AERIAL REMOTE SENSING & DIGITAL PHOTOGRAMMETRY

UNIT 10

Figure 1. 1:3000 Aerial Photograph (Reduced to 85%)

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Advantages and Limitations of Airphotos for Photogeological Analysis, Interpretation and Terrain Mapping

Advantages

The most familiar type of black and white airphoto film is sensitive to all visible radiation - so-called *panchromatic film.*

The film provides excellent spatial resolution and has a high information content.

Stereo cover is the most valuable aid for geological interpretation.

Airphotos cost relatively little, and are readily available from numerous repositories of existing survey collections.

Multitemporal record of site changes are frequently available.

Advantages and Limitations of Digital Satellite Imagery for Photogeological Analysis, Interpretation, and Terrain Mapping

Worldwide coverage gives access to all countries.

Long term repetitive coverage can provide cloud free images of various seasons.

The synoptic view provides initial appreciation of a regional geological context.
Landsat data are free, in the public domain.

Digital terrain models (DTMs) at 30 m and 15 m resolution are available for many areas.

Sub-metric panchromatic resolutions are available on specific satellites.

A zoom (monoscopic) of a high resolution image can, in some instances, reveal details not resolved in the airphotos.

The ability to filter, enhance contrast and apply transformations to maximise geological information content (*spectrolithologic* mapping).

Interpretation strategies

- Field observation.
  - Required when the image and its relationship to ground conditions are imperfectly understood
- Direct recognition.
  - Interpreter derives information directly from inspection of the image
- Inference
  - Based on visible features can derive information about invisible features
  - Certain relationships and identify features

PHOTO INTERPRETATION KEYS & ELEMENTS

Two Steps:

1. Recording of the Observed Data:

Collection of Qualitative and Quantitative Information

2. Judging the Significance of the data:

The Collected Qualitative and Quantitative Data are to be Processed

To find out the significance of Geology of the Area.

This is Useful

- To Establish Geological History
- Its Geomorphic Evolution
- Tectonic Relationship of Folds, Faults and Intrusive Bodies to Country Rocks and amongst themselves.
- The data to be sorted out to suit to the requirements.

Interpretation Key

Valuable Aid and helps to evaluate the Information in an organized and consistent manner

It provides guidance about the correct identification

Key Sets

Selective Key	-- Photos + Text
Elimination Key	-- Step By Step (General To Specific)
Dichotomous Key	-- Two Alternatives

Convergence of evidence approach:

- Inductive (or) deductive approaches

In inductive method – the general condition of an area is inferred from a particular recognized object, for example

- A volcanic cone – indicate a volcanic area
- Swarm of sand dunes – desertic / arid region.

In deductive method – a particular object is identified based on the general conditions prevailed there, for example:

- Glaciated region – identify esters, trumlins, etc.

The ability of photo-interpreter to carry out reliable interpretation depends on several factors, such as

- The quality of aerial photographs
- Types of viewing instruments
- Working conditions and
- The personal acuity of photo-interpretation.

The last factor is the most important one and it differs from person to person in Photogeologic interpretation and

Knowledge of Geomorphology, Stratigraphy, Lithology, Structural Geology, Pedology, Vegetation, Groundwater Geology

is Essential.

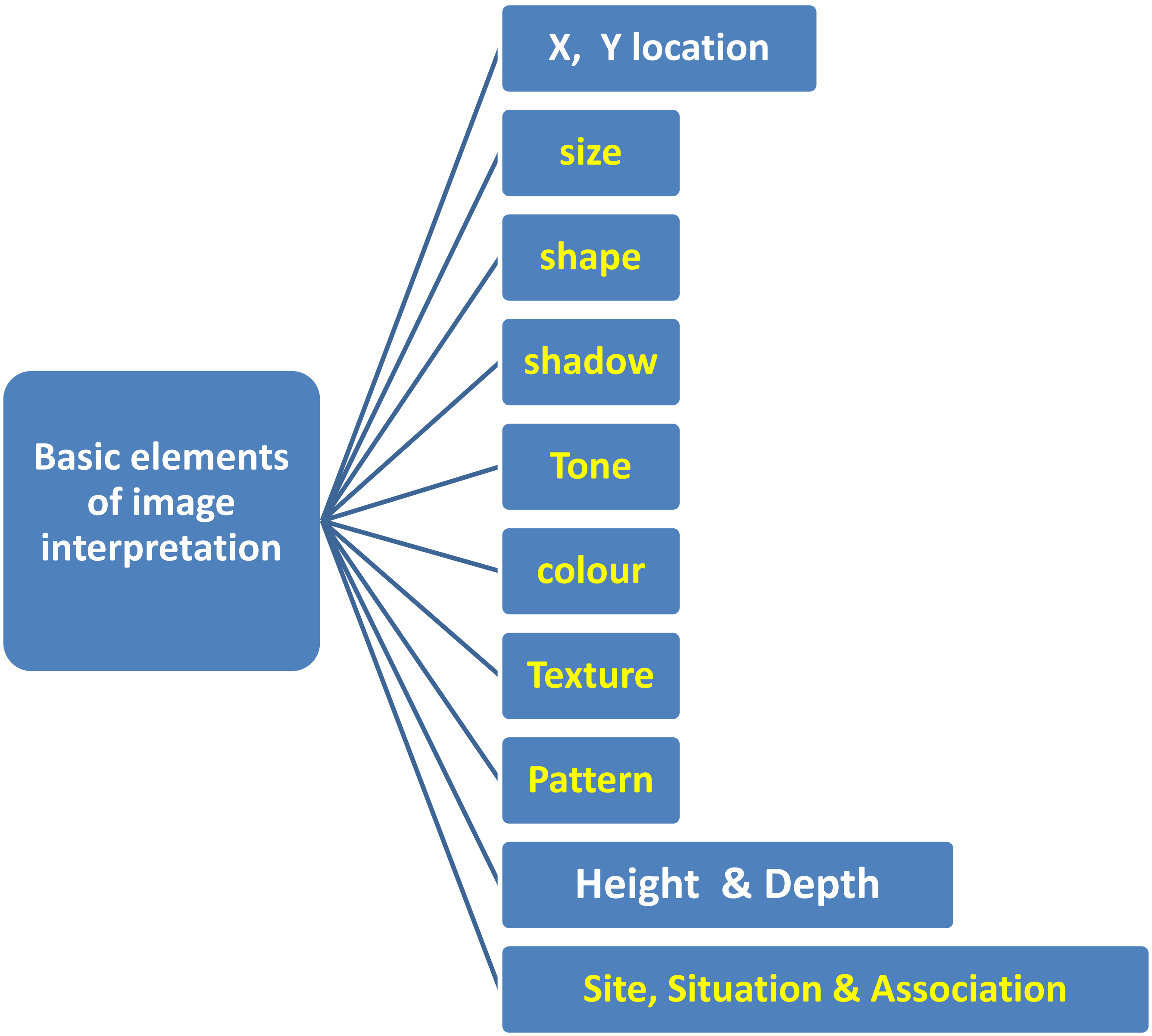
Further a specialized knowledge in Specific subjects helps in making interpretation of specific fields such as

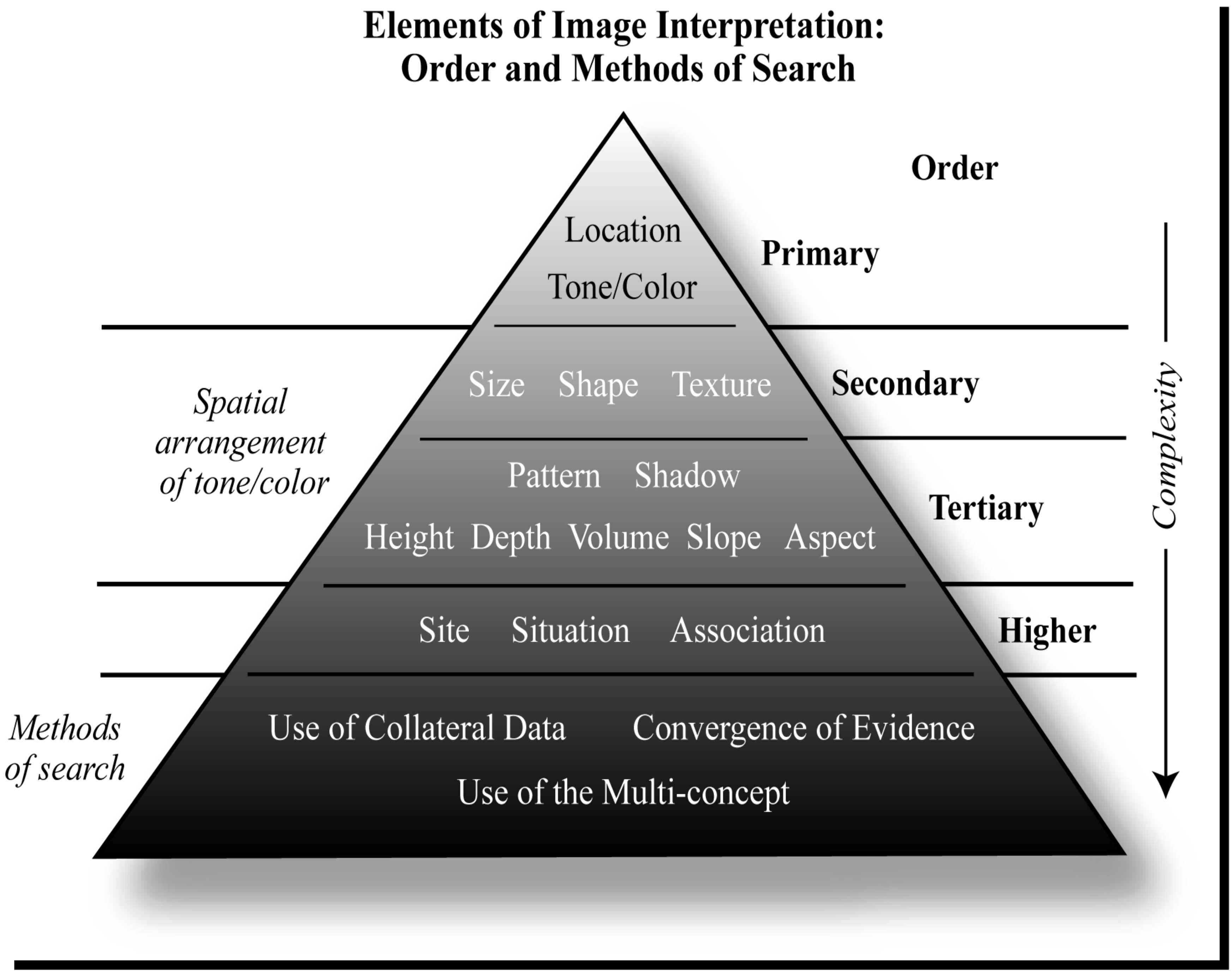
- **Morpho-tectonics**
- **Engineering geology**
- **Ground-water surveys**
- **Mineral prospecting**
- **Terrain evaluation**
- **Landuse planning, etc.**

Principles of Analysis and Interpretation of Geounits and Variants in Airphotos and Digital Satellite Imagery

LOCATIONAL	Provides regional geological context, existing documentary and cartographic information of the regional terrain of a study area and anticipation of presence of specific geounits.
SPECTRAL	***Tonal density*** - the direct or relative brightness of a surface aids discriminant grouping of exposed geounits, and can be an indicator of permeability or moisture status of surface materials.
	Colour **-** hue, saturation and density aid correlation to specific geounits.
	Texture **-** relative relief roughness or smoothness of an image or photo sub-area is a geounit indicator.
SPATIAL	***Relief*** **-** three-dimensional stereoscopic grouping of slope steepness and orientation to sun aspect of a geounit. Shadowing relates to the geounit morphology and solar elevation and azimuth. Relief reflects the origin and composition of geounits and the erosional processes that have and are acting upon them. ***Drainage*** **-** variable channel densities and patterns are indicative of topographic, lithological and structural components of geounits. ***Geolineaments*** **-** the location, spacing, azimuth and group relationships of anomalously straight continuous or discontinuous traces of drainage channels, vegetation or relief are indicators of crustal and inter or intra-unit fracture or displacement. ***Pattern*** **-** spatial repetition or macro-arrangement and distribution of similar phenomena, e.g. drainages, colours, or a grouping of unlike features (e.g. lineaments and relief or colours). Similar patterns are frequent indicators of similar geounits; unlike patterns suggest unlike geounits.
ASSOCIATIONAL	Correlations of any two or more criteria that characteristically occur together in functional relationships lead to a convergence of evidence that can predict the occurrence of a specific geounit.

Basic elements of image interpretation





Elements of Image Interpretation:
Order and Methods of Search
Order
Location
Tone/Color
Primary
Size Shape Texture
Secondary
Spatial arrangement of tone/color
Pattern Shadow
Height Depth Volume Slope Aspect
Tertiary
Site Situation Association
Higher
Methods of search
Use of Collateral Data Convergence of Evidence
Use of the Multi-concept
Complexity

Tone

The tonality of aerial photograph is influenced by the following factors:

i. The light reflectivity of the object
ii. Angle of reflected light
iii. The geographic latitude
iv. Type of photography and films sensitivity
v. Light transmission of filters
vi. Photographic processing

- Band of EM spectrum recorded by RS system may be displayed in shades of grey ranging from black to white
- Tone:-
  - continuous grey scale varying from white to black
  - It refers to relative brightness or colour of objects in an image

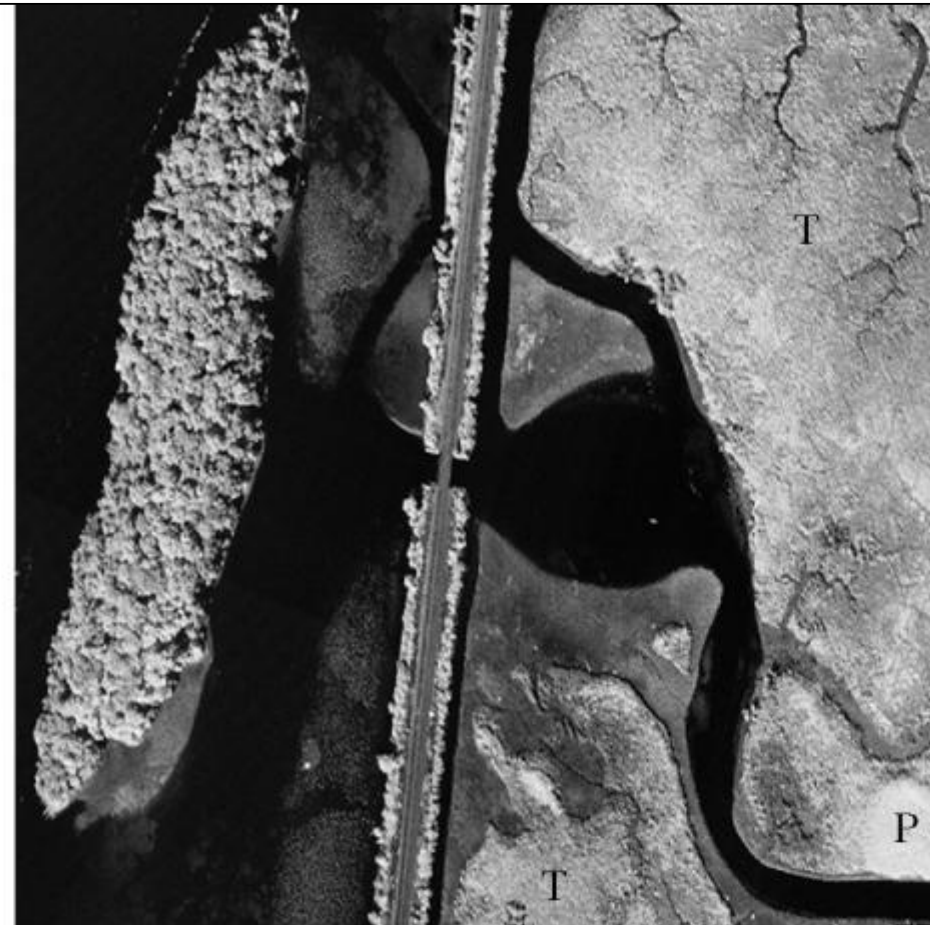
Note:- Humans differentiate 40- 50 individual shades of grey RS image

- Colour
  - more convenient for the identification of object details
- Texture
  - Characteristics placement & arrangement of repetitions of tone or colour in an image
  - Visual impression of roughness or smoothness of an image region

Obtaining Knowledge Beyond our Human Visual Perception

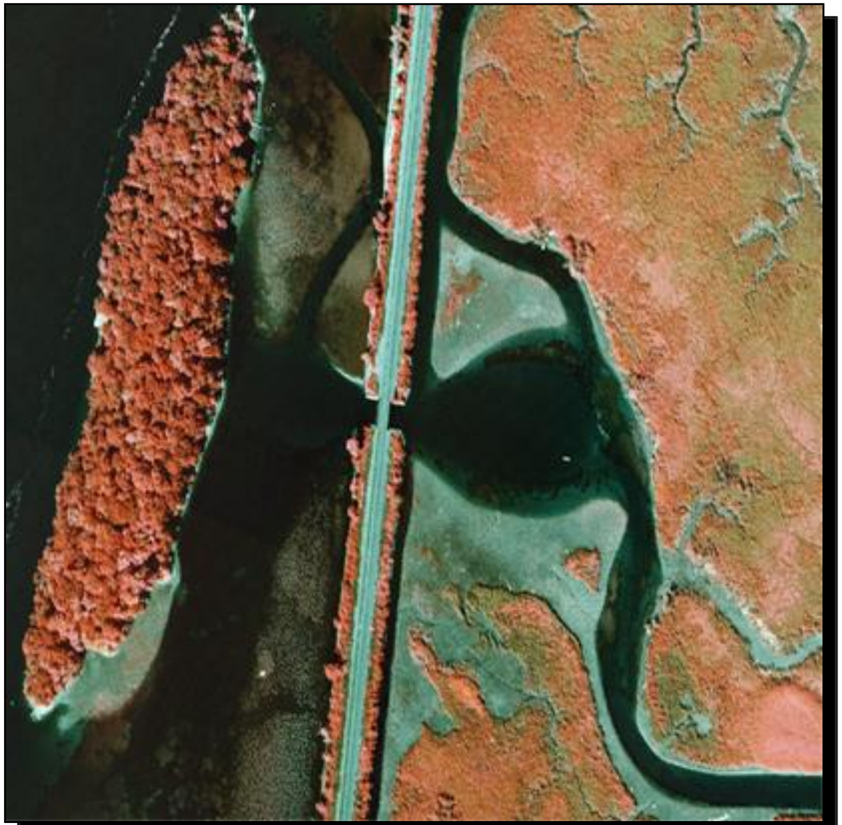
Panchromatic

Black and White Infrared



Aerial Photography

Normal Color

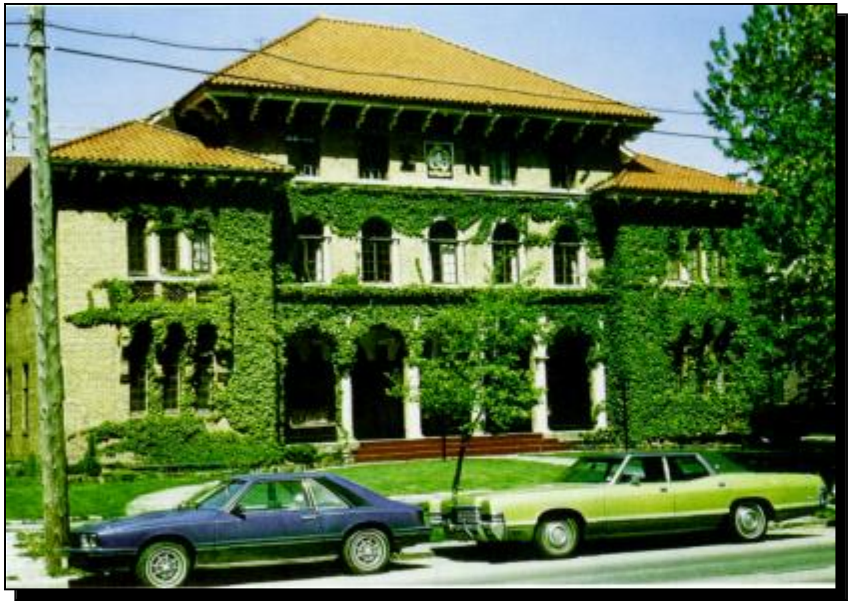


False-color Infrared Using Wratten #12 filter

Different kinds of image

- Panchromatic image
- True-color image
- False-color image

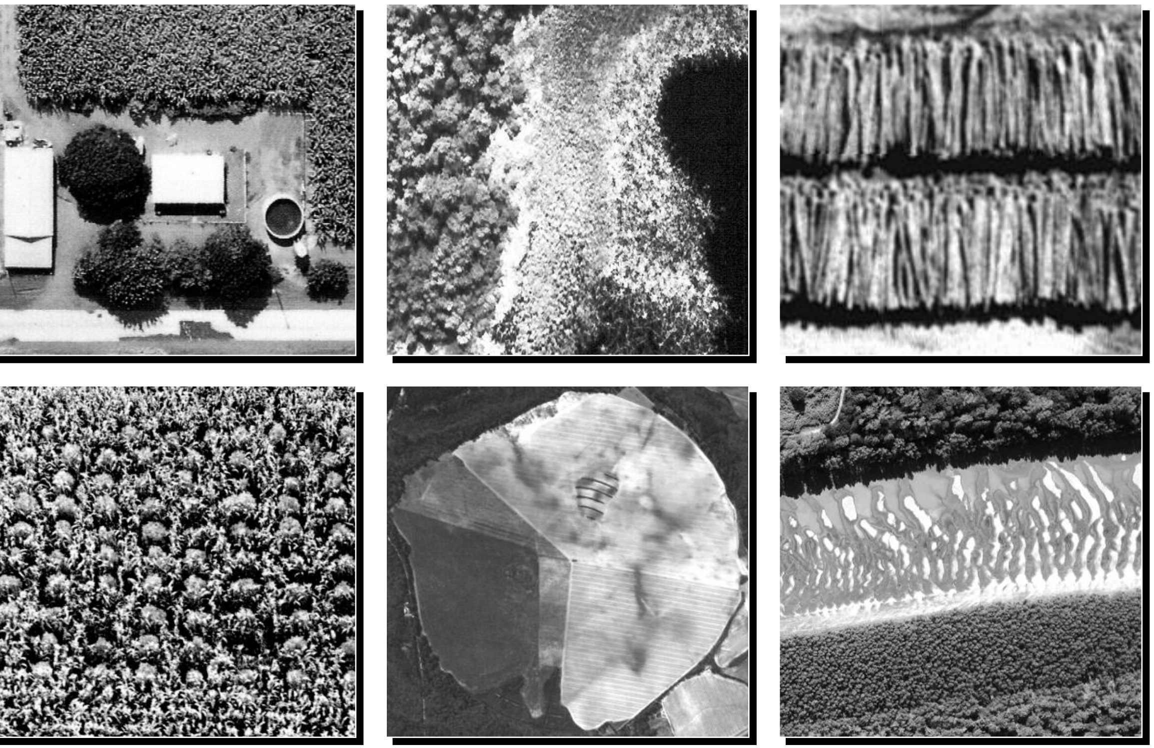
Terrestrial Photography



Normal Color

False-color Infrared
Using Wratten #12 filter

Photographic Texture



The frequency of change and arrangement of tones in a photographic image and it is produced by an aggregate of unit features too small to be clearly recognised individually on an aerial photograph. And can be classified as 1) Coarse, 2) Medium, 3) Fine, 4) Smooth, 5) Rough, 6) Rippled, 7)Mottled, 8) Speckled, Criss-Cross, Etc.

