Minicourse Study Guide

Photogeology

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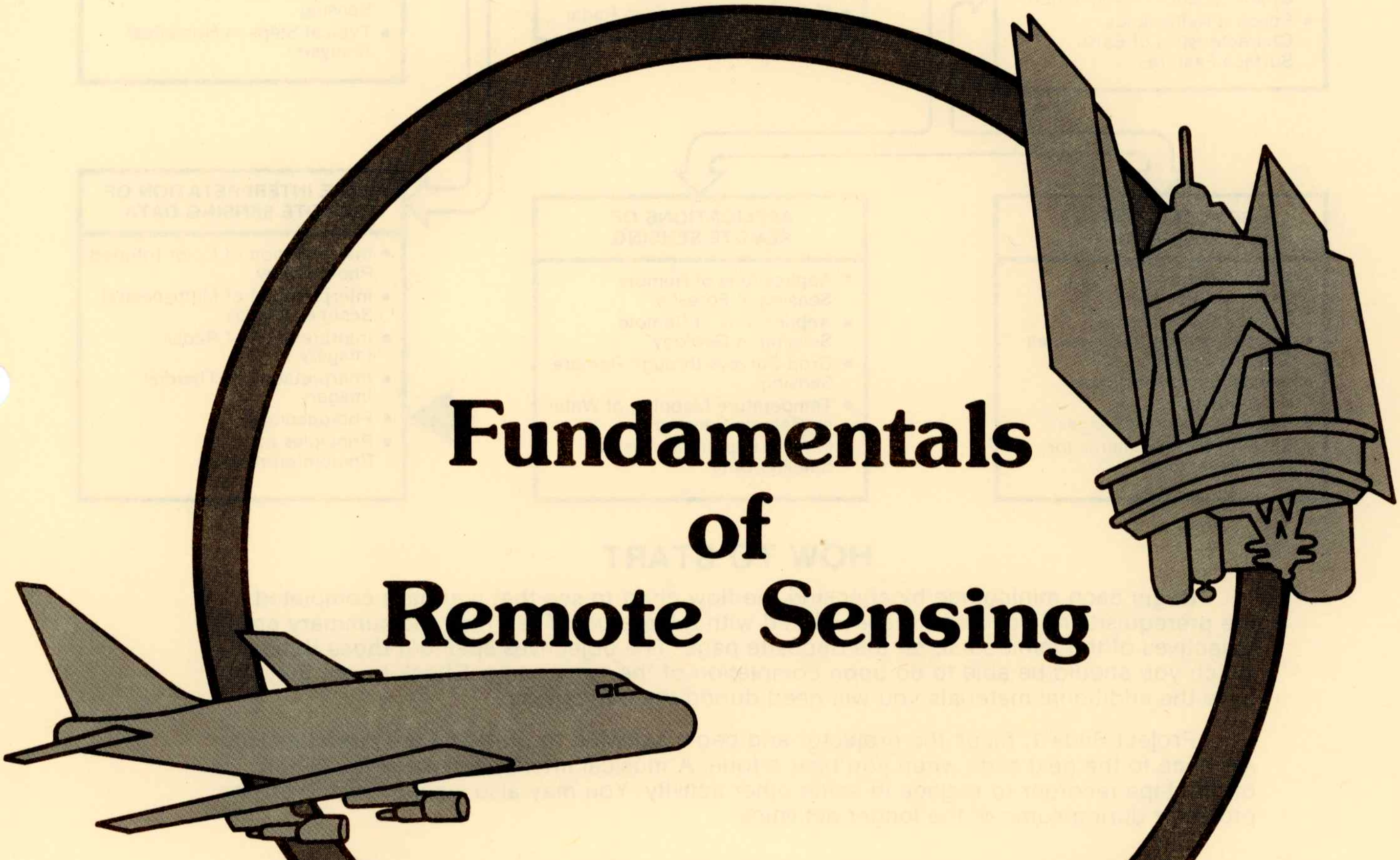
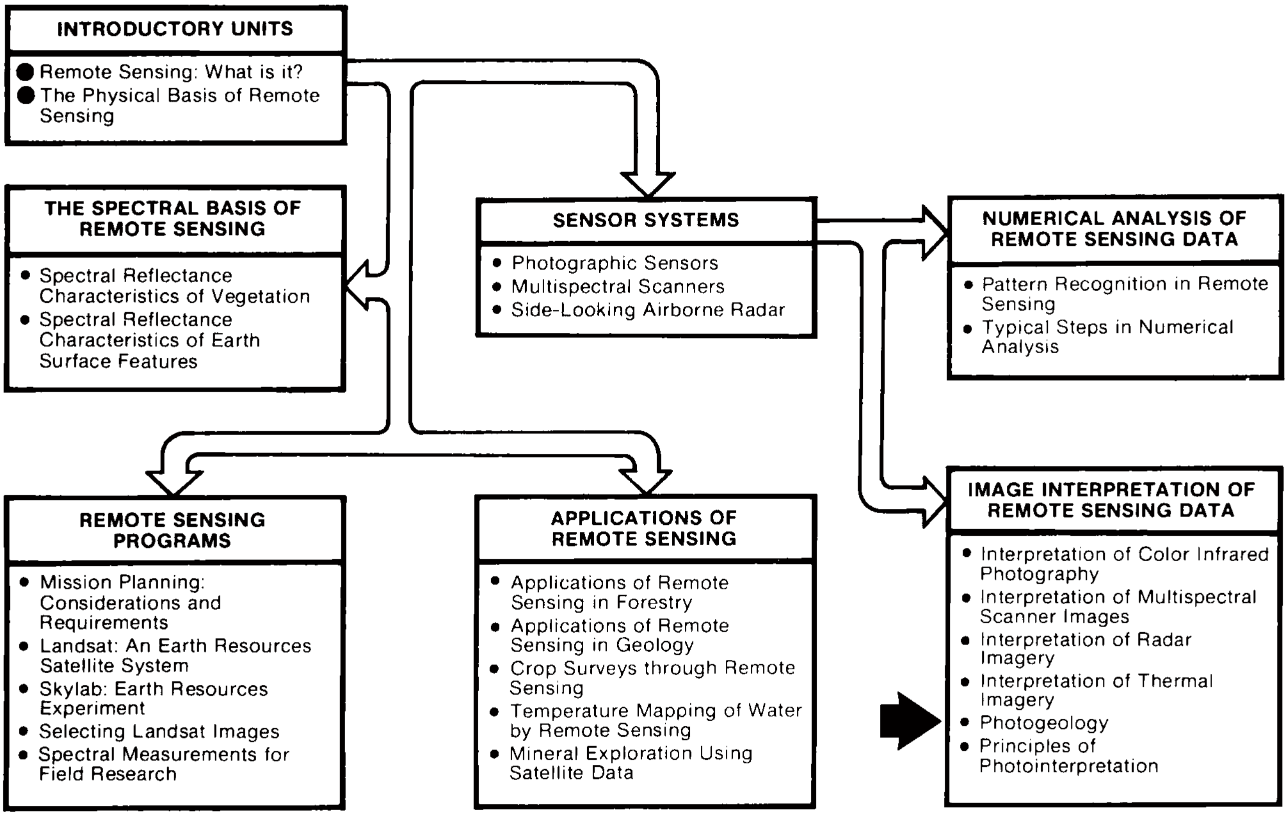


Fundamentals of Remote Sensing

The Minicourse Series is a Continuing Education Activity of Purdue University

PREFACE

This minicourse is one in a series on the Fundamentals of Remote Sensing. The complete set presents basic information about remost sensing at an introductory level. Each minicourse is comprised of a study guide, an audio tape, and a set of slides; several also contain additional tangible items such as maps, photographs, and overlays. The modular design of the series enables students to design their own learning programs by selecting from among available minicourses and progressing at their own rate. A flow chart of the series of minicourses is shown below.



