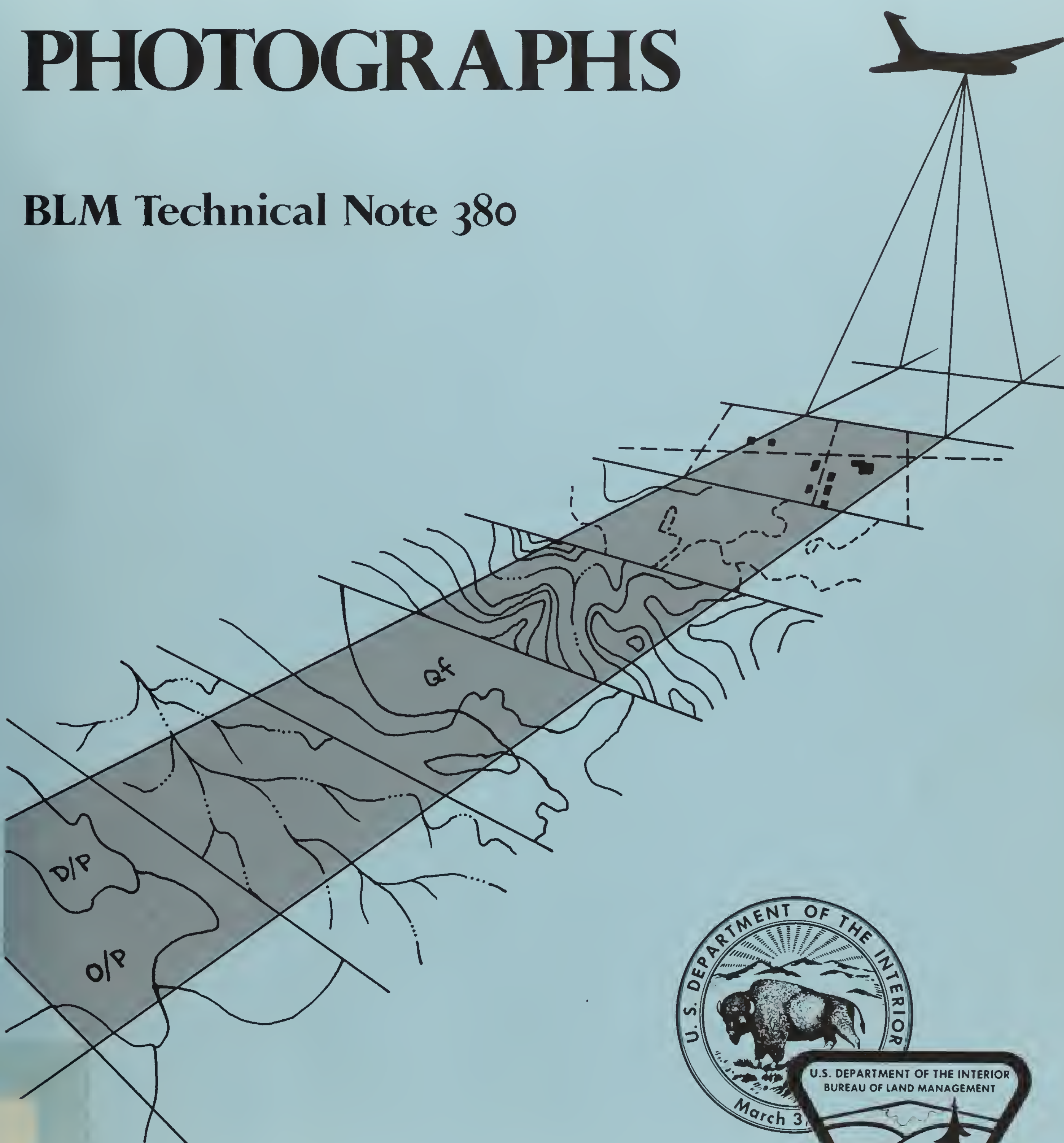
ERPRETATION OF AERIAL PHOTOGRAPHS

BLM Technical Note 380



U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

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The Department works to assure the wisest choice in managing all our resources so that each shall make its full contribution to a better United States now and in the future.

BLM Technical Note 380

INTERPRETATION OF AERIAL PHOTOGRAPHS

by

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PREFACE

This publication is designed to provide the necessary content for a basic aerial photo interpretation course. The order in which subjects are addressed may need to be varied. The depth of instruction about various portions may need modification depending on the experience or training background of the audience. It is hoped that the utilization of this material in conjunction with site specific information (field site photo's and other data) will provide the basic components (off the shelf) for many Photo Interpretation Training courses.

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INTRODUCTION

INTERPRETATION OF AERIAL PHOTOGRAPHS

This publication deals with aerial photographs and how they can be used in the various phases of land management within the Bureau of Land Management. It is intended to furnish sufficient guidelines to encourage the use of aerial photos. Emphasis has been placed on basic data in this publication for its general application to Bureau activities where aerial photos can be appropriately used.

The aerial photograph offers the easiest, most complete way to examine an area in it's entirety. It's unique portrayal of all visible detail makes it possible to analyze, measure, quantify and interpret more information than can be obtained from any other single source. It has revolutionized topographic mapping and brought new search techniques to such diverse fields as geology and archaeology.

An aerial photograph is simply a photograph of the surface of the earth. It may approximate the normal view from an elevation but more likely it will have the unfamiliar view of the scene directly below the airplane. The Bureau can make classifications of land with a high degree of accuracy by skilled photo interpreters. Soils, building materials, and timber stands are being accurately determined in the same manner. The increased workload and decreased workforce necessitates advanced planning and programming to utilize photo interpretation to collect and analyze reliable data for managing the public lands.

Even the fact that a photograph grows old is of value. The record made by a photograph is so inclusive at the time it is taken that it becomes a valuable historical document and will serve as an excellent reference for measuring our progress and accomplishments on the land itself.

Recognition of the value of the aerial photograph comes from use and understanding of the photograph's limitations as well as its capabilities. If fully utilized, aerial photographs are a tool to make our work easier and enables us to do it better. This publication is aimed at presentation of fundamentals in the use of aerial photography.

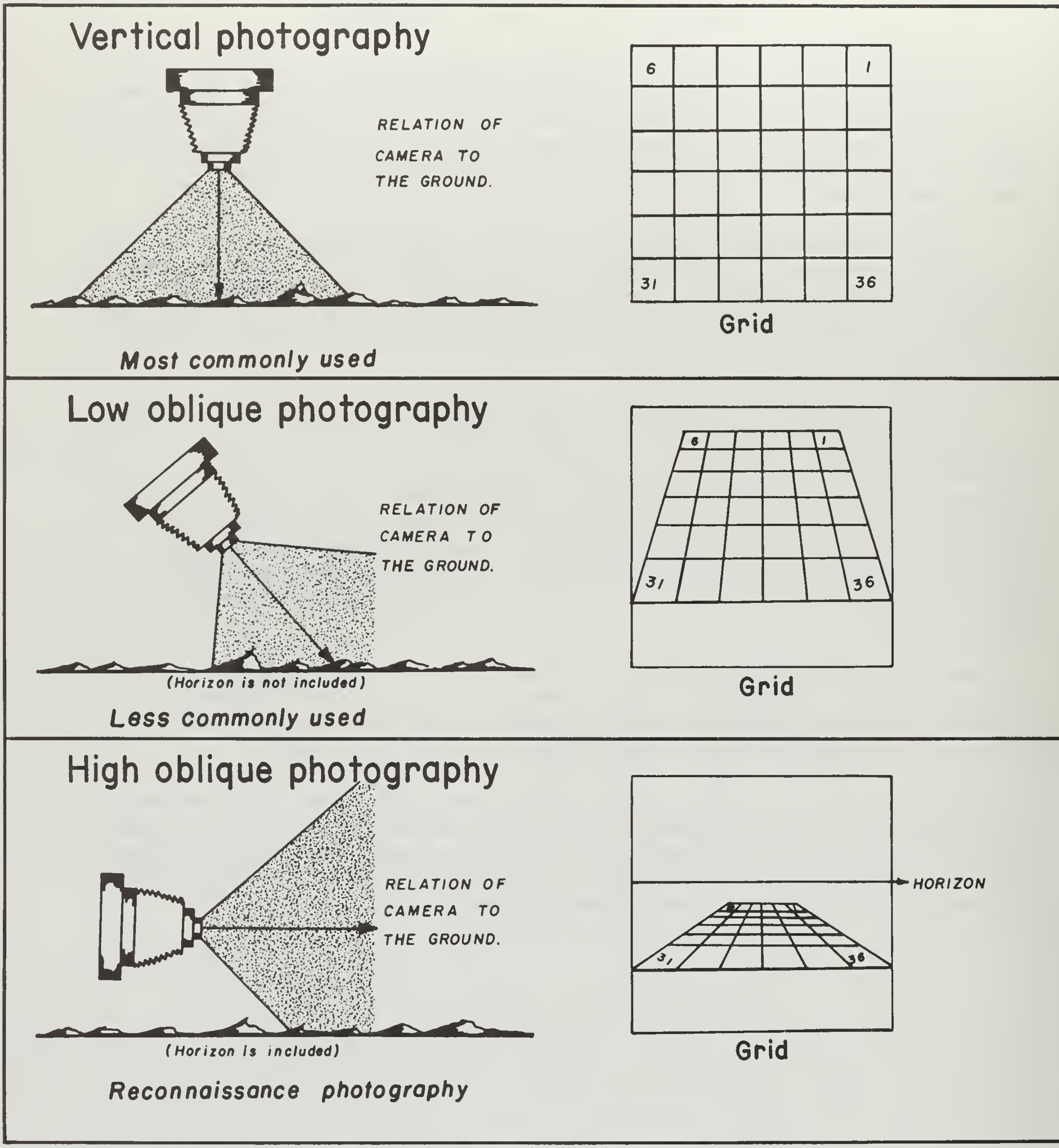


Figure 1. Types of aerial photography.

ELEMENTS OF AERIAL PHOTOGRAPHY

Types of photography

Three common types of aerial photography are: Vertical, Low oblique, and High oblique (Figure 1).

The vertical photograph is taken from a viewpoint directly below the airplane. This gives a map-like photograph of the earth's surface, however, it is not a map. The map-like qualities are emphasized only where the terrain is flat and level. A grid in that case will be relatively square and suitable planimetric maps can be prepared directly by overlays because corrections are easy. Distortions and displacements will require some corrections.

This is the most commonly used photograph. All parts of the terrain are visible, scale is fairly uniform throughout, except in mountainous terrain, and complex methods are not needed to make simple maps. A three-dimensional effect of terrain can be easily seen with the aid of a stereoscope.

Oblique photographs have one factor in common; the camera is at a predetermined angle to the ground. Division into low and high oblique photographs refers only to the angle not to the altitude of the camera.

The low oblique photograph can be defined as an angled camera shot that does not include the horizon. The angle provides a panoramic view of a larger area than does the vertical photograph. The photographs may be "restituted" by rephotography in the darkroom and made into verticals if their angles were low. Higher angles require special mapping techniques. Obliques may be used to bring maps up-to-date in small areas but the methods are tedious for larger areas.

Principal use of this type of photograph is usually limited to the large-scale single photograph taken at low altitude, for public education, reports, demonstrations, and similar needs.

The high oblique photograph includes the horizon. The perspective is natural or the way we normally see things. Reference to objects in the photograph is readily understandable because of its familiar angle of view. It is therefore, very good for displays, presentation of entire watersheds or other problems, especially with the public, where quick reference and recognition are desirable. The limitations of high oblique photography come in mountainous or hilly areas as slopes facing away from the camera are unseen or minimized.

In summary, the Bureau confines most of its use to the vertical photograph because it requires minimum equipment to record the information in a usable form. This is related in turn to its relatively uniform scale, the map-like presentation of information, and its general availability and inexpensiveness.

Obliques are more specialized. The specialization is advantageous in that the perspective may approach a normal viewpoint, thus interpretation is easy for the average person.

All types demand infinitely greater integration into Bureau programs as they will perform services that cannot be achieved by other means.

Films

The film used for most aerial photography is a dimensionally stable base film (e.g., Estar Base). Project requirements normally dictate whether black and white, color negative, color positive, or color infrared film should be used.

Black and white photography of metric quality is most commonly used for photogrammetric operations such as precision topographic mapping and riparian surveys.

Natural color (positive or negative film) is widely used by geologists and others to locate potential oil well drill sites as well as other energy sources. It is used extensively for resource inventories such as Forestry, Range, Wildlife, Watershed, and others.

Strip mining operations can be accurately monitored and trespass verified by proper utilization of this tool. There are many other applications for this kind of imagery in various disciplines.

Color infrared (CIR) is extremely helpful in vegetative inventory work because of the ease in differentiating between species. Consequently it speeds up the interpretation process and increases accuracy of the interpreted data.

Another application of CIR is in inventorying water sources (such as springs). When properly used the wet areas stand out clearly from surrounding vegetation. Most of the applications listed under natural color can also be accomplished with CIR.

Filters

Filters are used for many purposes with both black-and-white and color films. The filters vary the contrast and tonal rendering of the subject in a photography, either to correct to the normal visual appearance or to accentuate special features. The photographic effect obtained with a particular filter depends on four main factors: (1) the filter's spectral absorption characteristics, (2) the spectral sensitivity of the sensitized material, (3) the color of the subject to be photographed, and (4) the spectral quality of the illuminant.