Texture

- the physical characteristics of an object will change the way they appear
- Smooth - pasture, bare fields, water, etc.
- Coarse - forest

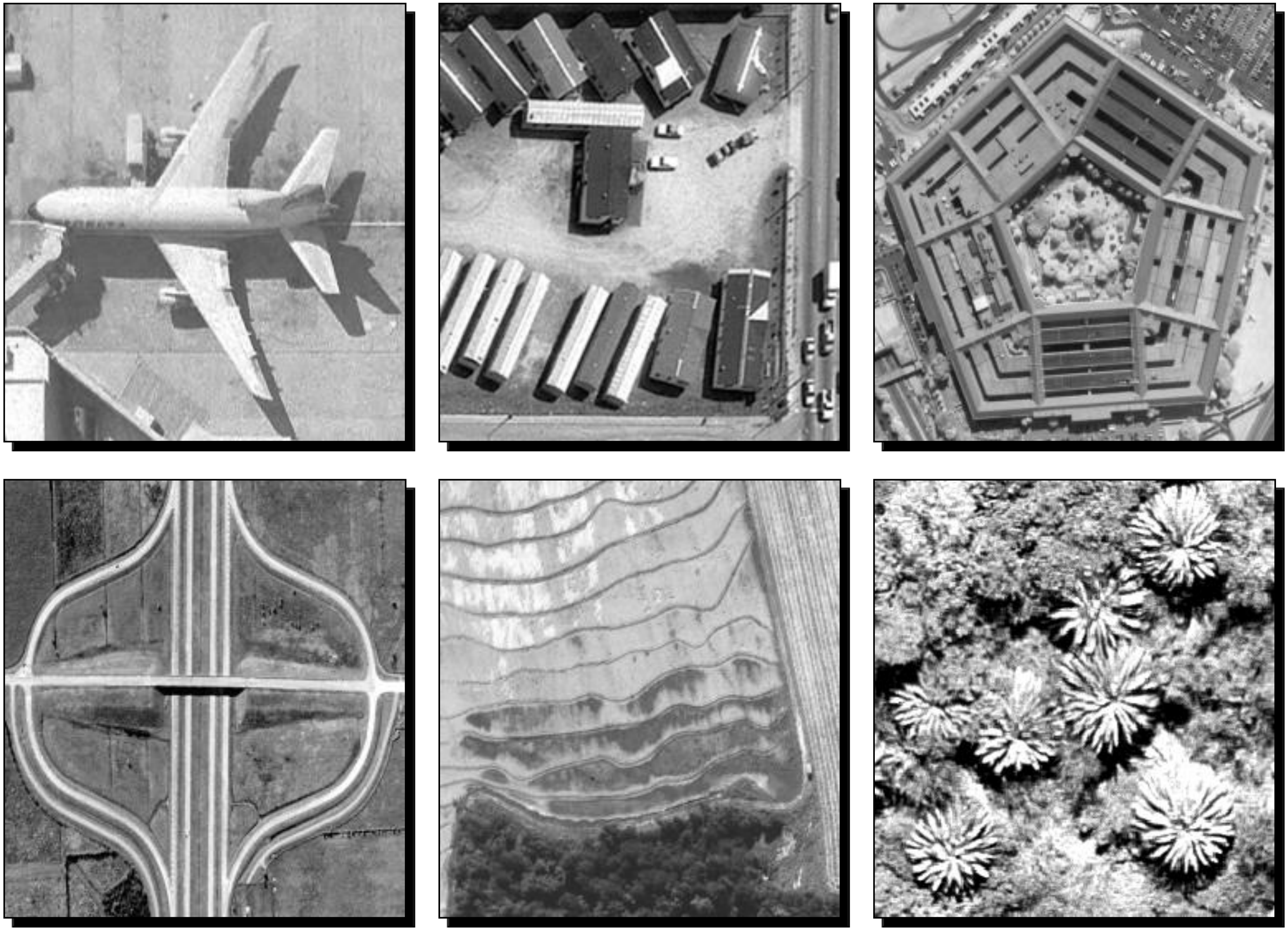
Photographic elements - Shape

- Shape of an object is described as the geometric form represented form represented on an image
- Regular shapes are signs of man-made objects
- Irregular shapes with no distinct geometrical pattern are signs of a natural environment

The following Geological features can be identified with the help of their shapes

Circular – Craters, Ring Dykes
Oblong / Elongated – Doubly Plunging Syncline / Anticlind
Linear – Dyke, Sill
Ovular – Aureole, Doubly Plunging Folds
Rectangle / Diamond – Fracture Swarms
Crescent - Dunes
Cone – Volcano, Alluvial
Fan - Alluvial
Zig-Zag (Ridge And Valleys) – Plunging Folds
Annular – Domes
Concentric- Basins
Irregular – Igneous Body

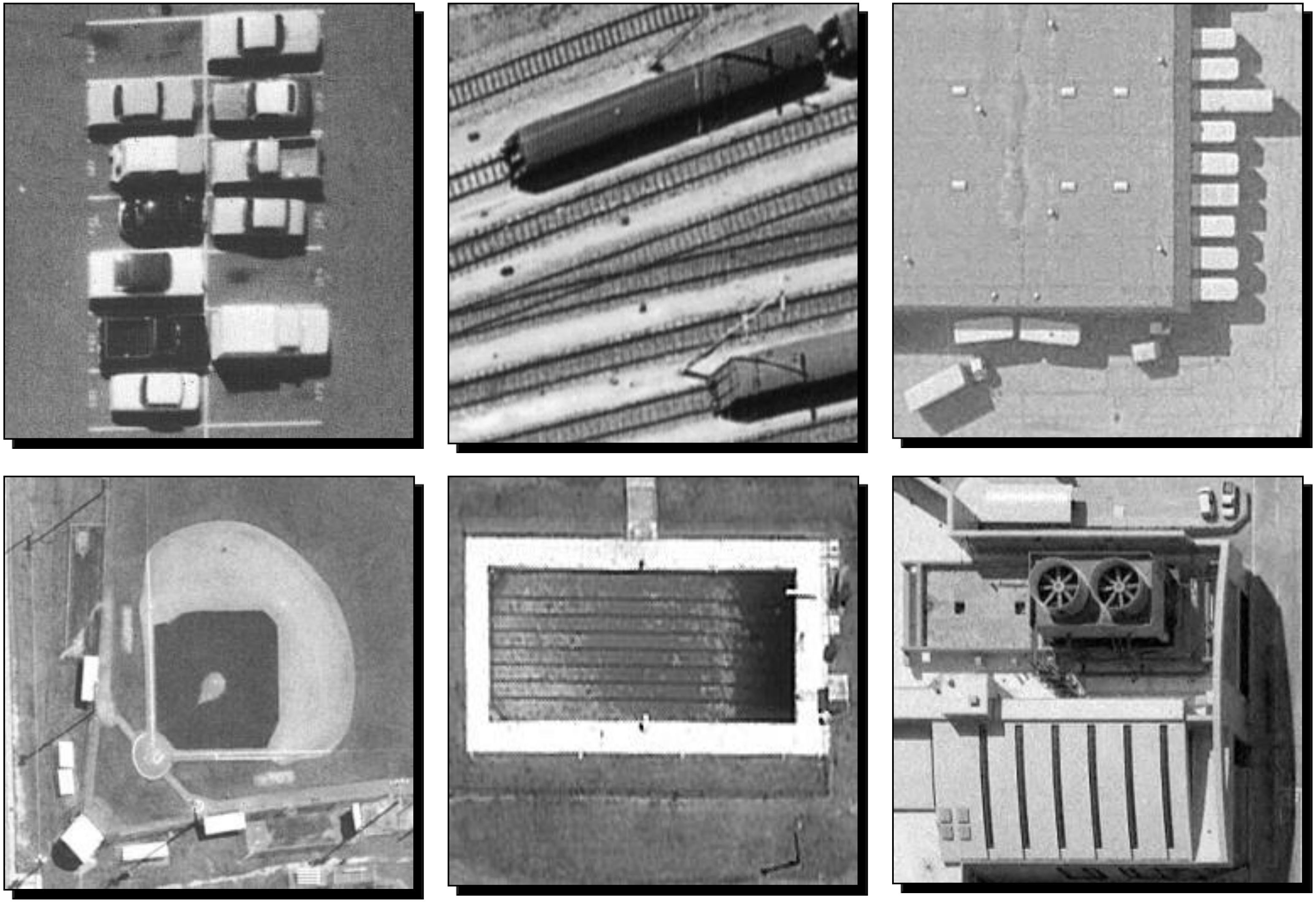
Elements of Image Interpretation - Shape



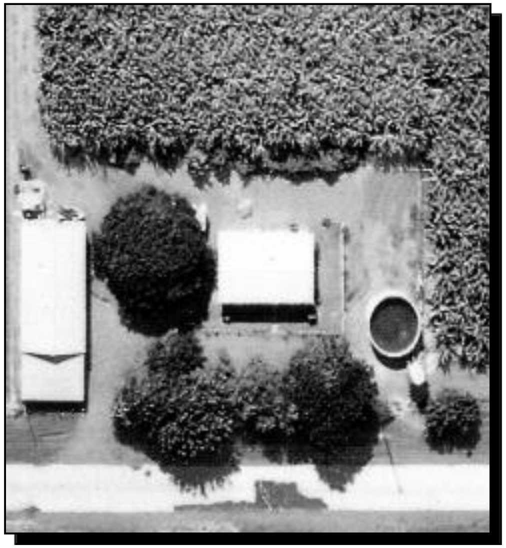
Size

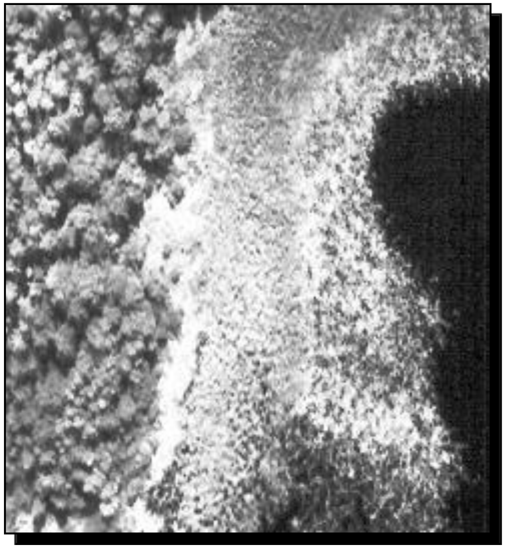
- **Size of objects in an image is a function of scale**
- **Proper photo scale selected depending on the purpose of interpretation**
- **Most commonly measured parameters:- length, width, perimeter, area and occasionally volume**
- ***Relative size* determined by comparing the object with familiar nearby features**
- ***Absolute size* refers to the use of the aerial image to derive measurements**

Elements of Image Interpretation - Size

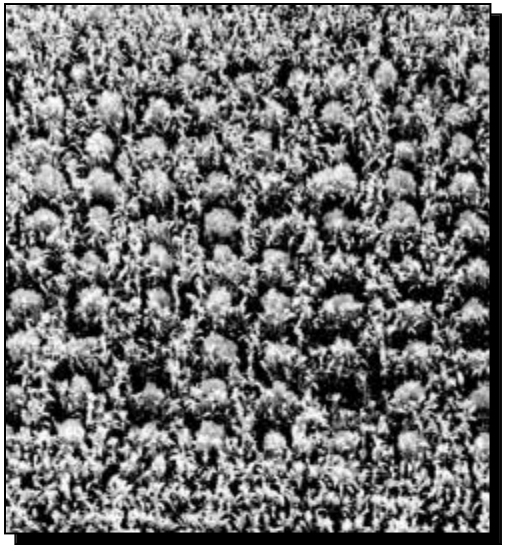


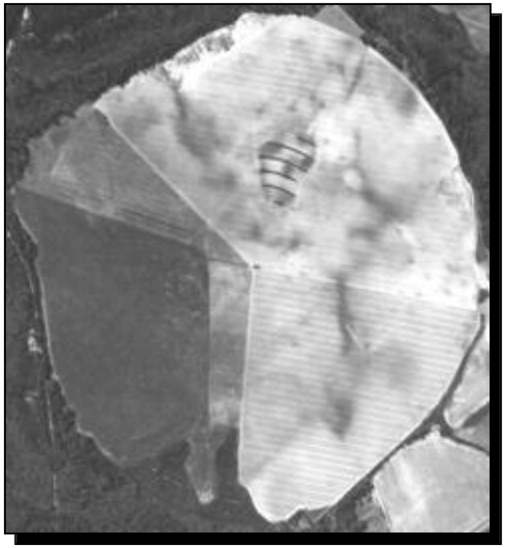
Elements of Image Interpretation - Texture

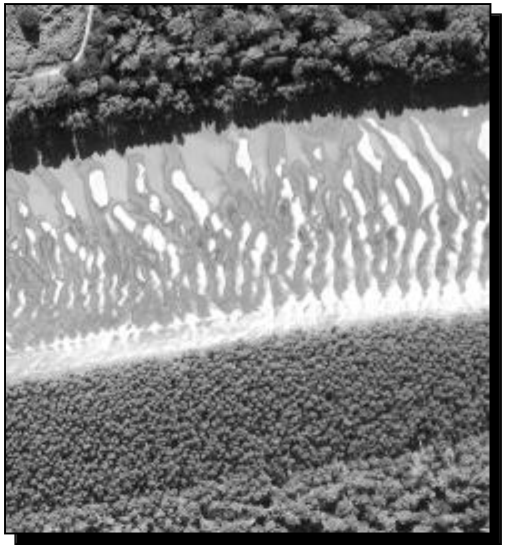




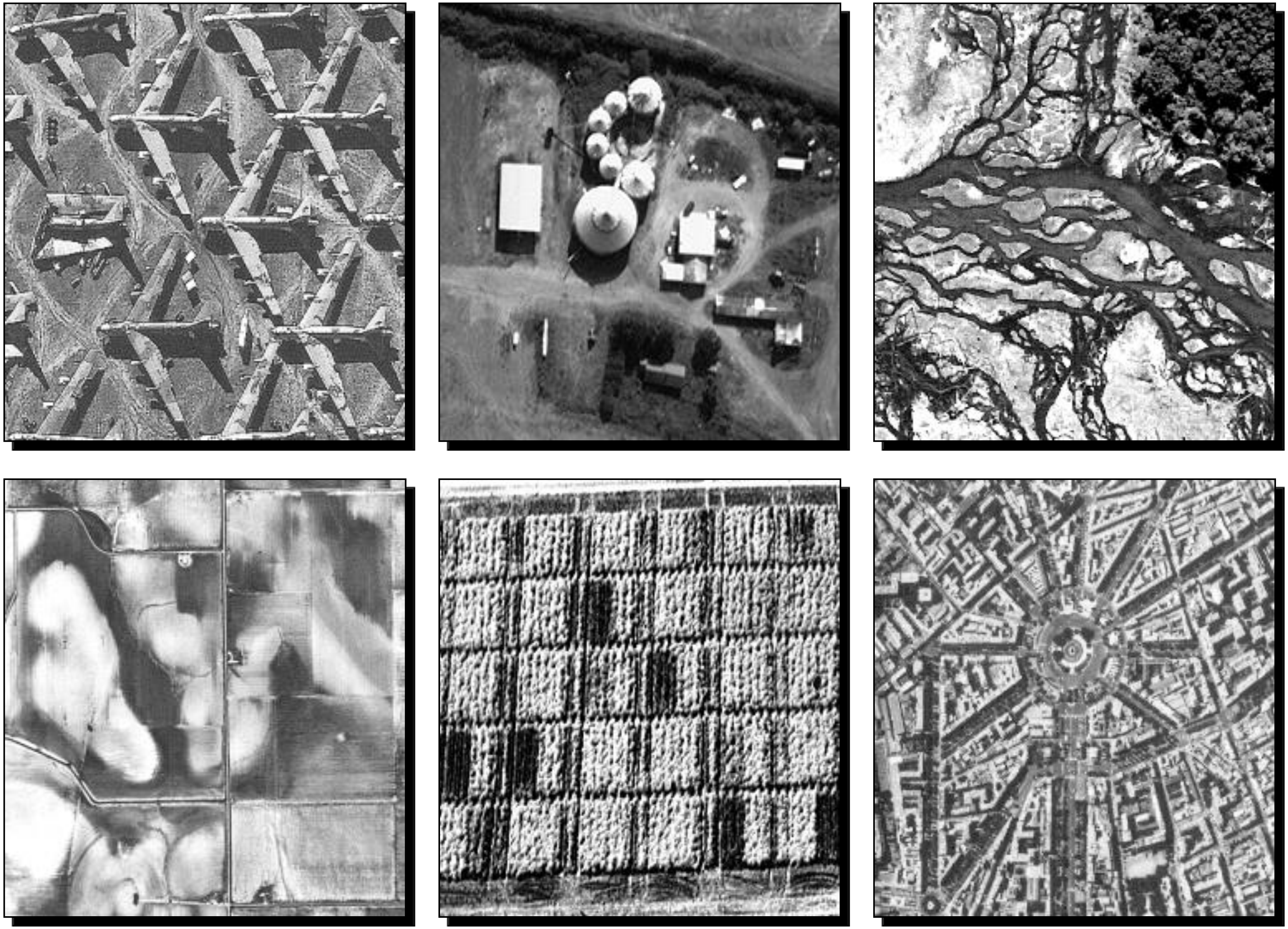
Refers to the variation in tone over a surface or the apparent roughness of the surface as seen in the photo Created by micro shadows in small irregularities in the surface.







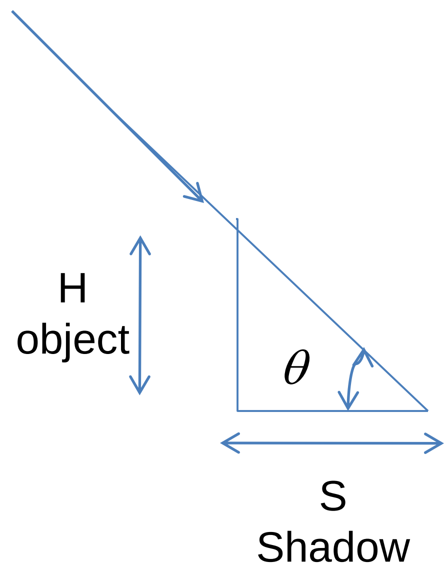
Elements of Image Interpretation - Pattern



Pattern - Orderly man-made patterns of fields, orchards, and roads
Random natural patterns of river and forest

Shadow

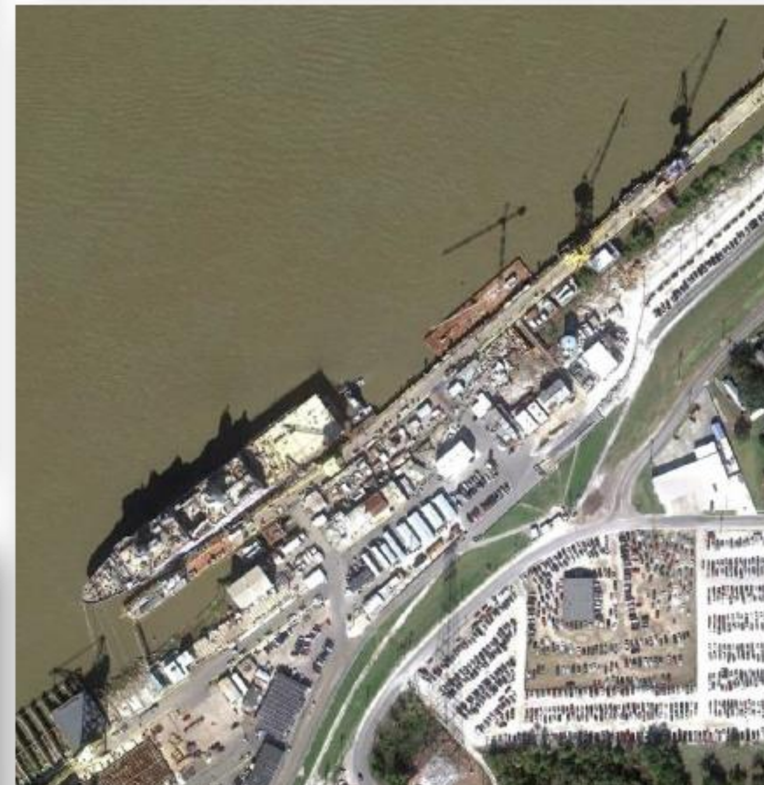
- Shadow – usually a visual obstacle for image interpretation
- Gives height information about towers, tall buildings Refers to large distinctive shadows that revealed the outline of a future as projected onto a flat surface.
- Depends on the nature of the object, angle of illumination, perspective, and slope of the ground surface



$$\tan\theta = \frac{H}{S}$$

Important Characteristics Used in Interpretation

Shadows… Relative sizes of buildings & ID of other features



Fotoğraf: George Steinmetz

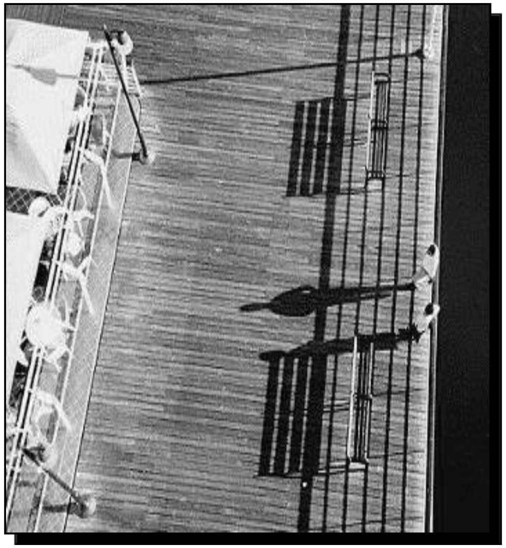
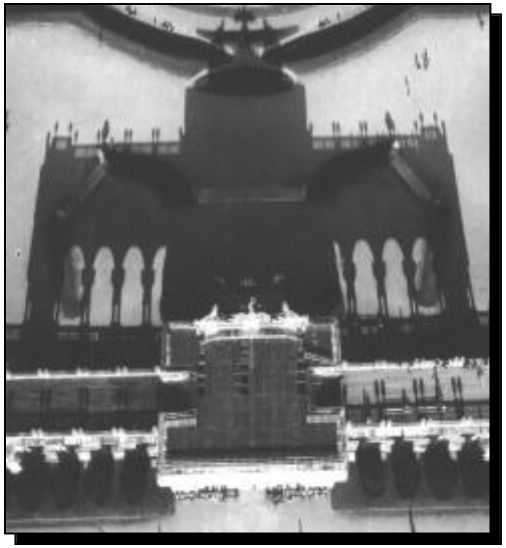
Dev Develer

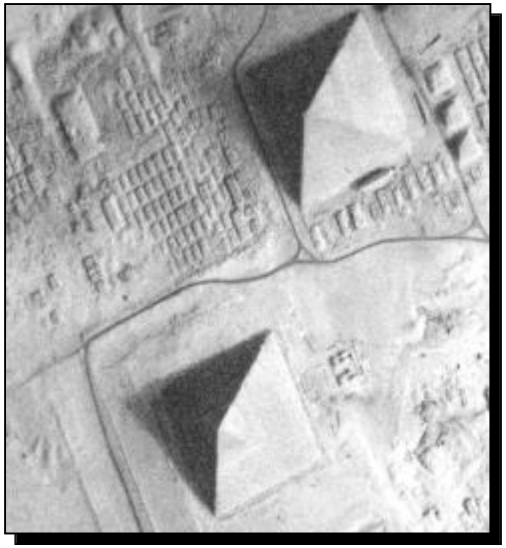
National Geographic Türkiye, Şubat 2005

Shadow: provides information about the object's height, shape, and orientation (e.g. tre species)

Species?