HOW TO START

Begin each minicourse by checking the flow chart to see that you have completed the prerequisite minicourses, those marked with a large dot. Then read the summary and objectives of the minicourse on the opposite page. The objectives spell out those things which you should be able to do upon completion of the minicourse. Check to see that you have the additional materials you will need during the minicourse.

Project Slide 1, focus the projector and begin listening to Side 1 of the cassette tape. Advance to the next slide when you hear a tone. A musical interlude signals you to turn off the tape recorder to engage in some other activity. You may also want to switch off the projector during some of the longer activities.

Inquiries about the Instructor's Guide and other educational materials in remote sensing may be directed to:

CONTINUING EDUCATION ADMINISTRATION
116 Stewart Center
Purdue University
West Lafayette, Indiana 47907 (USA)

Photogeology

SUMMARY

Through the interpretation of aerial photographs, geologists can quickly gain geologic information that is useful in planning subsequent field work. They can, as well, gain a regional overview not easily acquired in the field. A systematic approach based on the interpretation of image elements (tone, texture, pattern, shape and slope) and interpretation elements (outcrops, landforms, drainage, vegetation, and cultivation) enables geologists to deduce the probable lithologic and structural characteristics of the area of interest.

OBJECTIVES

When you have completed this minicourse, you should be able to:

1. Identify common rock types on air photo images of outcrops.

2. Identify from air photos important structural features of an area, including dips, anticlines, synclines and faults.

3. Sketch a cross-section of a selected area using a stereoscope and air photos.

4. Describe an approach to geologic image-interpretation that is useful where geologic features are obscured by vegetation.

5. Perform a geologic analysis that shows lithologic boundaries, drainage patterns, and basic structural features using air photos and a stereoscope.

6. Name the probable lithologies and structures in the area analyzed for objective 5, stating the reasons for your deductions and the degree of confidence you place in these deductions.

SPECIAL PREREQUISITES

Students will need to have a basic background in geology and be able to see stereoscopically using a pocket stereoscope and stereograms.

SUPPLIES NEEDED

-- a pocket stereoscope
-- annotated overlay transparency accompanying the minicourse
-- a sheet of clear acetate and marking pens in red, black, and blue.

APPROXIMATE TIME: 2 hours with intermission at mid-point.

-- PROJECT THE FIRST SLIDE --

-- START THE TAPE --

I. What Is Photogeology?

Definition ⇨ photogeology

The use of photointerpretation techniques to aid in geologic applications, such as regional and local mapping, exploration, and engineering geology.

-- RETURN TO TAPE --

Four image elements:

tone:

texture:

pattern:

shape:

Activity 1

Complete the statements below by writing the letter of the best answer in the space provided.

1. A geologist uses photogeology in order to ____.

   a. avoid field work
   b. increase field work
   c. prepare for field work

2. One advantage of photo survey over field work is that the geologist can better ____.

   a. identify rock types
   b. view regional patterns
   c. penetrate vegetative cover

3. Match the image elements on the left with the appropriate descriptive term on the right.

____ tone	a.	rough
____ texture	b.	sloping, rectangular
____ pattern	c.	repeated curves
____ shape	d.	light

4. When photographs are going to be viewed stereoscopically, they must be taken ____.

   a. on black-and-white film
   b. so that they overlap
   c. to show different textures
   d. in the field

-- RETURN TO TAPE --

II. Lithologic Interpretation

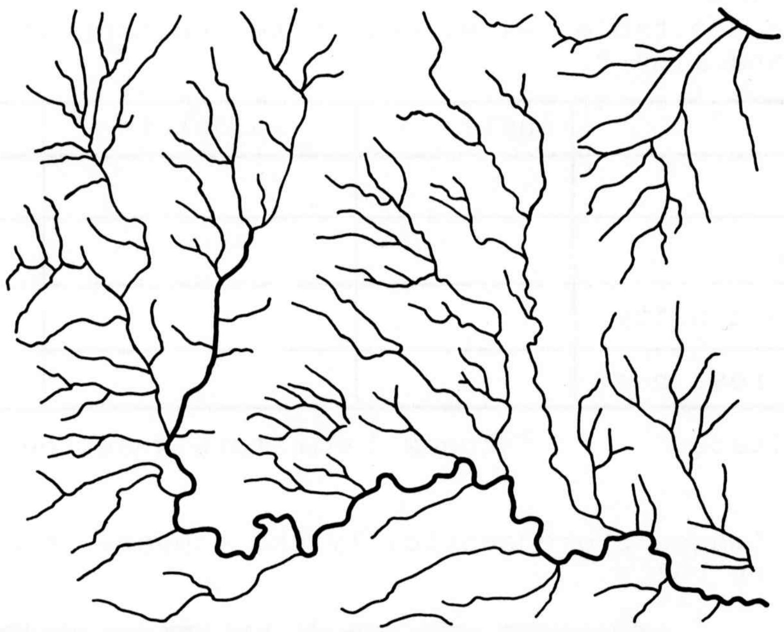
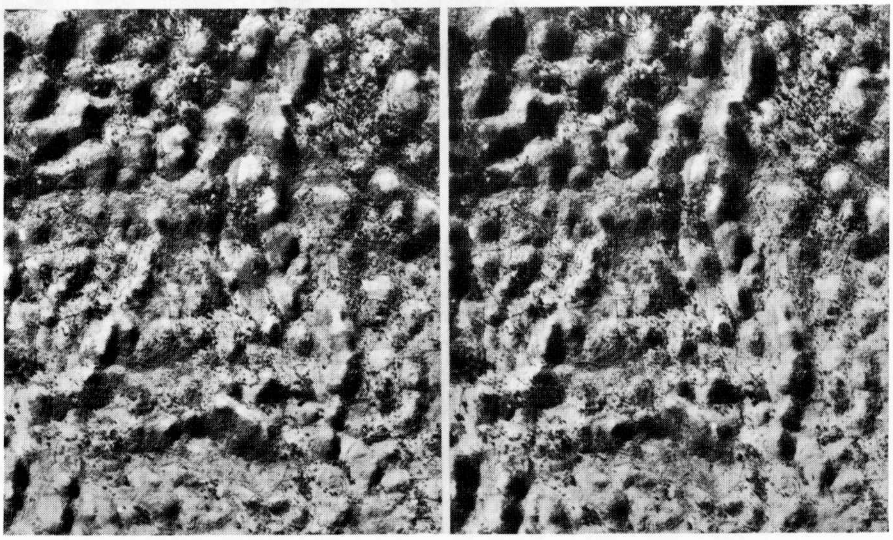


Figure 1. Dendritic drainage pattern in exposed shale (Slide 15).

For your reference, a sketch glossary of common drainage patterns appears on page 16.

When you can see these images stereoscopically, turn on the tape for related comments. Have the transparent overlay at hand.

Stereogram 1



Note: Stereograms reproduced photographically are usually sharper and contain more detail than the ones appearing here. Hints for using a stereoscope are given on page 13.