Aerial views, when photographed without a filter, often appear veiled by atmospheric haze. This condition is caused by scattering of ultraviolet and blue radiation by water vapor and dust particles in the atmosphere. The high sensitivity of aerial films to these radiations compounds the effect. Since atmospheric haze scatters decreasing amounts of green and red light, and virtually no infrared radiation, haze filters are primarily ultraviolet and/or blue absorbers. Filters such as the KODAK WRATTEN Filters No. 2B and No. 2E absorb ultraviolet to reduce haze effect without affecting the monochromatic rendering of other colors.

Greater haze reduction results from the use of yellow or red filters which absorb the shorter wavelengths. However, these filters also affect the monochromatic rendering of colors. The greatest penetration of atmospheric haze occurs when an infrared-sensitive material is used with a suitable filter.

Most aerial films require some type of filter in the camera system to eliminate the effects of atmospheric haze. Haze imparts an overall bluish cast to color aerial photographs and lowers the contrast in aerial black-and-white negatives. Filters that are appropriate to a particular film have been indicated in the data section for that film. In addition to the preceeding information from Kodak publication M-29, other technical data about filters may be obtained from Kodak publications M-5, and B-3 as well as other sources.

Photographs

There are many types of photographic materials available that produce varying results, depending on the emphasis desired. Therefore, one should be aware of this in order to acquire the kind of product needed for a specific project. There are numerous kinds of paper that render different surface characteristics such as: glossy; high lustre; lustre; semi-matt; and matt. All of these have different degrees of smoothness or roughness that may require special pens or pencils to write on them. Various contrasts are available as well as different weights (thickness) of materials. The most commonly used for color photos is a resin-coated water resistant base paper, and probably a polycontrast paper would be the most common product used for black and white photo's.

Also, there are stable base materials (similar to mylar) such as Kodak Duratrans Display Film, and Cronapaque by Dupont. Duratrans yields a color product and Cronapaque yields a black and white product that is scale stable. Of course, these will cost more than the paper products.

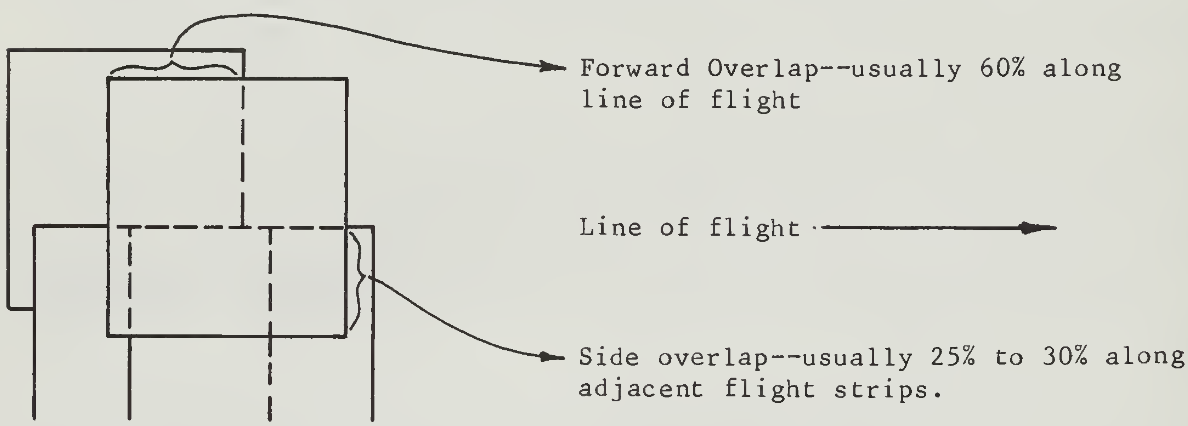
A general rule is that the smoother the surface, the sharper the detail but the more difficult it is to write on. If you use an overlay it shouldn't matter.

Photography Acquisition

Considerations for planning a photo mission: 1) Intended use of the photography, 2) Who will fund the project, 3) Scope or size of project (how many square miles or lineal miles), 4) Season (start and completion dates) (What are you trying to emphasize), 5) Time of day to fly (especially for cliff areas), 6) Camera focal-length (3-1/2, 6, 8-1/4, or 12 inch), 7) Scale (depends on camera focal length and project needs), 8) Type of film (black & white, color, or CIR), 9) Type and number of prints (1 set contacts, or ?), 10) Special requirements (film to wind in direction of flight, new film, etc.)

BLM standard or special aerial photography specifications should be used to assure consistant quality imagery. Some of the specific requirements are discussed and illustrated in the following pages.

Aerial photographs are taken on clear days when the sun is high enough to avoid distratingly heavy ground shadows. The project is flown at a specified flight height above mean terrain throughout the area. Each flight must parallel those adjoining for blocked areas that require multiple flights.



The ideal flight pattern is difficult to maintain. Sidewinds require flight corrections, the camera may be at an angle to the flight, then forward overlap and side overlap will grow inadequate with "crab." If the pilot fails to correct for the wind he will "drift" off the line of flight. Both "crab" and "drift" may require rephotography. See Figure 2 for an illustration of crab and drift.

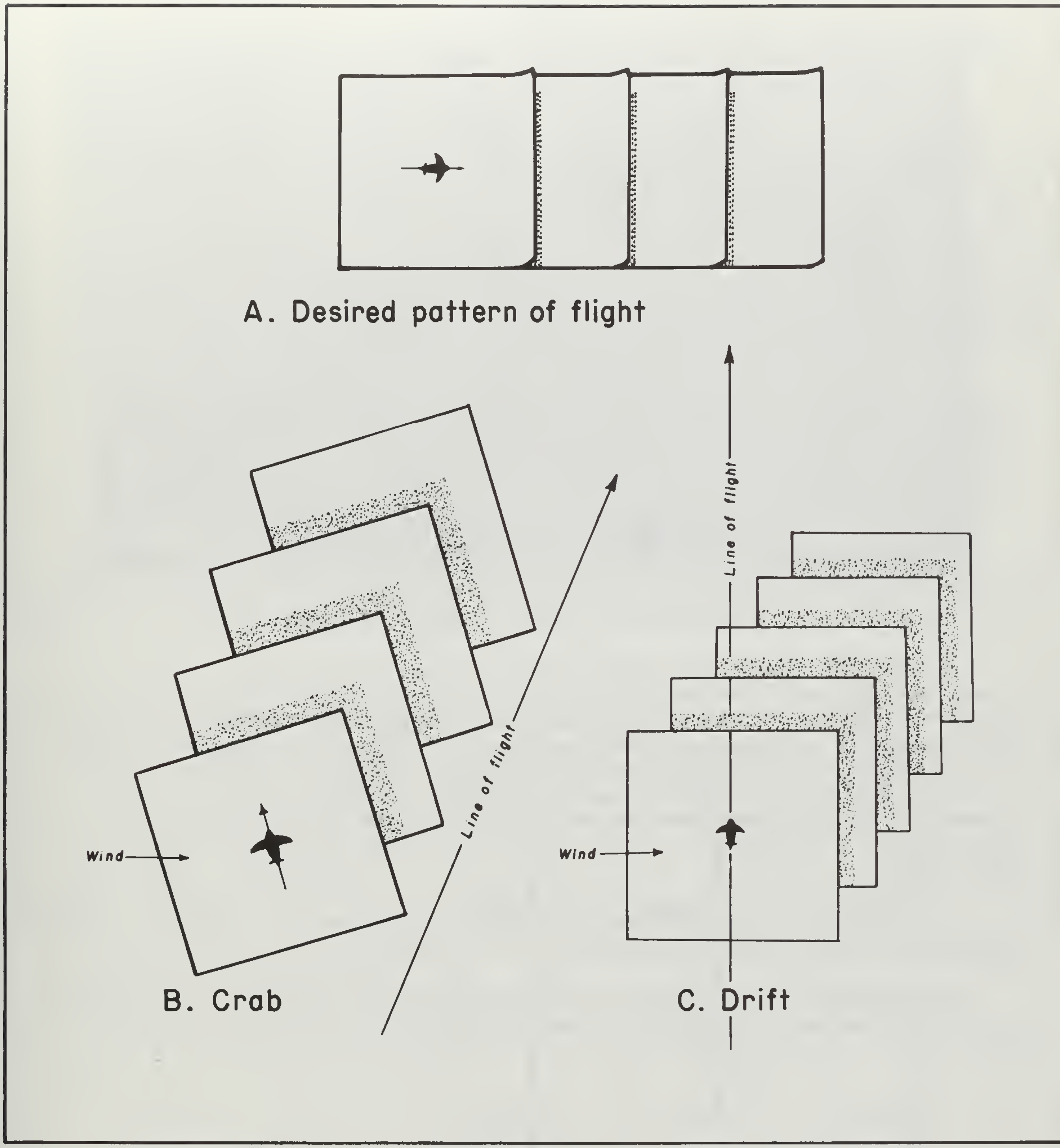


Figure 2. Index flight paths.

Titling and Indexing

Photographs are individually titled. Each photograph is numbered consecutively as it was taken. Usually the date is included and the entire series may be as shown in the following example.

Month/Day/Year	Contracting Agency	Scale	Project Symbol	ROLL/STRIP/Exposure No.
5/15/83	BLM	24	CO-83 AC	1-5-25

1-5 25
1-5 26
1-5 27
1-5 28

These photograph numbers indicate "full" coverage.

Every exposure is necessary for stereoscopic work.

These photographs are "alternates." Cost is cut one-half when prints are purchased. Does not give good coverage for stereoscopic work--but will suffice for simple planimetric maps.

1-5-14
1-5-16
1-5-18
1-5-20
1-5-22

Indexes are an effective way to catalogue photo coverage for future use. An aerial photographic-index or spot (line) index may be used. These indexes identify the aerial photograph with the terrain.

Aerial photo contractors usually will prepare a photo-index (photographic index) at additional contract cost, which varies with CIR, color, or black and white. Photo indexes are prepared by placing the photos in their relative positions with individual identity accented; a large photograph is then made of this group. If there are prominent features evident, the photo-index can be used for location of desired photos. A measure of control is present; townships can be superimposed on these photo-indexes with fair accuracy. Unfortunately an index of this sort usually is difficult to read and use, see Figure 2a.

Spot indexes or line indexes are relatively inexpensive, especially if BLM provides the maps or matte mylars for their preparation to the contractor.

The spot index is plotted on a map base showing flight lines and exposure stations. The land net on the map makes using this index very easy, see Figure 2b.

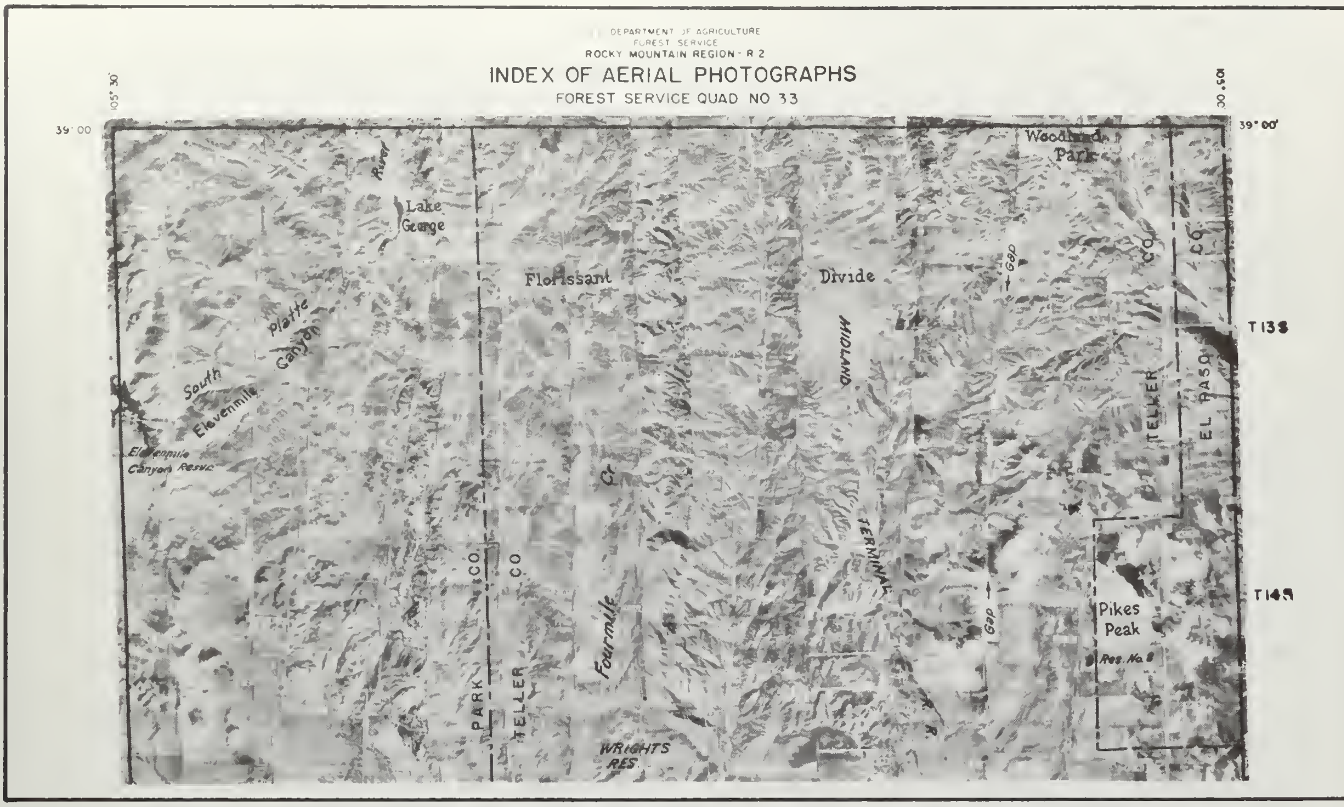


Figure 2a. Typical photo-index.

