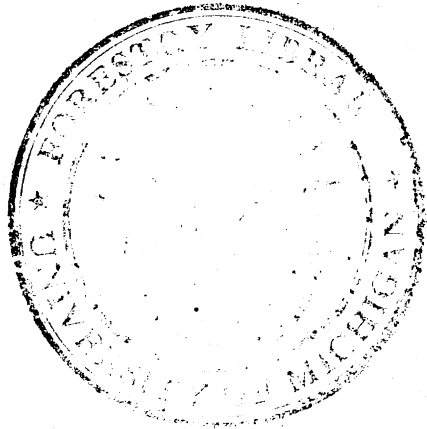


Steigerwaldt, Edw



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ARTES SCIENTIAE VERITAS

School of Forestry & Conservation
University of Michigan
Ann Arbor, Michigan

"How to use aerial photographs
in Forestry".

by

Edward F. Steigerwaldt

June 10, 1947

Presented in partial fulfillment of the requirements for a degree of Master of Forestry.

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Foreword

In my thirty nine months of Army career, I had the good fortune to be assigned to the Military Intelligence Training Center, Camp Ritchie, Maryland, where I received 13 weeks of special training as an aerial photo interpreter. Because of my high marks, I was retained as an instructor in the photo interpretation school for a period of six months. It was during this latter period that I became interested with the idea that my knowledge of aerial photography could be very useful if applied to forestry. With this in mind, I began collecting data, sample photographs, maps, sketches, etc., that would eventually give me a backlog of material I could use in writing my Master's thesis on this subject. My commanding Officer, Lt. Col. A.M. Apmann, was kind enough to allow me ready access to surplus photos which resulted in a well-illustrated thesis. This thesis has been almost entirely put together from material I accumulated, and has served admirably to give me an over-all review on aerial photography and how the knowledge of its use can be applied to forestry. Consequently, my bibliography is rather limited; but I have attempted to read all the background material available, particularly in past JOURNALS OF FORESTRY.

Nowhere in my readings, did I run across a book that started from the basic facts of aerial photographs and step by step continue to enlarge upon their use for forestry.

My thesis is an attempt to get under cover a booklet that would enable a reader to get a good idea of what aerial photos are and how they are useful in various phases of forestry. In two semesters, it was physically impossible to go into the detail various subjects called for, so an attempt was made to touch upon each subject briefly; and then include a reference in which the reader could look up more material if he were interested.

I would like to thank Professor Shirley Allen for acting as chairman of my review committee, and Messrs. Frank Murray, and John Carow for the many helpful comments and suggestions given to me on the contents, layout, and material I put into my thesis.

AERIAL PHOTOGRAPHY (1)

An aerial photograph is a relatively exact reproduction of the earth's surface. Comparing it with a map which graphically represents a portion of the earth's surface, the aerial photograph has the following advantages:

- a. It possesses a wealth of detail no map can equal.
- b. It has accuracy of form.
- c. It is up to date to the moment it was taken.
- d. It can be obtained and developed in a very short time.
- e. It may cover otherwise inaccessible areas.
- f. It may be quickly reproduced in quantity.

g. However, there are also a number of ways in which maps are superior to aerial photos:

- (a. Relative relief is readily apparent.)
- d, ~~b~~. Marginal data is more complete.
- b, ~~c~~. Absolute and positive elevation can be obtained.
- c, ~~d~~. Emphasizes certain detail.

TYPES OF AERIAL PHOTOGRAPHS

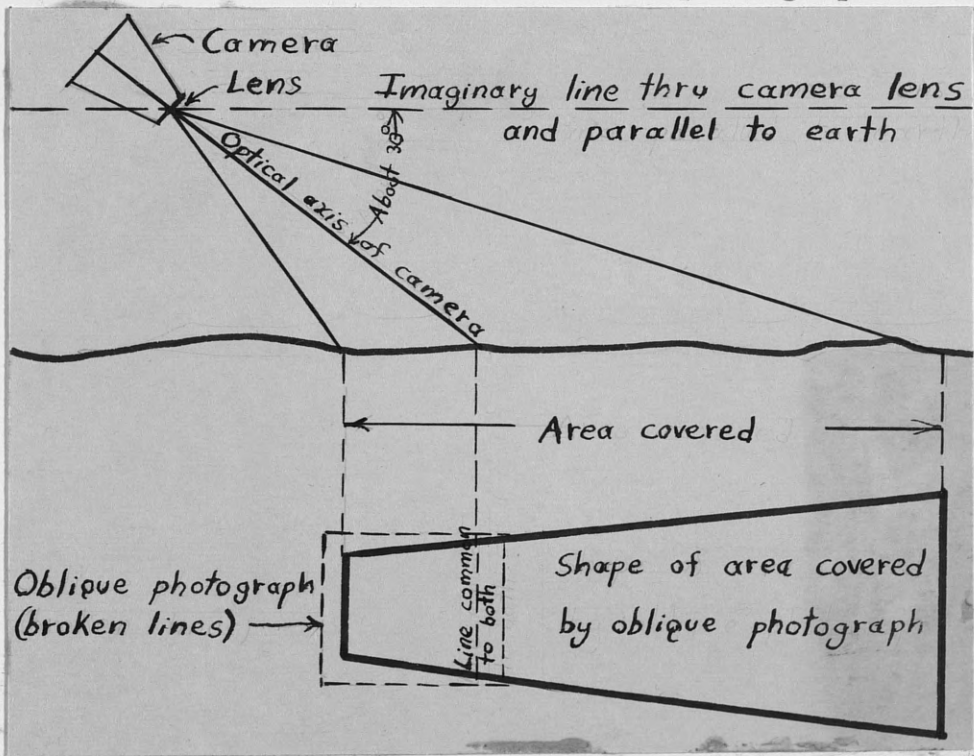
There are three recognized types of photographs taken with the aerial cameras—verticals, obliques, and composites.

1. Vertical. When the optical axis of an aerial camera is pointed at the earth and is as nearly vertical as possible, the resulting photograph is called a vertical. The accompanying



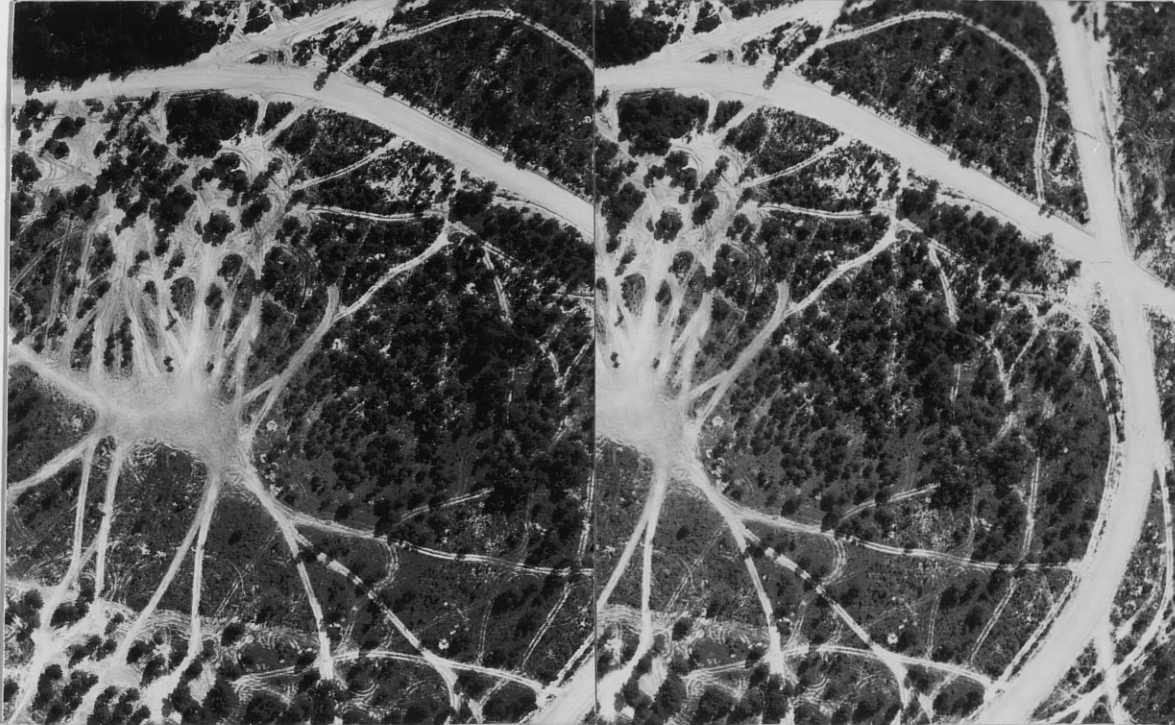
vertical was taken over Baltimore, Maryland, and is a good example of a vertical photograph. By far the greatest majority of aerial photographs taken are verticals. It most closely represents a map, but since distortion due to ground relief, tilt of the camera, and condition of the lens all affect the resulting photo; it is not a true map. (A detailed explanation of these errors may be found in 2). From the vertical photos, the main terrain features and man made improvements can be readily identified and plotted on an overlay. With stereo pairs of vertical photos much useful information can be gotten for forestry problems as will be discussed in following chapters.

2. Obliques. When the optical axis of the camera is purposely tilted from the vertical, an oblique photo will result. The portion of the earth photographed will take on



a square or rectangular shape, depending on the film size; but the area covered on the ground when plotted will be in the form of a trapezoid.

a. Low oblique. A low oblique is an oblique photograph which does not include the horizon.



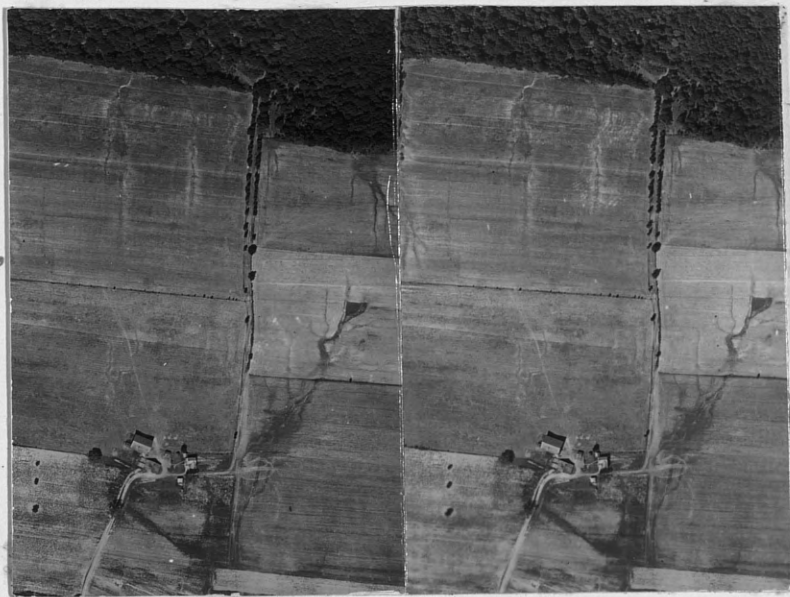
In the vertical set of stereo pairs above taken at Fort Bragg, North Carolina, a pretty clear idea of the terrain, vegetation, and activity (Army maneuver area) can be interpreted; but the low oblique below of the same area, eliminates many doubts we had about certain things and makes identification and interpretation a simple matter. Notice how clearly the timber

stands out and notice how easy it is ^{in this case} to get a good picture of density, ~~age~~, height, and possibly species.



b. High oblique. A high oblique is an oblique photograph that includes the horizon.

In this set of vertical stereo pairs of a typical Pennsylvania farmhouse and fields (Fairplay, Penn. 1:7500), fair interpretation could be made of the buildings, crops, and terrain. However, when a



high oblique of the same area is taken it can be clearly seen how advantageous and helpful an oblique photo can be; as it brings out detail impossible to pick up on vertical photos (see below).

To summarize the advantages of obliques over verticals we can say:

1. Ground forms are emphasized.

2. Detail not readily interpreted on verticals can be easily analyzed.

3. Can be taken



under circumstances where verticals are impractical-bad weather.

c. Composites. A composite is the assembled photograph made from simultaneous exposures of one or two multiple lens cameras. Commonly referred to as Tri-metrogon aerial photography it was used by the United States Army for extensive reconnaissance and mapping work. When five lenses are used the composite takes on the shape of a Maltese cross. This type of photography is rarely used at the present time.

Affect of obliques on the scale of photographs:

On the following page we have a vertical photo taken at 10,000' over Camp Whiteside, Fort Riley, Kansas. For all practical purposes, the scale anywhere on the vertical can be considered constant: at 1:10,000. Points A, B, C, and D which make up a parallelogram, have been marked on the photo.