Activity 2

To complete the table below, return to the tape after filling in line 1 and line 3.

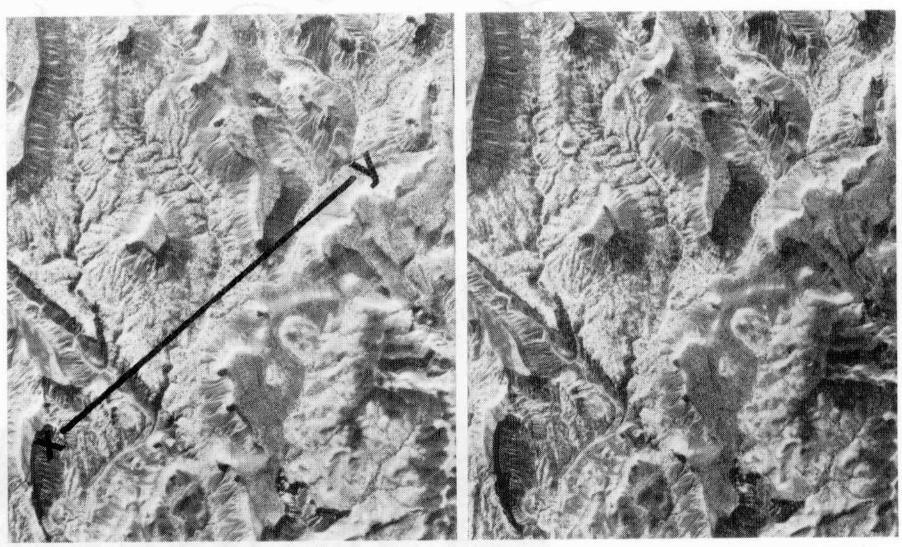
		shale	sandstone	limestone
1	tone[1]			
2	resistance			
3	drainage density			
4	special features[2]			

[1]weak indicator

[2]strong indicators when they occur

View these images stereoscopically and compare them with the cross-section below.

Stereogram 2



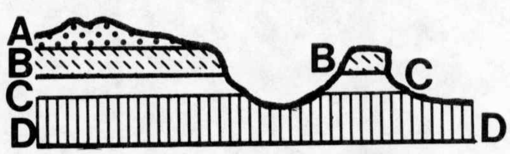


Figure 2. Cross-section along the line x-y in the sedimentary area above. (Also slides 18 and 19)

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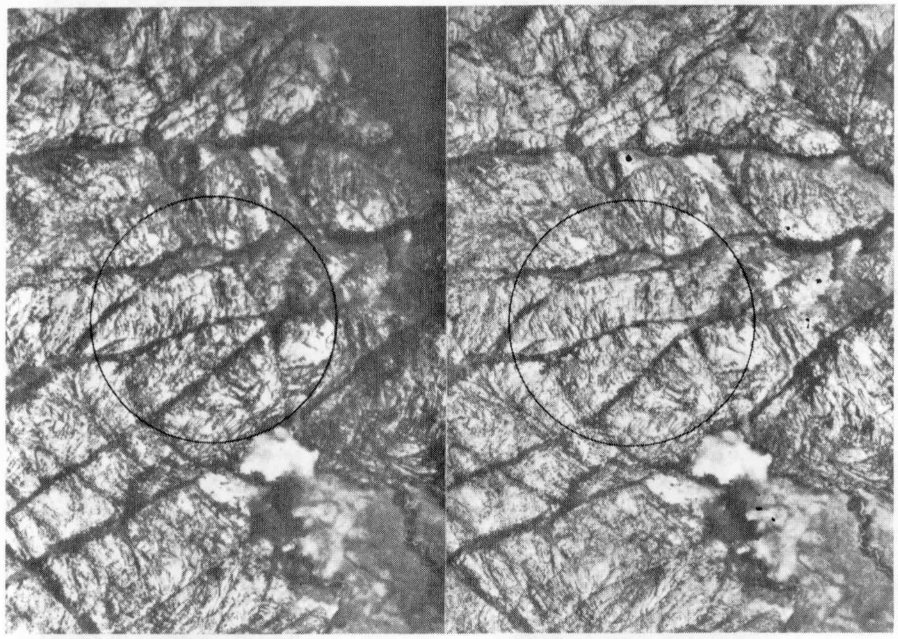
Activity 3

Using Stereogram 3, sketch the drainage in blue and the fractures in red, as directed on the tape.

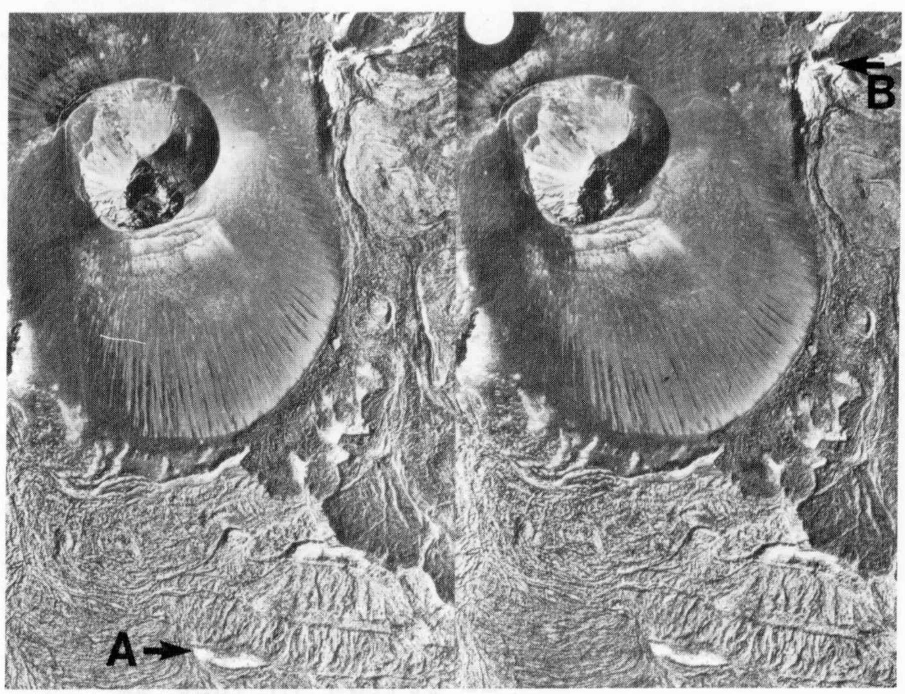
Stereogram 3



-- RETURN TO TAPE --

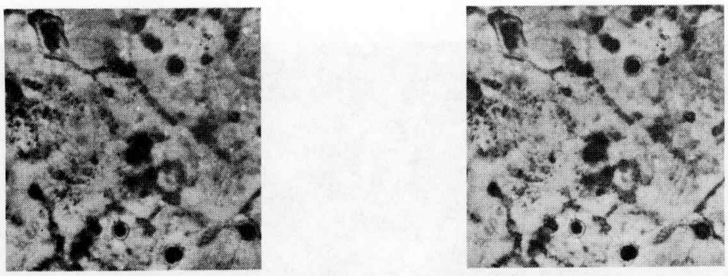
While viewing these images stereoscopically, turn on the tape for related comments.