Figure 2b. Typical spot (line) index.

Displacements and Distortions

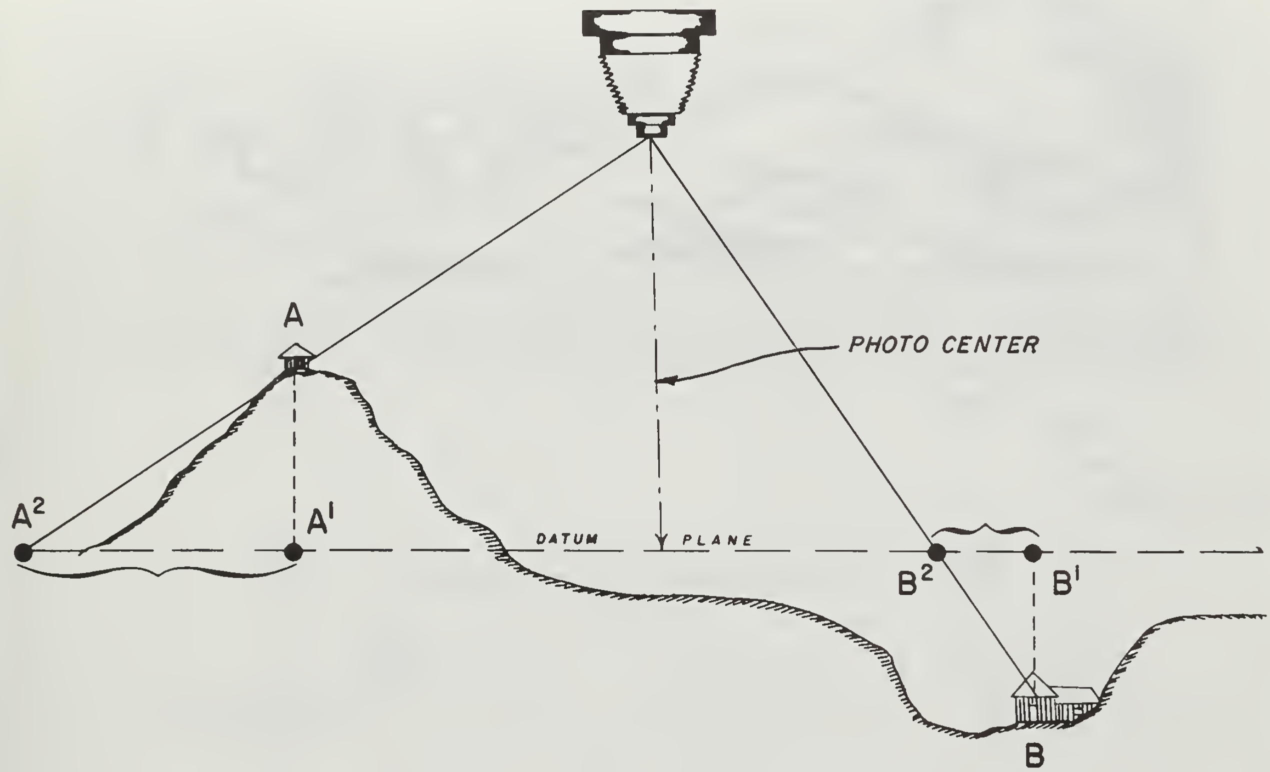
Displacement due to relief is common within the photograph. The effect of elevation in photographic displacement is shown in Figure 3. The datum plane is identified for reference. Point "A" on a hill properly should be located on a true horizontal distance from the center of the photograph at "A^1," but is displaced outward in the photograph to "A^2." Point "B" is below the datum plane. Its correct location on the datum plane is displaced toward the photograph center, in this case to "B^2." A matter for emphasis is that in both situations the displacement of a point inward or outward is on a straight line from the center of the photograph.

Displacement of a point then is caused by the effect of relief. No matter to what degree points are displaced they move inward or outward on a line radiating from the center. A compass bearing from the center to the object point will not change with displacement. A hilltop, in the several photographs surrounding it, is displaced outward on a line from each center. Assume this center of each photograph is located correctly in its relative ground position. Every line bearing on the hilltop from each center is on a true bearing. The point where the lines intersect represents the true horizontal location of the hilltop.

Intersecting rays from the centers of overlapping photographs are plotted to locate points in true horizontal position and thereby eliminate displacement due to relief. This is the basis of the "radial-line" and "slotted-templet" method of map preparation. We can adapt this technique to locate single objects, such as a new radar site on a hill.

Remember:

Points above datum plane are displaced outward from the center.
Points below the datum plane are displaced toward the center.
Displacement is radial relative to the center of the photograph.



A^1 to A^2 = Distance of displacement away from center of photograph.

B^1 to B^2 = Distance of displacement towards center of photograph.

A^1 and B^1 = Corrected positions.

A^2 and B^2 = Displaced positions on photograph.

Figure 3. Displacements and distortions.

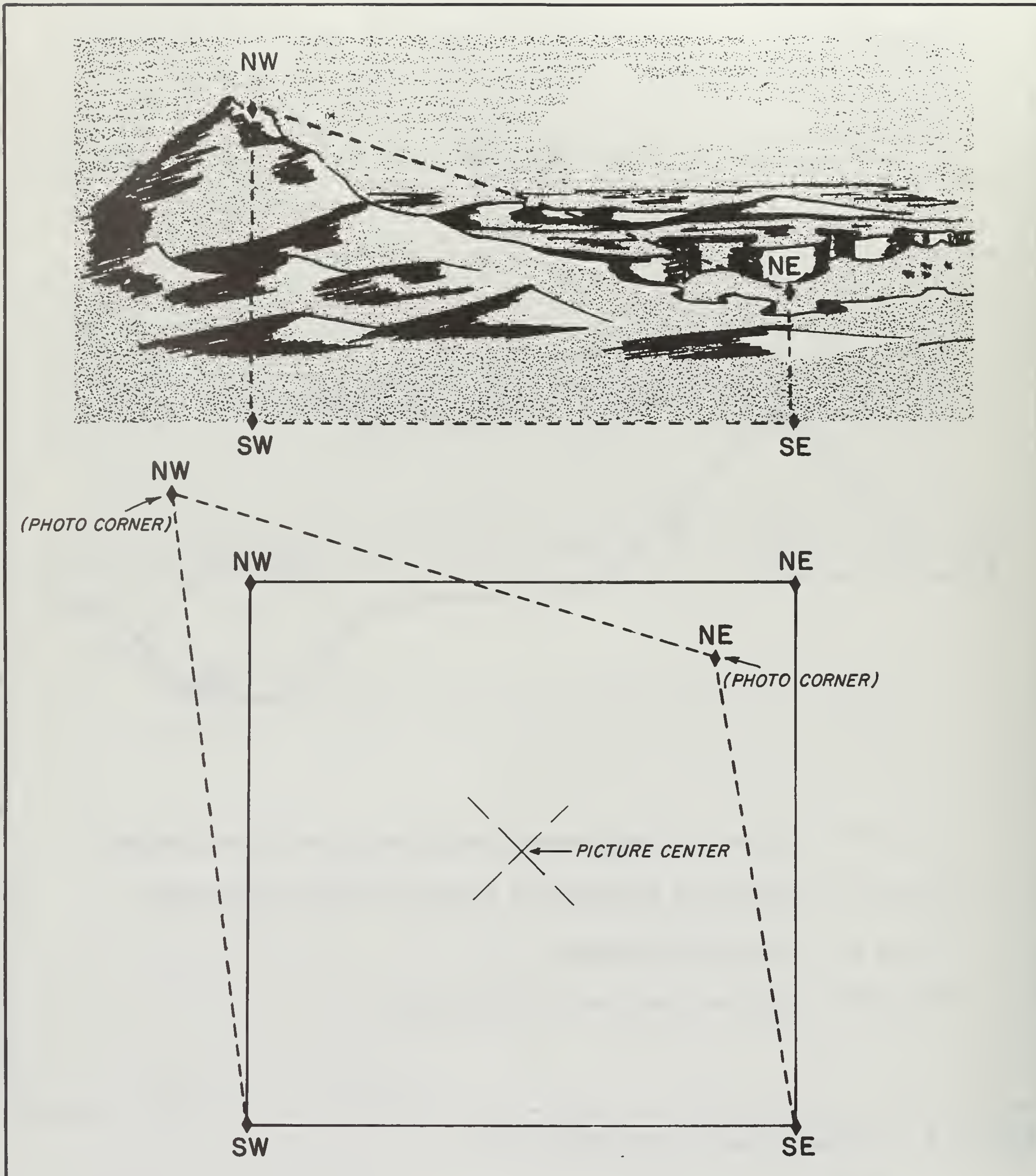


Figure 4. Displacement due to relief.

Figure 4 illustrates a square section with rugged terrain. The centers of the section and photograph coincide. The SW and SE corners lie on the datum plane, whereas, NW is above and NE is below it. NW will displace outward, radially, from the center and NE will displace inward, radially, toward the center because it is located in a deep canyon. The square section is illustrated with solid lines; dotted lines show the distorted view of the section as it is depicted in the photograph.

Distortion in the photograph may be caused by several things, e.g., photolab processing, film or paper instability, camera lens, tilt or tip of the camera at the instant of exposure, etc.

Photolab processing accounts for some minor distortion in photographs. The wet paper print may stretch in one direction and shrink in another dimension upon drying. Such errors are lessened by use of resin coated paper. Single-weight paper is used in mosaics where stretching sometimes is done purposely for a match of detail.

Distortion from the camera lens may be present. If the photographs are enlarged, the enlarging may introduce further errors. This difficulty can be minimized by confining your work to the center of the photograph (or neat model). Use more photographs if necessary. Modern "distortion-free" camera lens have minimized this problem.

Tilt and tip causes the photo to have a distorted scale similar to that of a low oblique photograph but is uncontrolled. Tilt is divided, sometimes, into two parts--tips and tilt--for computing corrections. Tip in a photograph is caused by the airplane climbing or diving at an angle to the ground. At right angles to tip is "tilt" as the airplane banks in flight. Bureau specifications state that tilt shall not average more than 2° in any flight line nor more than 1° for the entire project. Relative tilt between any two successive exposures exceeding 6° may be rejected.

Photographs contain invaluable information but also have errors (displacements and distortions) which must be recognized and, if necessary, corrected. You can correct many of these errors as you gain experience but for now to minimize the problems:

From photolab processing; order resin coated or other stable base materials.

From camera lens; use the center portion of photographs.

From tip and tilt; require photography of less than 3 percent error.

Scale Considerations

The scale of an aerial photograph is a vital piece of knowledge for your work. It is the ratio of a distance on the photograph to its actual distance on the ground. This ratio of photo distance: ground distance (PD:GD) is the scale. It is expressed usually in three ways:

A. Descriptive scale

The descriptive scale is in common use. It is a statement of ratio in familiar terms, such as "1/2 inch = 1 mile." It is awkward, however, because two different units of distances are used, one for the ground and one for the photograph. Inches on the photograph are related to miles on the ground.

B. Graphic scale

The graphic scale permits direct measurement on the photograph in a convenient unit (miles, yards, feet). There is no calculation in its use; hence it is rapid and easily used.

C. Representative fraction scale or RF

The representative fractions (RF) is the ratio of photograph distance to ground distance with both distances expressed in the same unit of measure.

$$\text{Scale} = \frac{\text{photo distance}}{\text{ground distance}} \text{ or } \frac{PD}{GD} \text{ or } PD{:}GD = \frac{1}{GD/PD} \text{ corresponds to } 1{:}\frac{GD}{PD}$$

This is the basic statement of scale for all map and photograph work. It is best suited for calculations. Example of an RF is 1:63,360, which is the same as stating "1 inch = 1 mile" (63,360 inches). Thus the RF is really the familiar descriptive scale with the confusion of two units of measure removed.

The scale of an aerial photograph is determined by two factors at the moment it is taken (Figure 5).

1. Height of airplane above the ground (not the altitude of the plane).
2. Focal length of the camera lens taking the photograph.

Problem: Scale is calculated by the ratio :H (focal length:Height above-ground. Both in same unit of measure). Find the scale when airplane altitude = 10,000', focal length of lens is 12", ground elevation is 3,000 feet.

Solution: Subtract 3,000' from altitude = 7,000', or H. f = 12 inches or 1 foot. Scale = f:H, or 1:7,000.