Elements of Image Interpretation - Shadow



Elements of Image Interpretation - Site, Situation and Association

Refers to a futures position with respect to topography and drainage. Some things occupy a distinctive topographic position because of their function

Sewage treatment facilities at the lowest feasible topographic position.
Power plants located adjacent to water for cooling

Association refers to the distinctive spatial interrelationships between features. Schools often associated with athletic fields.
Large parking lots often associated with malls

Association & Location .....plus all the other clues

Industrial? What?

- Piles of black stuff
- RR tracks
- Electrical features
- Water port w/slip
- Large building
- Large smoke stack

Another puzzler

Convergence of Evidence

Geotechnical / Geomorphic Elements:

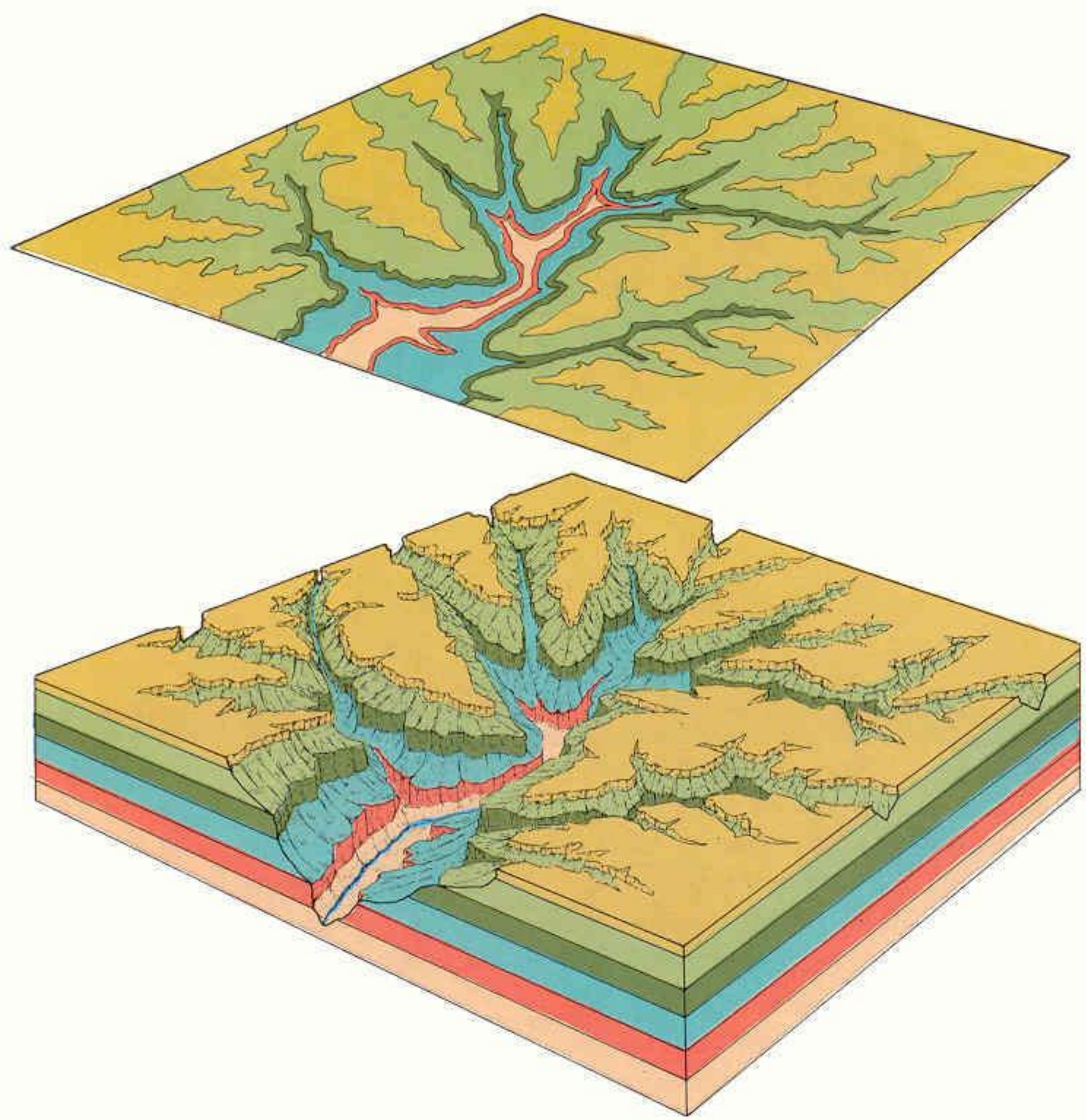
Recognition of Landforms

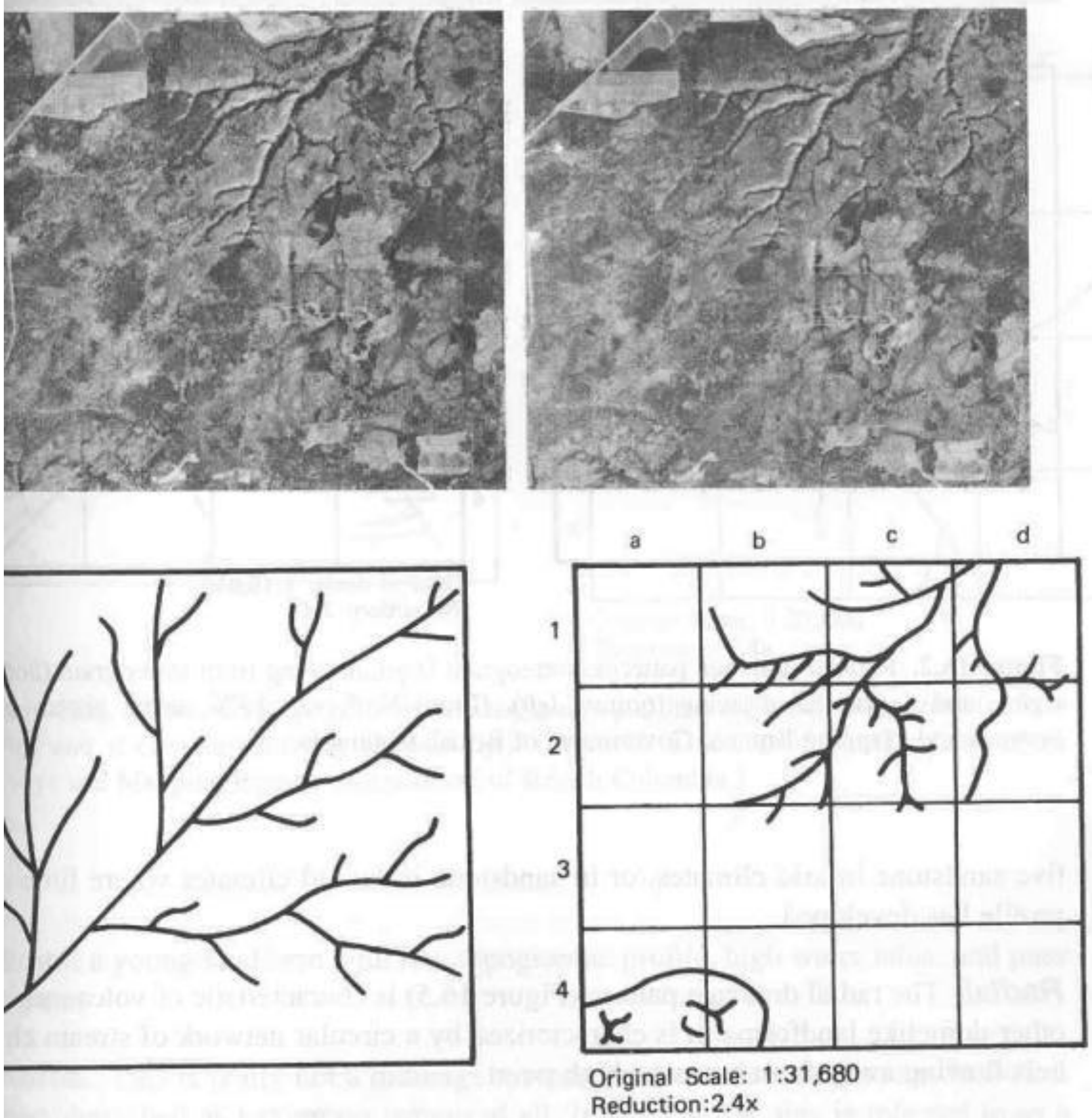
There are seven basic pattern elements that the photo interpreter can use to identify and categorize landforms and landscapes such as

- Topography
- Drainage Pattern
- Drainage texture
- Gully types
- Photo tone and photo texture
- Vergetational patterns
- Land use pattern

An analysis of topography and drainage patterns gives the much information about the underlying geologic structures, parent soil materials and erodability of a particular area

Dendritic drainage patterns characteristically develop on horizontal strata and cut canyons or valleys in which progressively older rock units are exposed. As a result, the map patterns of horizontal strata parallel stream valleys and produce a dendritic pattern on the geologic map





ure 16.1. Dendritic drainage patterns: stereogram (*top*) drawing from stereogram (*bottom ht*), and a classical drawing (*bottom left*). (From N. Keser, 1976, aerial photos from veys and Mapping Branch, Government of British Columbia.)

Trellis: Trellis drainage pattern are modified dendritic forms where secondary streams occur at right angles to the main stream with the tertiary streams at right angles to the secondary streams.

This type of pattern is typical in belts of tightly folded sedimentary rock

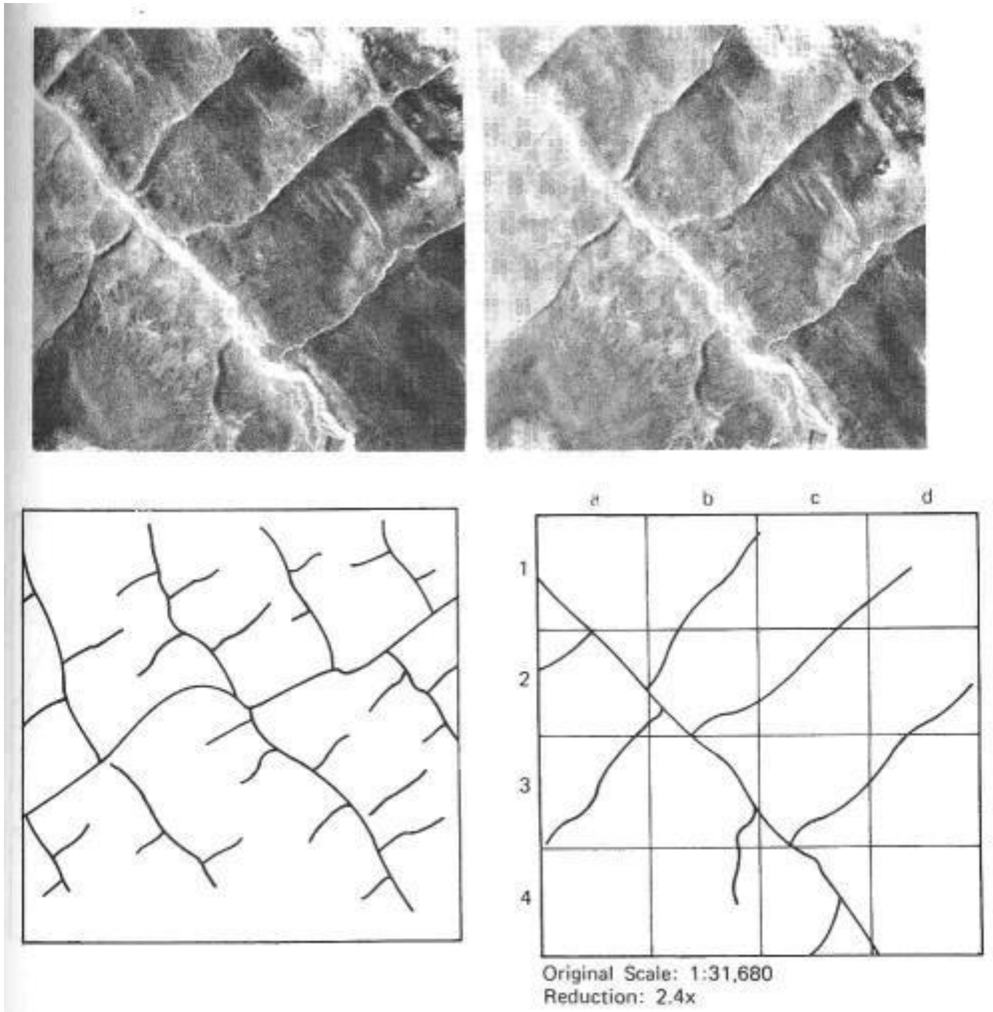
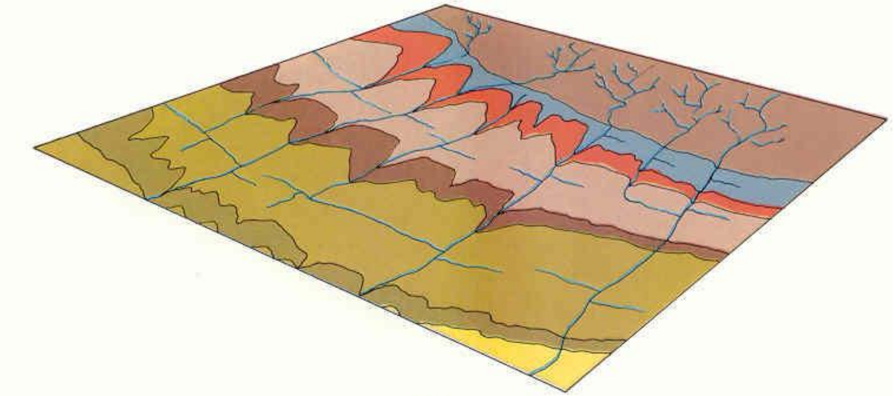
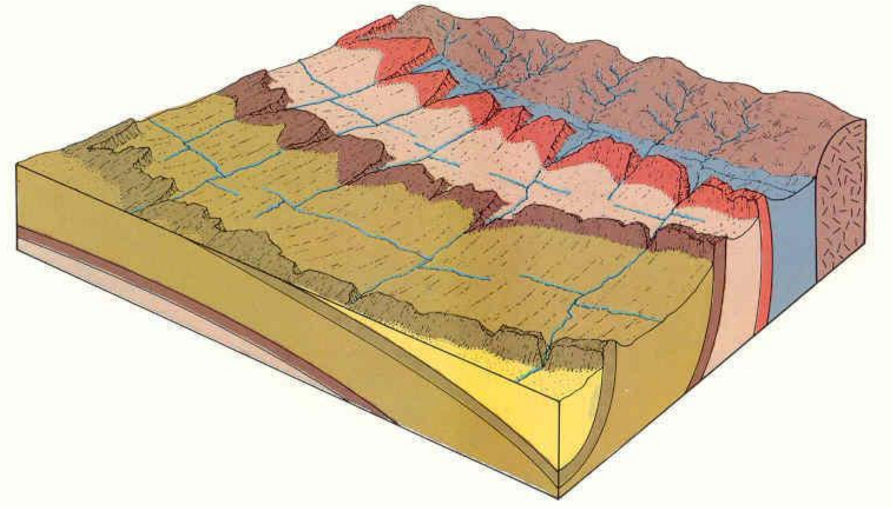
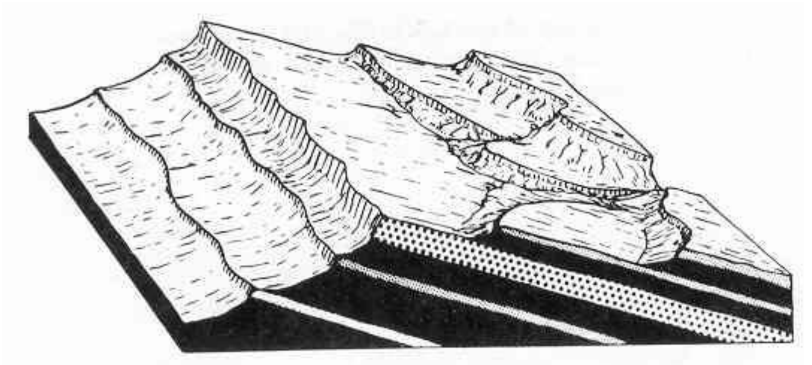


Figure 16.3. Trellis drainage patterns: stereogram (*top*), drawing from stereogram (*bottom right*), and a classical drawing (*bottom left*). (From N. Keser, 1976, aerial photos from Surveys and Mapping Branch, Government of British Columbia.)







When a sequence of rocks is tilted and truncated by erosion, the outcrop patterns will appear as bands which, on a regional basis, are roughly parallel.

Rectangular: Rectangular drainage patterns are also modification of dendritic form, but the secondary streams joining the main streams are more at right angle

Rectangular patterns frequently reflect the regional pattern of intersecting joint systems. This pattern are often formed in slate, schist or in resistive sandstone in arid climates or in sandstone in humid climates where little soil profile has developed

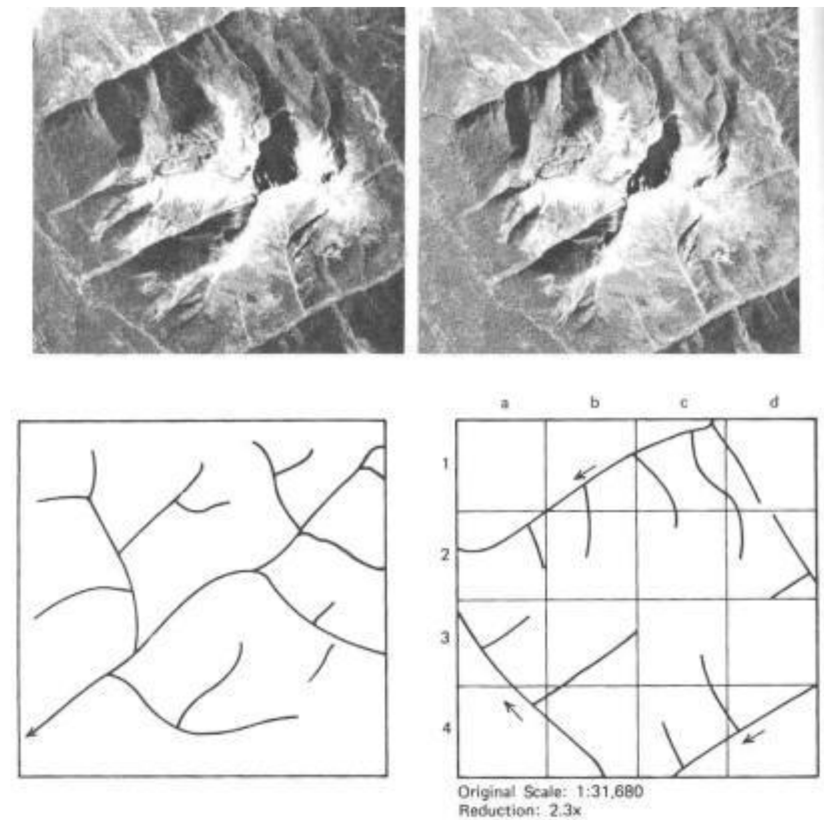
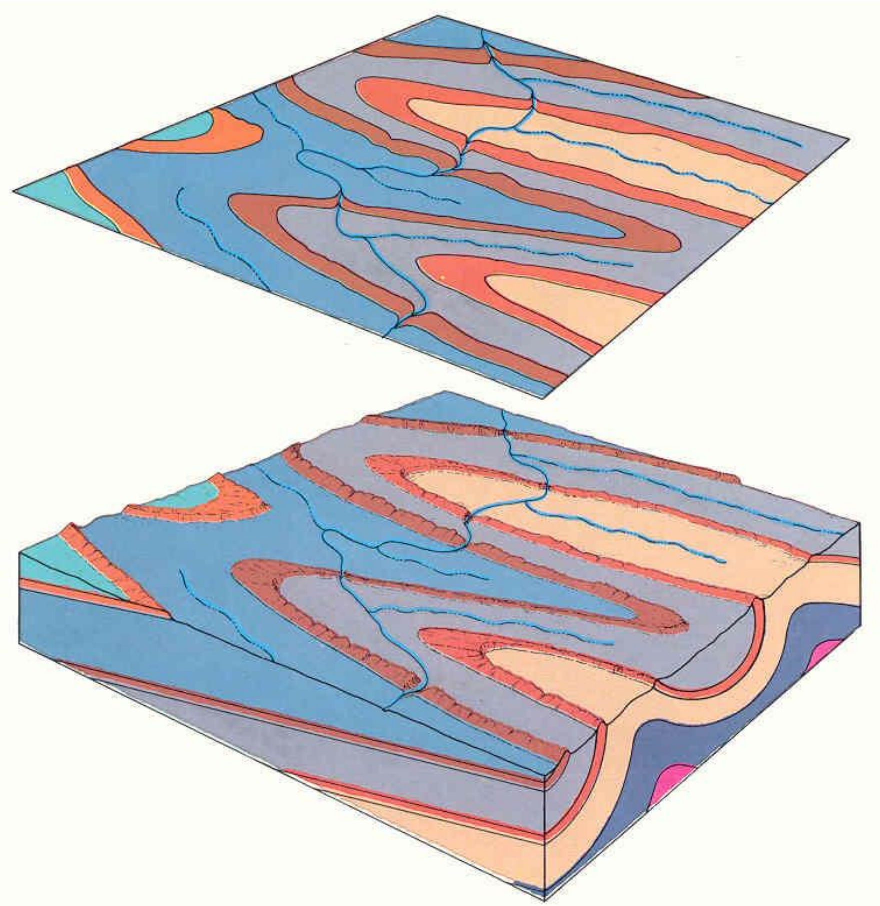
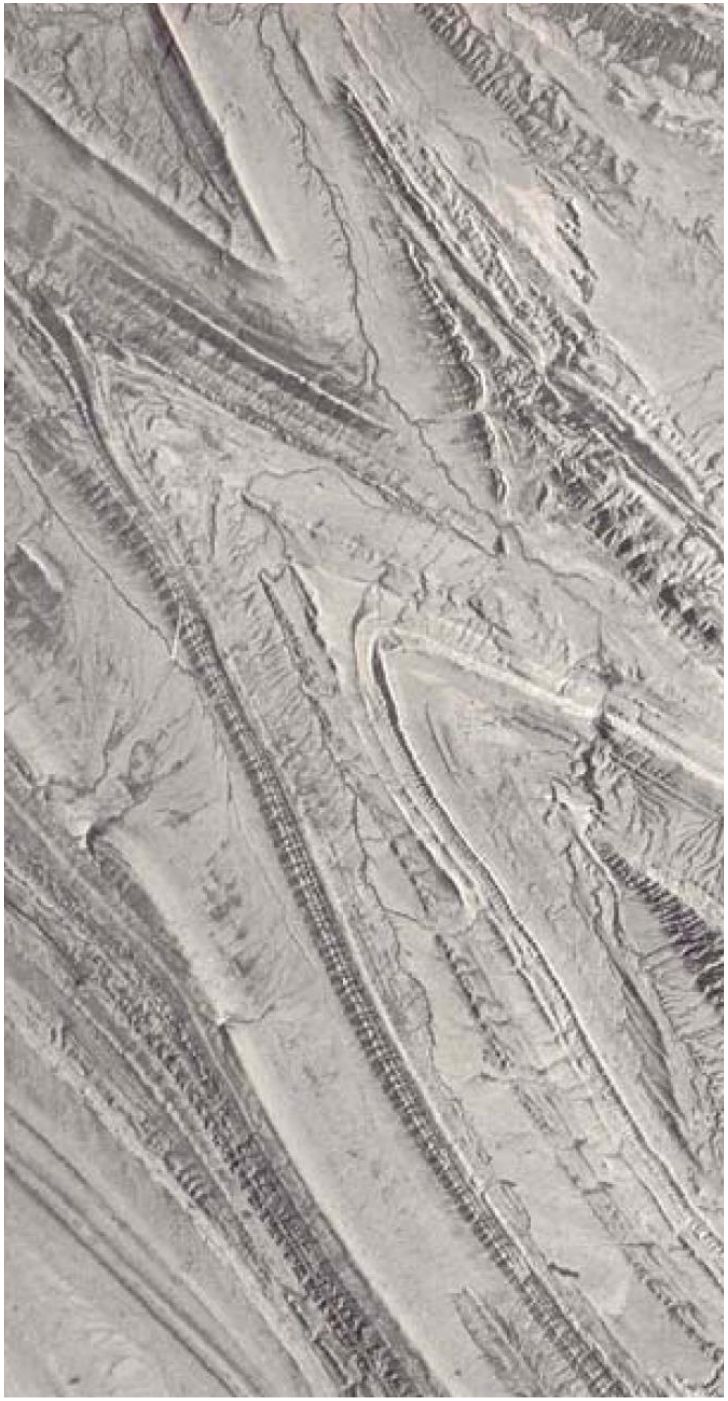


Figure 16.4. Rectangular drainage patterns: stereogram (*top*) drawing from stereogram (*bottom right*), and a classical drawing (*bottom left*). (From N. Keser, 1976, aerial photos from Surveys and Mapping Branch, Government of British Columbia.)