Stereogram 4

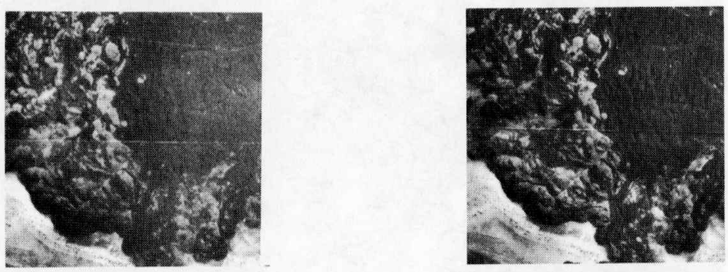


Activity 4

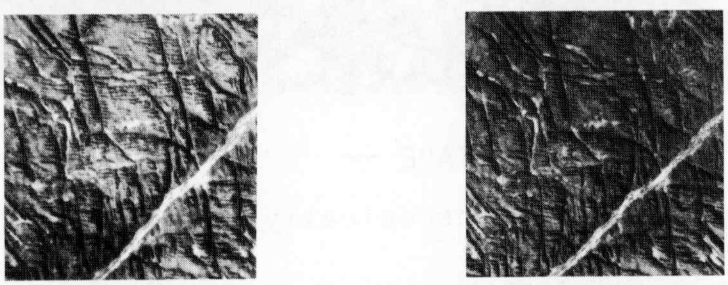
Identify the rock type in each of the five stereograms below and write your answer in the space to the right. There are two examples of sandstone and one each of shale, limestone and igneous rock.



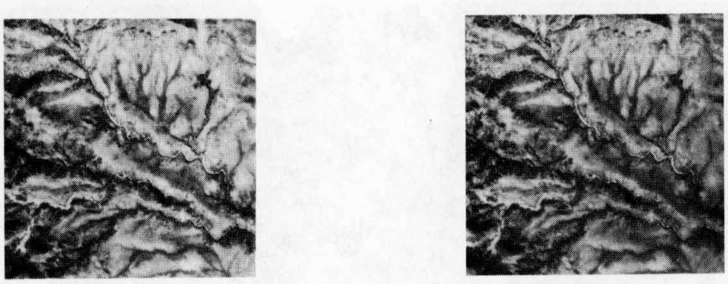
a ____________________



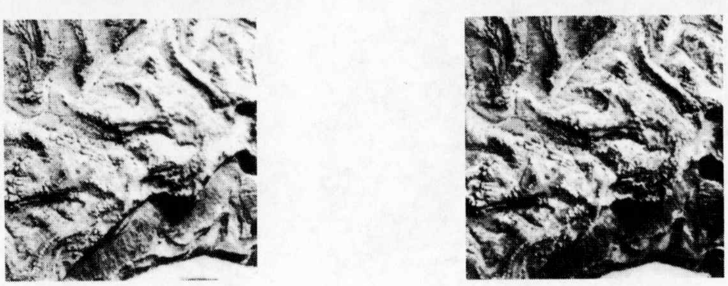
b ____________________



c ____________________



d ____________________



e ____________________

You may check yours answers on page 18.

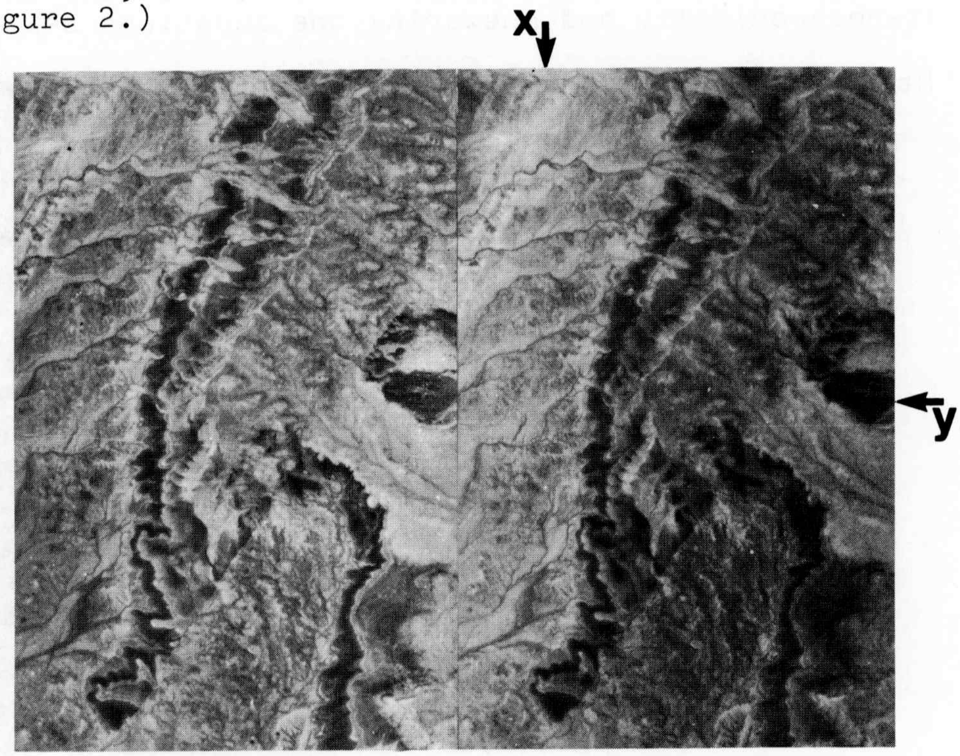
-- RETURN TO TAPE --

III. Structural Interpretation

Activity 5

In the space below, sketch the cross section at line XY. (Refer to Figure 2.)

Stereogram 5



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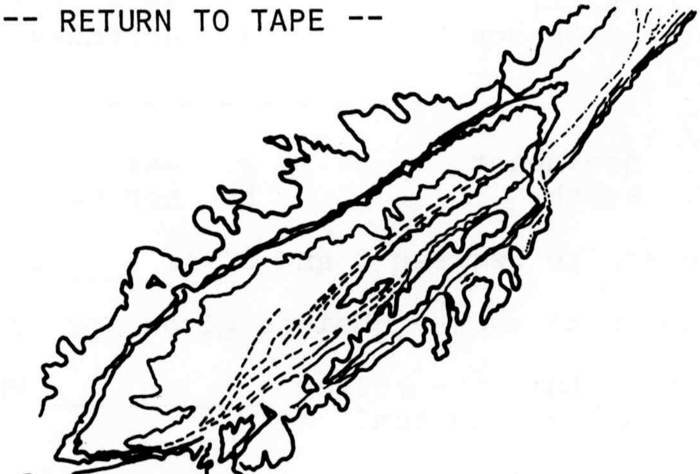
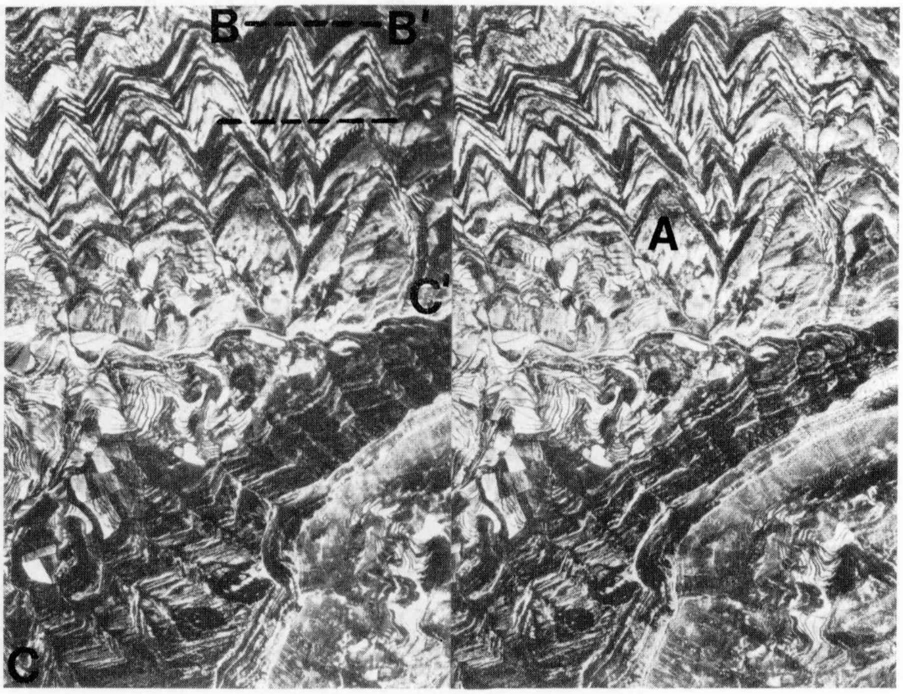