The scale of photographs is usually given as a representative fraction (RF) and written on one line (1:5,000). If a vertical photograph contains the altitude and focal length of the camera, the scale is obtained as shown below.

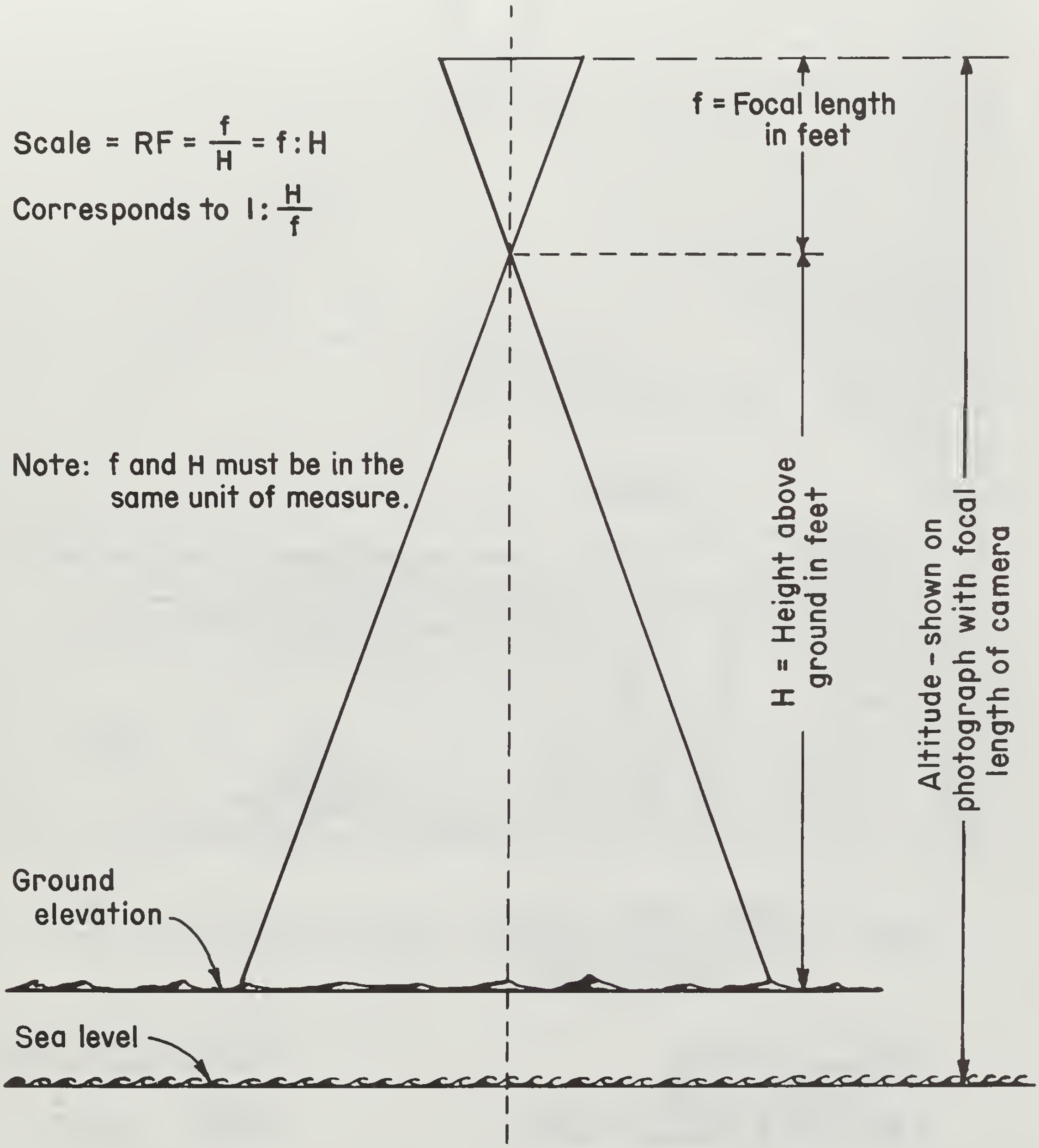
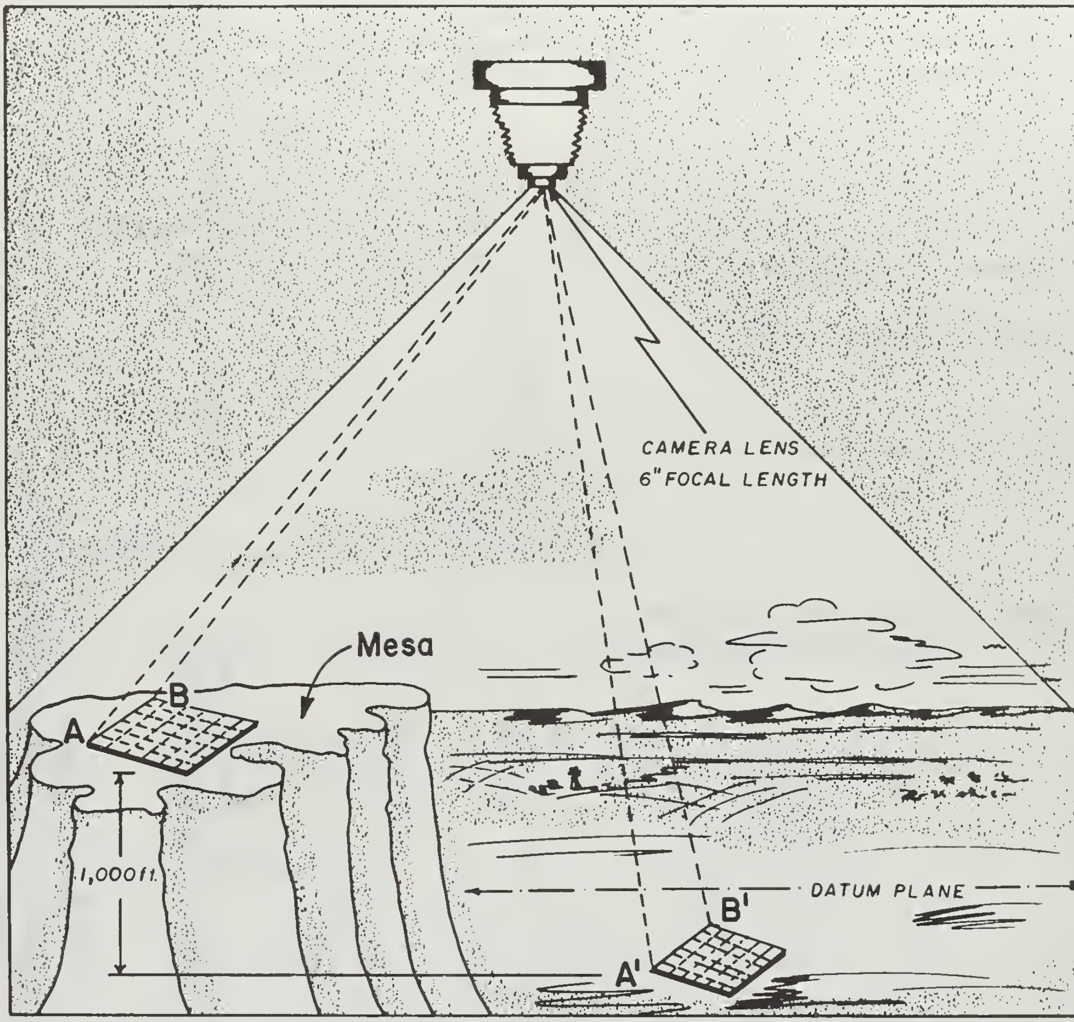


Figure 5. Determination of photo scale from lens focal length and altitude.



$$\text{Scale} = \frac{\text{FOCAL LENGTH IN FEET}}{\text{FLIGHT HEIGHT IN FEET ABOVE GROUND}} = \frac{1}{\text{FH/FL}} \text{ Corresponds to } 1:\frac{\text{FH}}{\text{FL}}$$

Scale on mesa top

$$\frac{.5' \text{ (FOCAL LENGTH)}}{9{,}000 \text{ (ABOVE GROUND)}} = \frac{1}{18{,}000}$$

1 Mile = 3.5"

Scale on valley floor

$$\frac{.5'}{10{,}000} = \frac{1}{20{,}000}$$

1 Mile = 3.2"

Figure 6. Effect of elevation on scale.

Scale varies with the height of the camera above the surface of the datum plane or mean terrain elevation. It follows then that the scale varies within each photograph with every elevation change. Figure 6 (Effect of elevation on scale) shows this problem. However, the effect of terrain height on the photo scale is not confined to such violent contrasts. A tall building will have a different scale at its base from that of its roof.

You may be classifying a perfectly square section lying on a gently sloping side hill with only a small grade (a rise of 300 feet in 1 mile). The section will be deformed on a photograph. At a scale of 1:21,000, the low side of the section will measure 3.0 inches; the higher side 3.1 inches--a 3% error.

Scale Determinations

A quad map is good for calculating the scale of a photograph. The same points must be recognizable on both map and photograph. Each point should be located as far distant from the other as possible and be within your project area.

The calculation of Figure 7 is typical for one pair of points. Here "A" and "B" were recognizable on both map and aerial photograph. First determine the actual ground distance between "A" and "B." The distance between them on the map is 1.2 inches. Map scale is 1:50,000. Therefore, ground distance is 1.2" x 50,000 = 60,000 inches from "A" to "B." Now to determine the photograph scale as the ratio of photo distance to ground distance (PD:GD). PD is 2.5" on the photograph (by measurement) and GD is 60,000" (calculated from the map). The ratio, therefore, is 2.5":60,000." Divide both parts of the ratio by 2.5 which gives the answer:

$$\frac{2.5}{60,000} \div \frac{2.5}{2.5''} = \frac{1}{24,000} \text{ or } 1{:}24,000$$

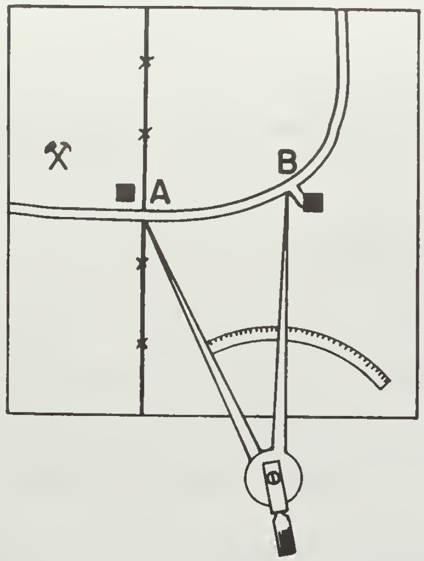
which is the photo scale.

The scale of a photograph is easily determined in the field. A pair of points are located on the photograph along roads or routes that can be measured easily. Example: Assume the distance between two points on a road is 1.7 miles and the distance measured on the photograph is 2.3 inches. Find the photograph scale.

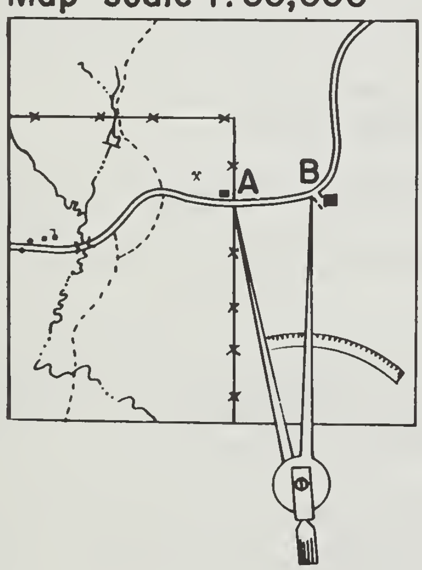
Converting miles to inches gives all measurements in a common unit (1.7 x 5280 x 12" = 107,712"). The scale PD:GD 2.3';107,712" = 1:46,831, or, in round numbers, 1:47,000.

By comparison, the photograph will sometimes reveal square sections. A quick measurement can give the inches per section on the photograph, perhaps 3" = 1 mile (3"=63,360"), which can be resolved by inspection into the nominal scale of 1:21,000.

Photo-scale unknown



Map-scale 1:50,000



Distance AB = 2.5" on photo

Distance AB = 1.2" on map

PROBLEM:

Determine scale of photograph.

Scale = ratio of photo distance to ground distance.

THEREFORE:

1.2" x 50,000 = 60,000" ground distance between A and B.

Photo scale

$$\frac{\text{photo distance}}{\text{ground distance}} = \frac{2.5'' \div 2.5''}{60{,}000'' \div 2.5''} = \frac{1}{24{,}000}$$

ANSWER:

$$\text{Photo Scale} = \frac{1}{24{,}000} \text{ or } 1:24{,}000$$

Figure 7. Determination of photo scale.

Acreage Determinations

Some typical uses of photo scale are for: locating legal subdivisions (sectionizing); determining the size of objects on the ground such as dams, buildings, recreation areas, etc.; and calculating approximate acreage directly from the photographs.

Many field offices have access to digital planimeters that calculate the acreage when a photo scale is entered. Another technique that can be used in the field is the Dot Grid method. Examples for determining the value of a dot and acreage calculation are as follows.