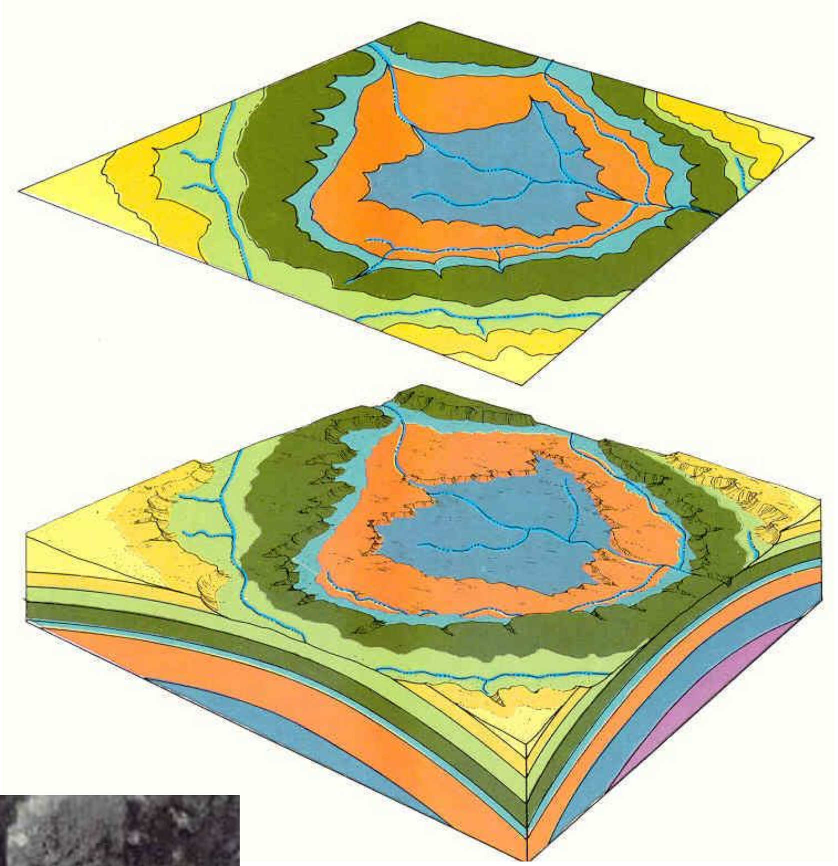
Drainage pattern in folded strata:

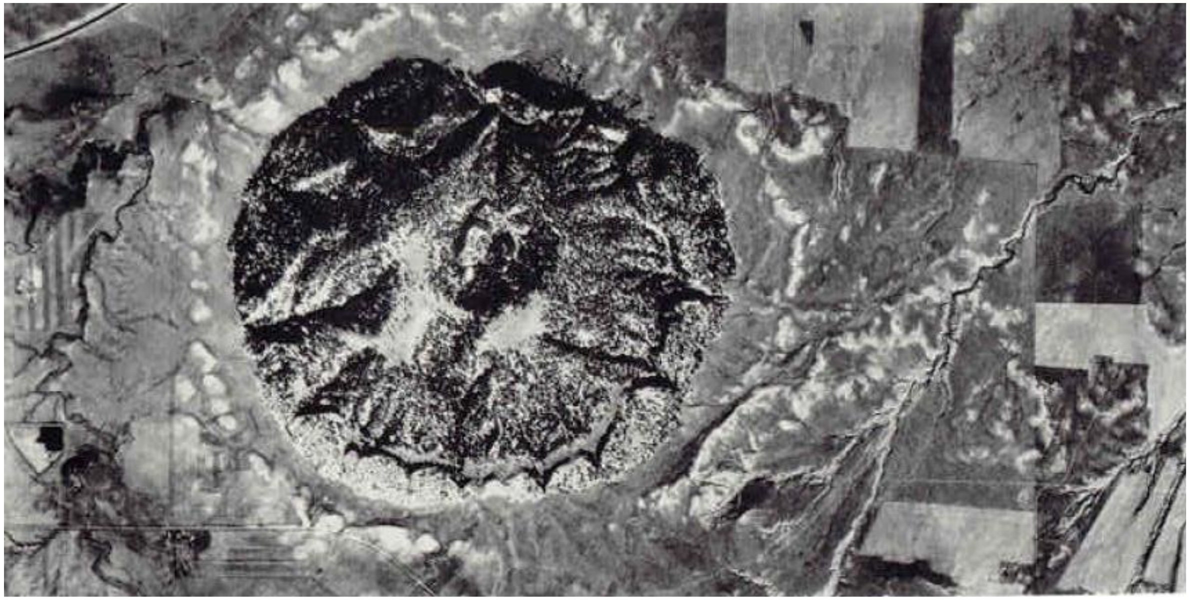
Folding is one of the most common types of structural deformation and is found in complex mountain ranges and in less deformed lowlands and pla



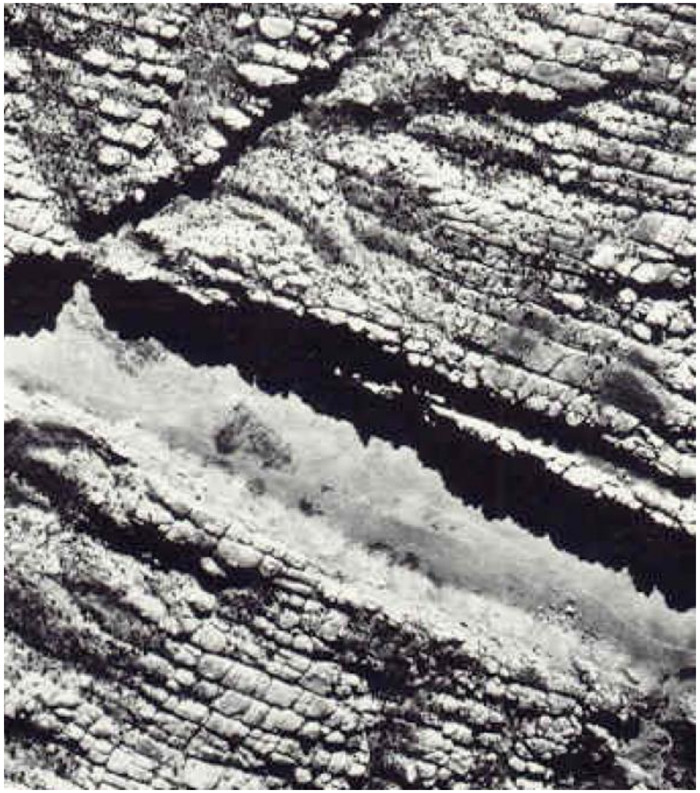


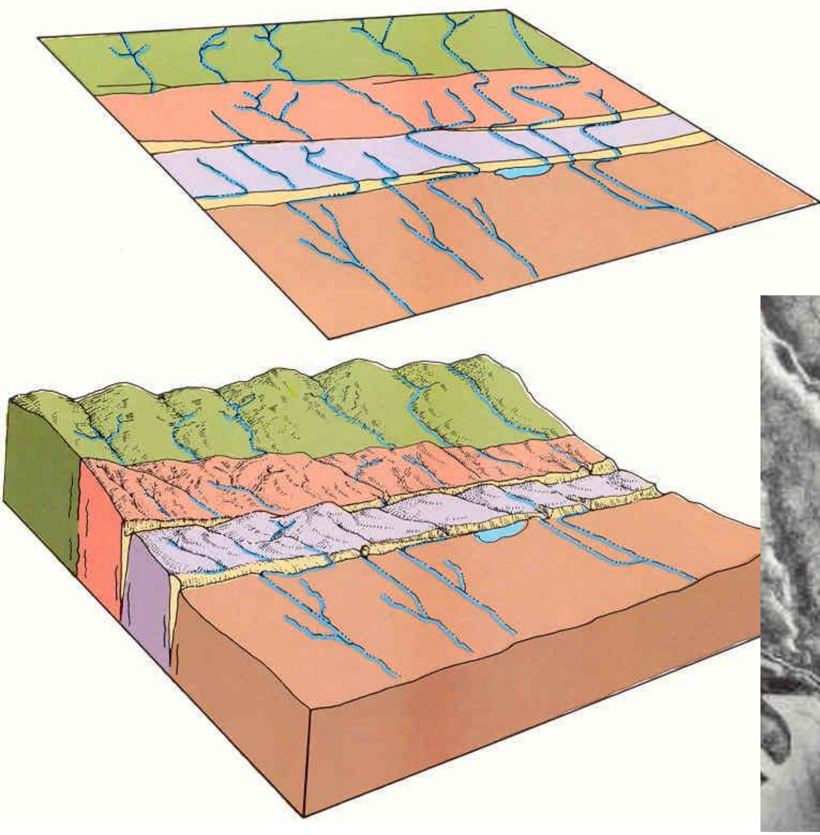
Radial Drainage: Eroded, dome-shaped structures form a roughly circular to elliptical outcrop with beds dipping away from a central area. These structures may range in size from small warps a few feet in diameter to regional features covers hundreds or thousands of square miles.

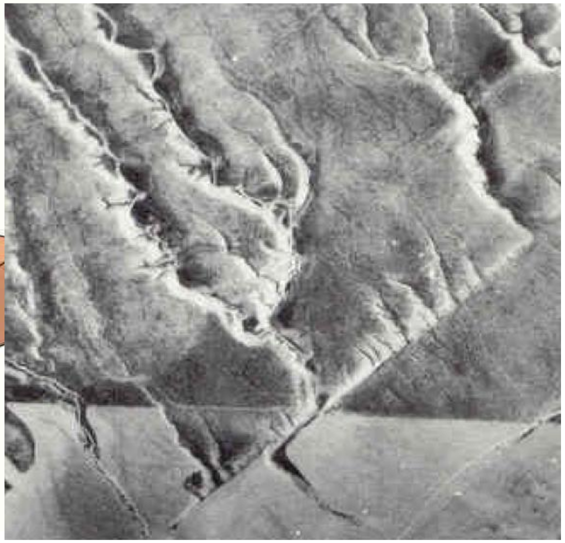




Thick, resistant sandstone formations in the Colorado Plateau commonly show the characteristics of fracture systems





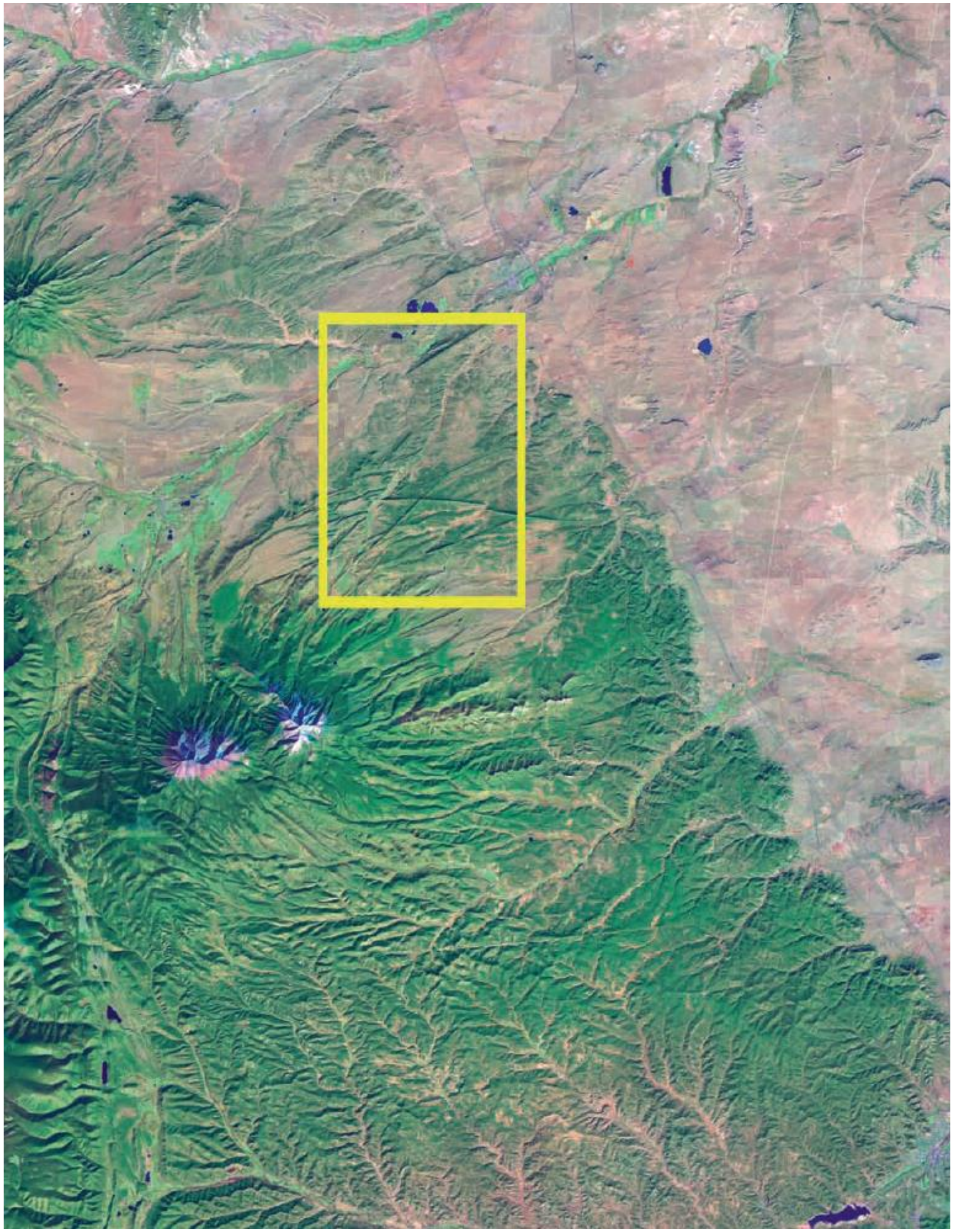


Outcrop patterns of strike slip faults and strike-slip faults of California

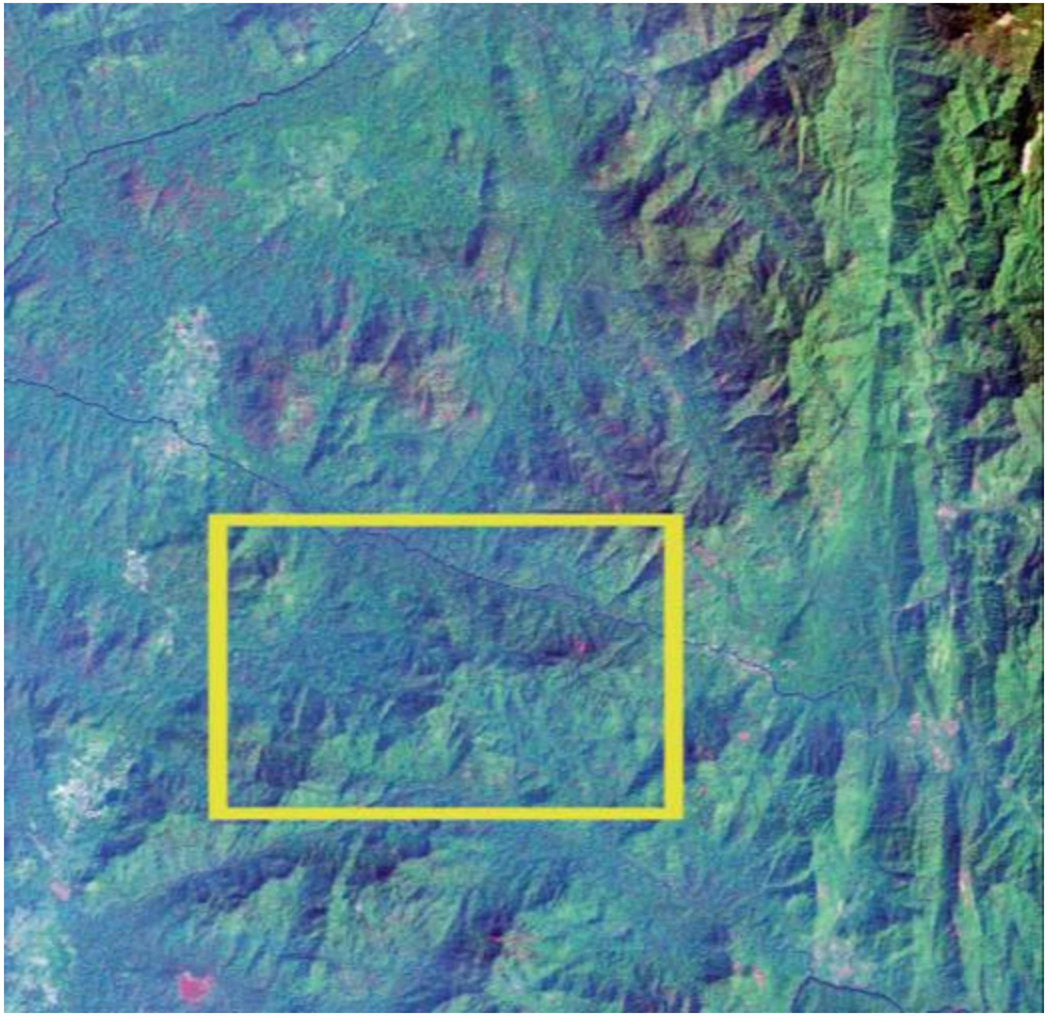
Lithology Interpretation

Intrusive magmas in pre-existing rocks

Deeply glaciated Carboniferous granite stock intruded into morphologically distinctive folded Devonian sedimentary rocks



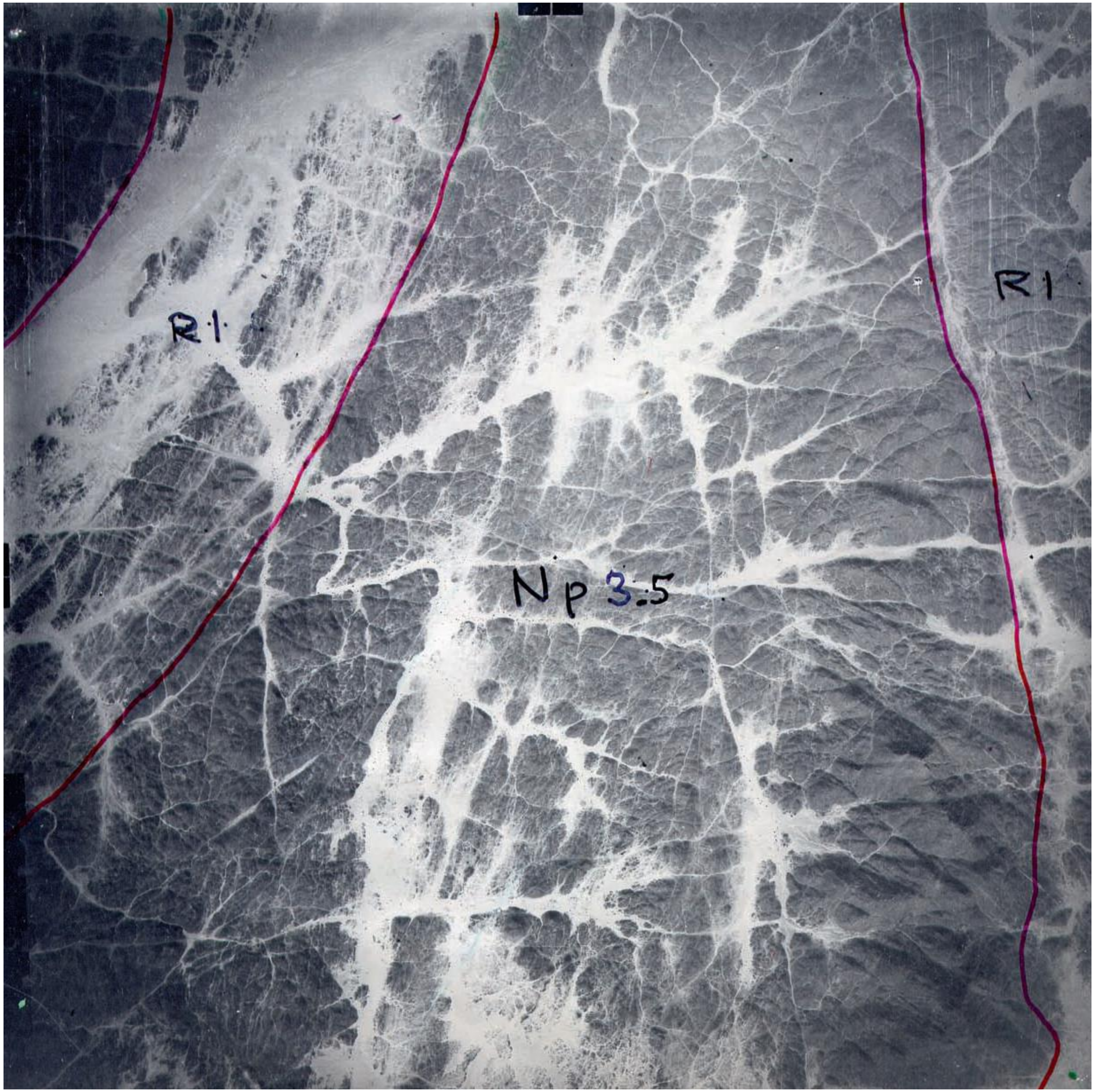
(Bands7-4-2), 05 Nov. 2010, area coverage 3,500 km2
The image shows the dykes to have emanated from two snow-capped volcano-like structures to the southwest.
These are 4,000 m elevation



Bands 7-4-2), 12 Dec. 1986, area coverage 1,050 km2

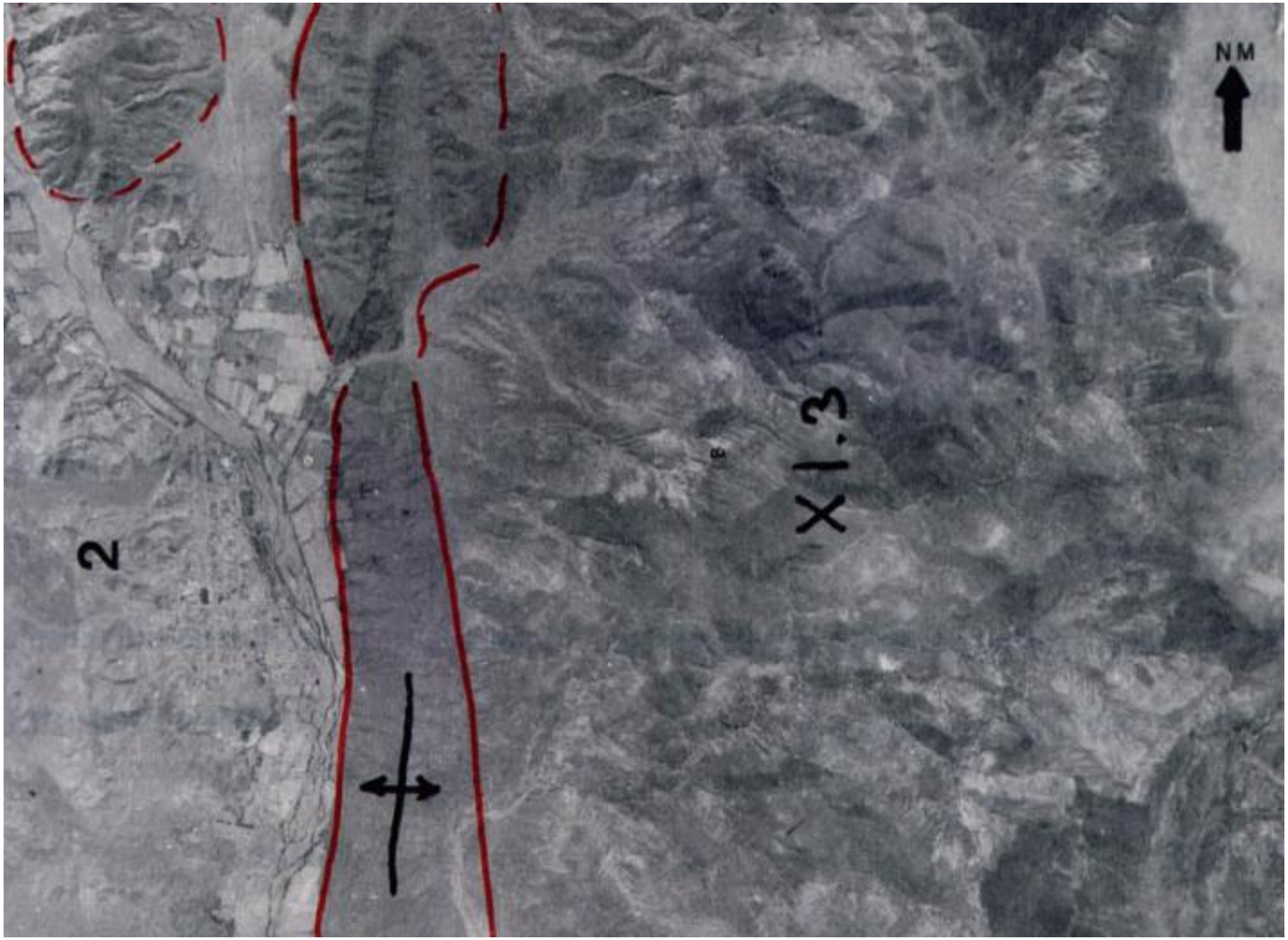
Sets of master joints are visible throughout this image. The local NW-SE oriented river crossing the photos may be a fault. *Macroscale* north-south striking *lineaments* in the higher terrain on the right are probable faults associated

with a possible post-tectonic intrusion.