Figure 3. Boundaries of tonal feature on slide 26.

Activity 6

Develop a structural interpretation by viewing the area stereoscopically and answering the questions below.

Stereogram 6



1. The feature at (A) is ____.

   a. a dome c. a flatiron
   b. a syncline d. a fold

2. The strike between B and B' is ____ and the dip is ____.

   a. east-west c. northeast-southwest
   b. north-south d. northwest-southeast

   - - - - - - - - - -

   e. northeast g. east
   f. south h. northwest

3. The strike between C and C' is ____ and the dip is ____.

   (use same answer choices given for question 2)

4. What is this structure? ____________ What is your evidence for this conclusion?

   a. monocline b. syncline c. anticline

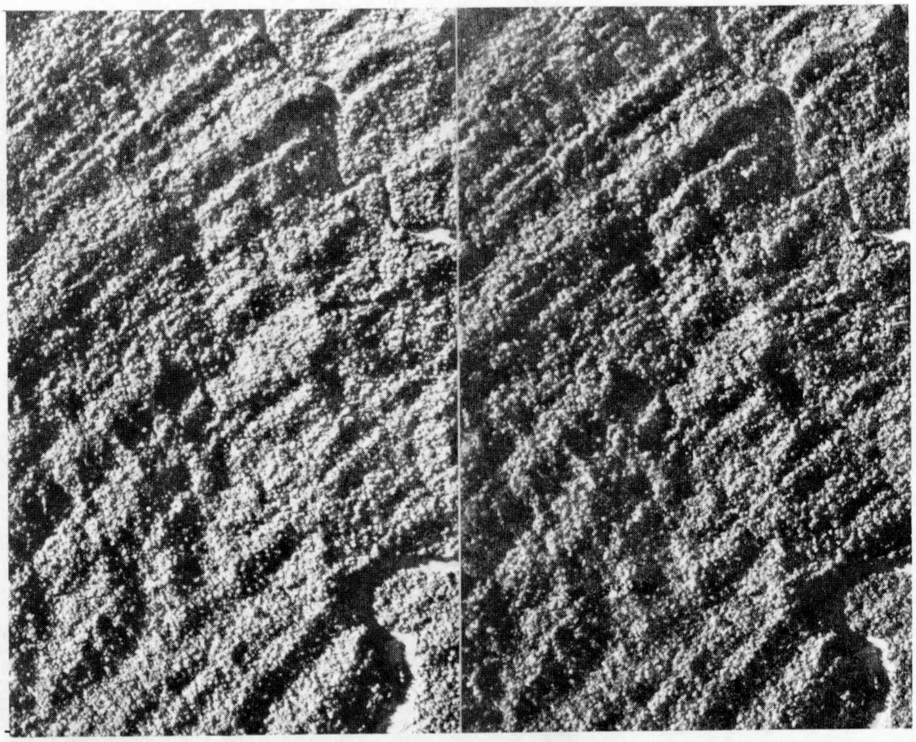
5. Draw in the axis of the structure. Its direction is ____.

   a. east-west c. southwest-northeast
   b. north-south d. northwest-southeast

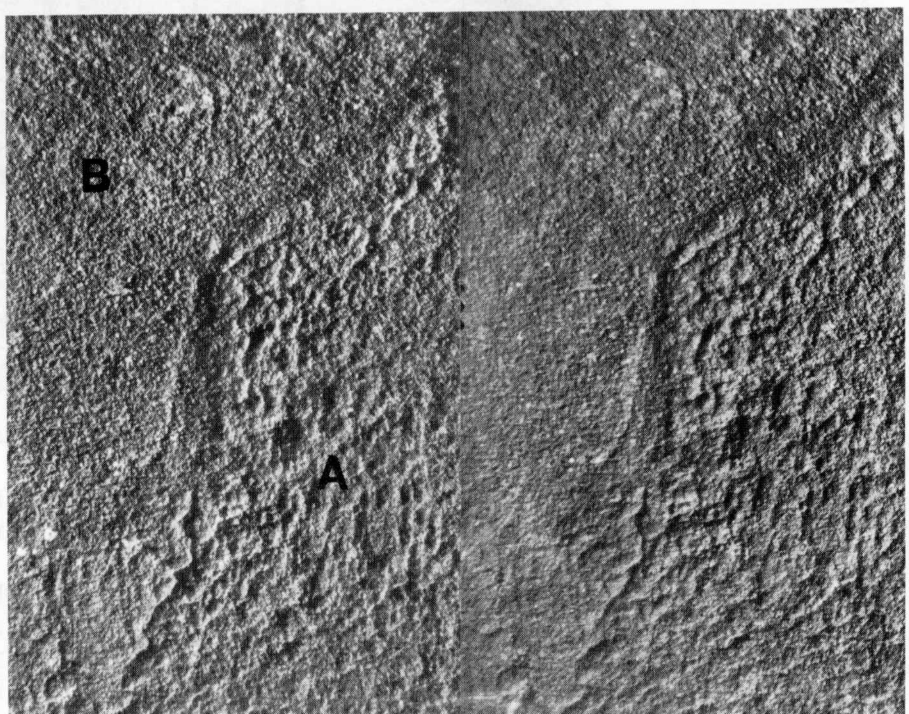
-- RETURN TO TAPE --

IV. Interpretation with Limited Evidence

Stereogram 7



Stereogram 8



The resistant beds in stereogram 7 are probably _______________.