Dot value for Dot Grids example: Photo scale 1:24,000

Step one: Convert photo scale to feet per inch,

answer; 24,000 ÷ 12 (inches per foot) = 2,000' or 1 inch of photo coverage is equal to 2,000' on the ground.

Step two: Determine how many square feet are in 1 square inch at a scale of 1:24,000 or 1" = 2,000'.

answer; 2,000' x 2,000' = 4,000,000 square feet in 1 square inch of photo coverage at 1:24,000 scale.

Step three: Determine how many acres are in 1 square inch at 1:24,000 scale.

answer; 4,000,000 sq. ft. ÷ 43,560 (number of sq.ft. per acre) = 91.8 acres per square inch of photo coverage, at 1:24,000 scale.

Step four: Determine the value of each dot at a scale of 1:24,000

answer; 91.8(acres) ÷ 100 (no. of dots per square inch) = .918 or .92 acres per dot.

Note: The reason for converting scale 1:24,000 to feet per inch is to get the formula; feet times feet = square feet (4,000,000 in this example) and convert that to acres. It also accommodates pocket calculator limitations.

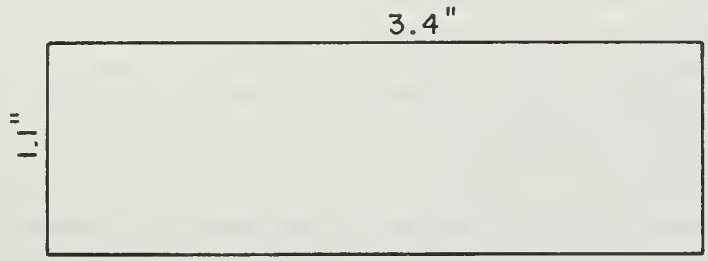
Use of Dot Grid -- randomly lay the dot grid over the area to be measured (polygon, rectangle, square, etc.) and count each dot, (count the dots that fall on the boundary line(s) as one half dot) and multiply the total by .92 to determine the number of acres in an area at 1:24,000. This should be done two or three times for each area and average the results.

Acreage Determinations Continued

The following examples show how acreage can be calculated on square, rectangular, or triangular areas once the photo scale has been determined.

For both examples assume a photo scale of 1:24,000 or 1" on the photo is equal to 2000 feet on the ground.

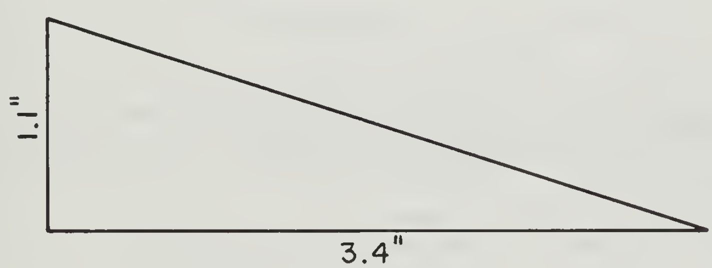
Example No. 1 - You have an area on the photo that is 1.1 inch wide and 3.4 inches long.



Multiply 1.1" x 2,000' = 2,200' wide
Multiply 3.4" x 2,000' = 6,800' long
Width (2,200') x length (6,800') = 14,960,000 sq. ft. in the area
14,960,000 ÷ 43,560 (no. sq. ft. in 1 acre) = 343.4 acres

(Note: This same formula works for a square area.)

Example No. 2: You have a triangular area that is 1.1" high and 3.4" long as follows:



Multiply 1.1" x 2,000' = 2,200' (height)
Multiply 3.4" x 2,000' = 6,800' (length)

$\frac{2,200 \times 6,800}{2}$ = 7,480,000 sq. ft. in the triangle

7,480,000 ÷ 43,560 (no. sq. ft. in 1 acre) = 171.72 acres in triangle

Figure 8. Acreage determinations.

Image Characteristics

During interpretation of aerial photographs occasionally the terrain features will "reverse" themselves; that is, the drainages appear as the highest points. Turn the photographs around; this will force the features into their proper relationship.

Direction is sometimes a very important aid to the interpreter. In northern latitudes the shadows in the photograph fall toward the northwest if taken in the morning and northeast for those taken in the afternoon. North may be determined with greater certainty by comparing the photo with a map of the area or orienting by compass. Resource photography flights are usually flown in cardinal directions--east-west or north-south--with photo-identification uniformly presented at one end of the photograph--the west or north side. (SPECIAL FLIGHTS, e.g., stream photography or other special projects may not be flown in cardinal directions, therefore, the titled information may not indicate direction).

Some of the photo image characteristics that assist in the identification of objects are illustrated in Figures 9 and 10 and are listed and elaborated on in the following pages.

Shape - Shape may identify.

Size - Comparative sizes may identify.

Shadow - Shadow is often a clue by characteristic shape.

Tone/Color - Photographic tone or color is the characteristic colors and/or gray shades of scenes and objects.

Texture - Texture in aerial photographs is created by the frequency of tonal or color changes.

Pattern - Pattern is a more or less orderly arrangement of manmade objects or natural elements.

Relation to surrounding objects - This subhead might just as well be labeled "Deduction." Actually all interpretation hinges here to some degree, consciously or unconsciously.

Shape. The shapes of objects seen in vertical view are sometimes surprisingly difficult to interpret. The plan or top view of an object is so different from the familiar profile or oblique view that inexperienced interpreters have failed to recognize the image of the building in which they were working. The ability to understand and make use of the plan view has to be acquired like another language. It then becomes a powerful tool, for the plan view of objects is an important and sometimes conclusive indication of their structure, composition, and function. To the interpreter who is experienced in industrial studies, the vertical view of a factory tells more about its function than a stroll past its front door. The vertical view of a forest may reveal its economic and recreational value. The vertical view of a landform may show spectacular effects of tectronic and gradational processes. To the motorist, a cloverleaf road intersection is an incomprehensible maze through which one must find his/her way by faith and strict attention to signs; to the aerial observer, the intersection is perfectly clear in form and function.

Much of the training of the photo interpreter is aimed at the reorientation of perceptions; so that he/she can easily recognize objects seen from above. This reorientation is greatly aided by the impression of depth in stereoscopic pairs.

Size. The size of an object is one of the most useful clues to its identity; by measuring an unknown object on an aerial photograph, the interpreter can eliminate from consideration whole groups of possible identifications. An irrigation ditch and an anti-tank ditch, for example, are very much alike except in size and a simple measurement may suffice to make the identification. It is always advisable, when faced with an unknown object, to measure it. When working with photography on variable scale, the interpreter should make frequent measurements of the objects of interest.

The interpreter can avoid errors in identification by paying attention to the size of objects. Misidentifications are possible even though the interpreter may have carefully considered such clues as shapes, shadow, tone, texture, and pattern.

Shadows. Shadows are familiar phenomena, and in ordinary life we often judge the size and shape of objects or persons by observing the shadows they cast. The shadows present in aerial photographs sometimes help the interpreter by providing profile representations of objects of interest. Shadows are particularly helpful if the objects are very small or lack tonal contrast with their surroundings. Under these conditions the sharp tonal gradients of the shadows may enable the interpreter to identify objects which themselves are just at the threshold of recognition.

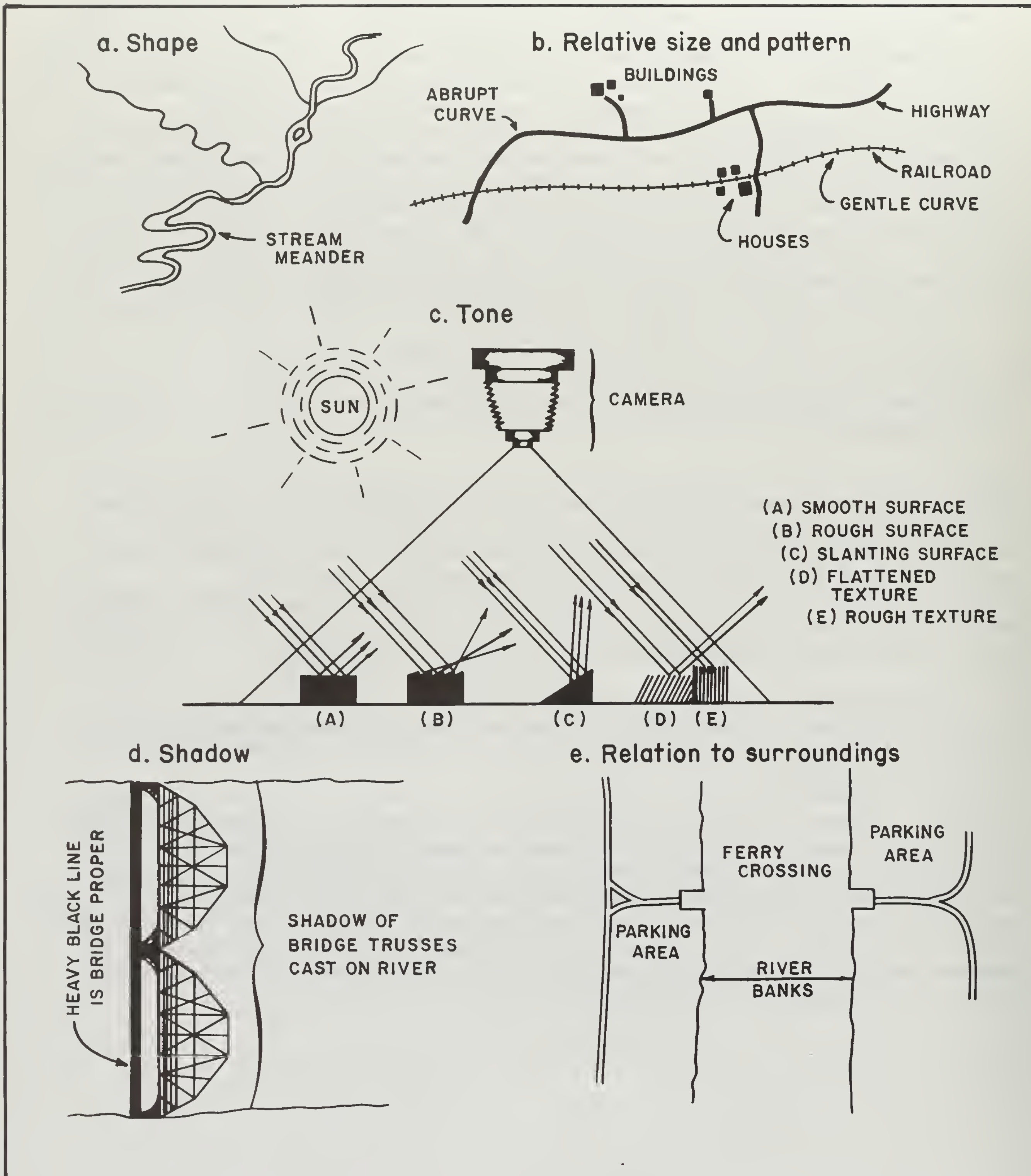


Figure 9. Identification of objects.

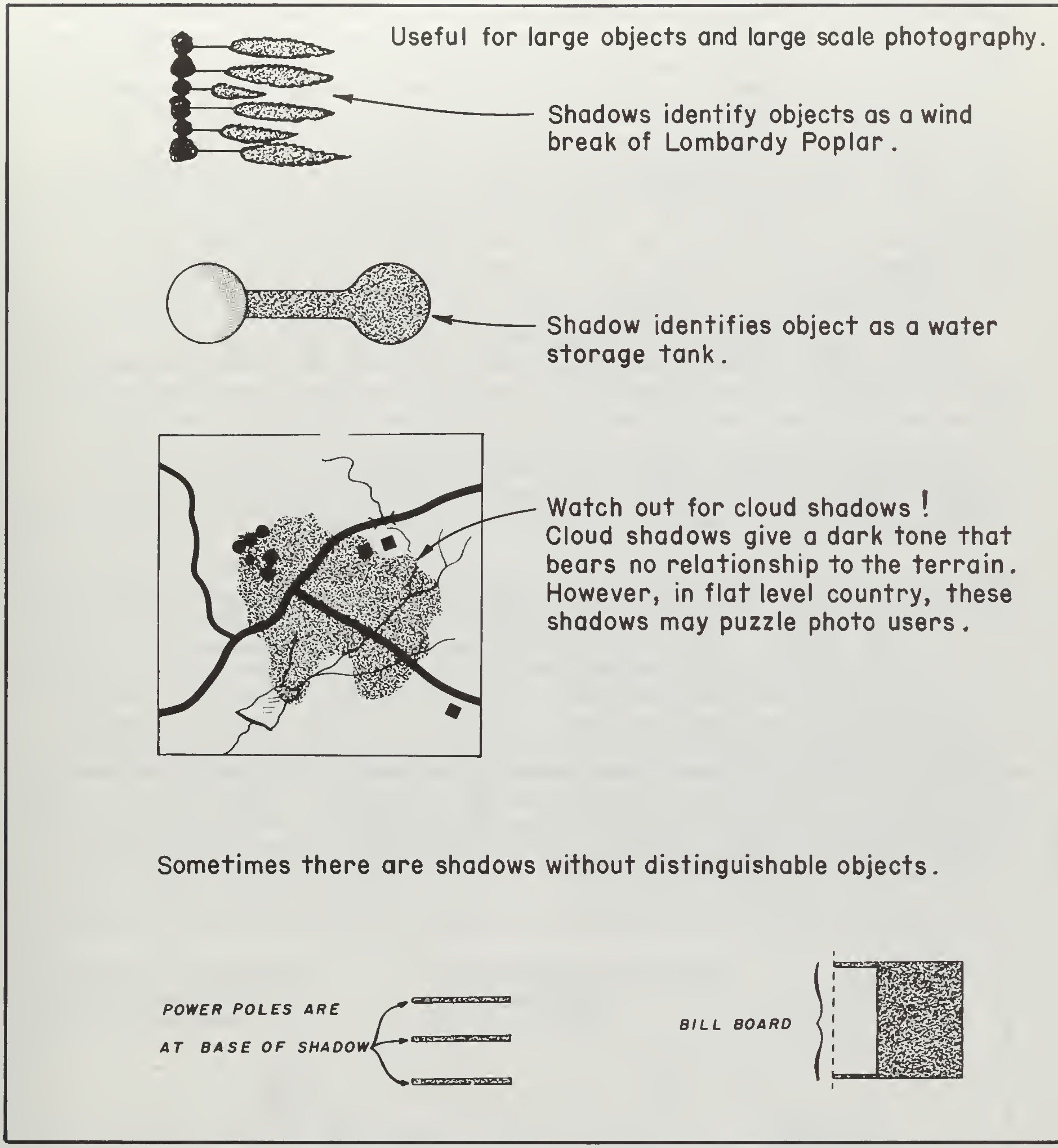


Figure 10. Shadows.