The other photo is an oblique photo taken of the same area and will show the marked effect that a tilted camera will have on the scale of that photo. Points A, B, C, and D have again been located, and now it is apparent that the shape of the area within the points is a trapezoid. The scale now varies from large to small as one moves from the bottom of the photo (closest to the camera) to the top of the photo and infinity of the horizon (furthest from the camera).

CVS-504D-1stOp.S7(8-18-37-10A)X12-100007 / CAMP WHITESIDE / FT. RILEY / 4th ARMY MANEUVERS 1836





1837

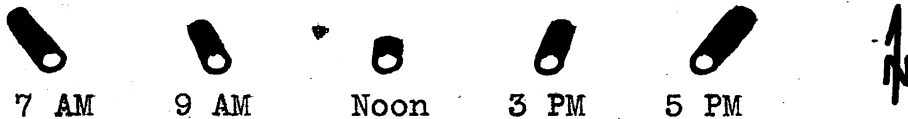
4th ARMY MAN. 35th DIV. WHITESIDE & PAWNEE POINT CAMPS, BLUE

67-504D-1810.S.X8-18-37-815A112-600

ORIENTATION AND SCALES

Orientation: An aerial photograph is said to be oriented when one knows exactly what area it covers on the ground. To indicate and record this ground area we frequently use a map, photomap, or a smaller scale photo. The following steps may be followed in orientation:

1. Orient for direction. Have north on photo point in the same direction as the north on the map. Most photos are taken between the hours of 10 o'clock AM and 2 o'clock PM; and in the northern hemisphere around noon, shadows will point generally North. (The opposite is true in the southern hemisphere)



"Pole viewed from above"

This illustrates the general rule. A more exact determination of north would require season of the year, latitude, etc., to be included in calculations. Most commercial companies flying aerial photographs have the center of each photo, fiducial mark on the center of each side, and occasionally the north arrow, automatically printed each time a photo is taken. As an example we will take the following photograph No. 1, and determine north by the shadow method. The photo was taken at 9 AM (0900 army time as in the marginal information); by checking the shadows of a few trees we see that the

ORIGINAL
PHOTO NORTH

CORRECTED
SHADOW NORTH

(45° RIGHT)

Shadow

N

1

shadow points to the upper left corner of the photo and is three hours to the left of its true north position. We also know that on an average, shadows will move 15° every hour. Therefore, we want to move an imaginary shadow line from its present 9 AM position, ahead three hours ($12:00 - 9:00 = 3$ hrs) to its position it would have at 12:00 when the shadow would be closer to its correct north position. This means we would lay off 45° right from our shadow ($3 \text{ hrs.} \times 15^{\circ}/\text{hr} = 45^{\circ}$) which would make our north now at the top of the photo.

If the photo were taken in the late afternoon, the angle of shadow correction would be to the left. In photo No. 2, the shadow falls to the lower right hand corner. Since the photo was taken at 4:30 PM (1630 army time) it means the shadow would have to be moved left 67° ($4:30 - 12:00 = 4 \frac{1}{2} \text{ hrs.} \times 15^{\circ} = 67^{\circ}$).

2. Compare scales of photo and map. After orienting the photograph for direction, the next step is to determine how large an area the photo will cover on the map or photomap in use. The formula used is:

$$\text{Map Distance} = \frac{\text{Side of photo} \times \text{Den. R.F. of photo}}{\text{Den. R.F. of Map}}$$

For example: We have a photograph 9" x 9" with a R.F. of 1:10000 and want to know how large an area the photo will cover on a map with an R.F. of 1:20000. Substituting in the

CORRECTED
670 LEFT

SHADOW TO

2

formula we have:

$$\text{M.D.} = \frac{9'' \times 10,000}{20,000} = \frac{90,000}{20,000} = 4.5''$$

Or the photograph will cover an area 4 1/2 inches square on the 1:20000 map.

3. Select the most prominent features of the photo and locate them on the map. Features should be of the type one would expect to find on a map such as roads, road junctions and intersections, rivers and streams, and mountains.

4. Locate finer features at the edges of the photo such as farms, buildings, fence lines, woods, etc.

When the four steps enumerated above have been completed, a photo is said to be oriented with a map.

Marginal information: An important aid to the photo interpreter is the information found on the margin of photographs. The R.F., area, date, time, negative number, etc., are annotated on all the photos of a strip; and normally the first photo of a strip will have more marginal information than the rest. Photo No. 3 is an example of what marginal information can be found on a photograph:

137PS	- 137th Photo Squadron-unit taking photos.
4	- Last number in year photos were taken.
M23	- Mission number.
11-V	- 11th roll, vertical. Camera position.
7:27	- Date photo was taken.
24:4,000	- Focal length in inches and altitude in feet.
FT. BRAGG	- Name of area.
CONFID	- Military classification-Confidential.



3

37 PS 4M 23 11-V 7:27:1230 24:4000 FT. BRAGG CONFID.

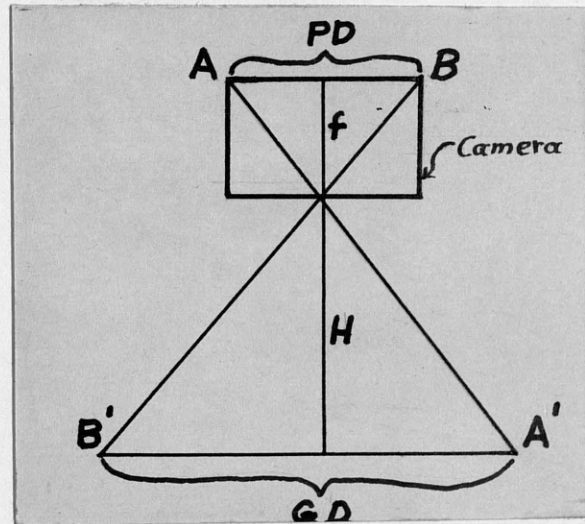
Geographic coordinates may be given for the center of the photograph to the nearest minute and would appear as (3936 N 7743 W).

Oblique photos would have the same marginal data except:

1. (0-40°) would indicate camera tilt from the vertical. In this case 40°.
2. "North", "West", etc., may appear - indicating direction in which camera is pointed.

Scale computation: The scale of a photograph is the relationship between distances appearing on the picture and the actual distances on the ground; and as with maps, it is referred to as the R. F. (representative fraction).

This is a function dependent on the focal length of the camera and the distance from the camera to the terrain being photographed (height of the camera station). The ratio between the photo distance (PD) to the ground distance (GD) is the same as the ratio between the focal length (f) of the camera to the height of the lens above the terrain (H).



$$\text{Thus: R.F.} = \frac{f}{H} = \frac{\text{Photo distance}}{\text{Ground distance}}$$

If the marginal information gives the focal length and altitude, we may compute R.F. from the formula: $\text{R.F.} = \frac{f}{H}$

Example: $(12-5,000) = \frac{12''}{5,000' \times 12''} = 1:5,000$

If it would be necessary to solve for H (altitude) we would use: $H = \frac{f \times R.F.}{1}$

In general the procedure in using the R.F. formula is:

- a. Substitute in the formula $R.F. = \frac{f}{H}$.
- b. Change both f and H to the same unit.
- c. Change the numerator of the fraction to one - by dividing both numerator and denominator by the same number.

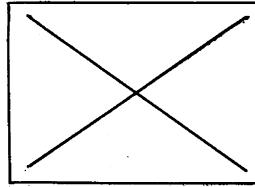
On flat ground with no tilt or dip of the plane taking the photo, the R.F. formula is considered accurate. However, there are three very common errors that affect scale:

1. Altitudinal fluctuations of the plane in flight.
2. Fluctuations in scale as ground elevation differences occur.
3. Tilt of the camera during photography.

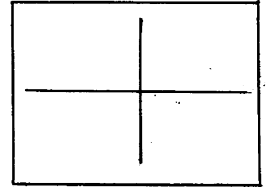
Estimation of scale: If a map is not available and if the marginal data is considered unreliable, the scale may be computed from any object on the photo whose dimensions are known or can be appraised. For an example, on a given photo, a two-lane road measures .003', .0025', and .0035' at different places. Taking an average we get .003'. Applying the formula $R.F. = \frac{PD}{GD}$ we get $\frac{.003'}{18'} = 1:6,000$. Our ground distance of 18' comes from the known fact that a two-lane road is normally 18' wide - 9'/lane. In like manner, any object of known or estimated size may be used.

Scale line method: By use of this formula $\frac{PD}{MD \times \text{Den. R.F. of map}}$ we may also determine R.F. of a photo. This method is usually the most accurate way for determination of scale. We use a map to determine the GD between two points. The line joining these points is called a scale line. Scale lines are drawn with the following characteristics:

1. One of these patterns



or



2. Points at the end of lines should be of the type that are generally plotted on maps by survey-bridges, primary road junctions, dams, etc.
3. In mountainous terrain points should be of medium elevation.
4. The above three should be balanced against each other.

Use of the scale-line method: See photo No. 5, and the Hagers-town Quadrangle 1:62,500 map.

- a. Points A, B, C, and D have been selected on the photo. Find them on the map by the steps in orientation discussed earlier.
- b. Measure between points AB and CD.
- c. Substitute measurements in the scale-line formula:

$$\frac{AB}{.216' \times 62,500} \text{ R.F.} = \frac{.648'}{62,500} = 1:20,833$$

$$\frac{CD}{.240' \times 62,500} \text{ R.F.} = \frac{.724'}{62,500} = 1:20,718$$

- d. Average the scales.

$$\frac{2/41,551}{20,775}$$

Our more accurate scale of the photo is 1:20,775

OB

$$\frac{AB}{RF} = \frac{PD}{60} = \frac{.648'}{2.16' \times 62,500} = \frac{.648}{1350000} = \frac{1}{20833}$$

20833
20718
14151
20775

OC

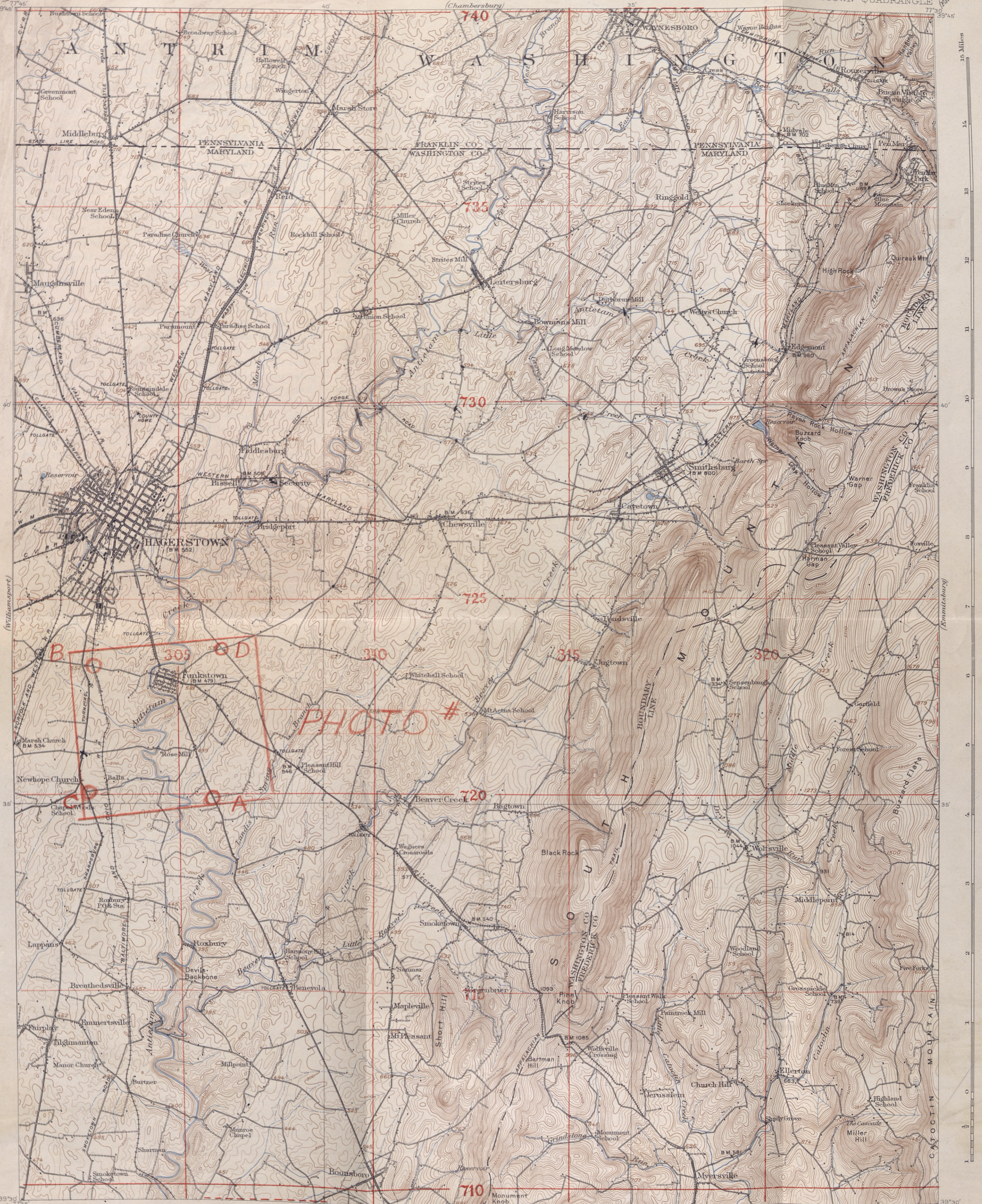
5

OP

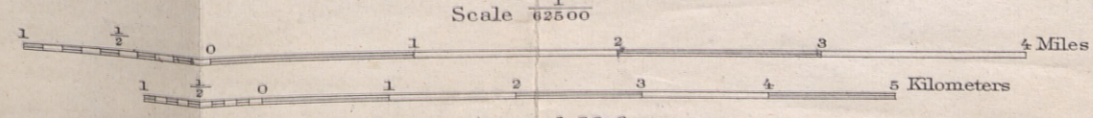
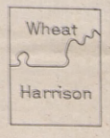
$$\frac{CO}{RF} = \frac{PD}{60} = \frac{.724'}{2.40' \times 62,500} = \frac{.724}{1500000} = \frac{1}{20718}$$