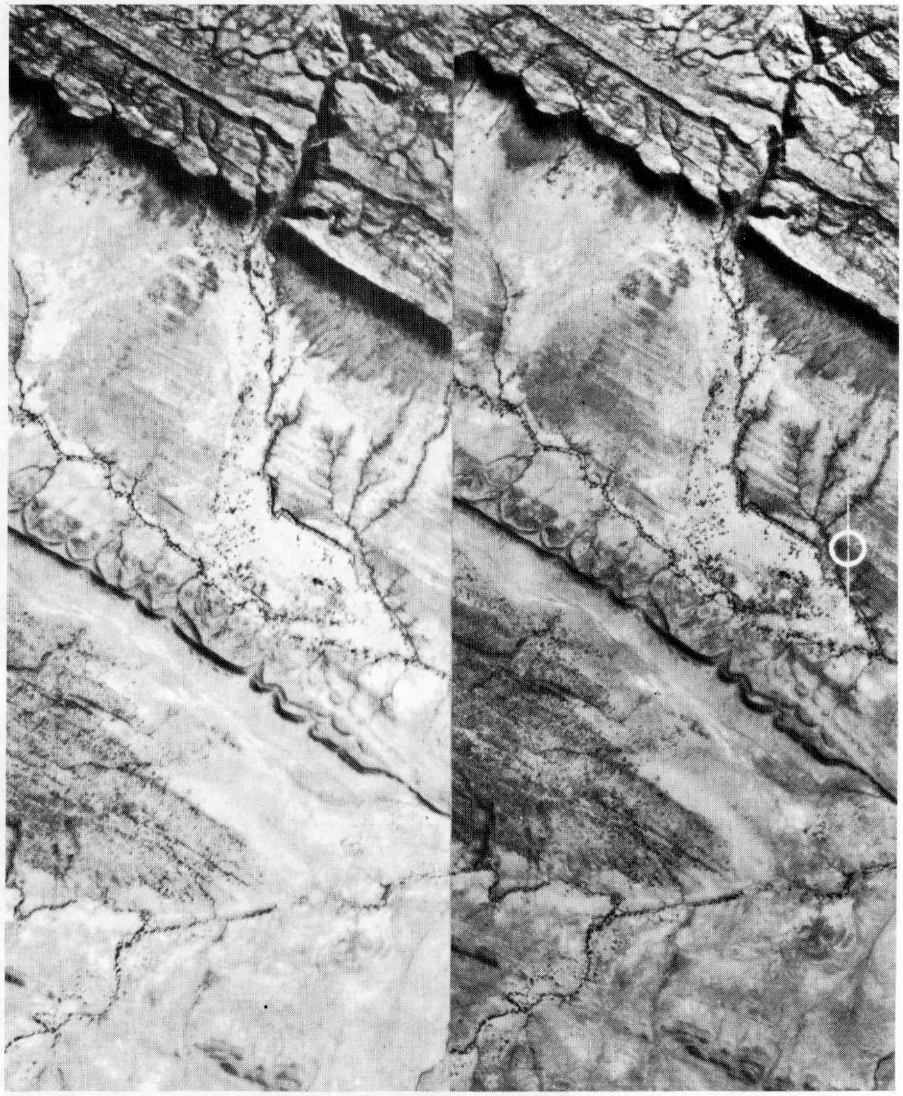
The resistant unit in stereogram 8 is probably _______________.

-- RETURN TO TAPE --

V. Preparing the Geologic Interpretation

Activity 7 - Part 1

Stereogram 9



Prepare a lithologic and structural interpretation of the area shown in the stereogram above. Place a sheet of clear acetate over the righthand image and, while viewing the area stereoscopically, draw in the lines called for in steps 1, 2, and 3 below:

Step 1: Draw black lines to delineate the five major geological units. Identify these units from oldest to youngest (i.e., stratigraphically lowest to highest) as A, B, C, D, and E.

Step 2: Using a blue pen, trace the drainage lines visible on the stereogram.

Step 3: With red, trace joints and fractures; annotate strikes and dips with standard symbols; draw in axes of anticlines or synclines.

-- RETURN TO TAPE --

Activity 7 - Part 2

Complete the chart below for the five rock units you have delineated. Use the terms provided below the chart.

		Exposed rock units				
		Unit A	Unit B	Unit C	Unit D	Unit E
Tone						
Drainage	Internal/ external					
	Pattern					
	Density					
Rock Properties	Resistance					
	Bedding					
	Attitude					
	Jointing					
	Boundaries					
Conclusions	Probable rock types					
	Probable structure					
	Degree of certainty					

TONE: dark; medium; light; medium-to-light; medium-to-dark.

DRAINAGE
External or internal drainage: persistent drainage lines; interrupted drainage lines; karst phenomenon; no surface drainage.
Drainage patterns: dendritic; parallel; angular; radial.
Drainage density: very low; low; medium; high; very high.

ROCK PROPERTIES
Resistance: very low; low; moderate; high; very high.
Bedding: none; very massive; massive; well-bedded; very well bedded.
Attitude: horizontal; gentle (5-29%); moderate (30-59%); steep (60-85%); vertical.
Jointing: none; one direction; several directions; persistent; not persistent; low density; medium density; high density.
Boundaries: sharp; vague; persistent; not persistent.

CONCLUSIONS
Rock type: Sedimentary (linestone, sandstone, shale); igneous (granite, extrusive); metamorphic.
Structure: gently folded or faulted; moderately folded or faulted; intensively folded or faulted.

-- RETURN TO TAPE --

SELF-TEST

If you were able to complete Activity 7, you have mastered the practical objectives of the minicourse. The questions following test your theoretical mastery of the objectives.

1. Fill in the blanks below with the proper term:

metamorphic	shale
igneous	sandstone
granite	limestone

   If exposed rock has sharply intersecting joints, it is probably a) ____________ or b) ___________. Sedimentary rock with high drainage density is probably c) ___________. Karst topography and haystack peaks are typical of d) _______. Two sedimentary rocks that generally have higher resistance to erosion are e) ___________ and f) _____________. Rock that appears homogeneous, massive and without bedding is often g)______________. The most difficult rock to distinguish on aerial photos is h)______________.

2. Is resistance to erosion a weak or strong indicator of rock type? What about the tone of the rock on aerial photography?

3. What does a cross-section sketch show?

4. When flatiron patterns occur on opposite sides of a geologic feature and point away from each other, is the feature an anticline or a syncline?

5. Describe how aerial photos can be used in lithologic and structural interpretation when heavy vegetation is present; mention the specific image elements and interpretation elements that are of most help.

6. List and briefly describe the four steps in the process of geologic interpretations based on aerial photography.

(Answers to self-test are on page 19.)

Appendix A: How to Use a Pocket Stereoscope

Line the stereoscope up as shown in the sketch; look at the image through the lenses and adjust until the images merge and you preceive the third dimension.

-- If your stereoscope is adjustable, start by spreading the lenses to about the 70mm mark; adjust to suit your own eye separation.

-- Be sure the top of the stereoscope is parallel with the top of the picture and the image is lying flat on the table.

-- Look through the lenses and try to fuse the two images into a single, three-dimensional image. Slowly move the stereoscope to the left or right, up or down, or rotate it slightly if necessary.

-- If you don't see the three-dimensional effect the first time, rest your eyes for a minute. As you try again, think about focusing your eyes approximately one foot below the picture.

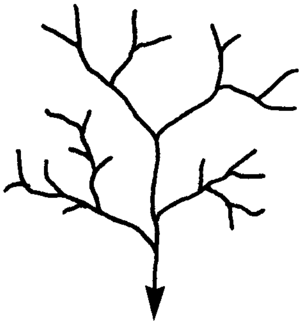
Appendix B: Glossary

Adventive cone	- A tuff or lava cone at the flank or foot of a major volcano.
Anticline	- An upfold of stratified rock in which the beds dip in opposite directions from the crest.
Dip	- The angle which a stratum makes with a horizontal plane, as measured in a plane normal to the strike.
Dome	- An upfold of which the ratio between width and length of the structural closure is approximately 1:1.
Drainage	- Network of streams.