Tone. Tone of a photograph is a relative blackness or whiteness and is the result of the amount of light reflected by an object. Tone is fundamental to interpretation of black-and-white photography and, used with other recognition elements, is a primary element for feature identification and interpretation. The tones of photographic images are influenced by many factors, and the tones of familiar objects often fail to correspond to our perceptions of those objects in nature. A body of waste may appear in tones ranging from white to black, depending on the angle of Sun and the number of wave surfaces reflecting light to the camera lens. A black asphalt road may appear very light in tone because of its smooth surface. A trail may appear white in dry weather and dark after a rain. A smooth, rounded, metal object of indeterminate color, like a tank truck, may reflect so much light that the tonal range of the film cannot record it and details are lost. Figure 9 illustrates degrees of reflection, under "tone."

When the photo interpreter understands the factors which govern photographic tone, he/she regards the tones of objects of interest as major clues to their identity or composition. The soil scientist uses tonal variations to classify soils; the forester, to distinguish hardwood from coniferous trees; the geologist, to map lithology and structure or prospect for minerals. In single photographs, where the shapes of objects must be inferred from monocular clues, or in stereoscopic pairs if the objects of interest have little or no visible height, tone is particularly important.

Color. A feature has a color when it reflects particular wavelengths of light. For example, vegetation appears green because the properties of the plant preferentially reflect a larger percent of green light compared to blue and red. Hue (color), value (saturation), and chroma (brightness) are the three variables that constitute color. The human eye can distinguish many more hues of color than it can tones of gray. Thus color permits recognition and interpretation of a greater amount of detail. In the interpretation of rocks, soils, and plants where there may be an abundance of features whose natural colors are important, some workers have found that color photography pays for itself in abundance and accuracy of information. False-color infrared film, developed during World War II, has been found useful for special studies of plant conditions, vegetation distribution, soil-moisture conditions and drainage delineation.

Texture. Relations of texture on tone are illustrated in Figure 11. Heavy grazing removes many of the tiny traps of sunlight--grass blades. Reflection is high with the grasses removed so the tones grow light. Ungrazed grasses give darker tones. As grazing is seldom the same on both sides of the fence, fences may be located by this difference in texture and tone. Sometimes stock will travel the fence line, removing all vegetation and making the surface very smooth. The result is a white line or trail paralleling the fence.

Taller grasses trap more light and reflect little toward the camera. Meadows with greater densities of grass will be darker accordingly than surrounding grassland. Shrubs and trees reflect little light and usually are very dark. The tone will vary with individual species.

In general, the smoother the surface or texture, the lighter its tone in the photograph. Dark tones come from rough textures--tall grasses and shrubs. Color is often secondary in its effect on tone when it is combined with texture. Check most carefully in puzzling areas where location is important (as in pricking a section corner on a photograph) to assure that the effects of texture on tone is evaluated properly.

Texture in aerial photographs is created by the frequency of tonal or color change in groups of objects which are too small to be discerned as individuals. It follows that the size of object required to produce texture varies with the scale of photography. In large-scale photographs, trees can be seen as individuals; their leaves or needles cannot be discerned separately, but contribute to the texture of the tree crowns. In photographs of smaller scale, the crowns contribute to the texture of the whole stand of trees. Within a given range of scales, the texture of a group of objects (e.g., a timber stand of a certain species composition) may be distinctive enough to serve as a reliable clue to the identity of the objects.

Texture is an important interpretative factor in using images acquired from orbital altitudes. For example, the relative erosional dissection of an area may be inferred only by its texture because individual drainageways cannot be delineated. Drainage pattern is an important indicator of the type of surficial materials and bedrock. In other cases, features may be similar in color but may exhibit considerable difference in texture (e.g., volcanic fields versus desert pavement).

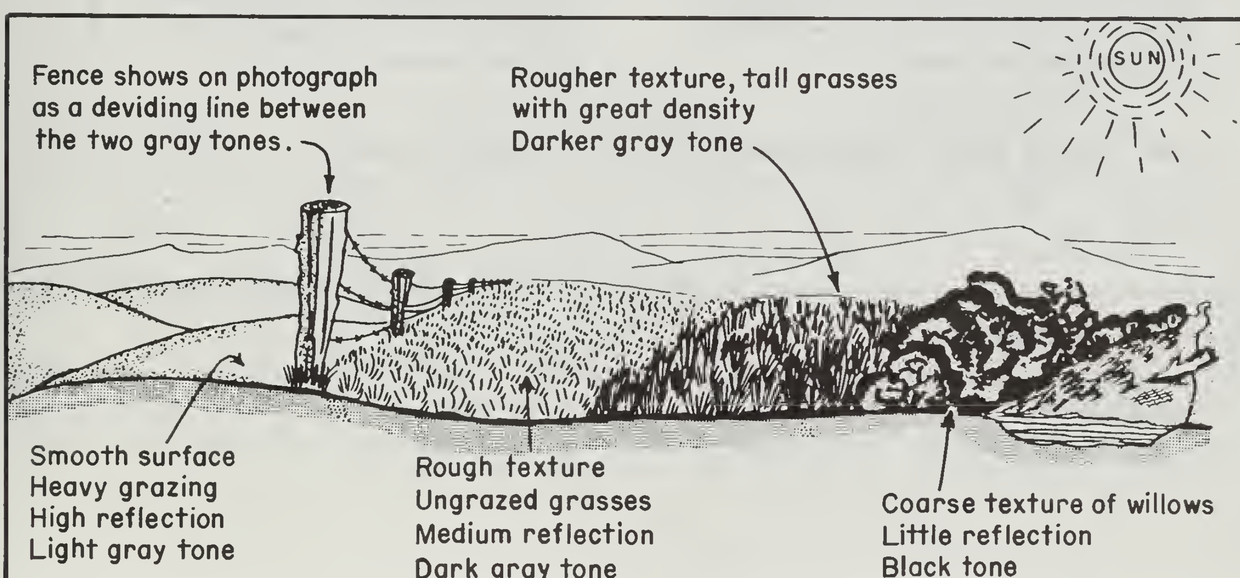


Figure 11. Effect of surface and texture on black and white photographs.

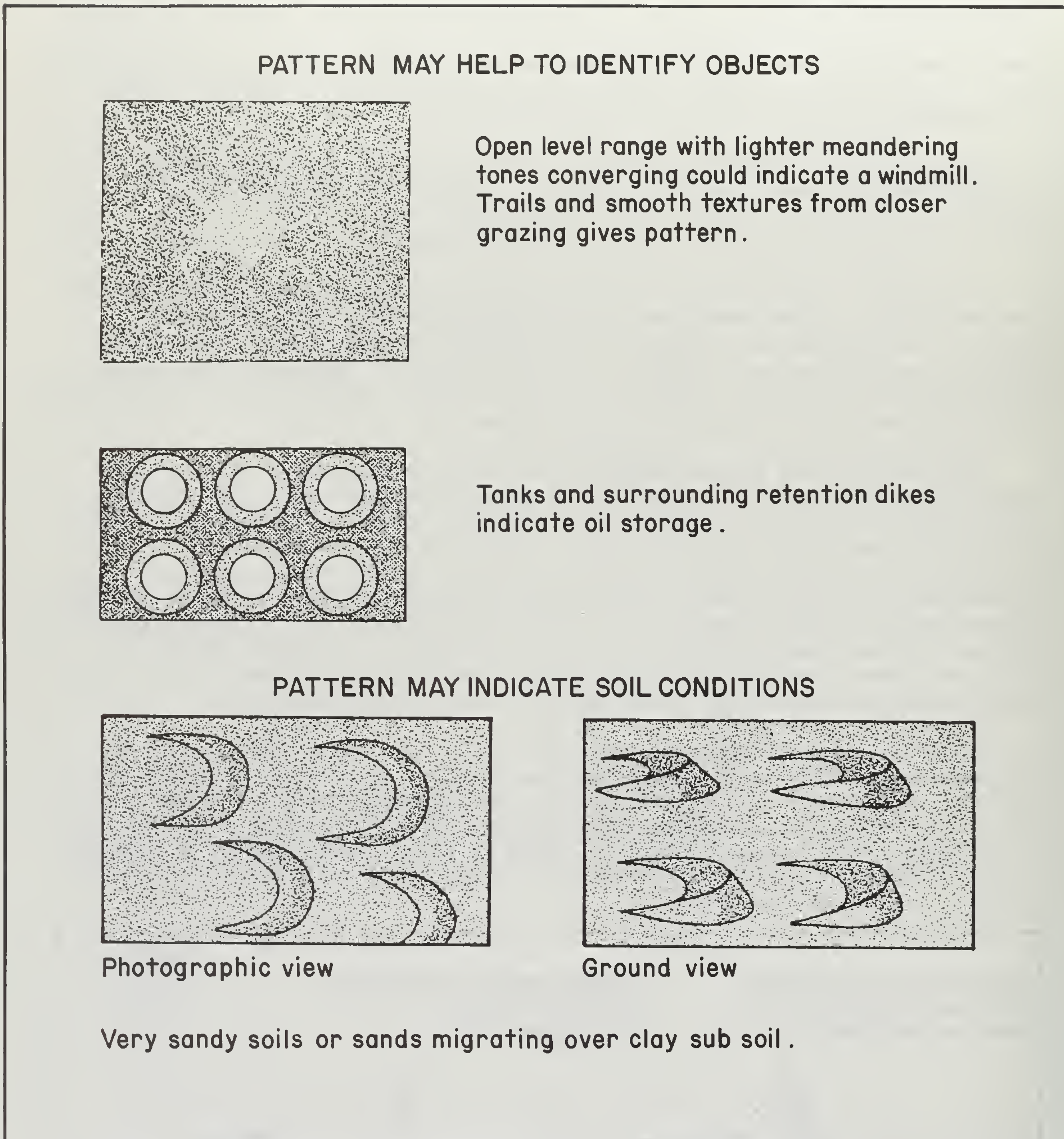


Figure 12. Patterns.

Patterns. Students of earth science have always laid great stress on the pattern or spatial arrangement of objects as an important clue to their origin or function. Geographers and anthropologists study settlement patterns and their distribution in order to understand the effects of diffusion and migration in cultural history. Outcrop patterns provide clues to geologic structure, lithology, and soil texture. The varying relations between organisms and their environment produce characteristic patterns of plant association.

Regional patterns which formerly could be studied only through laborious ground observation are instantly and clearly visible in aerial and space photographs. Aerial photographs capture many small but significant patterns which might be overlooked or misinterpreted by the ground observer (e.g., fracture traces and "halos"). Innumerable variations in classic patterns can be seen and exploited by means of image interpretation.

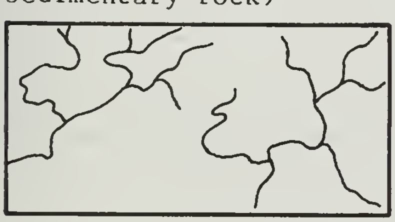
Some patterns are primarily cultural and others are primarily natural. There are, however, few parts of the world which have not been affected by man, and most of the patterns visible in imagery result from the interaction of natural and cultural factors. Even the photogeologist must sometimes take the activities of man into account.

Cultural features are conspicuous in aerial photographs because they consist of straight lines or other regular configurations. Most of man's activities leave scars on the earth which persist for a long time even after the activities have ceased. Patterns of settlement, mining, and agriculture may be visible from the air after thousands of years, directly or through altered patterns of vegetation and erosion, and photo interpretation has become an important technique of archaeology.