A

↑ 89PS M16 14V (26 APR 38 1210 X12-20000) 15936N 7743 W) FUNKSTOWN



R. B. Marshall, Chief Geographer.
Frank Sutton, Geographer in charge.
Topography by J. H. Wheat and R. L. Harrison.
Control by Sledge Tatum, Geo. T. Hawkins,
C. H. Semper and J. M. Harris.
Surveyed in 1908-1910.



Contour interval 20 feet.
Datum is mean sea level.

Edition of June 1912, reprinted 1943
with corrections
Polyconic projection, North American datum

HAGERSTOWN, MD.-PA.

N 3930-W 7730/15

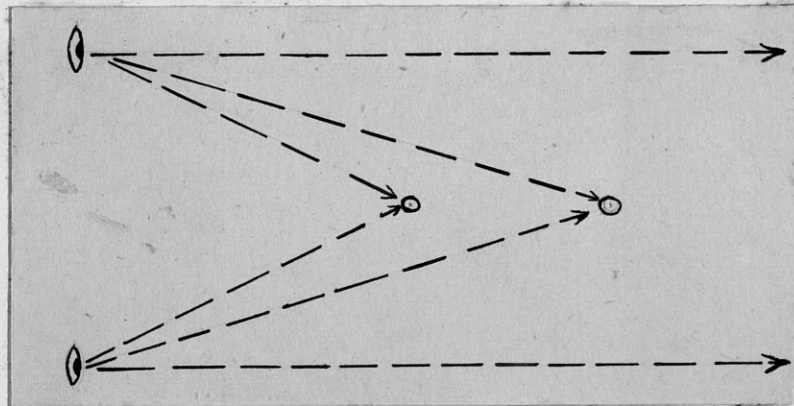
BASIC STEREOVISION

Before aerial photographs can be used successfully for forestry interpretation work, a thorough background in the theory and practice of stereovision is necessary.

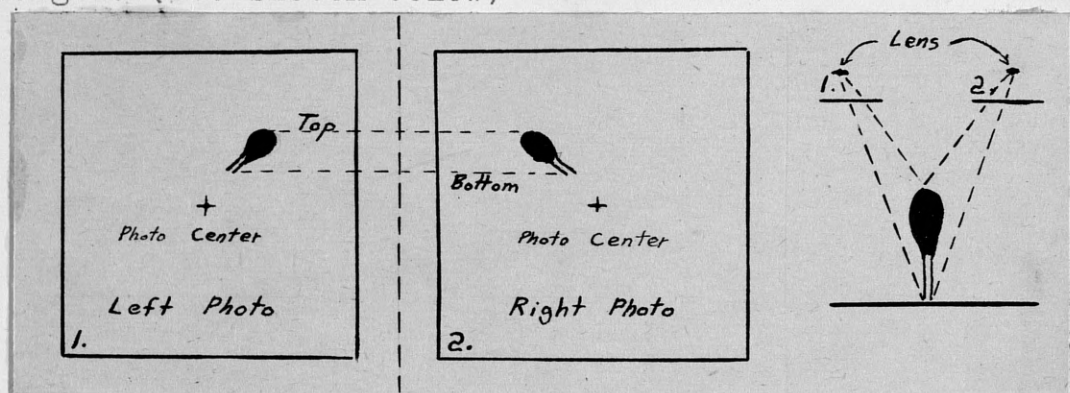
Throughout the thesis, "stereo-pairs" will be used to illustrate the subject matter discussed.

Stereovision: With aerial photos, stereovision is the ability to see objects on the pictures in relief. This is due to binocular convergence which occurs when two slightly dissimilar views of an object are observed, one with the left and one with the right eye.

1. "Binocular convergence". When viewing an object a finite distance away, the lines of sight from each eye will converge on the object; but when viewing an object an infinite distance away, such as a star, the lines of sight are nearly parallel. As the object approaches the observer, the eyes must turn inward to remain focused. This convergence increases as the distance decreases, each eye receiving a slightly different view. The brain fuses the two images giving one a sense of depth and distance.

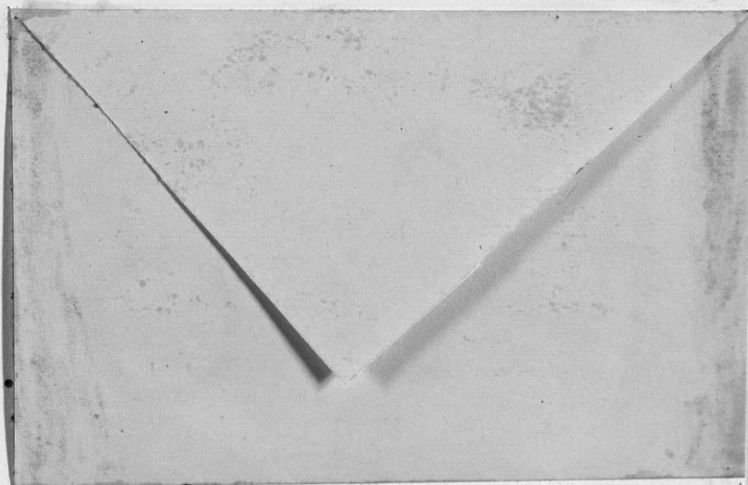


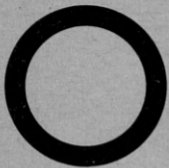
2. "Radial displacement". Because three dimensional objects appear on a photo as a two dimensional perspective view, displacement of the top of the object occurs. This displacement is always radial, and away from the center of the photo. The top of the object is always farther from the center than the base. When looking at a stereo-pair of an object, the tops of that object will be closer together than the bases causing the eyes to converge-giving the impression of height. (See sketch below)



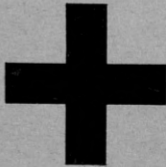
Practical stereovision: (Using cards in the envelope)

Take card A (left hand) and card B (right hand) and hold them 12" apart and 12" away from the eyes; gaze into the distance bringing the cards together until the X is fused inside the circle. Then you will note the cross is fused into one sharp impression flanked by two hazy impressions. Three dimensional effect is obtained similarly when the eyes converge more on the near side of an object and the brain synthesizes the two views



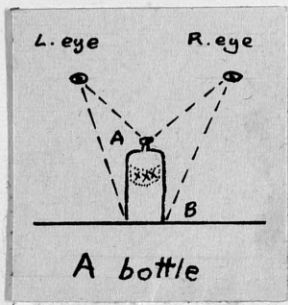


A



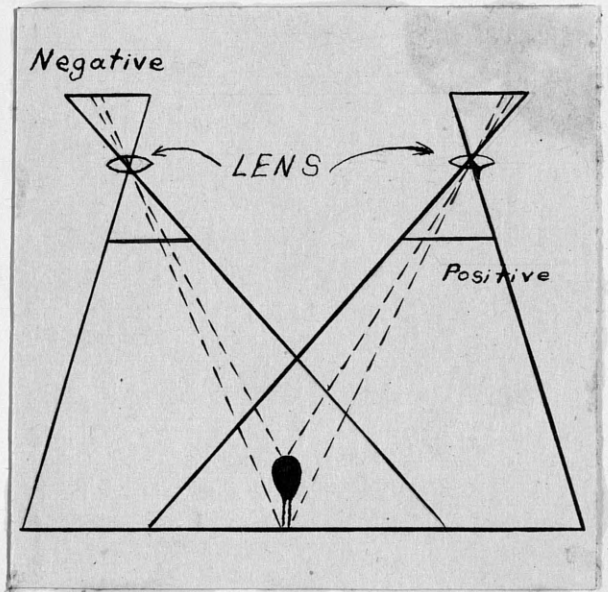
B

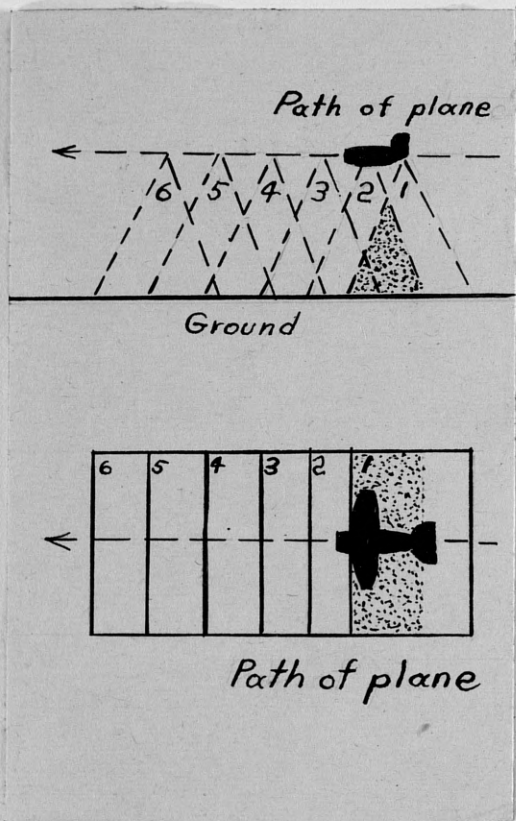
into one picture.



A appears to be higher to the observer than B when the observer looks at the object from above, because the eyes converge more on A than B. This gives the impression that A is closer than B, and the effect of third dimension takes place.

In stereovision the two camera positions take the place of the two eyes; thus, the inter-pupillary distance now becomes distance between the camera positions. By adjusting camera positions, depth perception is possible from any altitude. Thus, two views of the same object taken from these two camera positions are a stereo-pair. To use the "stereo-pair", one eye must focus on one photo and the other eye on the other photo.