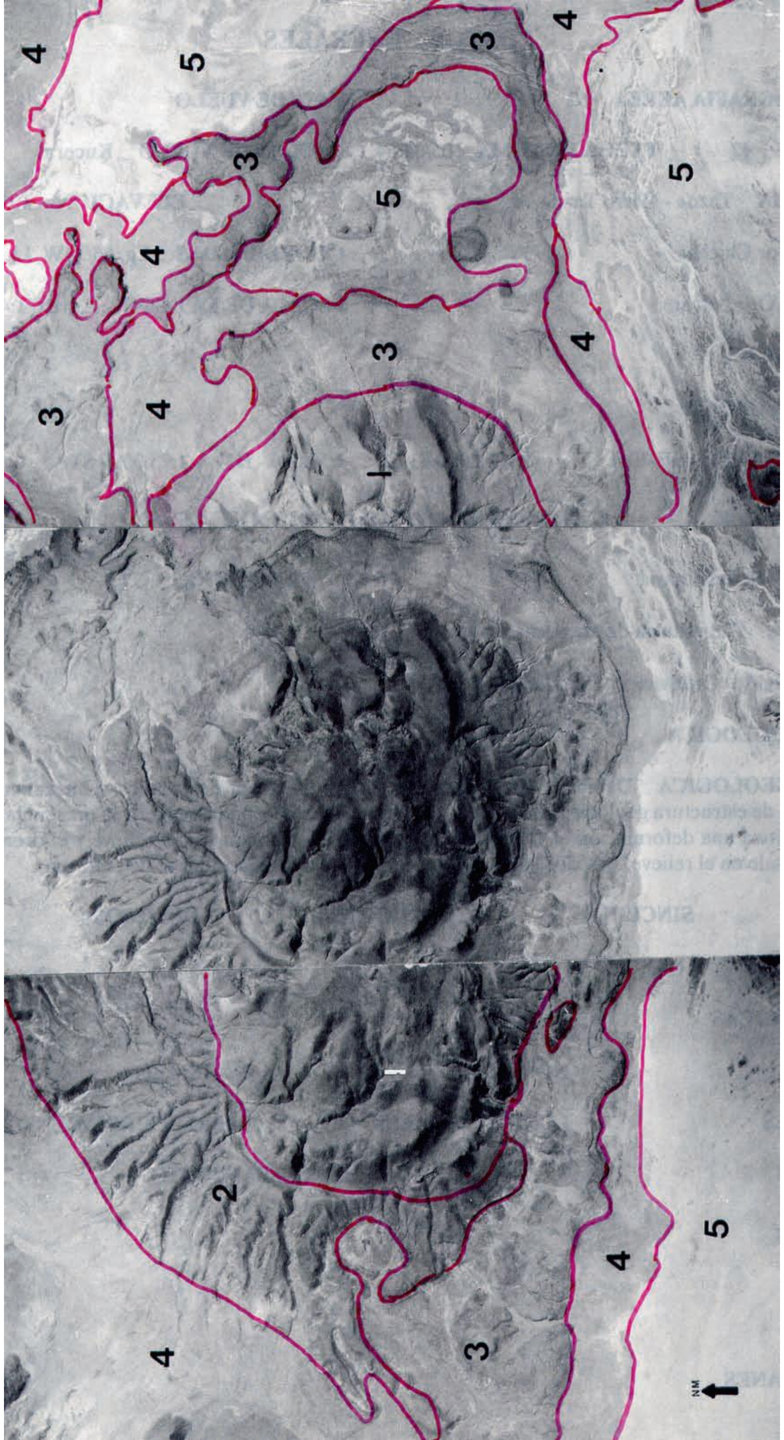
Typically irregularly *fractured* granitic stock with joint systems. The fractures are sand-filled.

The outcrop is flanked left and right by descriptors of *foliated metamorphic rocks*



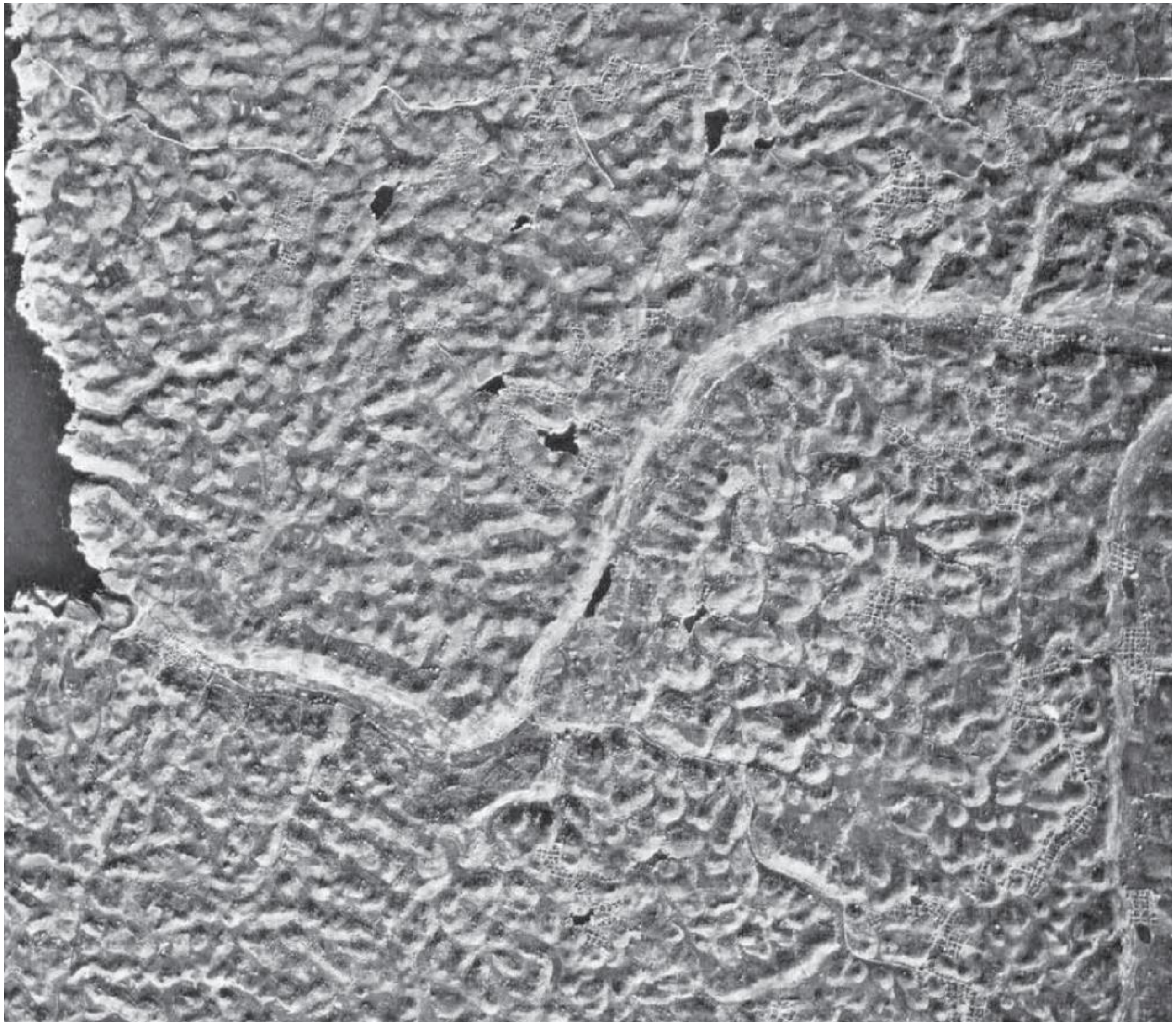
Source: Universidad San Andres, Bolivia. The rugged upland topography of dissected Tertiary basalts and dacites. The line and arrow symbol indicates an *anticline* structure in a ridge of sedimentary rocks. The bright valley (2) is in weaker sediments.

The large crater in the photo is a 1,050 m wide by 130 m deep 40 ka maar surrounded by lava flows and small, monogenetic steep-sided cinder cones in central *Nevada*.

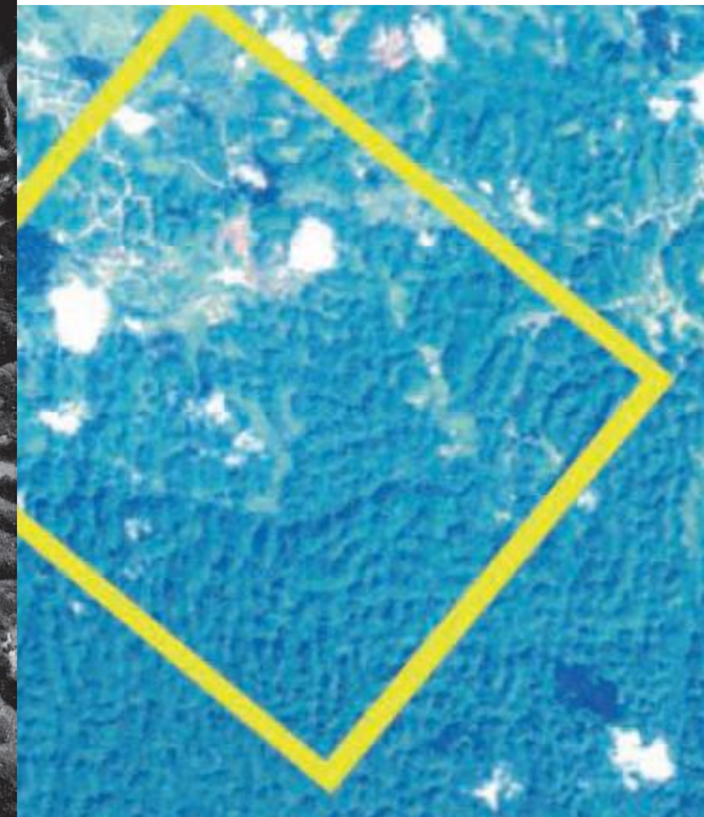


Unit **1** is the 2,300 m diameter 450 m high Holocene to Miocene slightly dissected dome.
Unit **2** is a one km wide also dissected apron of sloping Miocene to Oligocene tephra.
Unit **3** occurrences are plains of Miocene to Oligocene
tephra.
Unit **4** are Quaternary alluvial and aeolian deposits.
Unit **5** are saline *playa* deposits

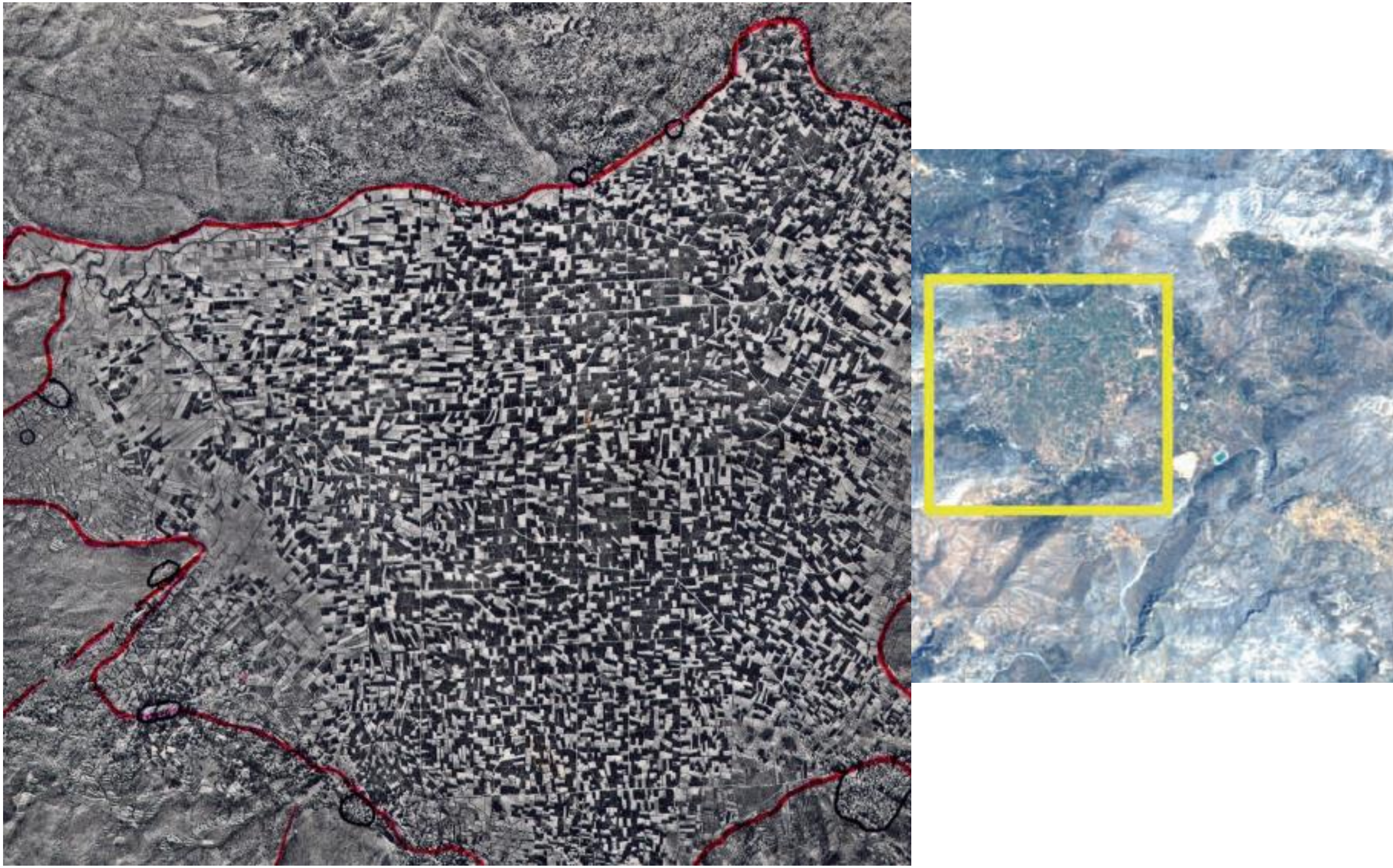
The stereomodel shows the flow-dome complex of *Glass Mountain* on the Modoc volcanic plateau of *northeast California*. It consists of two *obsidian* (volcanic glass) flows from the summit dome at 3,395 m. The flows are probably less than 1000 years old.



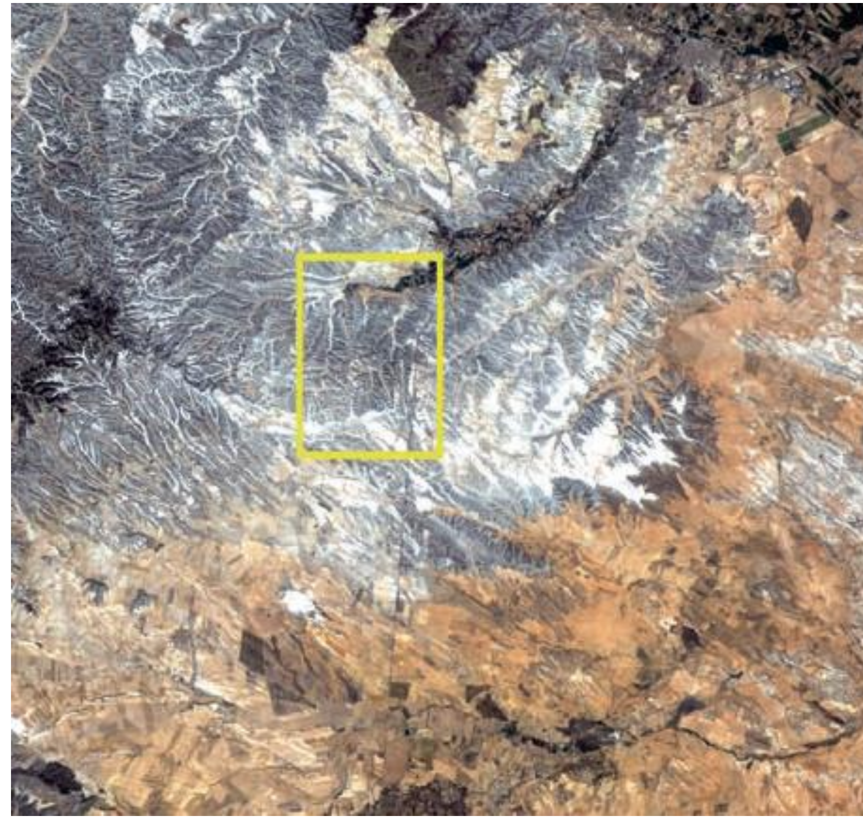
Upper Miocene carbonates near the *Giritontro dry valley* on the southeast coast of *Java*, Indonesia.



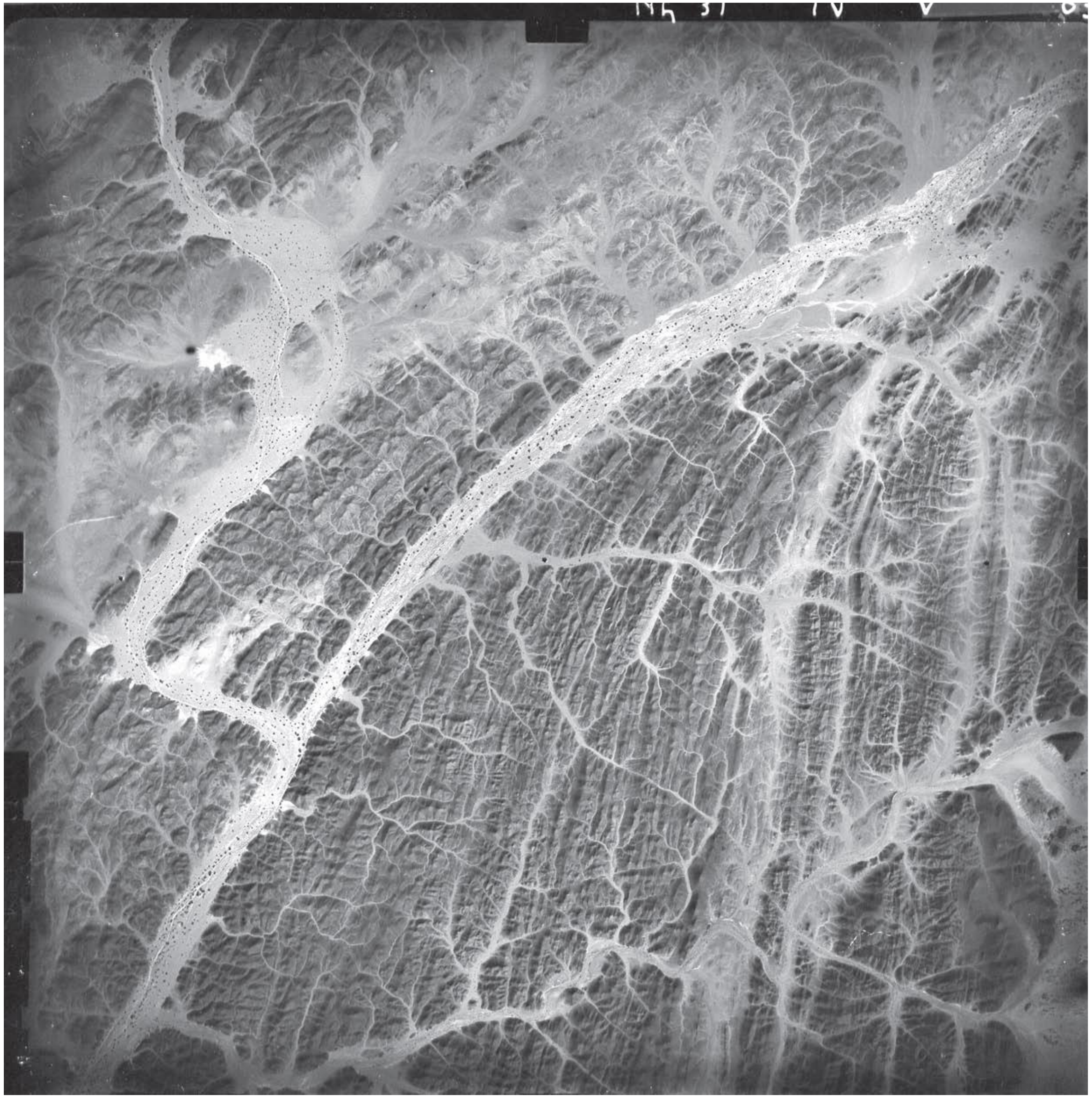
Eocene limestones
of northwest Jamaica.