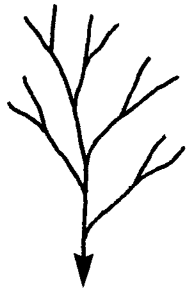
Extrusive Rocks	- Those igneous rocks which have cooled after reaching the surface; common types are lava flows and tuffs (volcanic ashes).
Fault	- A displacement caused by a slipping of rock masses along a plane of fracture.
Flatiron	- A triangular-shaped sloping-mesa type of hogback ridge, often occurring in series on the flank of a mountain.
Fold	- A bend or flexure produced in rock.
Fracture	- A break in rocks with or without displacement.
Hogback	- A ridge produced by tilted, resistant strata.
Igneous rocks	- Those rocks which solidified or crystallized from a hot, fluid mass, called magma.
Intrusive rocks	- Those igneous rocks which have solidified without reaching the surface.
Joint	- A fracture in rock, between the sides of which there is no observable relative movement.
Limestone	- A rock largely composed of calcium carbonate.
Lineament	- Any line on aerial photographs that is structurally controlled.
Lithology	- Physical character (composition and texture) of a rock, generally determined megascopically or with the aid of a low-power magnifier.
Metamorphic rocks	- Rocks which have been changed by mineralogical and structural adjustment to physical or chemical conditions imposed at depth below the surface.
Monocline	- A zone of tilted strata, as the flank of an uplift, of which the opposite limb is at a relatively great distance.
Morphology	- The external structure of rocks in relation to the development of erosional forms or topographic features.
Outcrop	- That part of a stratum which appears at the surface.
Pattern	- Refers to a more or less orderly spatial arrangement of particular elements shown; on the photo, it implies the characteristic repetition of certain general forms or relationships.

Sandstone	- A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.
Sedimentary rocks	- Rocks formed by the accumulation of sediment in water or from air. The sediment may consist of: - rock fragments or particles in various sizes (conglomerate, larger than 2 mm; sandstone, 2 - 0.0625 mm; shale, smaller than 0.004 mm); - the remains or products of animals or plants (certain limestones, coal); - the product of chemical action or of evaporation (precipitated carbonates, salt, gypsum); - mixtures of the foregoing materials. Some sedimentary deposits (tuffs) are composed of fragments blown from volcanoes and deposited on land or in water.
Shale	- A laminated sediment in which the constituent particles are predominantly of the clay grade.
Slope	- Inclined surface of a hill, mountain, plateau, plane or any part of the surface of the earth.
Strike	- The bearing or direction of the outcrop of an inclined bed on a level surface.
Syncline	- A downfold of stratified rock in which the beds dip from opposite directions towards a common trough line.
Tectonics or structural geology	- The branch of geology dealing with the form, arrangement and attitude of strata in the earth's crust as a result of deformations and dislocations.
Texture	- The composite appearance presented by an aggregate of unit features too small to be individually distinct.
Tone	- Each distinguishable shade variation from black to white.
Volcanic cone	- Cone formed by accumulation of lave and (or) tuffaceous material.

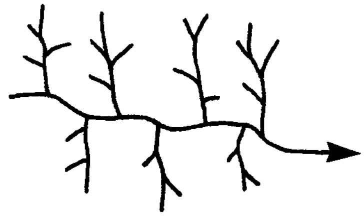
Appendix C: Drainage Glossary



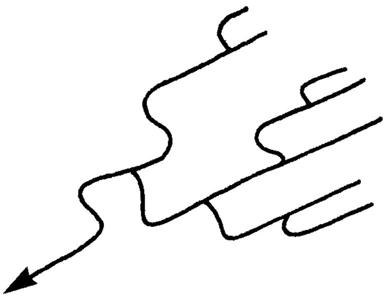
1. Dendritic



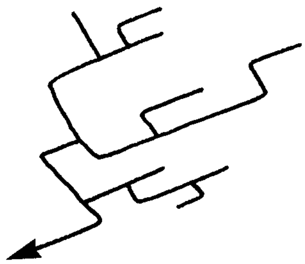
1.1 Sub-dendritic



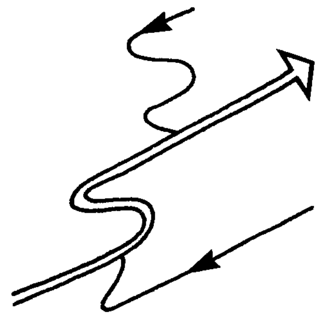
1.2 Trellis



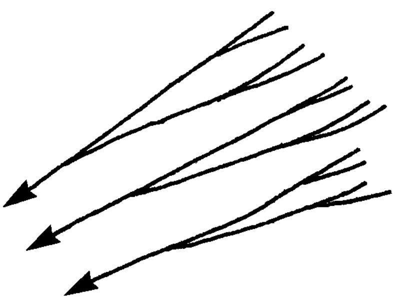
2. Angular



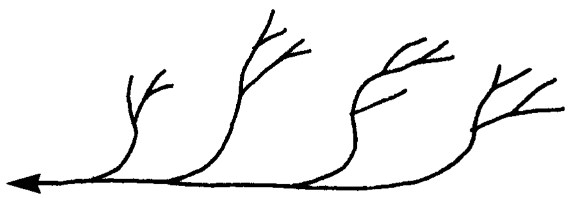
2.1 Angulate



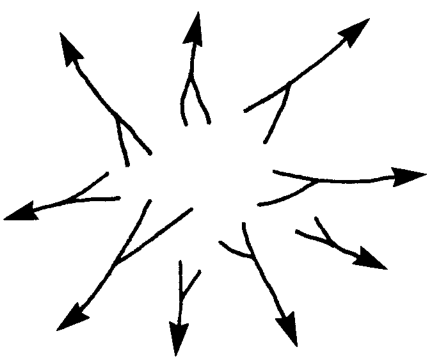
2.2 Contorted



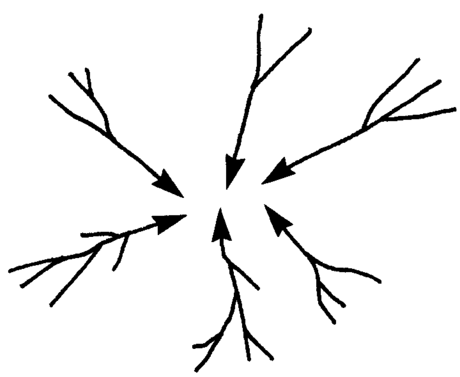
3. Parallel



3.1 Sub-parallel



4.1 Radial Centrifugal



4.2 Radial Centripetal

Appendix D: Further Reading

Allum, J.A.E. 1966. Photogeology and Regional Mapping. Pergamon Press.

American Society of Photogrammetry. 1975. Manual of Remote Sensing. Vol. I and II.

Bandat, F. von. 1962. Aerogeology. Gulf Publishing Company.

Mekel, J.F.M. ITC Textbook, Vol VIII-I: The use of aerial photographs for geological mapping.

Miller, V.C. 1961. Photogeology. McGraw Hill.

Ray, R.G. 1960. Aerial Photographs in Geologic Interpretation and Mapping. US Geological Survey, Prof. Paper 373.