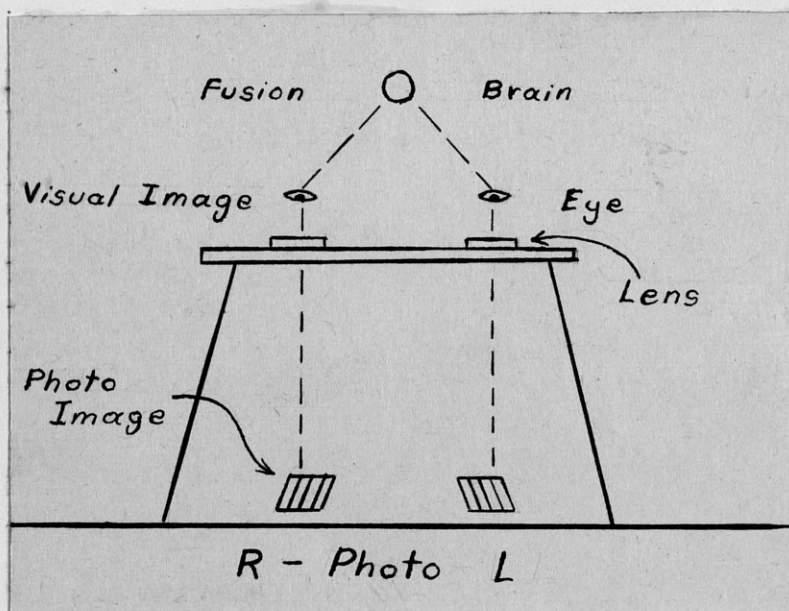




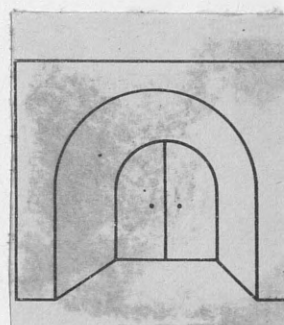
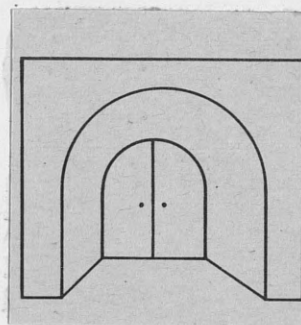
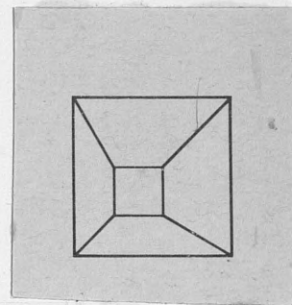
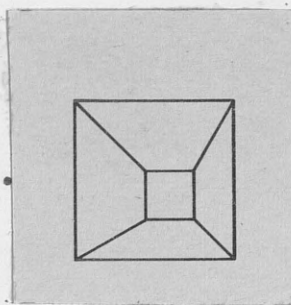
Stereo-pairs are only obtained from successive photographs taken in a "run". The dotted area of 1 and 2, or overlap area on the photos, is the area in which stereovision can be obtained from those two particular photographs.

"The Stereoscope"

The stereoscope is an optical aid with power magnification. The lenses are mounted to keep the line of sight parallel. A sliding bar graduated from 55-75 millimeters allows for adjustment of the eye pieces to individual inter-pupillary distance.



The cards to the right have been spaced about 2 1/2 inches for the interpupillary distance. Place the stereoscope over the cards and note how the three dimensional effect is brought out by "binocular convergence" and "radial displacement". The pyramid becomes truncated and the doorway shows depth.



The photo image of an object with height tends to lean away from the center of the negative. After reproducing the negatives of a stereo-pair, the tops of images with height located in the overlap area will be displaced toward each other; thus, making possible binocular convergence and the impression of depth as shown in the example below.



Power Plant HARRISBURG, PA 1:8766

Arrangement of stereo-pairs:

1. Place one photograph on top of the other so that the detail common to both matches roughly.

2. Turn the photographs as a unit until your eyes are parallel to an imaginary line running across the approximate centers of the photographs.

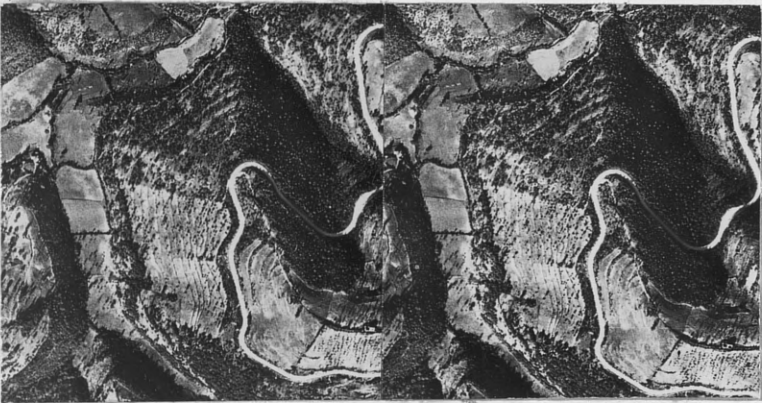
3. Place the stereoscope over the photographs so the left photograph is under the left lens and the right photograph is under the right lens.

4. Now separate the photographs along the line joining the centers (flight line), moving the right one to the right and the left one to the left. The photographs can be kept in proper relation by keeping parallel the details which appear in the overlap area, such as roads or streams. The two objects in the overlap area which are to be studied should be separated so each is directly under the left and right lens respectively. By slight movements the photographs can be adjusted to fuse the center images and thus obtain the effect of relief or depth.

Pseudo or false stereovision:

Occasionally the position of two photographs forming a stereopair is reversed so that the left print is viewed by the right eye and the right print is viewed by the left

eye. When this happens the impression of relief is reversed; hills appear as valleys and rivers and valleys become hills. Below is an example of correct and pseudo-stereovision.



Stereovision

Pseudo-stereovision



BASIC IDENTIFICATION AND INTERPRETATION

When riding along in a car through your neighborhood or countryside you have no difficulty in identifying every day objects because you are familiar with them. However, if an airplane ride would be taken over the same area it would appear very strange and different at first. A few things could be picked out such as the concrete road because of its shiny tone and straight lines, the cluster of homes because of their size and shape, the river winding through the countryside, and the dark-toned forests below. They would probably be identified with ease. Aerial photographs and their interpretation will present the same problems. When we identified the road, houses, river, and woods from the airplane, we indirectly used the five aids to photo interpretation. They are Size, Shape, Shadow, Tone, and Relationship to surrounding objects.

1. SIZE

On aerial photographs, the size between a number of objects on the same photo many times is the clue to their identity. On the following pages we have a number of examples to show this relationship between size and identification.



HARRISBURG, PA. 1:8766

In the photograph above, we have a large assortment of various size buildings, many chimneys, stock piles of coal or raw material, and a good railroad net all of which are indications of some type of large industry. Below the plant layout we have rows and rows of homes which contrast sharply in size to the larger buildings above. With a little study, we can determine that it is a steel plant by the following: Large size, the towers of the blast furnaces, stock piles of coal or ore, box cars on the sidings, and the fact that it is located in a large steel city.

This is a single vertical with a scale of 1:6500 taken from a sortie over the small town of Gettysburg, Pennsylvania. Our problem is to determine the nature of the largest building in the center of the photo. Comparing its large size to the clusters and rows of homes lining the streets, we know that it must be an important building connected with the town.

Having made a hasty interpretation, one might call it a factory, a city hall, or police station. However, when we take into consideration the track ring, football field, numerous baseball diamonds, and a large grassy play area; we must change our hasty interpretation and call it either a grammar or high school. Because of its large size and sport facilities, a high school would be the logical answer.



In this stereo-pair we have a view of a typical Pennsylvania farm. If we had to determine which were the house, barn, and out buildings; it would be no



problem whatsoever, for size would be the determining aid in identification. The barn is normally the largest building

on a farm. In this case the silo next to the barn makes its identification certain. (Note the radial displacement of the silo). The farm house is smaller and is situated nearest the road with a large lawn out front. The sheds, chicken coops, and small outhouse are scattered around the farm yard. Note the size of the tiny privy which has been placed in the small orchard to the right. From its small size and isolated position, we can identify it with ease.



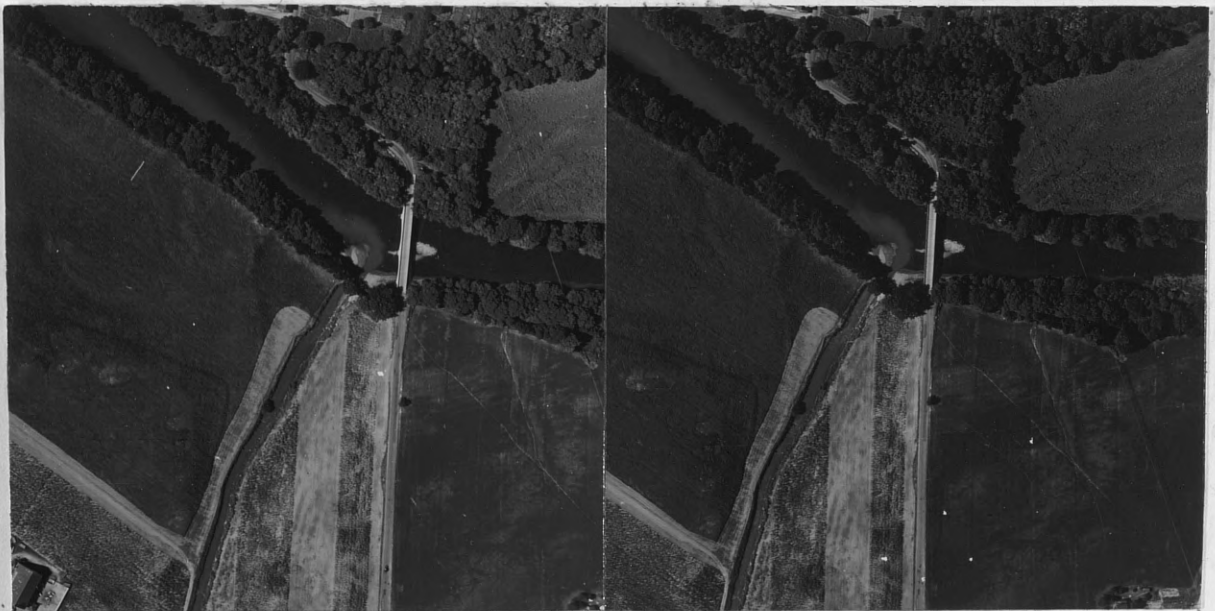
BALTIMORE, MD. 1:12,000

This and the following photograph show us by size alone which is the larger town. The number and layout of the homes, numerous streets, and the large size of the buildings in comparison with each other on the different photographs tells us the logical answer.

Small Pennsylvania
Town. 1:10,000



Rivers and streams are distinguished from each other mainly by their size. In the stereo-pair below we see a small stream entering into a larger stream. The lightness in tone of the narrower stream shows us that it has a collection of mud or silt in suspension. Note the evidence in the water which tells us the direction of flow. The muddy water is carried sharply to the left as it enters the larger stream, indicating that the streamflow is to the left.



2. SHAPE

Many items that appear on aerial photographs have a distinctive shape that is easily identified.

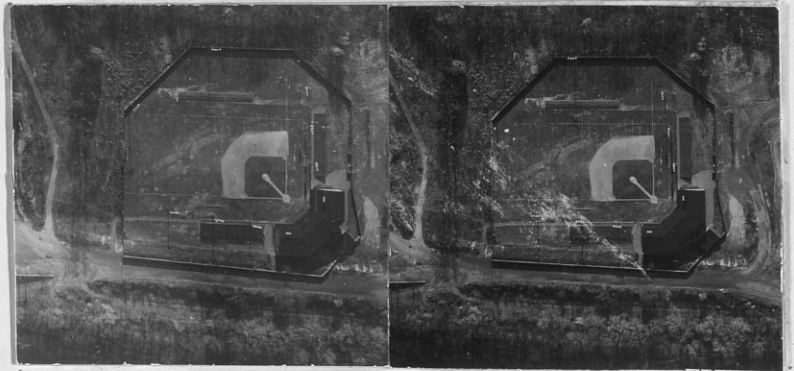


BALTIMORE, MD. 1:12,000

In the stereo-pair above, we have a very common industry that flourished in wartime. Without too much study we can quickly come to the conclusion that it is a shipbuilding yard. The primary reason for our decision is the shape of the particular units under construction in the ways. The outline of the ships is very distinct, and when studied under the stereoscope, all the steps in construction from laying the keel to finished ships can be easily made out.

HARRISBURG, PA.

1:8766



Without even using stereovision to determine what this is, we know already that it is a baseball park just by its shape and its pattern of layout. In stereo the dugouts, grandstands, diamond, night lights, and high board fence stand out in three dimension, and it becomes even more evident.



The shape and layout of the three single photographs above are the features that aid the photo interpreter in telling what they are. All photos were taken in an area just outside of small towns. After studying their geometrical layout, landscaping, thorough road net, and the many tiny white blocks laid out in the area, we come to the correct conclusion that they are examples of small town cemeteries. Their shape is the main characteristic that aided us in interpretation.

Here is a stereo-pair of the well-known Gettysburg National Cemetery just outside of the town of Gettysburg, Pennsylvania. This set offers us a check on the other small photos we interpreted previously. We can make out the same characteristics such as geometric layout, good road net, fine landscaping, and the white dots and blocks of the tomb stones in this cemetery as in the others.

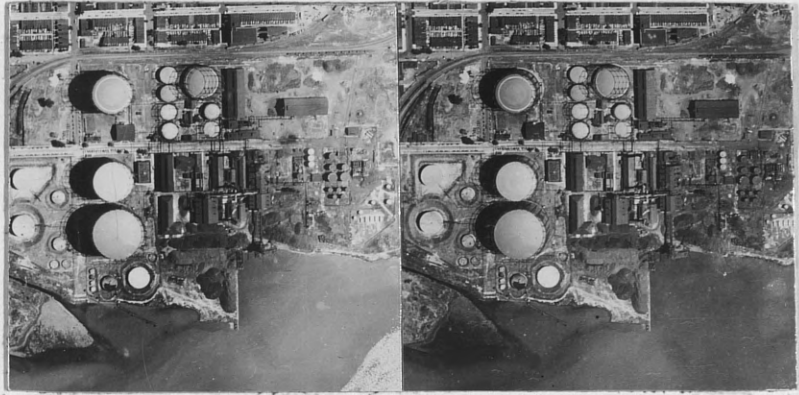


GETTYSBURG NATIONAL CEMETERY

1: 6500

BALTIMORE, MD.