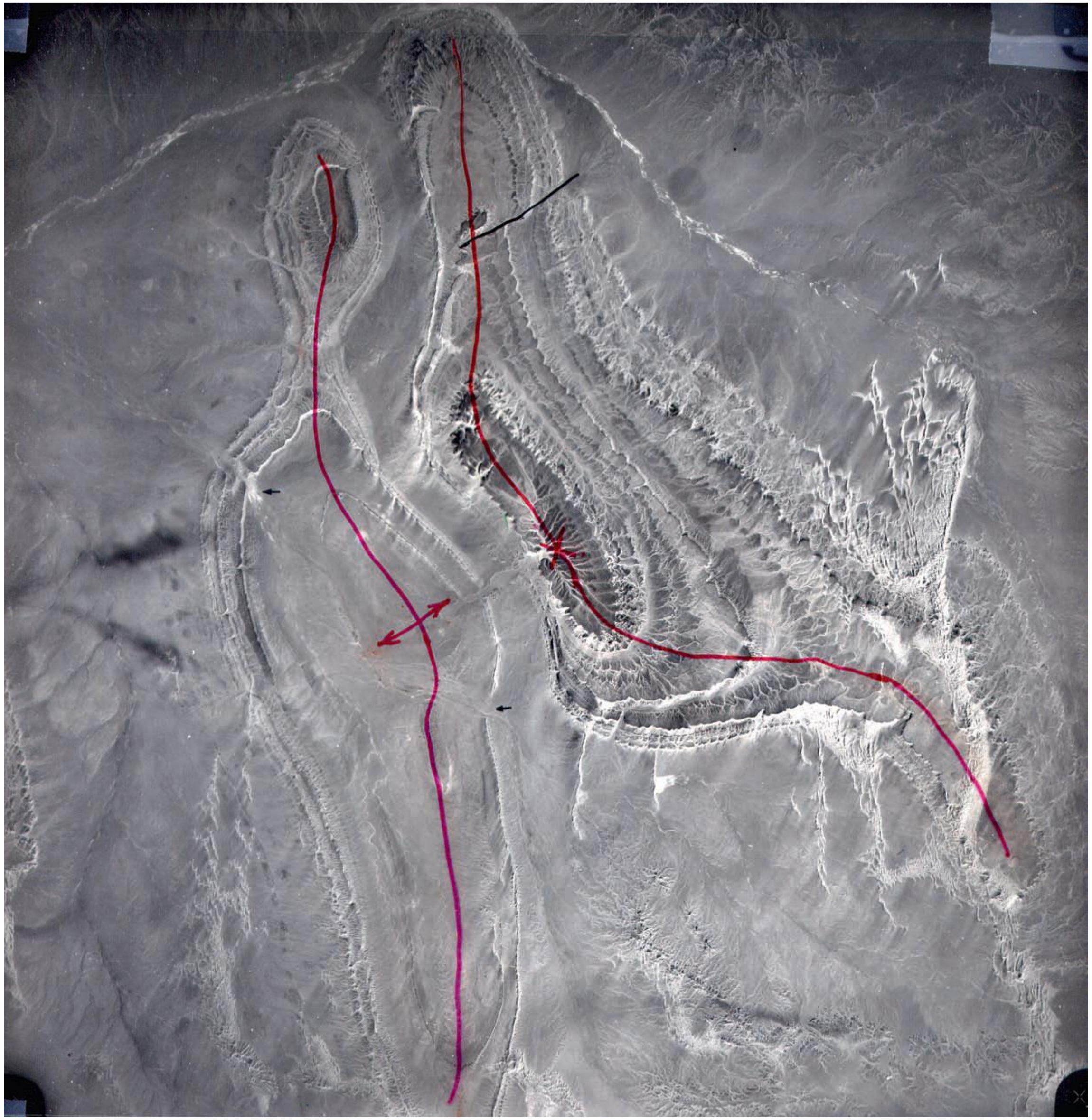
the *Lassithi* polje in eastern Crete shows a 20 km2 polje in Mesozoic carbonates. The Unit is clearly delimited by topography. The polje
floods regularly at the end of each winter as evidenced



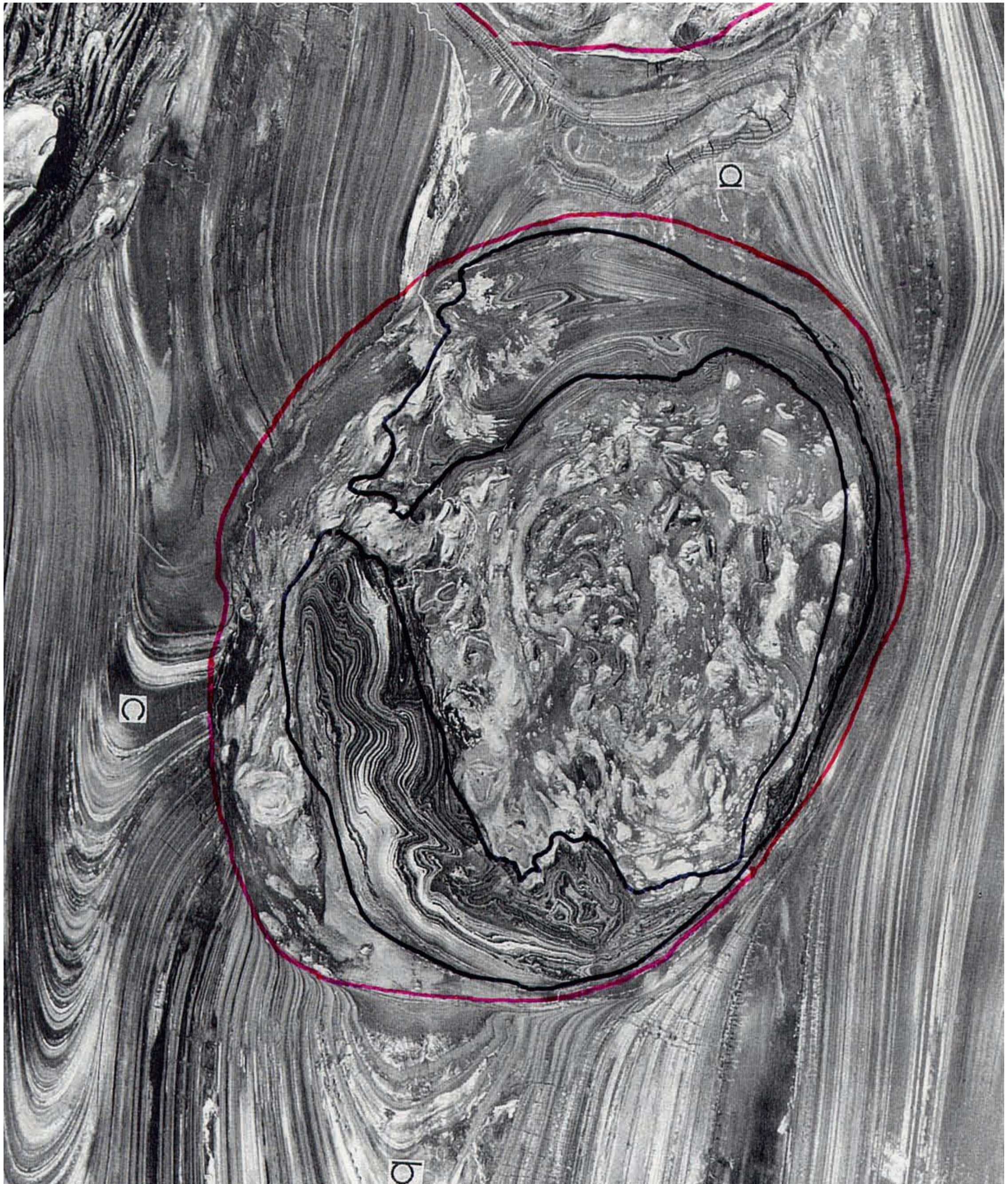
This stereogram depicts sub-horizontal Oligocene marls and sandstone of the Tertiary sedimentary *Ebro basin* of arid northeast Spain (300 mm annual rainfall).
The now stabilized dissected terrain of headward erosion of valley slopes results from climatic fluctuations in the Pleistocene. White stripes in the gullies are terraced cultivation.



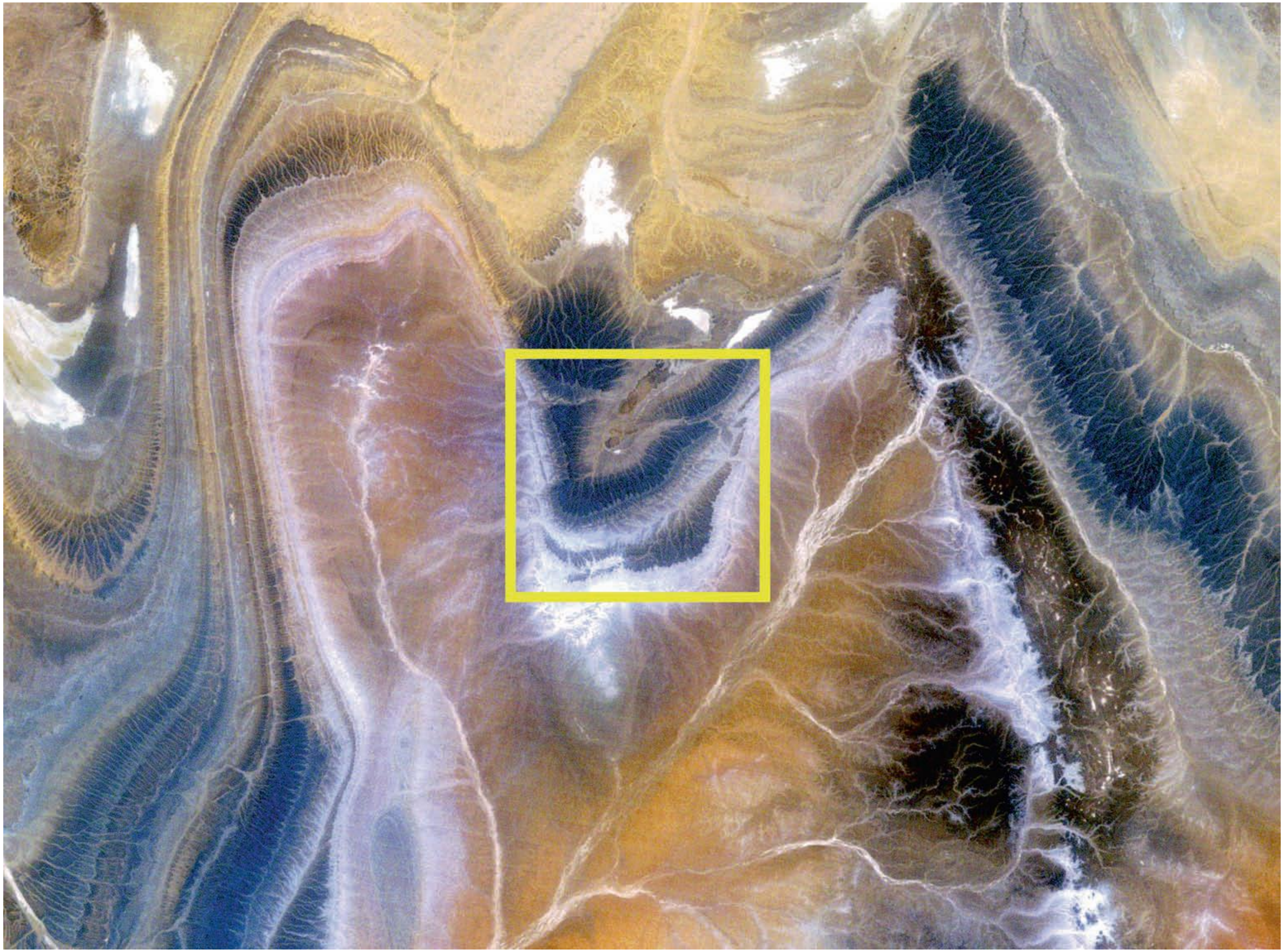
This stereo pair shows the characteristic banding of *flexural flow* (folding parallel to surfaces of foliation) of a 10 km wide section of strongly foliated Proterozoic schists of the Hoggar craton of southern Algeria.



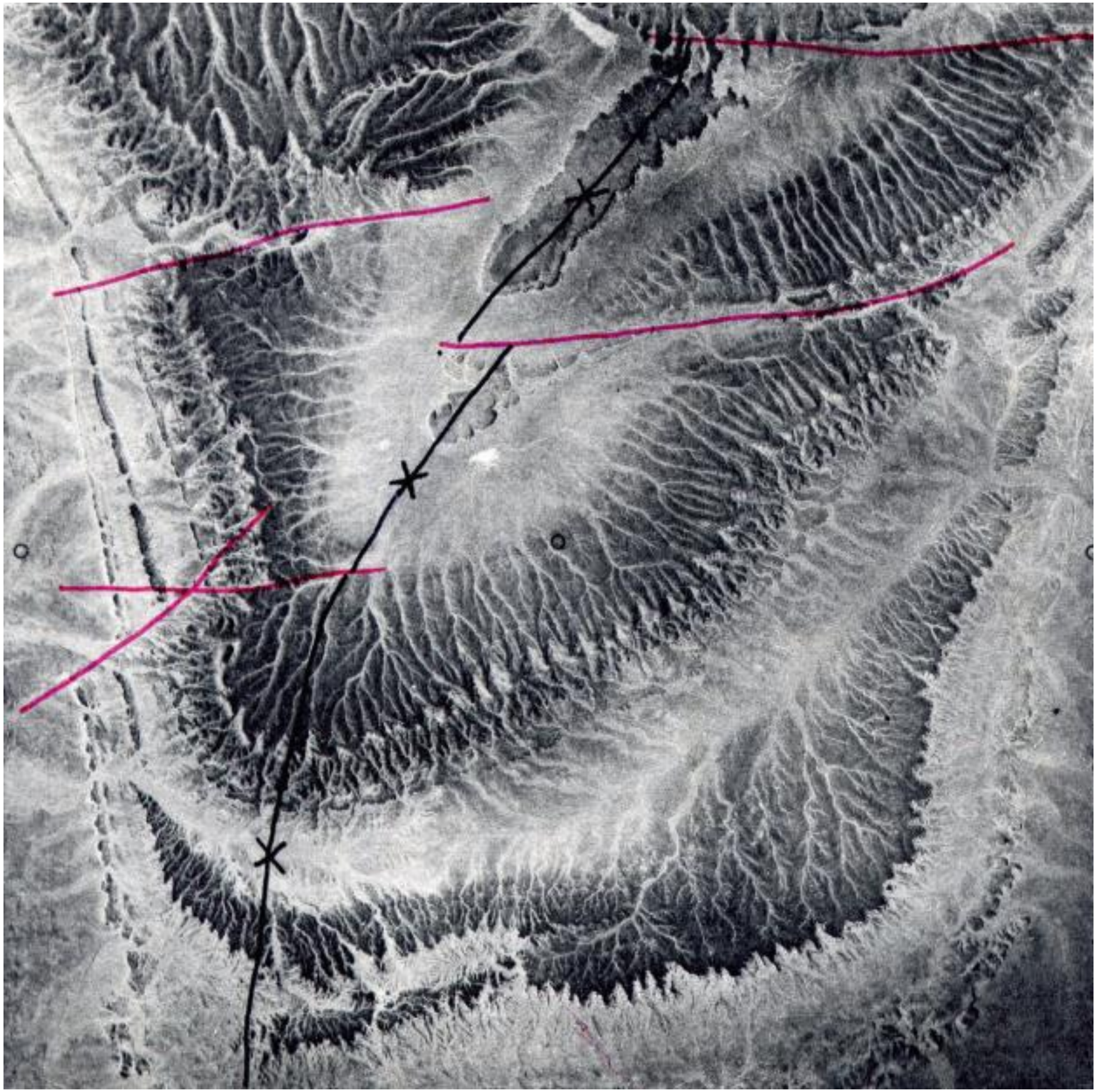
This Unit consists of deformed systems that are sets of congruent *anticlinal* and *synclinal* folds in bedded rocks that are produced by a same tectonic episode



This single airphoto of a 7 km diameter Eocene 45 Ma diapir shows the mottled salt outcrop surrounded by finely banded cycles of younger salt and gypsum. The intruded ground is part of the strongly banded *truncated* (removal of a part of a Geounit by erosion) surface of folded Miocene 15 Ma saline mudstones and gyprock sediments of an extensive regional playa in northern *Iran.*



The image shows the synclinal structure to be a deformation similar to the other folded rocks of the Ahnet basin 115 km to the northeast. As in the photo model the dark beds are shales and the light grey and white strata are sandstones; beige ground is alluvium.



The stereomodel in central Algeria has a drawn set of strike-slip faults displacing *interbedded* Devonian sediments of a *synclinal* structure whose axial hinge is drawn. The dark dissected rocks are shales, the bright rocks are sandstones.

Sedimentary Landscape

Sedimentary rocks were formed by the deposition of sediments by water, wind or ice. When the transporting agent slows, sediments are deposited with the larger particle settling first followed by the small particles. This results in sedimentary layers that are stratified by particle size. Though layers were laid down in roughly horizontal planes, many were later deformed, eroded, folded, faulted and uplifted to form various landscapes.

	From Aerial Photos and Geologic Maps				Inferences			
Landform Climate	Topography	Drainage & Texture	Photo Tone	Gully Type	Soil Texture	Soil Drainage	Land Use	Engineering Characteristics
Shale Humid	Rounded hills	Dendritic Medium-fine	Light (mottled)		Fine Silt-clay	Poor	Agriculture Forestry	Excellent base Poor septic system
Arid	Rough-steep	Dendritic Fine	Light (banded)		Medium Silty	Very poor	Barren	Excavation difficult. Poor aggregate
Sandstone Humid	Massive and steep	Dendritic Coarse	Light		Sandy	Excellent	Forestry	Excellent base Shallow to bedrock
Arid	Flat table	Dendritic Medium-coarse	Light (banded)	None	Fine	Poor	Barren	Poor septic systems
Limestone Humid	Flat or rough sink holes	Internal	Mottled		Silt-clay	Poor to good	Agriculture	Shallow soil Poor septic systems
Arid	Flat table	Dendritic	Light	None	Fine	Poor	Barren	Poor septic systems
Interbedded Flat (humid)	Terraced	Dendritic Medium-coarse	Medium (banded)	Variable	Variable	Variable	Some agriculture Some forest	Good base Variable to bedrock
Tilted (humid)	Parallel ridges	Trellis Medium	Medium (banded)		Fine	Fair	Agriculture Forestry	Good base Excavation difficult

Source: Adapted by permission from Way (1973).

Igneous Landscape: Igneous rocks are formed by the solidification of molten rock either within or on the surface of the Earth. They are classified as intrusive if they were formed beneath the surface of the Earth and extrusive if they were formed on the Earth's surface.

Rock types are classified as granitic or basaltic and are generally hard, durable and associated with poor surface drainage. Igneous rock landscapes make up about 18% of the earth

TABLE 17.2 Igneous Rock Characteristics

From Aerial Photos and Geologic Maps					Inferences			
Landform Climate	Topography	Drainage & Texture	Photo Tone	Gully Type	Soil Texture	Soil Drainage	Land Use	Engineering Characteristics
Granite								
Humid and intrusive	Bold and domelike	Dendritic Medium	Light (uniform)	Variable	Silty sand	Poor	Agriculture Forestry	Excavation difficult Poor aggregate Good base
Arid and intrusive	A-shaped hills	Dendritic Fine or internal	Light (banded)	None	Fine	Poor	Barren (rangeland)	
Basalt								
Extrusive flows	Flat to hilly	Parallel or internal	Dark (spotted)	None	Clay to rock	Good	Agriculture to barren	Blasting not difficult. Landslides common. Soil is unstable when disturbed.
Volcanic extrusive	Cinder cone	Radial C to F	Dark	Variable	Silty clay	Poor (surface) Good (subsurface)	Barren	
Fragmented tuff	Sharp-ridged hills (variable height)	Dendritic Fine	Light		Noncohesive sand to dust	Excellent	Forestry or grassland	Blasting not required. Unstable soil. Septic systems easily contaminated.
Embedded flows	Terraced hills	Parallel dendritic	Light and dark (banded)	Variable	Variable	Variable	Agriculture to barren	Unstable soil

Source: Adapted by permission from Way (1973).

EXPRESSION OF TERRAIN IN AIR PHOTO / SATELLITE IMAGES

TERRAIN CHARACTERS	IGNEOUS	SEDIMENTARY	METAMORPHIC
SIZE & DIMENSION	Small to Medium	Larger	Moderate
DISPLAY OF TERRAIN	Un-controlled	Perfectly Controlled	Moderate either Controlled /Uncontrolled
ELEVATION	Varies point to point without any regularity	Varies Uniformly & gradually	Moderate
TOPOGRAPHY	Peak & Cliffs	No Peaks-cliffs	Moderate
ORIENTATION/ TERRAIN	No trend/ Orientation	Perfect Orientation/trend	Moderate
SURFACE SMOOTHNES	Rugged	Smooth	Smooth & Rugged


Metamorphic
Igneous
Sedimentary

GINGEE GRANITE

LISS III – CUDDAPAH BASIN

METAMORPHIC TERRAIN

LITHOLOGICAL INTERPRETATION

- ***Land form***
    - ❖ **Strength of morphological out look**
    - ❖ **Relation to climatological Conditions**
    - ❖ **Stages of geomorphological development**
    - ❖ **Mode of occurrences**
- ***Drainage***
    - ❖ **Pattern**
    - ❖ **Texture**
- ***Tone***
    - ❖ **In Non Vegetated area**

IGNEOUS ROCKS

Criss-cross jointing

Homogeneous

Dendritic drainage

EXTRUSIVE ROCKS

Easy to interpret in undeformed areas

Lava Flow **:** **Lobate pattern of landform**

Regional parallel drainage

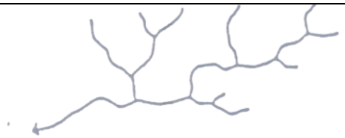
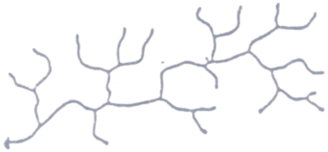
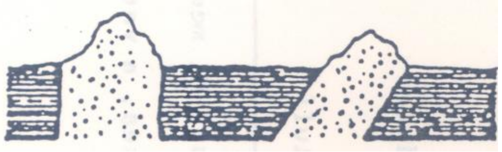
Viscous Flow**:** **Hummocky irregular surface**

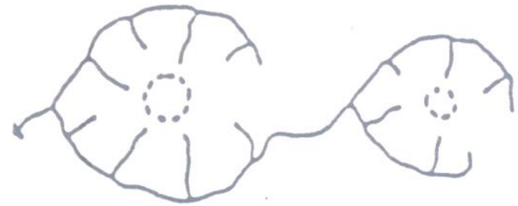
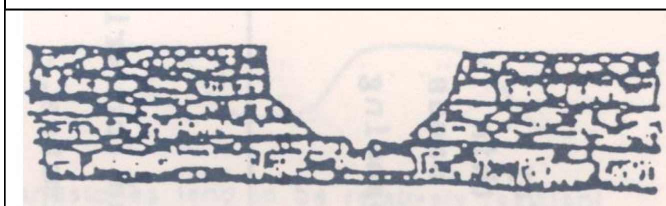
Tuff **:** **Dendritic drainage**

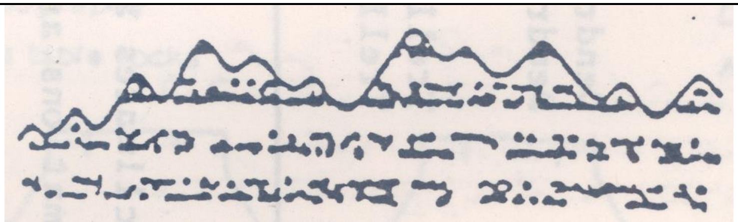
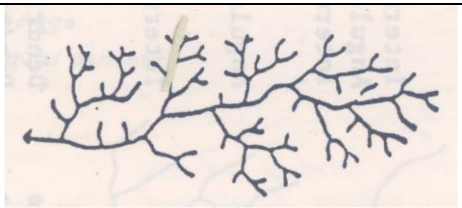
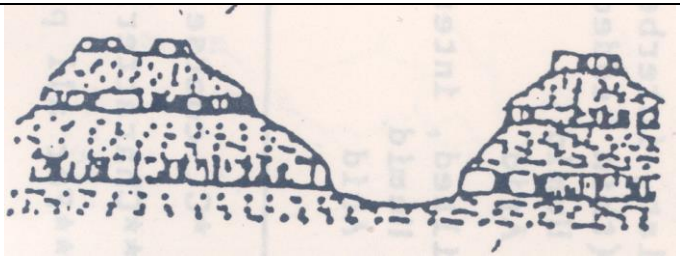
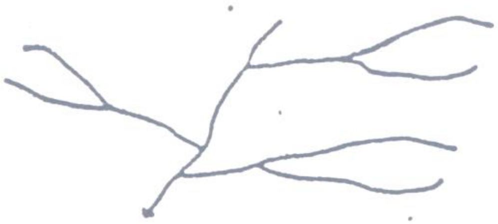
INTRUSIVES

DYKES**:** **Rectilinear or curved ridges dark light toned, smooth tops cross-cutting**

SILLS: **Difficult to interpret**

GRANITIC ROCKS: Large, Massive (Humid and Arid) (Way, 1973)	
Humid	
	
The topography of granitic intrusion is typically massive, rounded, dome like hills. The tops are softly rounded and the side slopes are steeper.	A dendritic drainage pattern with coarse texture. The dome like topography cause curvilinear alignments to develop.
Arid	
	
Bold, massive, dome like hills. Highly dissected areas appear having A- shaped hills with steep sided slopes	Drainage pattern is dendritic but finer texture than in the humid terrain, this because of intensive fractured dissection and drainage.
GRANITIC FORMS: Linear, Dikes (Humid and Arid) (Way, 1973)	
	
Long linear ridge due to more resistant than the surrounding. More sharper or rounded	It is too small land form to develop specific drainage pattern.