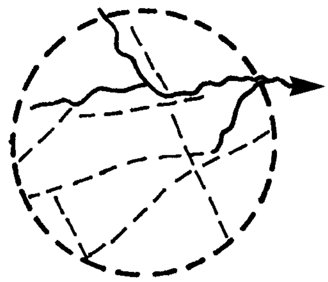
Appendix E: Credits

The fundamental principles presented in this minicourse series represent a distillation of research and development efforts by remote sensing centers around the world; the specific procedure described here was developed at the International Institute for Aerial Survey and Earth Sciences (ITC), Enschede, The Netherlands.

The authors would like to acknowledge especially the contributions of Mr. John Richardson, educational technologist at ITC's Center for Advancement in Learning and Teaching; G.W. O'Brien, Independent Studies, Purdue; Susan L. Ferringer, visual designer at Purdue; and the many students, staff and visitors of ITC and Purdue who reviewed and evaluated preliminary versions of these materials. Original music was composed and performed by Jeff Grinstead, Audio-Visual Production, Purdue University. Narrators are Roger D. Priest and Melissa D. Keeney, Radio station WBAA, Purdue University.

Appendix F: Answers to Activities

Activity 3



Activity 4

a) limestone; b) igneous; c) sandstone; d) shale; e) sandstone.

Activity 5

Activity 7

Note: this key deals with the major features only; details have been omitted. The same is true for the interpretation appearing on slide 31.

Unit A is a resistant unit of medium gray tone, showing pronounced jointing in SW-NE, N-S and NW-SE directions. Stratification (bedding) is difficult to detect due to the dense jointing, which masks the bedding outcrops, and the near-horizontal attitude. Drainage on this unit is external, poorly developed, sub-dendritic and of low density.

Unit B is of low resistance, has a light tone, and locally shows clear stratification. Drainage is external, subdendritic and of low density. Joint patterns are not visible.

Unit C forms a prominent strike ridge. It is a relatively thin layer of resistant rock, which locally shows clearly developed flatirons. Drainage is external; streams crossing this thin unit form part of a sub-dendritic drainage system of low density.

Unit D is essentially similar to unit B.

Unit E is formed by resistant and massive beds. The lower part of this unit is well-stratified, but higher in the succession bedding is less clear. The tone is rather dark. The medium dense drainage is external and exhibits combinations of dendritic and trellis patterns and is influenced by jointing.

Conclusions: Units A, C, and E show the characteristics of sandstones, although the possibility of limestone cannot be completely excluded. Units B and D are interbedded sedimentary rocks covered by alluvial material. The structure is an anticline. Unit A forms the core of the structure. The axis has a NW-SE direction and plunges toward the SE. The structure is slightly asymmetrical, the southern flank being somewhat steeper than the northern flank.

Appendix G: Answers to Self-Test

1. a) sandstone
   b) granite
   c) shale
   d) limestone
   e) sandstone
   f) limestone
   g) granite
   h) metamorphic

2. resistance is a strong indicator, but tone is not.

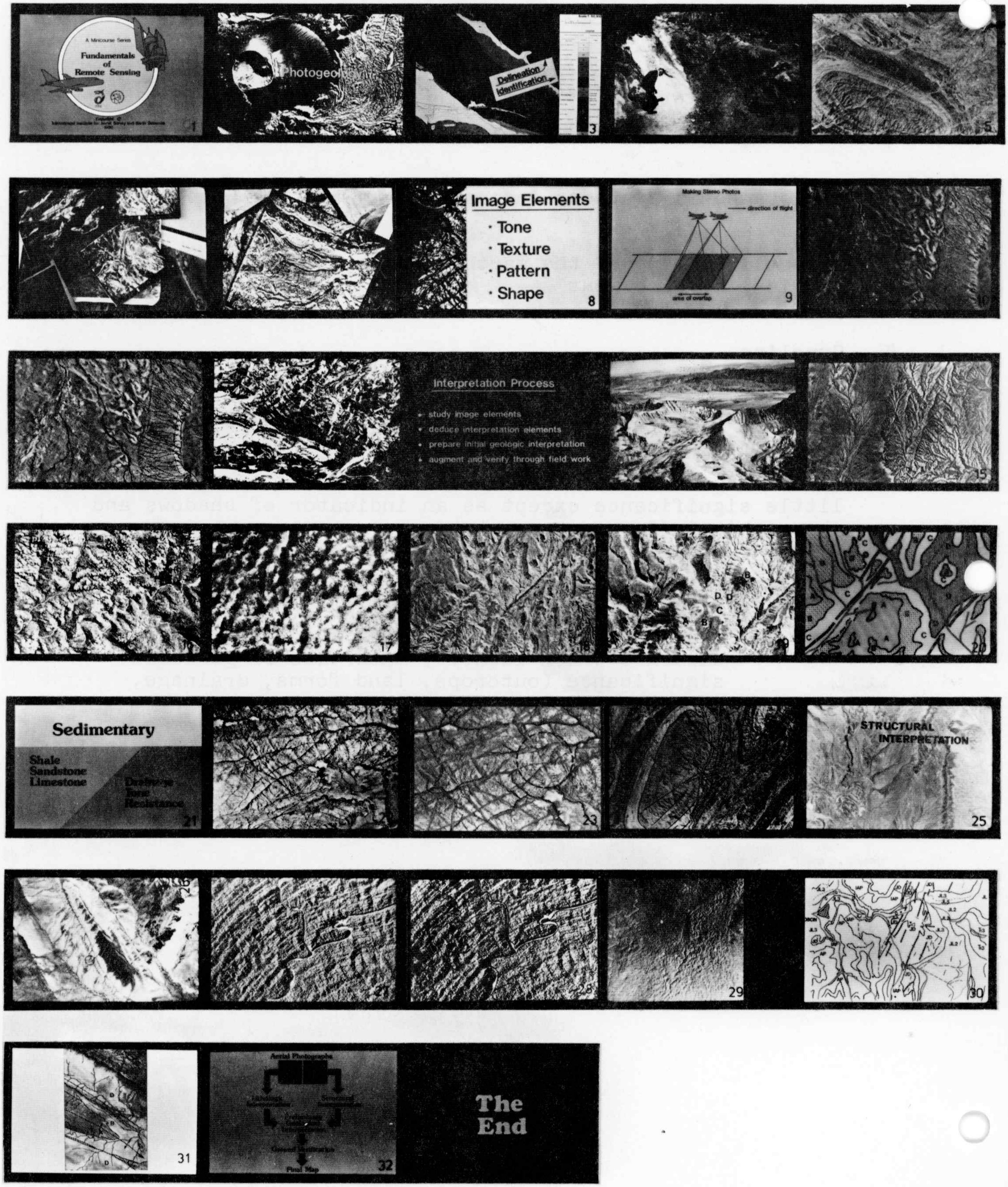
3. A vertical plane of the earth's crust with its bedding and/or vertical displacement

4. Syncline

5. A close study of topography (using stereophotographs), drainage patterns, and linear features can often lead to hypotheses about banding, relative resistance of rocks, and the morphology of the region. Because there is no exposed rock, tone is of little significance except as an indicator of shadows and changes in indigeneous vegetation.

6. Step 1: study image elements (tone, texture, pattern, shape and slope)
   Step 2: transform the image elements into interpretation elements which identify materials of geologic significance (outcrops, land forms, drainage, vegetation, and cultivation.)
   Step 3: use the interpretation elements to prepare a preliminary lithologic or structural interpretation of the area, rating your degree of confidence in the interpretations
   Step 4: field-check the interpretations

Appendix H: Slides



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