1: 12,000



This stereo-pair is another example of how the shape of an object gives us its identity. The roundness of the tanks with their steel framework serve as the main identifying feature. These are wet gas holders, part of a illuminating gas plant.



In this single photo, a high tension power tower can be made out due to a large amount of radial displacement which shows us clearly the characteristic shape of such a tower.

The shape of this particular bridge is very evident both by its shape on the photograph and by the shadow it casts. It is a steel arch type of bridge construction.



HIGHFIELD, MD.

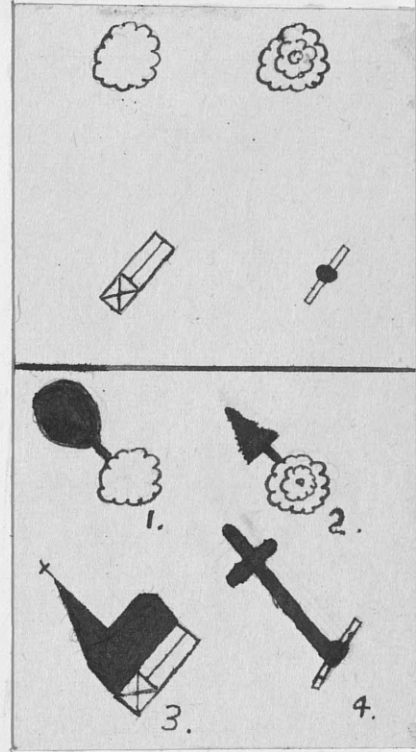
1: 6500



Above is a vertical of another object that is identified by its shape. It is a "Y" turn around for railroad trains so that they can turn around in the minimum amount of space. The oblique view shows the tracks very clearly. To the left of the photos is a round concrete emplacement which at one time was a turn table, but it was abandoned in favor of the "Y" turn around.

3. SHADOW

Perhaps the best aid to identification is by use of the shadow cast by the object. In the top sketch we see a number of very common objects as seen from above. The shadows have been removed. It can be plainly seen that with the shadow gone, identification of the objects becomes rather difficult. Snap on the light and note the change as shown in the lower sketch. Each item casts a distinctive shadow that tell us what the object is. They are as follows:
1. Deciduous tree, 2. Coniferous tree, 3. Church, 4. Telephone pole.



On aerial photographs, the same principle of the shadow aiding the interpreter is used extensively as will be shown in the examples that follow.



HARRISBURG, PA.

1: 8766

Aided very greatly by its shadow, which makes interpretation simple, this large gas holder stands out very conspicuously.

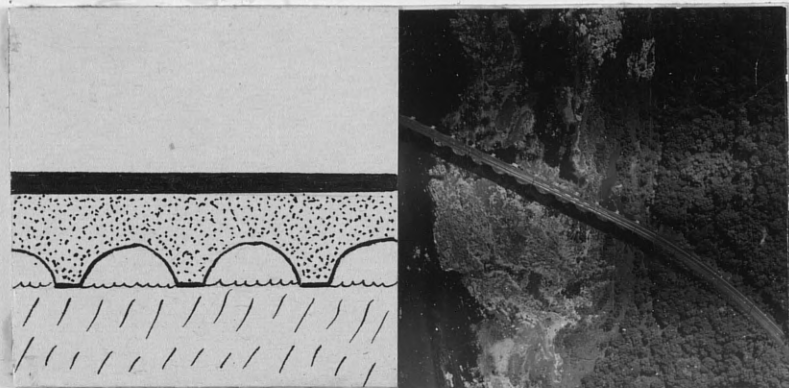
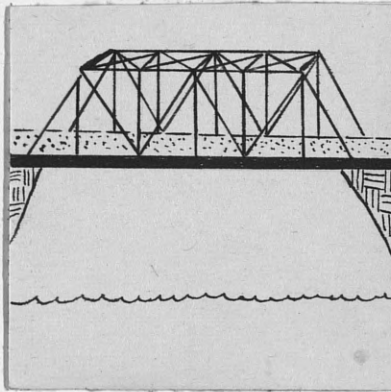
This is another example of how the shadow is an excellent aid in identification of certain objects on photos. Note how the steel framework shows it to be a wet gas holder. Without the shadows present, it would be difficult to determine whether it is a dry or wet gas holder.



A cylindrical water storage tank has a distinctive shadow as shown here, and without the shadow it would be fairly difficult to identify it as a large high water tank.



Shadows are very useful in determining the type and material used in bridge construction. In this particular photograph, the vertical view gives us a good idea as to its construction; but it remains for the shadow cast to give us the complete side view of the steel lattice work of the bridge.



The bridge on the left casts a low shadow, and a sketch of the bridge shows it to be a concrete or masonry arch R.R. bridge.

For the determination of hardwoods and softwoods, the shadow profile cast by a stand of timber many times

will serve as a help in determining pines from hardwoods. The upper half of the woodlot above is made up of hardwoods as can be seen by their lighter tone and rounded crowns. The pines are much darker in tone and cast a longer, more pointed shadow.



MONROE, N.C. 1: 6000



WADESBORO, N.C. 1: 6000

The shadows from the trees in the woodlot on the left are fairly tall, but are rounded and have a light tone characteristic of hardwoods. The smaller

darker trees appear to be young pine that have started in as secondary growth either wind blown or from a few scattered seed trees.

In the winter when deciduous trees have shed their leaves, the evergreens will stand out more prominently; especially on snow. The

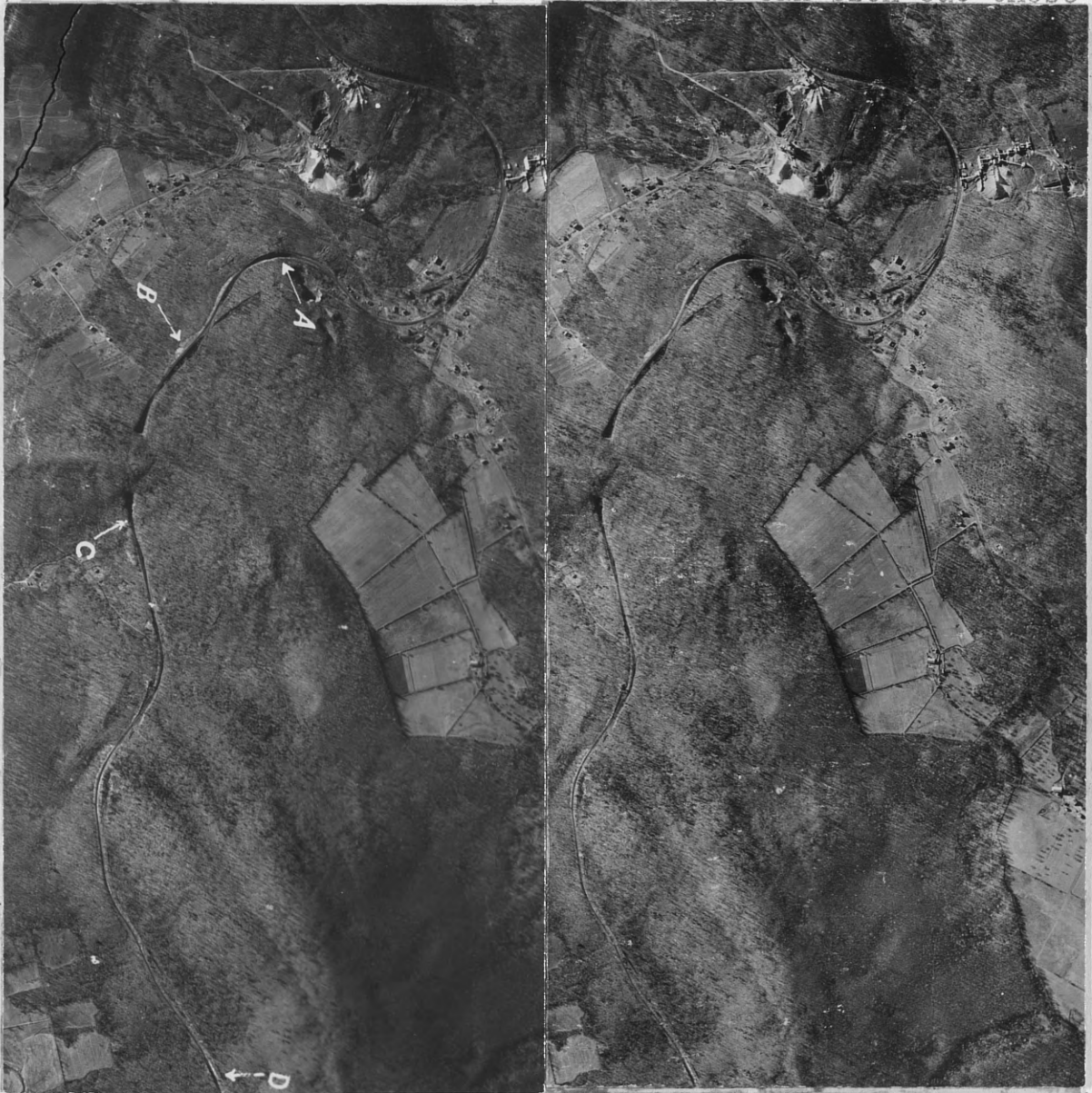


HIGHFIELD, MD. 1: 5000

shadows are distinct enough so that the trees in the stereo-

pair can be identified as cedar or spruce and one low juniper near the house.

In railroad and highway work, the engineer is constantly confronted with the problem of keeping the tracks and road beds within a specific tolerance of degree of slope and curve so that it is necessary to make cuts and fills or bridge larger gaps in the terrain. On aerial photographs we can pick out these



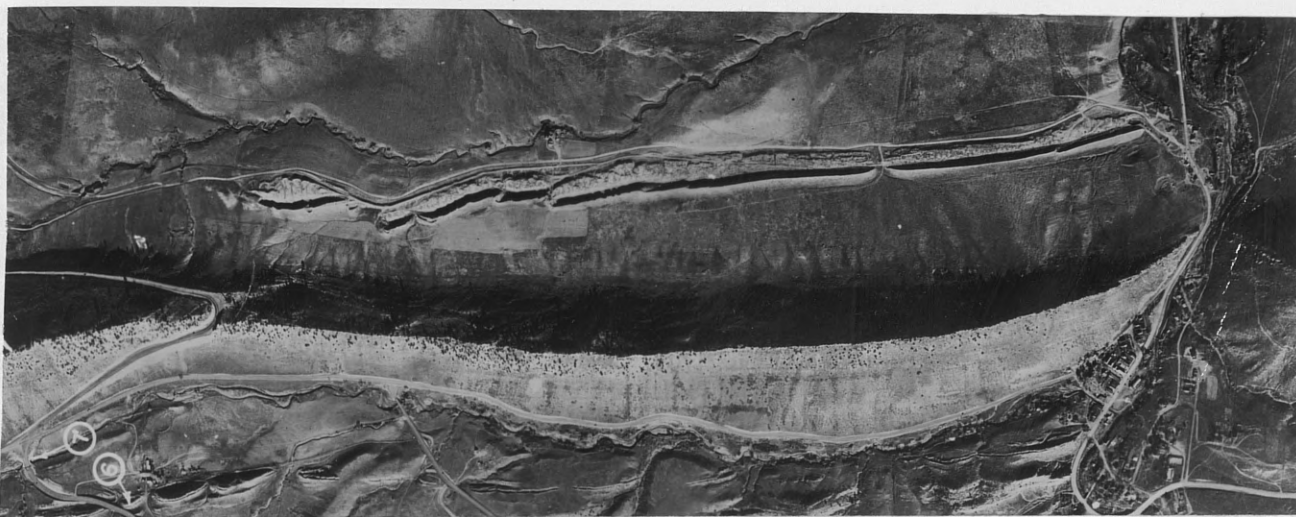
MONTEREY, PA. 1:7500

cuts, fills, and bridges; and tell them apart by shadow alone, all of which are good indicators of the terrain shown on the photographs. On the previous page is a stereo-pair that has a section of the roadbed of a railroad track going through a mountainous area in Pennsylvania. We want to pick out cuts and fills by their shadow. The first thing we do is check with a tree, house, or other tall objects to determine the source of sunlight. In this case it is from the upper left. Knowing this, we can determine cuts and fills. Starting with the area labeled "A", we notice that the track at that point is almost hidden from view by a dark shadow on the upper left portion of the track. This is plainly seen to be a cut in the hillside. At point "B" we see that the shadow falls again toward the lower right corner. This time it does not cast a shadow across the track but misses it. An elevation or fill of earth at this point would be the only logical explanation. Between point "B" and "C", the grade was so steep it was necessary to tunnel through the hill. The entrance and exit of the tunnel stands out very distinct. Point "C" is a cut tapering from the hillside as well as point "D" below.

