges a finer saw-toothed appearance.

Drainage

Trellis: Fine



In arid climates tilted sedimentary rocks are identified by a trellis drainage pattern which is normally fine-textured. If there is a regional uniform slope, the trellis pattern may be modified, showing some parallelism.