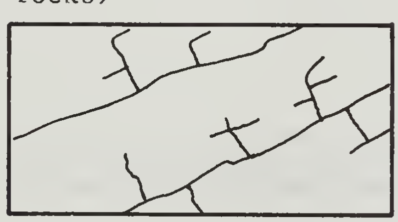
Patterns formed by agricultural practices, fracture alignments, drainage networks, and vegetation are important factors in the interpretation of an image. As mentioned above, intricate patterns may be reflected as a textural difference in space imagery. In many instances, regional patterns associated with other image elements provide clues to finer-grained patterns.

Patterns indicate relationships through repetition or arrangement of objects or form. The relationship may be the typical patterns imposed on a streambeo by geology, for example:

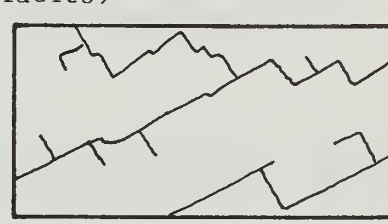
Dendritic (Homogeneous or flat-lying sedimentary rock)



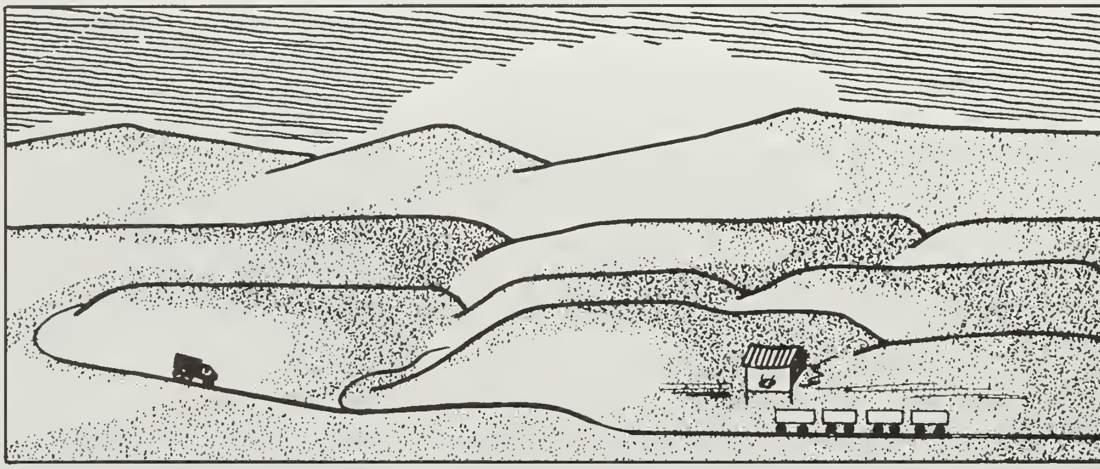
Trellis (tilted or folded sedimentary rocks)



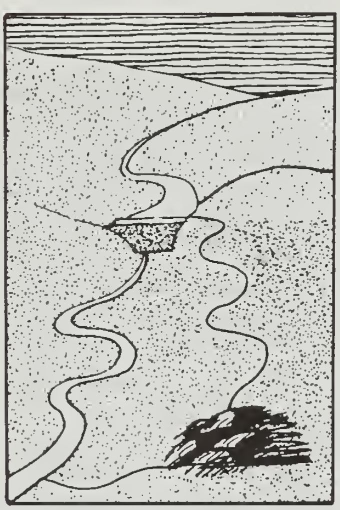
Rectangular (well-developed joints and faults)



The relationship may be typical patterns of land use, the symmetry of oil tanks surrounded by circling dikes, and soil conditions (Figure 12).



Parallel ridges might be a geological structure, but road net leading to railway siding indicates strip mining.



Diversion dam with ditch might be irrigation canal, but ditch is leading to tailings which indicates a flume used in a mining operation.

Figure 13. Relationship to surrounding objects.

Relationship. A link must be established in the chain of identification on a photograph. This link is the summation of the relationships of objects on the photograph. The other guides or keys to identification and interpretation sometimes are not enough.

A railroad may be easily identified (Figure 13). It ends in a field abruptly. In time of war, it could well be a railroad gun or a guided missile site, especially with a spur parallel to it. However, a sugarcane field might be ready for harvesting and these are the temporary tracks. The identification requires a relationship not only to the ground but to many factors implicit to the situation on the ground but perhaps incapable of being expressed in a photograph. This is where you, your background, and experience lead to a correct interpretation of the photograph.

A broad knowledge of cultural, economic and social factors means much in this phase of interpretation. A single example is given in Figure 9. A road going to a stream and continuing on the opposite bank, plus the lack of a bridge, is an indication of a ford or a ferry. The parking lot for cars awaiting for the return trip suggest a ferry.

Knowledge of local customs that influence structural design may help. Churches in Europe are oriented toward the east. The direction of the church is determined by the cross-like character of the building--east is at the altar. Customary driving on the roads (left or right) affects construction of cloverleaf intersections--an indication of the unconscious impact of customs of a country on design.

The obvious relationship of railroads to sidings, the abrupt curves of secondary roads, the broad sweep of a super-highway are more than just that. They represent our evaluation of the everyday happenings in our like as we see them, readily recognize the conditions, and relate them to the photograph. If we carry this relationship further in careful evaluation of conditions, not only on manmade features but geological and soil features as well, as a cause and effect, we are entering into the highly skilled field of photo interpretation where many of the Bureau employees rightfully belong.

Techniques and Procedures

Certain image-interpretation techniques, when properly applied, can improve the quality and quantity of useful information extracted from imagery. Among the techniques being refined are methods for using (1) methodical procedures, (2) efficient search techniques, (3) knowledge of factors-governing image formation, (4) the background and training of the interpreter, (5) the concept of "convergence of evidence," (6) the "conference system," (7) information available in analogous areas, (8) reference materials, (9) simple and sophisticated equipment, and (10) acquiring field data.

The image interpreter must have an understanding of: (1) how the image was formed, (2) what the image elements represent, and (3) the basic earth processes and phenomena that are present on the image. The amount of information that an interpreter can extract from an image is proportional to his/her experience, skill, and interest.

Efficiency in the analysis of imagery is dependent upon a number of factors. A systematic approach to the problem under study is perhaps the most important consideration. In general, a systematic analysis involves the convergence of empirical evidence drawn from the imagery. The following procedures (steps) illustrate this method:

1. Regional analysis
   a. Geographic aspects
   b. Physiographic aspects
   c. Geology
   d. Climate
2. Local analysis
   a. Landforms
   b. Drainage patterns
   c. Erosion
   d. Image patterns
   e. Vegetation
   f. Spectral features
3. Collateral information
   a. Reports
   b. Maps
   c. Field data
4. Summary of interpretation results
5. Field check in key areas

The approach works and results in a savings of time. Additional benefits and information are also obtained by using a multidisciplinary/interdisciplinary team approach.

Photo Preparation

The Effective Area is that central portion of a vertical photograph delimited by the bisectors of the overlaps with adjacent photographs. On a vertical photograph, all images within the effective area have less displacement than their conjugate images on adjacent photographs.

Effective area boundaries are important in photo interpretation for two reasons: (1) on photography of mountainous country, they define the smallest usable area of least displacement on each photograph, and (2) they provide interpretation "match lines" between photo pairs which avoid duplication or gaps in delineation between photographs -- both within, and between, lines.

When determining effective area boundaries proceed as explained and illustrated in the following, (Substitute your own numbers instead of the examples cited).

In-Line Effective Area Boundaries.

o Place photo 143 over photo 144 in overlap position with flight line segments coinciding (Step 1, Figure 14). Don't tape down.

o Visually locate and pencil mark the endlap midpoint on the west side of photo 144. Now slide 143 across 144 perpendicular to the line of flight until the format margin on the east side of 144 is showing. Mark the endlap midpoint on the east side of 144 (Steps 1 and 2, Figure 14).

o Connect these overlap midpoints on 144 with a ruler and colored lead pencil.

o Stereoscopically, or visually without a stereoscope, transfer 4-5 points along this mid-overlap line to photo 143. Do not pinprick! Accomplish quickly with pencil and locate the points at extremes of relief (ridge tops, valley bottoms, etc.).

o Connect the transferred pencil points on 143 with colored pencil (Figure 15). If there is considerable variation in relief, the transferred boundary will be crooked -- and it is! Viewed stereoscopically, if properly accomplished, the two lines will merge and "flow" over the surface of the landscape.

o Locate the in-line effective area boundaries between stereo pairs 143-142, 229-230, and 230-231.

o On the end photos in the flight lines (142, 144, 229, 231), rule straight pencil lines through the Principal Points (PPs) (Photo Centers), across the line of flight, to within about 1" of the east and west fiducial marks on each of these photos as in Step 1, Figure 16.

Between-Line Effective Area Boundaries.

o Place the two lines of photography side-by-side in front of you with the titling away from you (Step 1, Figure 16).

o Overlap 229 over 144 on the basis of matching ground features to determine the sidelap zone.

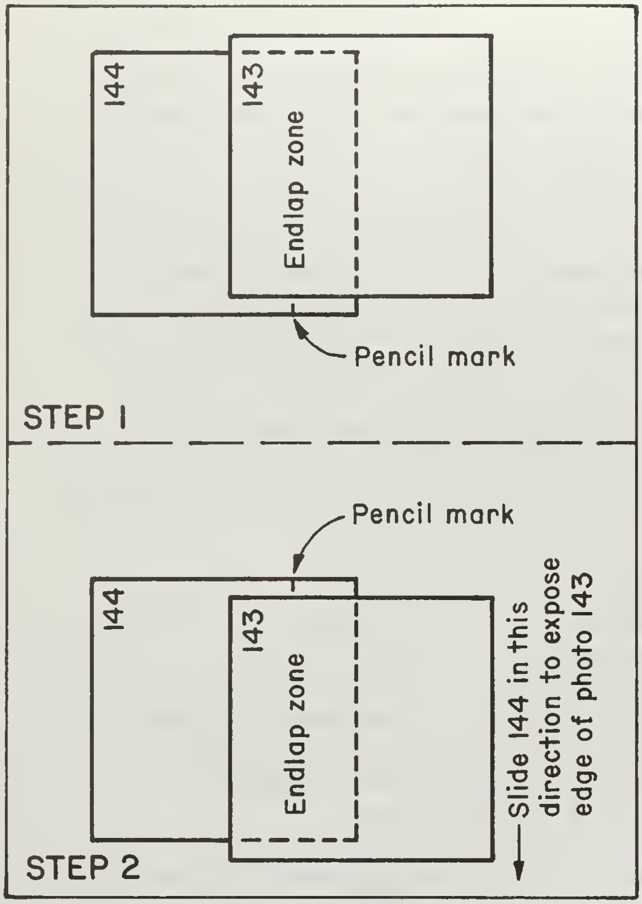


Figure 14. Location of endlap midpoint.

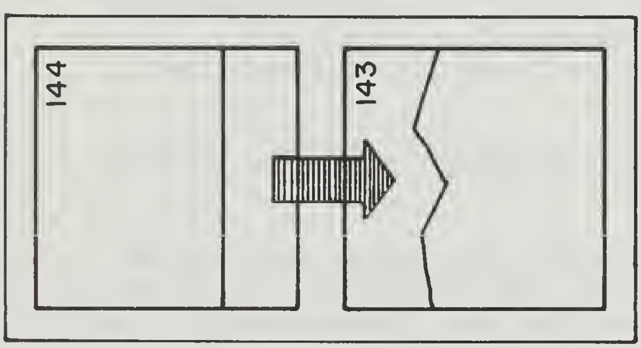


Figure 15. Transfer of endlap bisector on photo 144 to 143 results in a crooked line on 143 due to relief variations.