When it is possible to have a stereo-pair, cuts and fills are very easy to pick up, but on single vertical photos, the application of the shadow is the best feasible method.

To read a photograph correctly, the shadows should be held toward the interpreter; otherwise, serious errors in judgement

and interpretation can be made. This is especially true when viewing single photographs of hills and mountainous terrain, as shown on these individual photographs taken in the Garden of the Gods, near Pikes Peak, Colorado.



With the shadows held properly toward us, we get the impression of a sharp razor-back ridge with a steep hair pin road going up and over the ridge, and a gap through the ridge on the left.

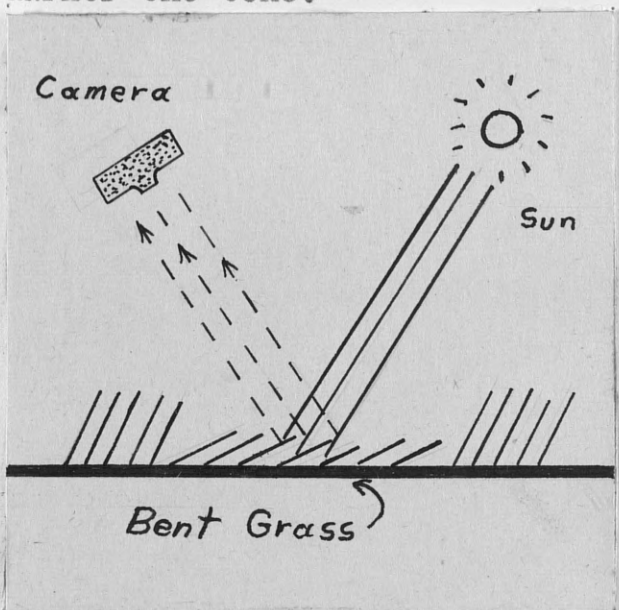


Hold the photograph incorrectly, however, and the ridge becomes a depression. High rock formations sink below ground, and our gap is now a ridge.

4. TONE

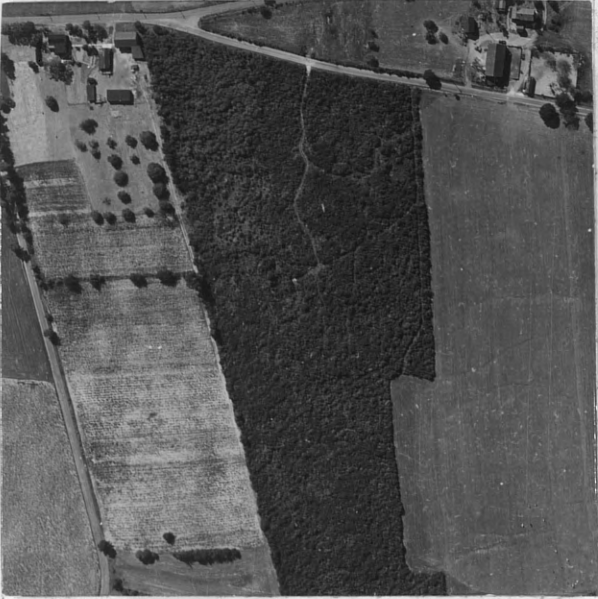
On aerial photographs tone is the intensity of white and black. It may range from almost pure white to almost pure black. Tone will depend 80% on texture and 20% on color. (Texture is smoothness or roughness of an object on the surface as seen on a photo).

Smooth surfaces are good and even reflectors; hence, they appear light in value when the camera is in a position to catch the reflected light rays and appear darker under other conditions. Since most surfaces have some roughness of texture even though it may not be visible to the naked eye, they reflect light at many different angles. Some light reaches the camera, whatever its position in the sky; and the object appears light in value. The deeper the texture, the greater the amount of light that is absorbed; the less light that is reflected, the darker the tone.



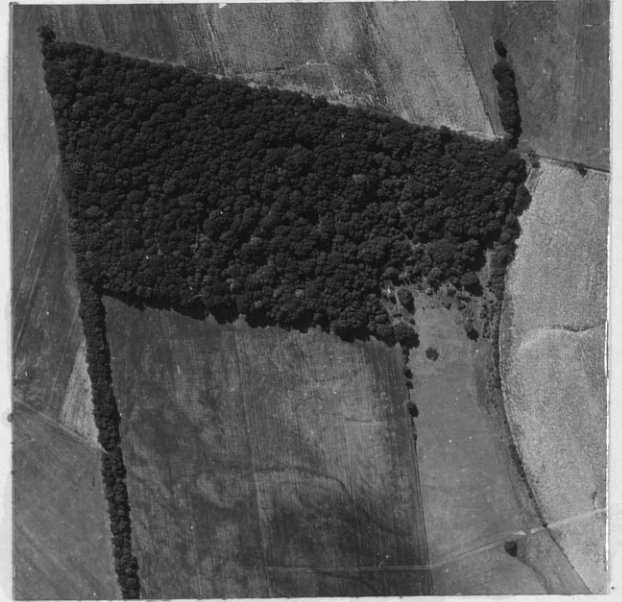
The angle of the reflected surface also affects its value. Long grass, for example, when pressed down by passing men and vehicles may reflect toward the camera and appear light; as in the stereo-pair above, and as

illustrated by the sketch on the previous page. If the source of light behind the camera were as in this sketch, the light rays would be reflected away from the camera and the track would register darker.



The tone of this cut-over woodlot is darker than grey, because it has patches of light grass and weeds mingled with the low scrubby tree growth.

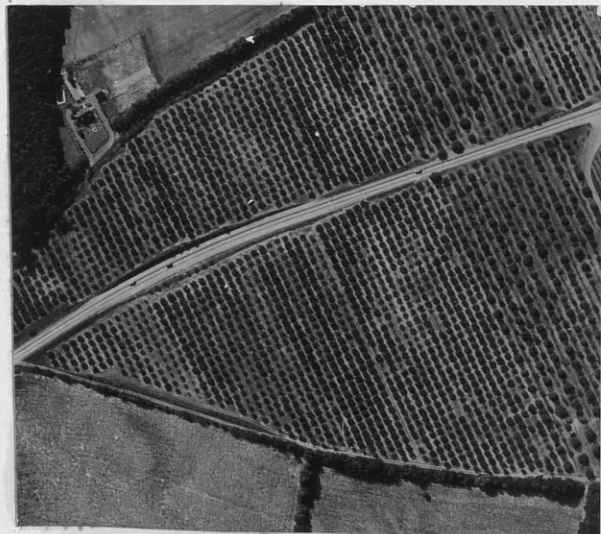
Contrasted with the cut-over woodlot is an even-age woodlot which has a darker, wooly tone; because of the larger trees which almost have a complete canopy shutting out the lighter grass and vegetation below.





An orchard will have a dark tone generally, but if the earth beneath the trees has a cover crop or has just been plowed; it will also affect the over-all tone. This particular orchard on the left is dark in tone because of vegetation on the ground.

This orchard to the right had the rows between the trees plowed recently which turned up raw earth that reflected light into the camera giving the orchard an over-all lighter tone than the previous one.



A field with a growing crop takes on a light grey tone. When the bare ground shows up after a plowing, it stands out distinctly in a much lighter, almost white tone, as shown here.



As the time for harvesting nears and the grain is cut, it is dry and reflects a lighter grey tone as contrasted by the still-standing grain.

Examples of tone changes in a dense corn field. The lightness of a recently plowed field can be compared to the field with a growing grain crop.



Cut and uncut portions of a corn field are seen in the immediate foreground of this oblique, showing the noticeable difference in tone.

Since the road is concrete, it reflects much light and stands

out as a white ribbon. Note how the trees and other shrubs have almost a black tone.



In the majority of aerial photographs, water is appreciably lighter or darker than land depending on its depth and clarity, the extent to which its surface is ruffled by wind, the direction of light with relation to the camera, and seasonal changes in the temperate zones.

Still, deep water is very dark (except in



those unusual instances when the sun is reflected directly into the camera), because the light rays are reflected away from the camera and refracted down into the water being gradually

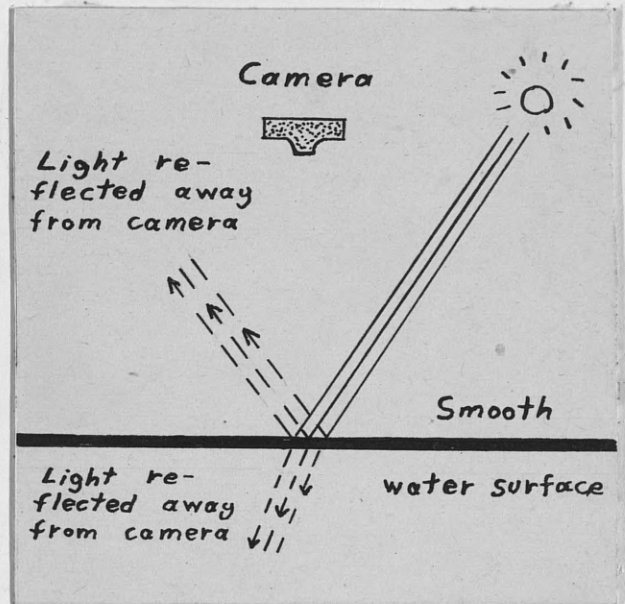
absorbed. The shallower the water, the lighter its value. Other conditions remaining constant. Ordinarily, still, deep water and shadows are the darkest values in a vertical photo.

Because of the reflection of light rays from many dirt

particles in suspension and the decreased light refraction down into the water, muddy water is light. The muddier the water is, the lighter its tone.

Swamps or flooded areas are normally darker than surrounding dry land and blurred in appearance. If light is reflected from the wet surface directly into the camera, high lighting is present.

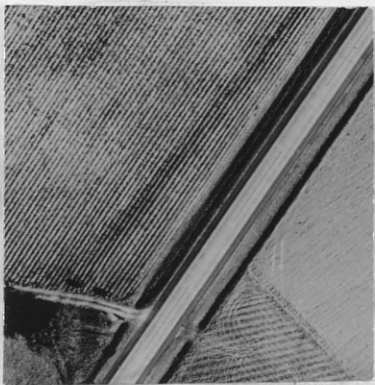
The material that roads are made up of can be detected from aerial photographs by their tone. Concrete highways will be very light in tone, because of the large amount of reflected light. Bituminous roads will be darker with occasional dark or white repair patches here and there. Gravel roads vary from very white to dark grey, depending on the age and type of gravel. Also a determining factor is whether the road is wet at the time the photographs were taken. A light gravel road can be disting-



ished from a light concrete road by the rough unkept shoulder and edge of the gravel road in comparison to a smooth, even-width edge concrete road.



A two lane (18') bituminous highway runs diagonally across the photo and has a very dark grey tone. The other road is also bituminous, but has a new coat of limestone gravel that reflects a lot of light giving it a much lighter tone value.



Here is a two lane concrete highway. The sharp and distinct edges stand out as straight lines on the photos. Note the rough, light tracks of a dirt road entering onto the concrete road at the lower left.



In this photograph, the change in tone from a dark bituminous road on the left to the light concrete road on the right can be clearly seen. A portion of the side road is coated with bituminous, while the rest is a light-toned gravel road.

5. RELATIONSHIP TO SURROUNDING OBJECTS

If an object cannot be identified by any of the previous aids, often its relationship to surrounding objects will offer a clue to identification.



A railroad station has characteristics that stand out on a photo and are an aid to interpretation. It must be next to the track, have a road going close to the station, is normally set apart by itself, and usually has a waiting platform of some sort. This particular photo above

is a small village station, and can be identified as such by its relationship to surrounding objects. A large city would have a few other indications as to its identity. The photo on the right is of a railroad station in Baltimore, Maryland, showing a terminal for many railroad tracks ending at a depot or station.



The large shed-like buildings as compared to the other houses would indicate the warehouses, sheds, and station, typical of a railroad station in a large city.