VOLCANIC CONES:	
	
Rounded cinder cones are common in active zone.	A radial drainage is developed around the circular volcanic cone. There is parallel drainage along the slopes
BASALTIC FLOW:	
	
Form level or gently sloping, broad level plains. Matured terrain will have dissected plateau with mesa and buttes. Vertical escarpments with columnar jointed blocks	A coarse regional parallel drainage pattern

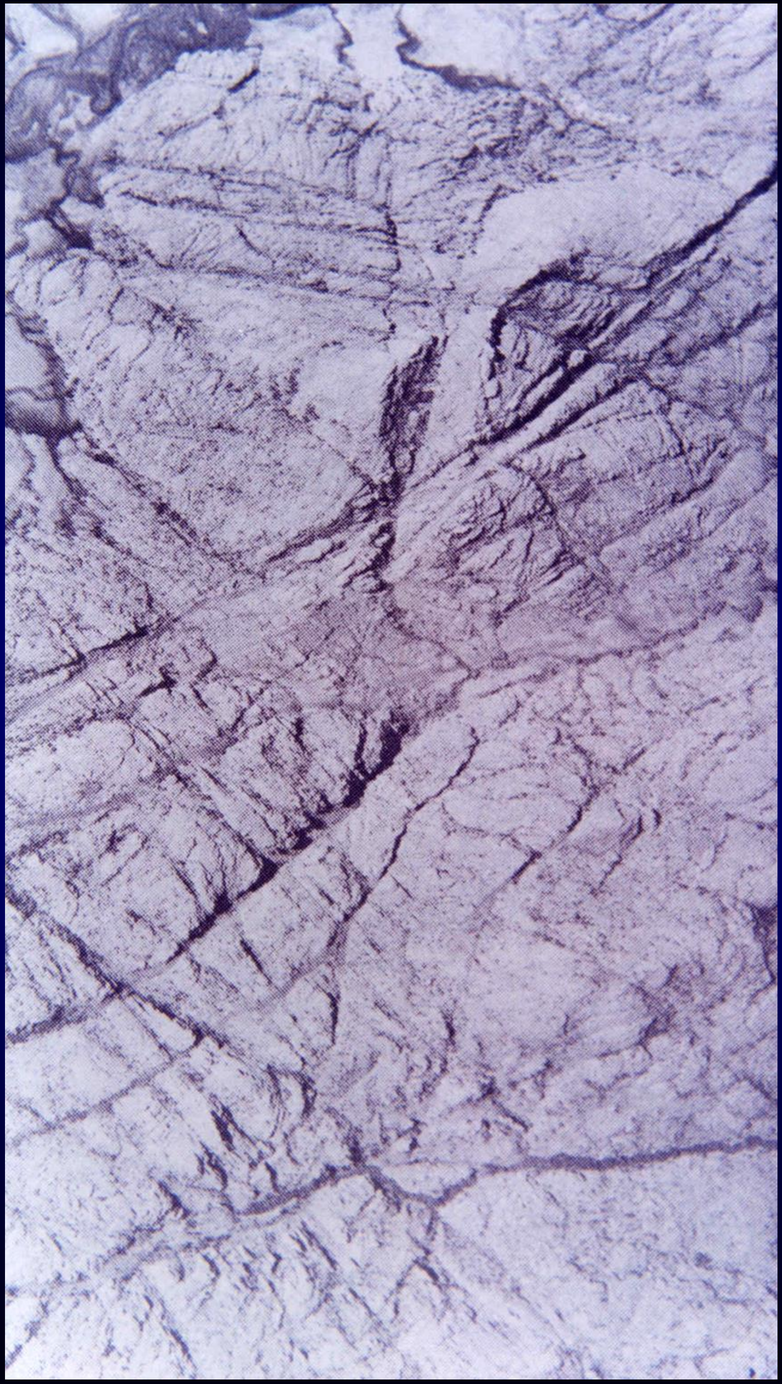
FRAGMENTAL TUFF:	
	
Tuff formations in all climates erode quickly and form sharp, knife-edged ridges with highly dissected topography similar to clay and shale. But the hill tops do not occur at equal height unlike the clay shale terrain.	Extremely very fine textured dendritic drainage indicating uniform composition. Welded tuff terrain will have comparatively less drainage texture.
INTER BEDDED FLOWS:	
	
A dissected topography exposes stratified layers and inter bedding along the sides of hill. Hill slopes will have step like character.	Inter bedded deposits commonly develop dendritic pattern with parallel tributaries.

IGNEOUS ROCKS: (Summary chart). (Way 1973)

	Topography	Drainages*	Tone	Gullies	Vegetation & LandUse
Intrusive granite (large masses)					
Humid	Bold, domelike hills	Dendritic curved ends, M	Uniform, gray	U-Shaped	Forested & Cultivated
Arid	A- Shaped hills	Dendritic curved ends, F	Light, fractures	Few to none	Barren, grass cover
Intrusive granite (linear dikes)					
Humid & Arid	Narrow, linear ridges**	None	Light or dark	None	Natural cover
Extrusive Volcanic	Cinder cones	Radial, C - F	Dark gray	Vary	Barren, natural cover
Extrusive basalt flows	Level plain	Regional parallel, C - F	Dark, flow marks	Soft, U-Shaped	Cultivated / Barren
Extrusive interbedded	Terraced hillsides	Parallel dendritic	Banded	Vary	Cultivated or natural
Extrusive luff	Sharp ridged hills	Dendritic, F	Dull, lt. gray	Vary	Natural cover

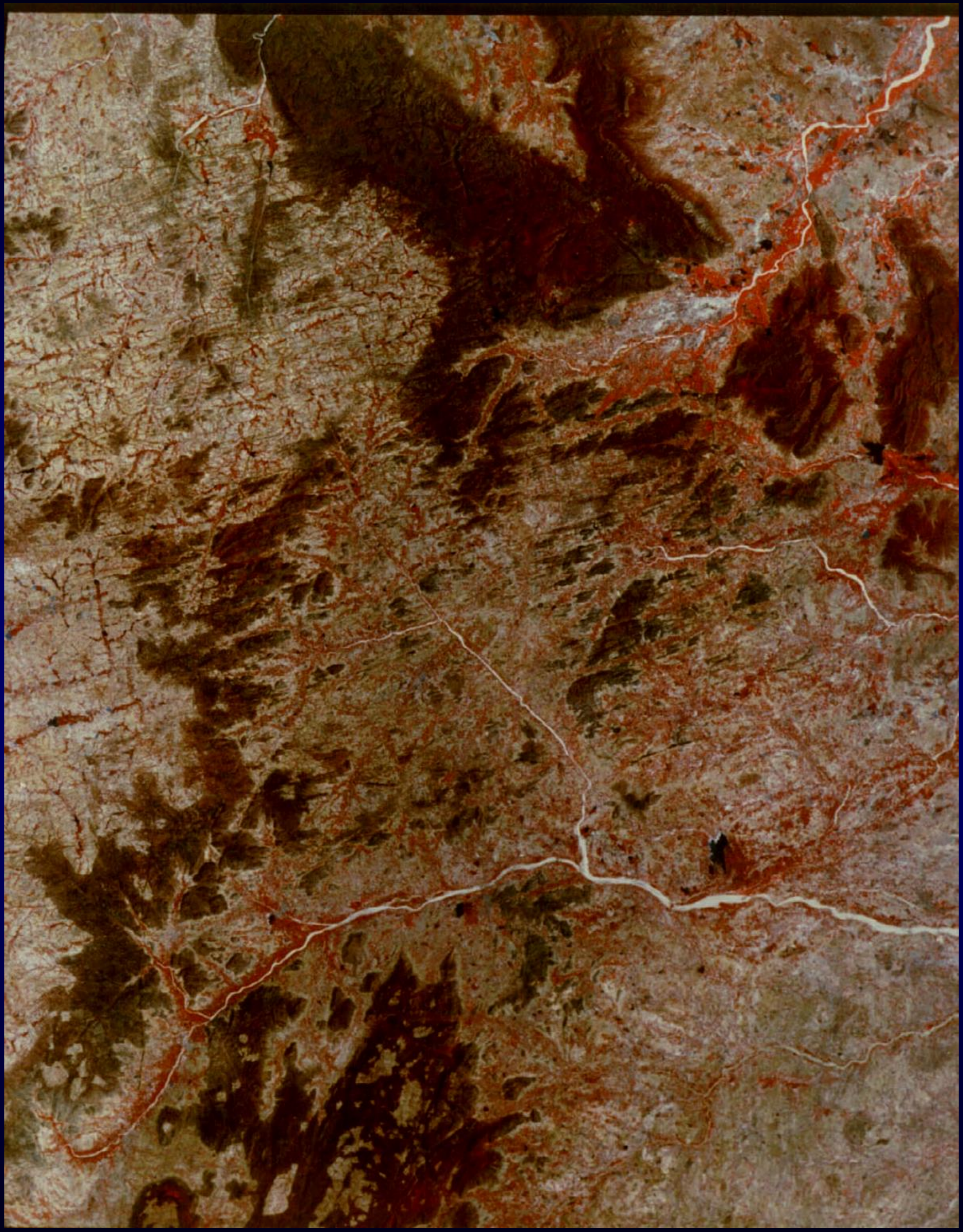
* C- Coarse; M- Medium; F- Fine.

** Ring dykes, a variation of this landform are found with a circular narrow, sharp ridge.



Granite in arid terrain

Basaltic flow



Dyke swarms

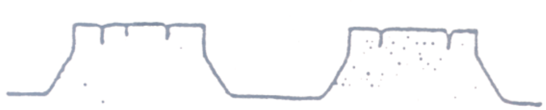
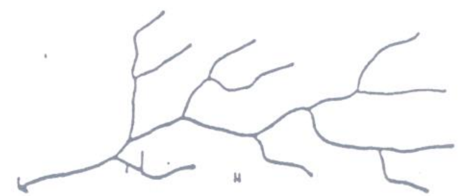
SEDIMENTARY ROCKS

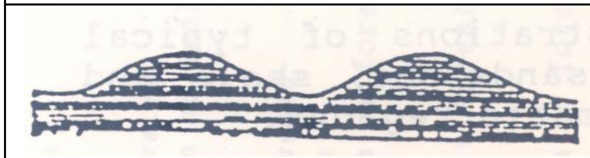
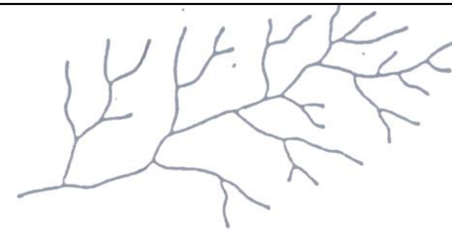
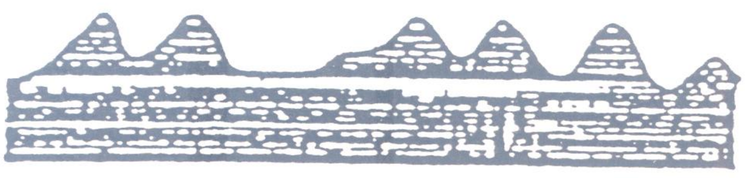
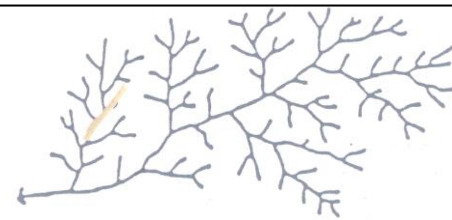
CONSOLIDATED SEDIMENTS

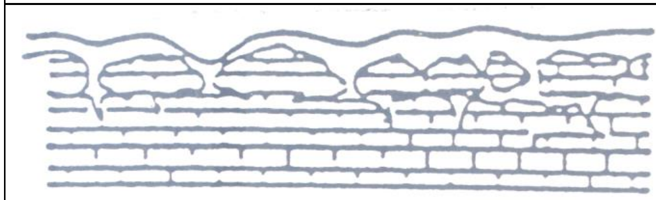
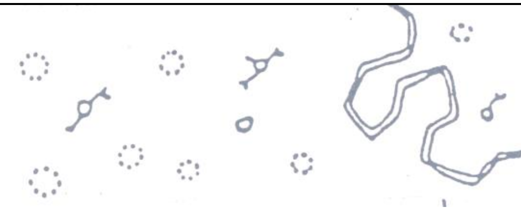
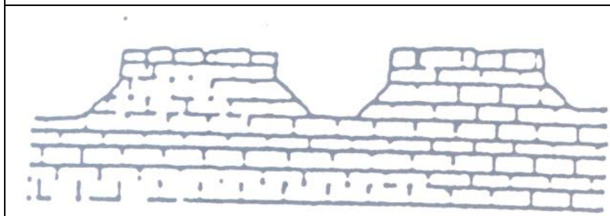
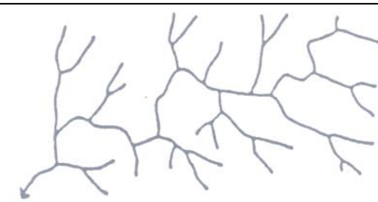
- ❖Differential resistance to erosion
- ❖Tonal contrast
- ❖Difference in permeability-related drainage
- ❖Geomorphic features(Cuesta hills, plateau tops)

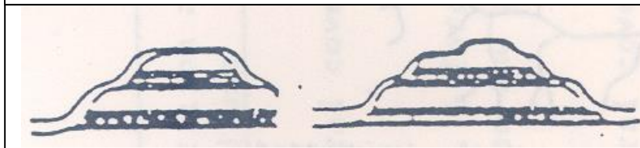
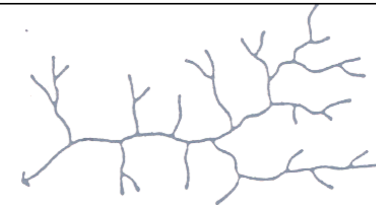
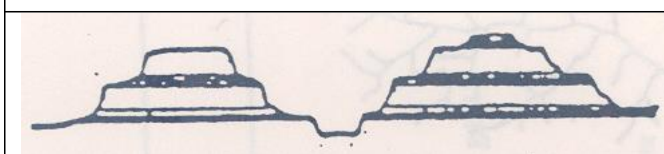
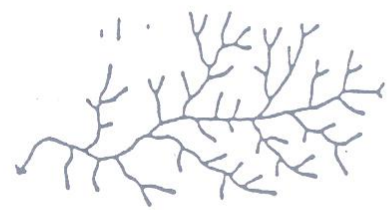
UNCONSOLIDATED SEDIMENTS

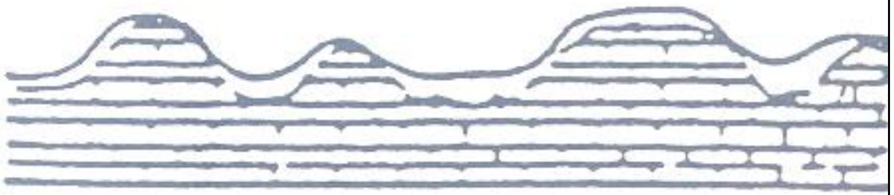
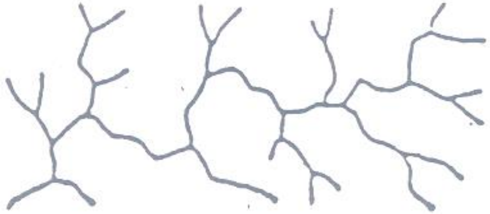
- ❖Land Forms: Dune, Alluvial plains
  Alluvial fans, terraces.
- ❖Drainages:

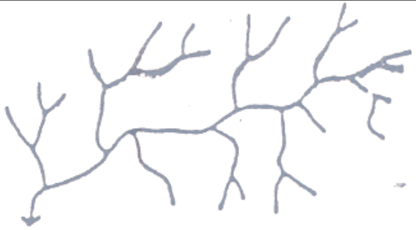
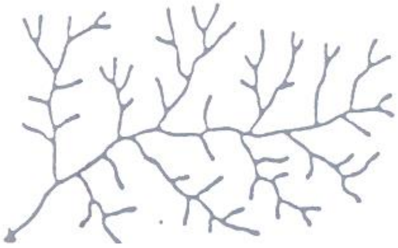
SANDSTONE (Humid and Arid). (Way, 1973)	
Humid	
	
In a sedimentary terrain, the sand stone is relatively more resistant to erosion, so they appear massive, bold topography with steep side slopes. Generally they are found as cap rock for other sedimentary rock in that region	Generally dendritic, but with joint development it may also be somewhat angular or even rectangular. The texture generally coarse.
Arid	
	
Flat table top with fracture and joint pattern. Cliffs are common and the near same elevation of the hill tops.	Due to dry climate and weathering the joints take over the drainage flow so the pattern generally is angular dendritic or even rectangular, medium to coarse texture.

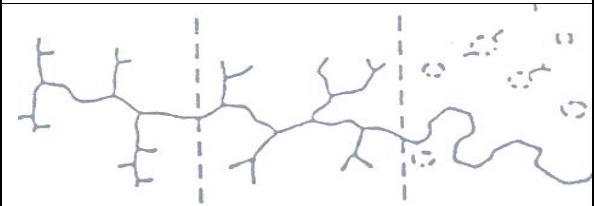
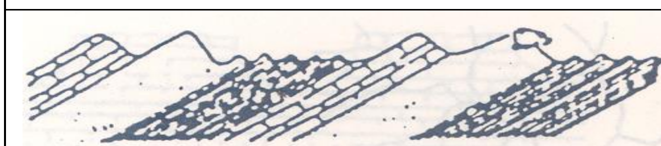
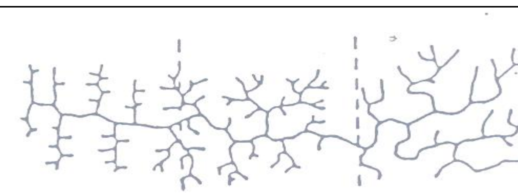
SHALE (Humid and Arid – Way, 1973)	
Humid	
	
A smooth, sag and swale topography, appearing as soft hills and mounds. The attitude of the bedding layers does not affect the appearance of the topography abd it is difficult to observe the bedding.	The soft shale exerts no control over the drainage system allowing medium to fine dendritic pattern and tributaries enter streams of the next order at acute angle.
Arid	
	
The topography is characterized by steep side slopes and a highly dissected. Ridge lines are rounded and faint bedding may be observed along the sides of the hill.	Shale regions show a very finely dissected pattern, dendritic in nature.

LIMESTONE (Humid and Arid- Way, 1973)	
Humid	
	
Chemical weathering dissolves the rock along joints and bedding planes, thus developing a collapsing surface of sinkholes and depressions known as “karst topography”. The surface is undulating with distinct boundary relation with other surrounding rocks. Sink-holes are rounded in flat lying beds, elongated in tilted beds.	The solution cavities within the rock and the high permeability of the residual soil cause internal drainage leaving little water to be collected in the surface water system.
Arid	
	
Since little moisture is available for chemical weathering in arid climate, the limestone erodes very little. Pure, thick limestone deposits form cap or table rocks with no typical karst topography characters.	The surface drainage system is well developed (karst topography does not exist in arid climates). The pattern is very angular, following joint alignment in the bedrock and is medium to fine textured.

THICK INTERBEDDED SEDIMENTARY ROCKS (Humid and Arid – Way, 1973)	
Humid	
	
Hill sides appear terraced, hill tops are at the same elevation. In s.st and shale combination the more resistant s.st form the cap rock with steep side slopes; the underlying shale has a more gradual side slopes. In the limestone – shale combinations the limestone occupies the hilltops and uplands and may have solution features.	Since the top cap rock is commonly a single lithology they show dendritic pattern with medium to coarse commonly the sandstone. If limestone form the hill top, the characteristic solution sinkholes with major streams following angular alignment.
Arid	
	
Topography similar to the humid region but with very sharp terraced character (alternatingly very steep and gentle slopes.	Dendritic medium to fine textured drainage is common, reflecting the upper surface strata. The limestone does not develop solution cavities but may the angular jointing system control the drainage.

<table>
<tr><td colspan="2">TROPICAL LIMESTONE, DOLOMITIC OR CHERTY LIMESTONE (Humid –Way,1973)</td></tr>
<tr><td>Tropical limestone.</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>A very rugged tropical karst topography is developed with conical hills and large depressions (upto to 1000 feet deep and I mile in diameter)</td><td>All drainage is internal through the highly permeable soil and bedrock.</td></tr>
<tr><td>Dolomitic or cherty limestone</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>These areas are similar to sandstone in appearance with little or few solution cavities or sinkholes. Nodules of chert can be observed in open lands.</td><td>A dendritic pattern or medium texture is characteristic in humid climates with angularity reflecting jointing control.</td></tr>
</table>

THIN INTERBEDDED SEDIMENTARY ROCKS (Humid and Arid)	
Humid	
	
Thin interbedded sedimentary materials do not have terraced slopes, although faint banding may be observed. Sanstones have steeper slopes than shale or limestone. Hill tops throughout have approximately the same elevations.	Drainage pattern is dendritic and of medium texture, similar to shale drainage in humid climates. The presence of shale in the interbedding, however, increases surface run-off resulting in a more dissected topography.
Arid	
	
The well – dissected topography shows very marrow terracing following hillsides contours. Sandstones and limestones have vertical cliffs, where shale forms more gradual slopes.	Develops dendritic patterns with fine textures. If shales are present, they provide impervious layers which increases surface run-off and dissection.