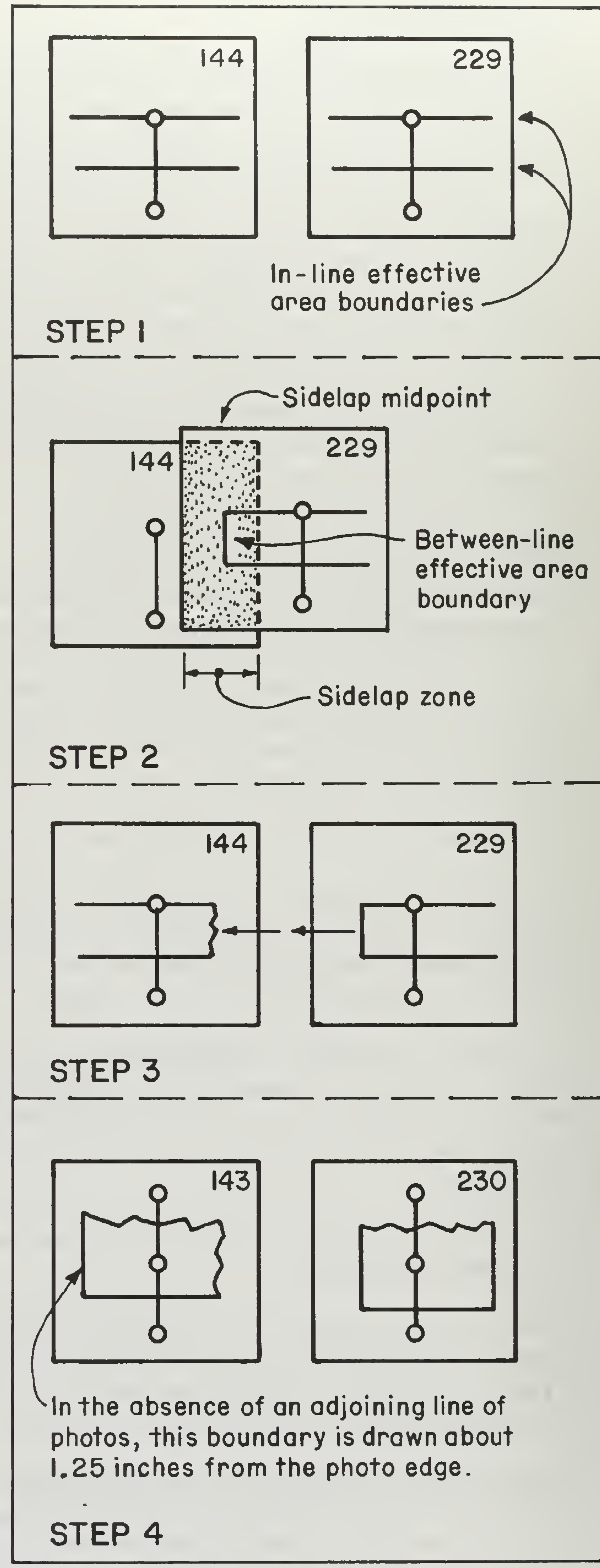


Figure 16. Location of the in-line effective area boundaries.

o Visually locate the sidelap midpoints and rule in as a straight line on 229. Do not extend the line beyond the endlap effective area boundaries (Step 2, Figure 16).

o Visually transfer this line to its conjugate position on photo 144. When there are extremes in relief in the sidelap zone, this line will be irregular -- reflecting variations in topographic displacement (Step 3, Figure 16).

o Repeat procedure between 143 and 230, 142, and 231.

o Since there are no adjoining photographs on the east of 229-231, or on the west of 142-144, put in the final side of each effective area at about 15% of the width of the photo from the edge (circa 1.25 inches) - as illustrated in Step 4, Figure 16, for photos 143 and 230.

o Please note that, where transferred boundaries are indicated in the above diagrams, the degree of irregularity has been purposely exaggerated.

o It is not unusual for the effective area boundaries to sometimes be located on alternate photos - particularly in areas with little, or no, steep topography. In such cases, the effective area boundaries are determined in precisely the manner described above - but between every-other photo.

Overlay Preparation:

Clear acetate overlays (9 in. x 9 in.) should be placed on each frame to be interpreted. A fine point, permanent marking pen should be used. Delineate a line over each fiducial mark observed on the photo. Trace the photo number (e.g., 143) precisely over the lettering on the print. Trace the match lines precisely from the print. The interpretation overlay is now registered to either a particular transparency or its paper print. It can be removed from over the photo and replaced without fear of misregistration. Figure 17 shows examples of properly prepared overlays.

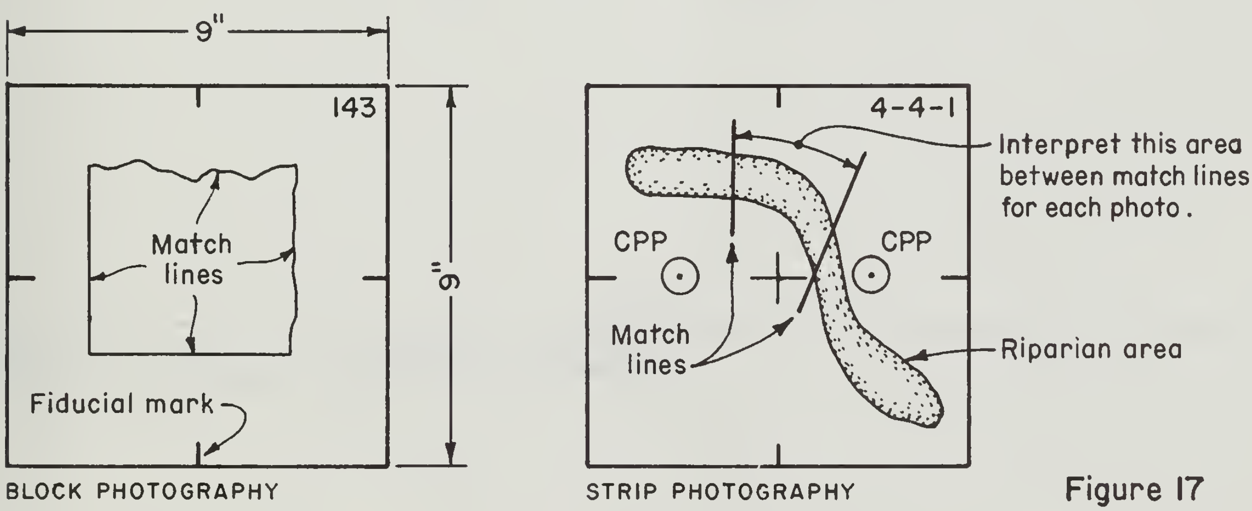


Figure 17

Figure 18 is an overlay representing typical classifications of vegetation within a specific area. Symbols O/P is oak and pine with oak being dominant and pine sub-dominant. D/P is Douglas fir and pine, O/G is oak and grass, etc.

Figure 19 is a typical drainage overlay.

APPROXIMATE SCALE = 1:18,600

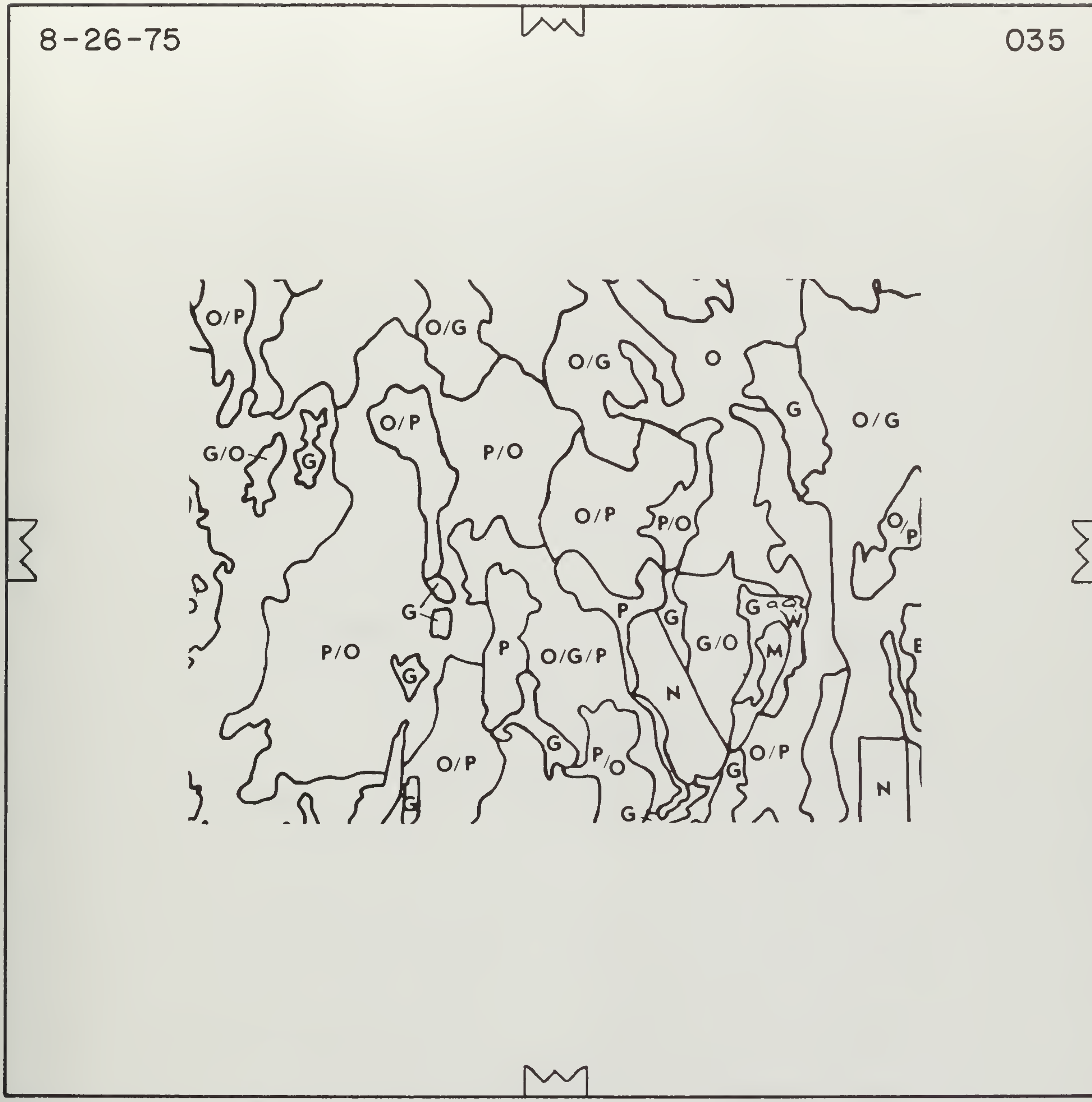


Figure 18. Typical vegetation overlay.

APPROXIMATE SCALE = 1:18,600

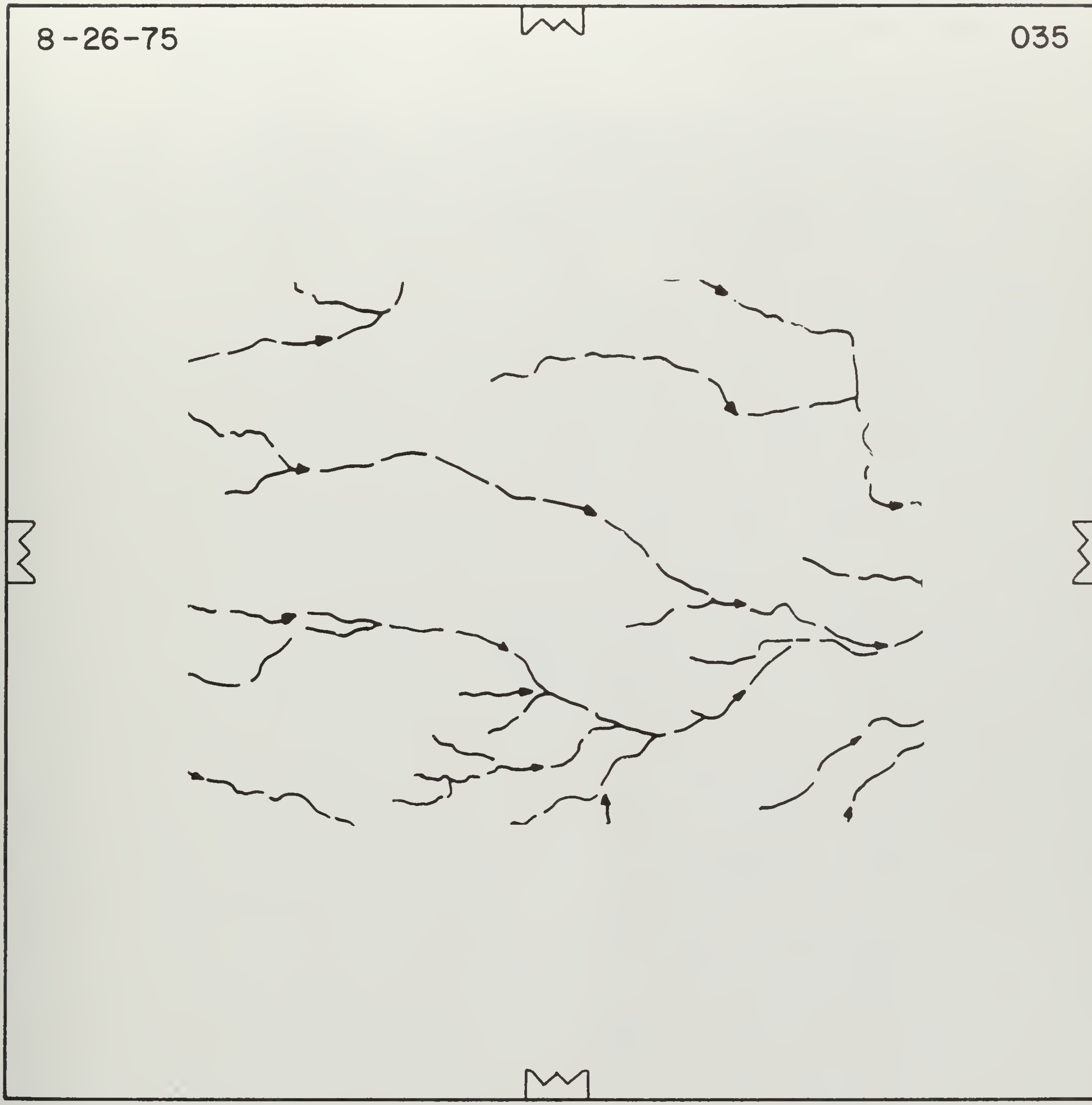


Figure 19. Typical drainage overlay.

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

This publication provides information on basic interpretation of aerial photographs. Included are discussions on types of photography, films, and filters. Photo interpretation and usage are also covered, with discussions of scale and acreage determinations, image characteristics, and photo preparation.

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