The photograph on the next page presents a problem to the interpreter, because of its large, spacious and geometric layout, and numerous buildings. However, if all the known things are

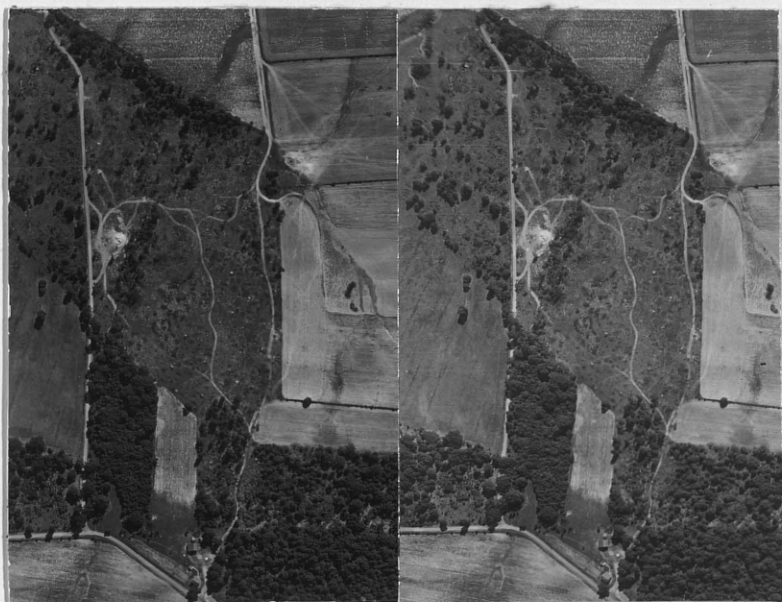
gathered together, their relationship to each other would tell us what the object is. First, the large and fancy building could be one of the following; a hospital, hotel, or a country club.



These three choices come to our mind as the best possibilities for our answer. The surrounding area has a number of objects that help us make our final decision. There are four sets of tennis courts in the white rectangular space above the large building. The two fancy pools are possibly swimming pools.

All the grounds around the area have the appearance of being a golf course with tees, greens, and water holes in evidence. To the left is a very decorative, geometrically laid out formal garden. The surrounding vegetation appears to be part of a planned landscape design. Having used the relationship to surrounding objects as our aid in interpretation, and combining all these known facts, we would limit our choice to a large country club or resort hotel.

If we apply interpretation to a forestry problem, we can use the stereo-pair shown here. Suppose we were instructed to report on the activity shown in this stereo-pair. Looking at the area in stereo, we can see that it has the appearance of



FAIRPLAY, PA. 1: 7500

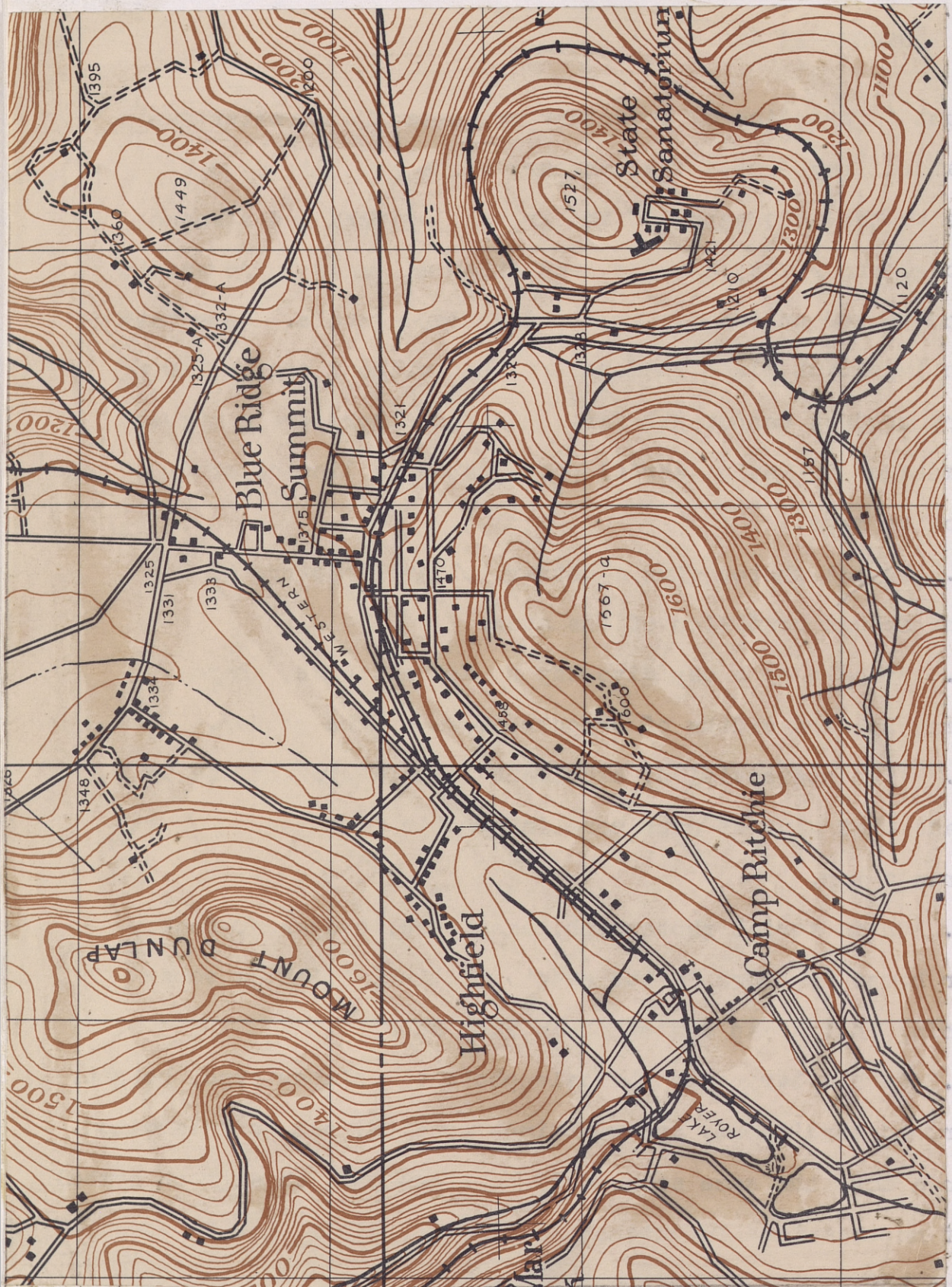
being a cut-over farmers woodlot. Further searching will bring out indications for this claim. The two large white piles with the roads and tracks congregating around them have all the characteristics of sawdust piles. All through the cleaned out area we can see many branches and discarded logs. The ground

appears to be well tracked and scoured from skidding. Typical woodlot clear cutting methods are in evidence. There are still a few piles of cordwood stacked up in the lower part of the area. From personal experience and observation of portable saw-mills used in this area plus the evidence shown in the photos, we could be correct in stating that the stereo-pair is of a cut over woodlot.

AERIAL PHOTOGRAPHS AND TERRAIN

Much information of important value to the forester can be obtained from maps. The contours alone give him a good idea as to the topography of the ground. Rivers and streams are shown, and roads, bridges, and other man made improvements are represented on the map by standard map symbols. Maps have such an important place in forestry that without one, a large forestry project cannot get far. However, there are a number of advantages in having aerial photographs in lieu of or in addition to maps.

1. Aerial photos give a better, clearer picture of the actual condition of the area.
2. Symbols on a map give way to actual sizes, shapes, lengths, and widths of objects shown on the photos.
3. With stereovision, excellent terrain studies can be made that give us much more information than we could get from a map.
4. On an aerial photograph, each tree, hedgerow, fence, or house is shown in its exact position, which is something that a map cannot do in such detail.
5. With a large enough scale photo the timber type, height, ground conditions, and sometimes species, can be determined. On a map, the same area would be shown only as a green symbol of no technical importance whatsoever, other than to show the boundary of the forest.



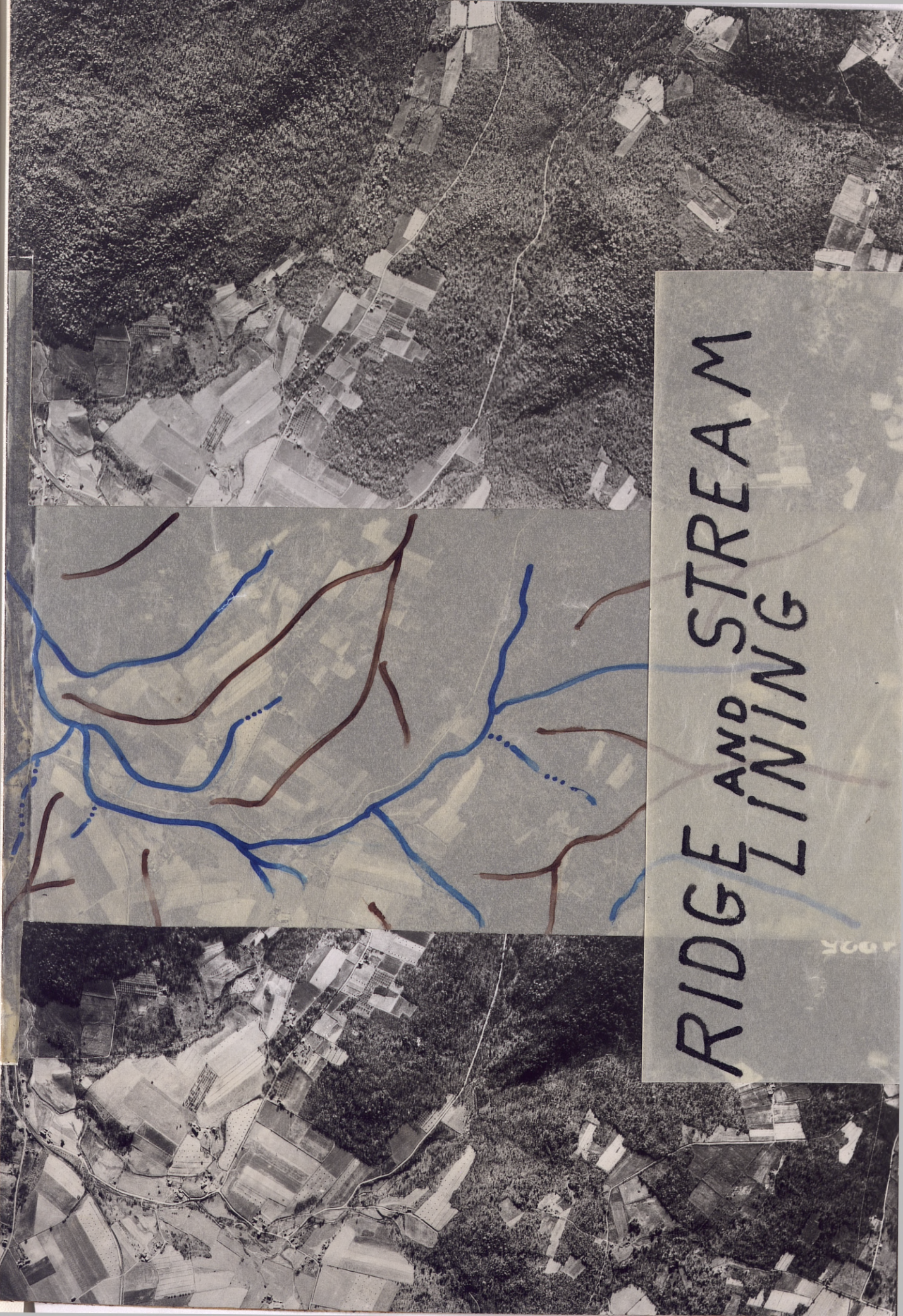


To better understand how much more valuable an aerial photograph is ^{than} over a map, let us look at the illustration on the previous page. It is a vertical taken over the vicinity of Camp Ritchie, Highfield and Blue Ridge Summit, Maryland, and with it we have a map of the same area. With the scales being the same, 1:20,000, even the most untrained individual at a glance can see the immense detail that the photo gives. This is impossible to ascertain from the symbols on the map. Perhaps the greatest advantage of photos lies in the exactness in which the vegetation cover of an area is indicated. This is just for what the forester is looking - a "birds eye" view of his forest so that he can tell what he has in the way of timber types, forested area, inaccessible places, lakes, streams, existing roads, and improvements. When using two overlapping photographs to make a stereo-pair, the forester or timberland owner can get stereovision, and by going over the photographs he can interpret a wealth of information. It should be stressed that experience is required in order that one may be a good photo interpreter; but with a short, intensive training period, the average individual can become fairly adept at interpretation.

Ridge and stream lining.