TILTED INTERBEDDED SEDIMENTARY ROCKS (Humid and Arid)	
Humid	
	
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 formation and karst topography with rounded or oval sink holes in limestone areas. Thin beds give the ridge topography a saw – toothed appearance.	In most situations a trellis drainage pattern of medium to fine texture exists, controlled by 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 low-lands, some angularity should occur as a result of jointing influence.
Arid	
	
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 strata. Sandstone and limestone both form resistant ridges; shale forms conical lowland hills. Thin beds give the ridges a diner saw-toothed appearance.	In arid climates tilted sedimentary rocks are identified by a trellis drainage pattern which is normally fine-textured. If here is a regional uniform slope, the trellis pattern may be modified showing some parallelism.

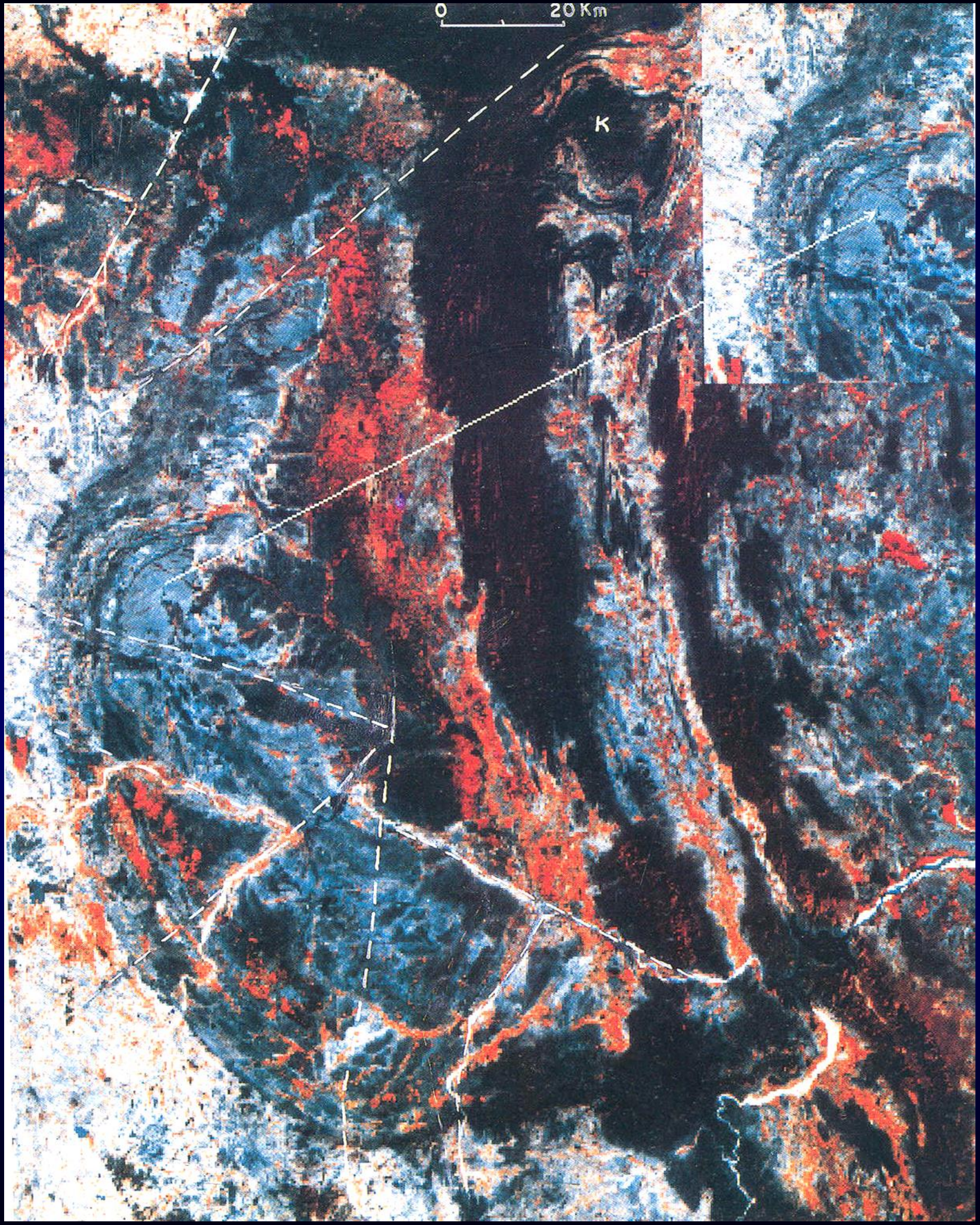
SEDIMENTARY ROCKS : (Summary Chart) (Way 1973)

	Topography	Drainage*	Tone	Gullies	Vegetation / Landuse
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	Cultivated & 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	Cultivated & Forested
Arid	Terraced hillsides	Dendritic, M-F	Banded	Varies to few	Barren
Flat, interbedded (thin bedded)					
Humid	Uniform slope	Dendritic, M	Med. gray	Soft U-Shaped	Cultivated & Forested
Arid	Minor terraces	Dendritic, F	Faint, thin bands	Few to none	Barren
Tilted, interbedded					
Humid	Parallel ridges	Trellis, M	Faint banding	Varies	Forested & Cultivated
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



CUDDAPAH BASIN

WiFs FCC -

CUDDAPAH BASIN

IRS-1C LISS III

A-Paniam qtz

B-Owk shale

C-Nargi L.st

D-Banganpalli SST

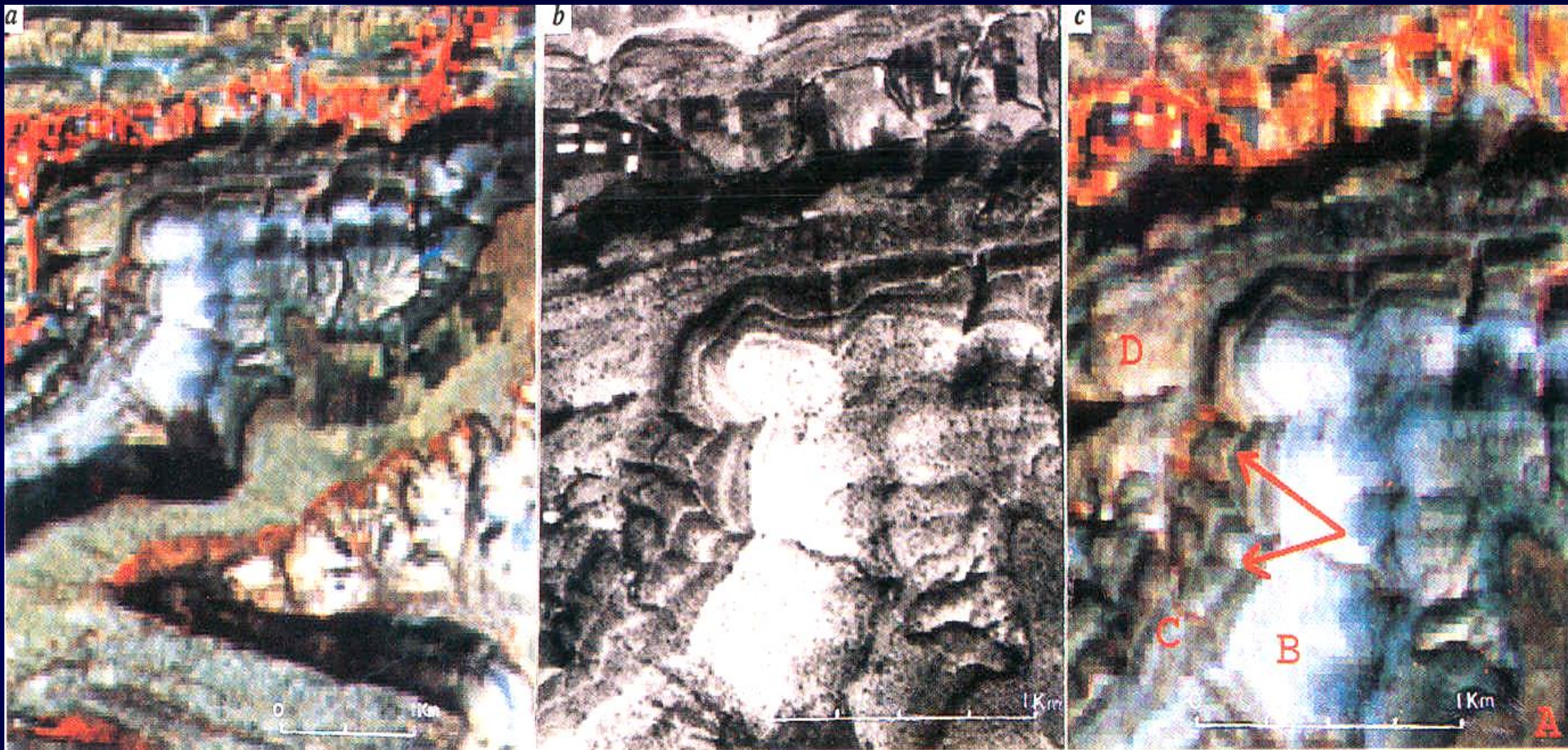
E-Tadpatri shale

F-Basic sills

T-Dip facet

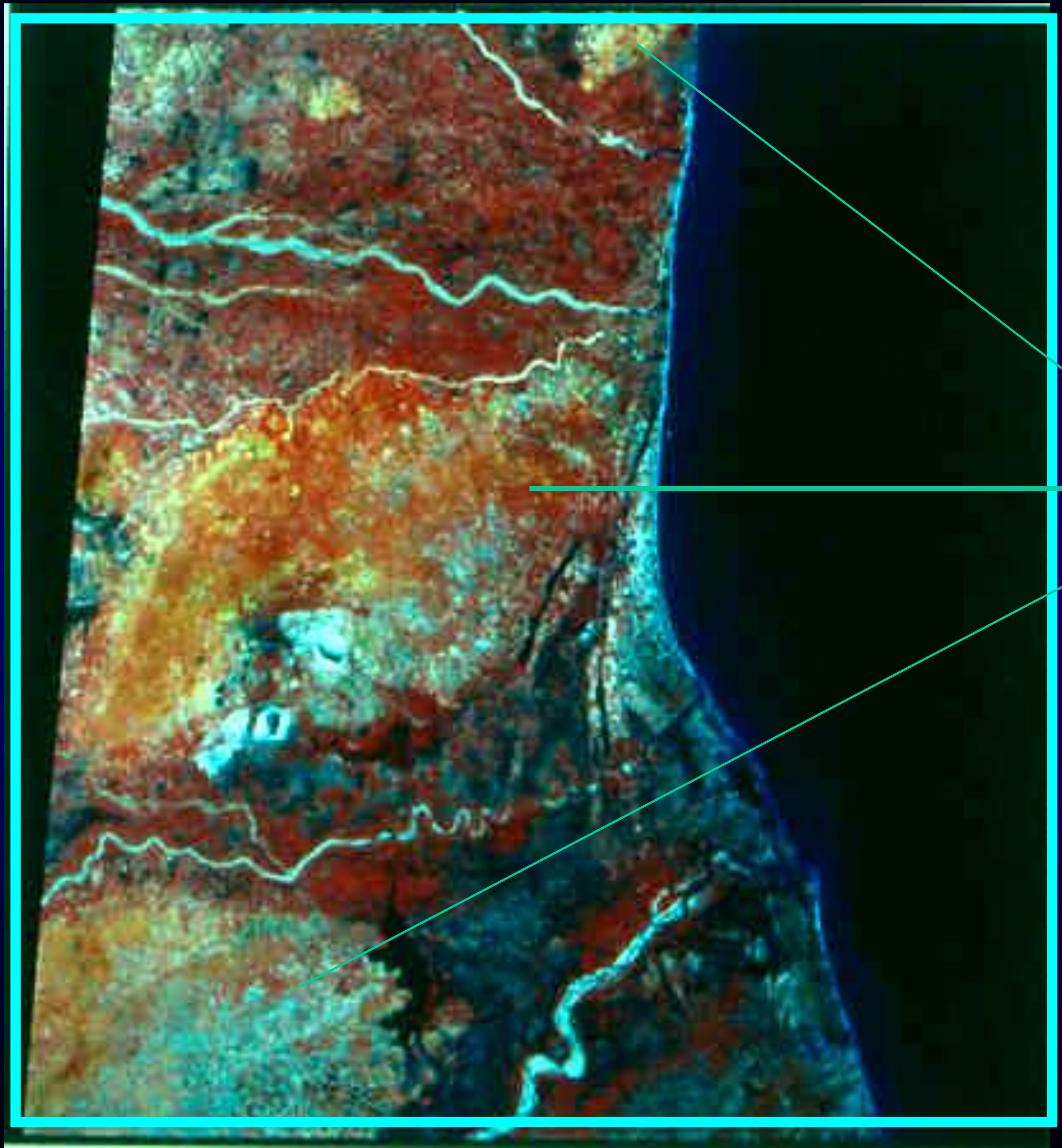
SF- Scarp face

CUDDAPAH BASIN



a b c

IRS-1C - a)FCC 432, b) Pan c)FCC – LISS III (43=RG) & Pan (Blue)



Tertiary S.St

METAMORPHIC ROCKS

More difficult

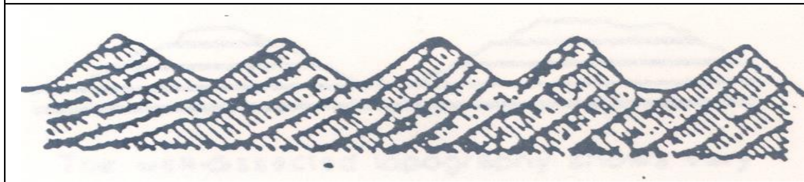
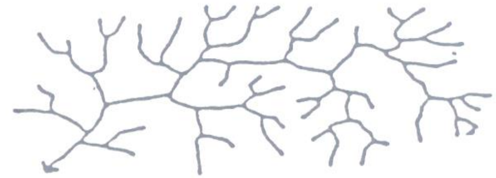
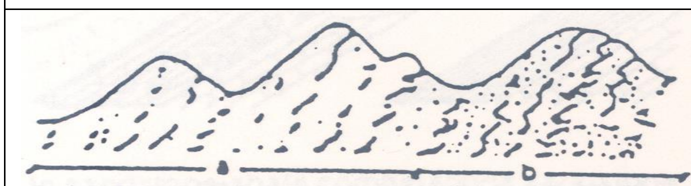
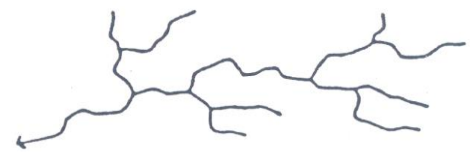
Significant: Structural features

a. Bedding- Flat, moderate,steep

b. Folds, faults, joints

Land forms: Generally alternating ridges & valleys

Drainage : Generally parallel with dendritic and trellis

SLATE (Huid and Arid – Way1973)	
	
Slate weathers quickly by mechanical means, developing a very rugged topography with sharp ridges and steep hillsides. The small ridges and valleys tend to be parallel to one another. Elevations of the hilltops and valley bottoms tend to repeat over the region.	The drainage pattern developed in slate region is a rectangular dendritic system, very fine texture. The thin foliations or cleavages of the slate provide initial planes of weakness which control the drainage system. The drainage pattern found in slates is finer than the similar pattern found in schist.
Gneiss (Way, 1973)	
	
Gneiss formations develop parallel, sharp ridged hills with steep side slopes; this topography is the result of differential weathering of the foliations with in the rock structure (a) glaciated regions (b) develop the same topography, except that ridge tops may be rounded as a result of glacial scouring.	The weathering of the rock foliation initiates and controls the placement of the drainage system which is angular and dendritic in regions where parallel ridges and valleys are developed, the system appears rectangular. The texture is generally fine to medium.

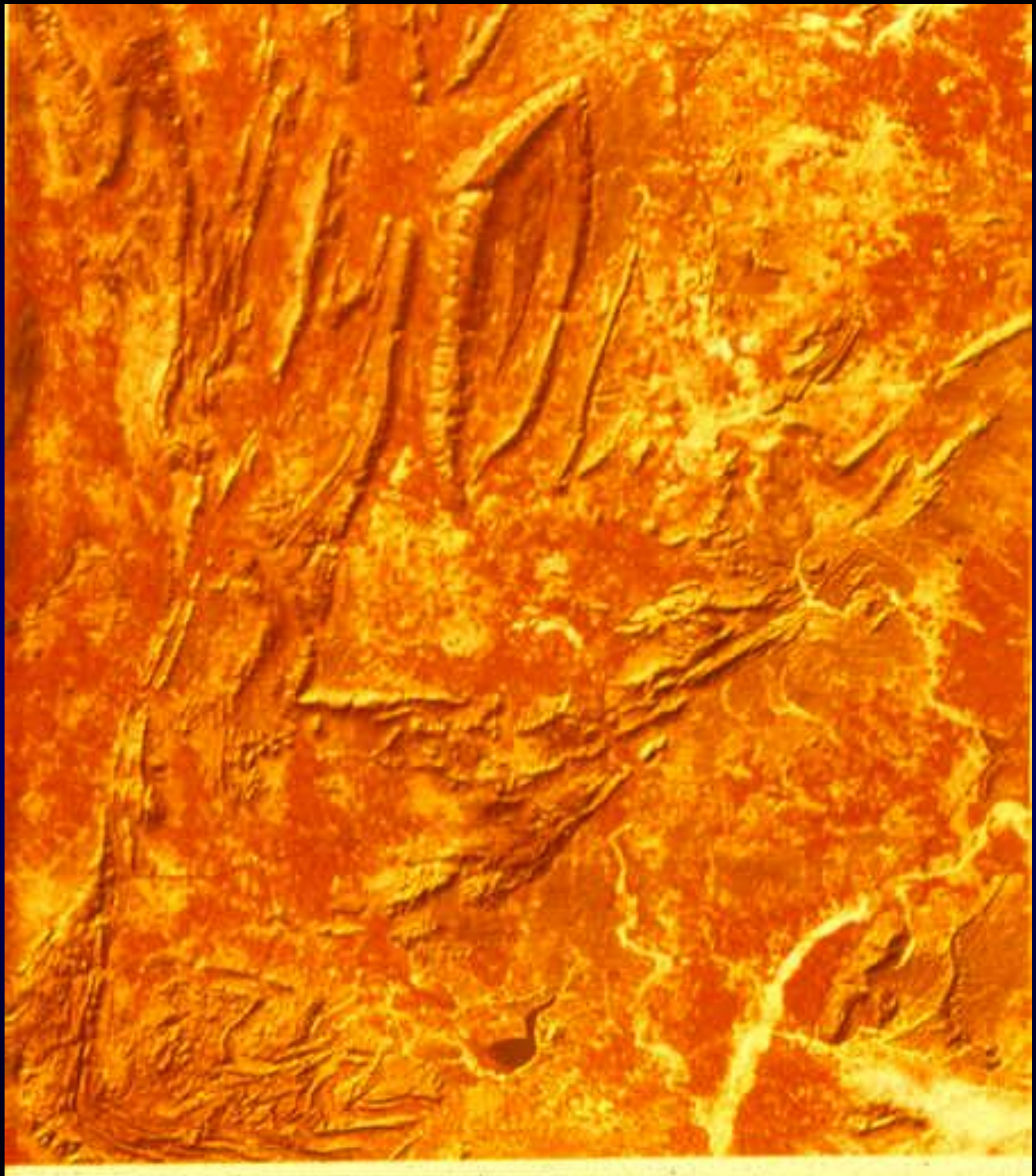
METAMORPHIC ROCKS: (Summary Chart) (Way, 1973)

	Topography	Drainage*	Tone	Gullies	Vegetation and Landuse
Slate					
Humid and Arid	Many sharp ridges	Rectangular, F	Gray	Short, parallel	Natural cover
Schist					
Humid	Rounded, steep hills	Rectangular, M to F	Uniform lt. gray	Parallel, U-Shaped	Cult. & Forested
Arid	Parallel laminations	Rectangular, M to F	Banded	Few, parallel, U-Shaped	Barren and grass
Gneiss					
Humid and Arid	Steep, parallel ridge	Angular, dendritic M to F	Light,uniform	U-Shaped, few	Natural cover

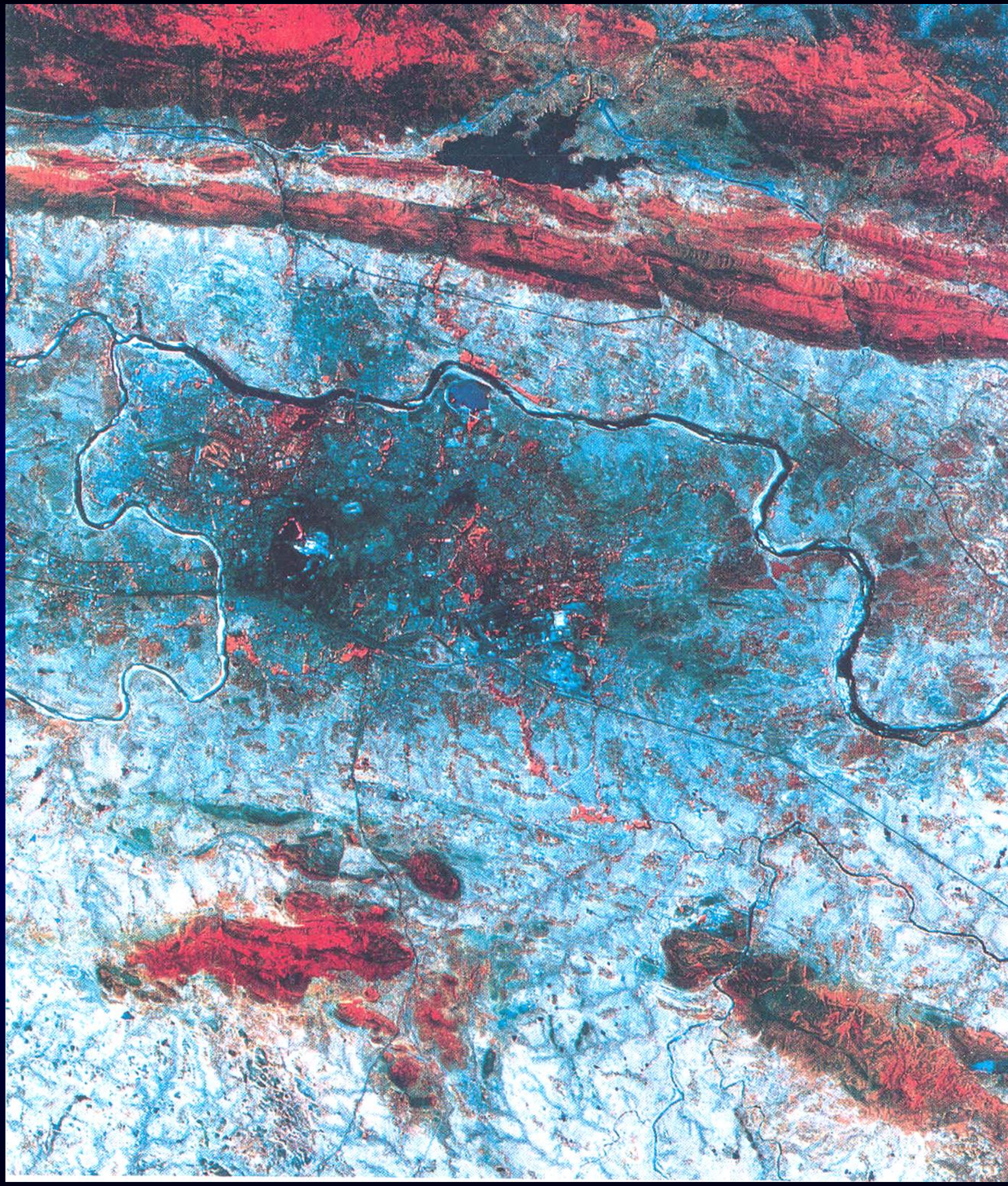
* F - Fine; M - Medium

IRS 1C – ARAVALLI

Eastern ghats



ALWAR
Quartzites



LISS III – JAMSHEDPUR