An easy method of getting a good picture of the drainage pattern over a particular area shown on photographs is by means of ridge and stream lines. This is simply sketching the drainage pattern on an overlay sheet as it is interpreted from the aerial photos. A training aid has been constructed to show this, and it was done in the following manner:

1. Overlapping photographs of the area in question were placed in their proper position along the line of flight.
2. The center photo is mounted to a piece of bristol board by glue, rubber cement, or scotch tape.
3. Photos on each side of the area which give the stereovision can also be mounted, but they may be simply held in their proper alignment.
4. A cursory examination of the area is made to get a rough picture of the terrain.
5. A sheet of overlay paper is placed over the center photo and glued or taped into position.
6. One side is then thoroughly scrutinized with the stereoscope (stereovision can be seen through the overlay paper) and the rivers or streams are traced directly on the overlay paper. A blue pencil is used to follow up or down the drainage network; when completed, all the lateral and intermittent streams will be sketched in as they appear on the photos.



RIDGE AND STREAM LINING

7. The ridges are sketched in with red or brown and will fall in between the river valleys.

8. Repeating the ridge and stream lines on the other half of the photo will result in a completed overlay of the area in question that gives a good picture of the lay of the land.

Terrain features as identified from aerial photographs.

It would require volumes of writing and hundreds of photographs to show how different kinds of terrain appear on aerial photographs. Since it is not within the scope of this problem to attempt that portion in detail, it will suffice to show examples of the more common terrain features.

A. Land Forms.

1. Hills and valleys: As long as streams and rivers continue to run over the earth's surface, we will have hills and valleys. Stereovision is the best method of determining these, as was discussed in "Ridge and Stream Lining". There are certain other things on photos which can aid in interpretation of land forms.

a. Contour plowing: On single verticals, the hills often can be distinguished by the contour plowing practiced on the land. The furrows will follow the contour of the ground. During



harvest time when grains are shocked, it is very easy to pick out the highest and lowest portion on a contoured field.



Using the stereoscope on this stereo-pair taken over a contoured field in Monroe, North Carolina, (1: 6,000), we can clearly see the high land forms as they stand out on our photos. The contour plowing makes the highs and lows stand out, and even without stereovision we could easily point to the hill on the photo.

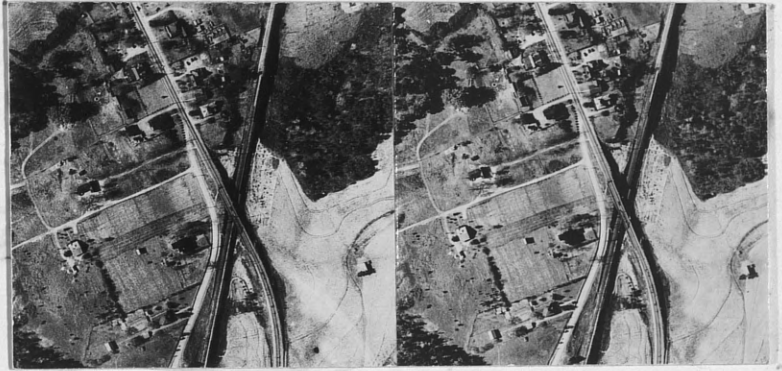
b. Erosion: Sheet or shoe string erosion on any terrain will always point down stream. Where



the small rivulets and intermittent gullies meet, they form a V pointing down to the lowest elevation. In the prepared illustration above, we have a Pennsylvania farmland with a heavily eroded hillside. Under the stereoscope the gulleys stand out and their V-shaped pattern on the hillside becomes very evident. Without an overlapping pair to give us stereovision we could still identify and locate the hills and valleys by these erosion signs that point the way to lower elevations.

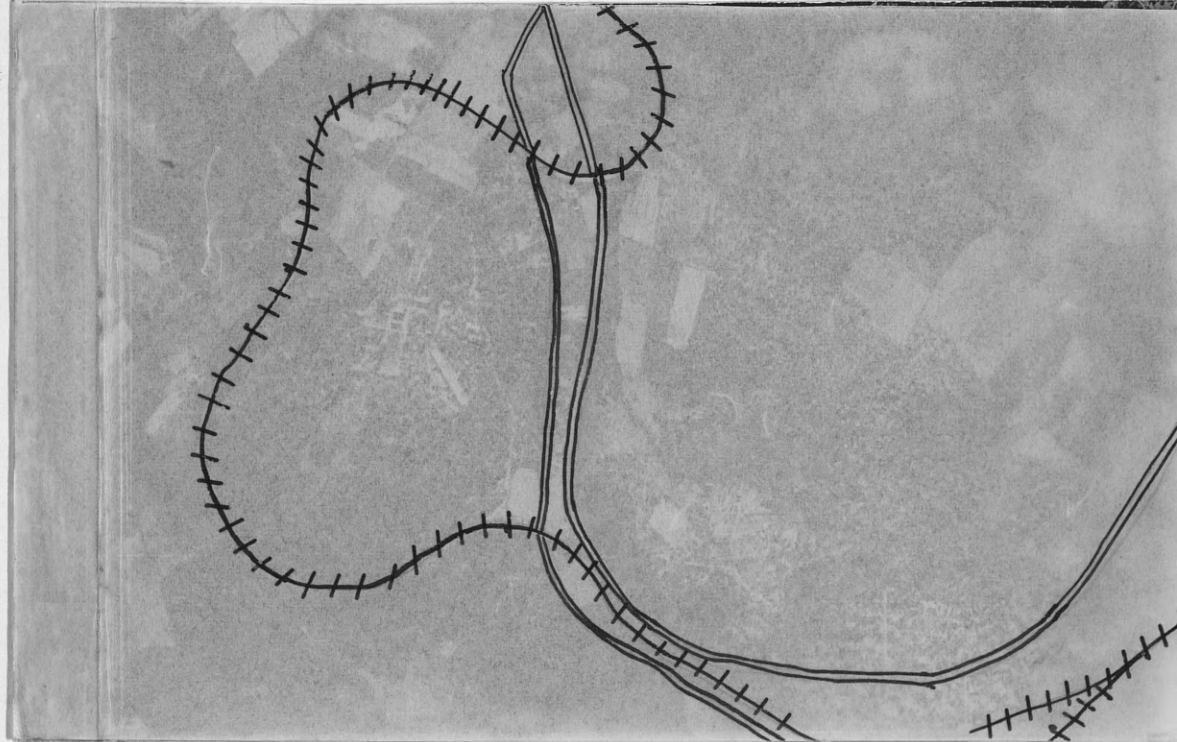
c. Cuts and Fills: It was previously shown on page 35, under the shadow method of identification,

that cuts and fills for road and railroad beds are good indicators of the terrain. The shadows cast by a cut or fill determine high or low terrain. On the adjacent stereo-pair there is only one cut shown.

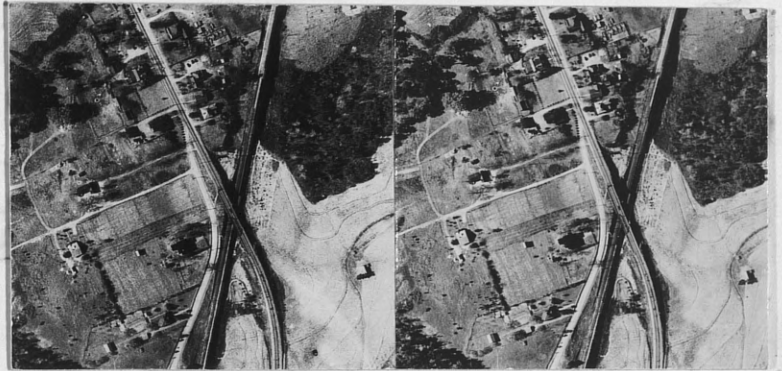


Can you pick out the cut from the fill on this stereo-pair? *No! there is none*

d. Roads and Railroad Beds: To seek a low grade and to eliminate expensive tunneling, cutting, and filling, roads and railroad beds often wind around hills. Below is a single vertical of the town of Highfield, Maryland, (1: 20,000), showing the railroad winding around a high mountain; while the roads are on relatively flat terrain and therefore are straight.

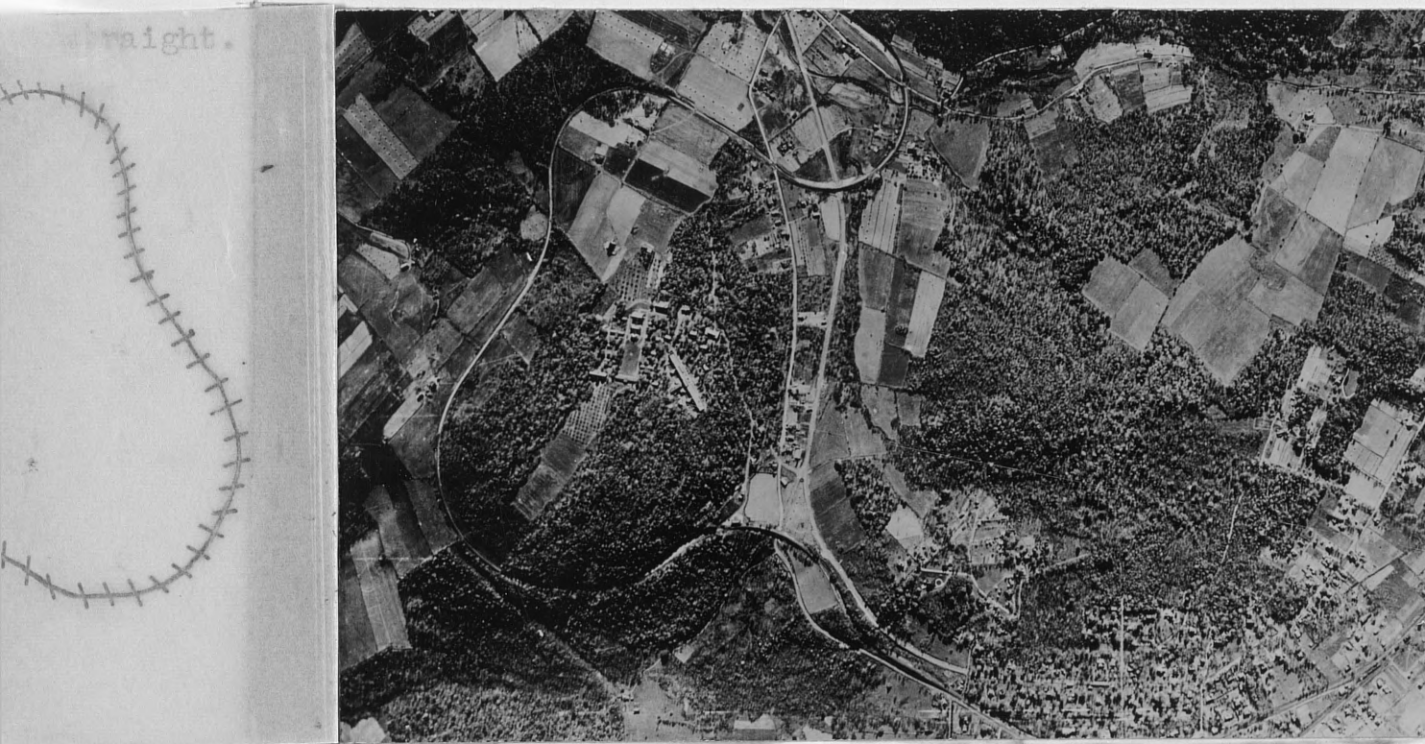


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B. Water.

Identification and location of all water forms on aerial photographs have important meaning to the forester using them in a management plan. Knowing the size, shape, approximate depth, and type of shoreline on a lake for example; a ranger would have a definite idea as to what recreational use the lake may have on his forest. This can also be applied to rivers and streams for recreational developments. If it could be utilized for river driving, often times the presence of wide rivers through a timbered tract gives a brighter picture on the "logging chance" of that area.

There are a number of general facts regarding identification of water forms from aerial photographs that are an aid to the photo interpreter such as:

1. On small, inland lakes with no inlet or outlet being fed entirely by springs and with evaporation and seepage controlling its level; we find that:
 - a. The shoreline is a contour line.
 - b. Vegetation growing to the waters edge indicates a constant water level.
2. Water is appreciably lighter or darker than land depending on the following:
 - a. Depth and clarity.
 - b. The extent to which its surface is ruffled by wind.

c. The direction of light with relation to the camera.

d. Seasonal changes in the temperate zones.

3. Still deep water is very dark (except in those unusual instances when the sun is reflected directly into the camera), because the light rays are reflected away from the camera and refracted down into the water.

4. The shallower the water, the lighter its tone.

5. The muddier the water, the lighter its tone.

6. Swamps or flooded areas are normally darker than surrounding dry land are blurred in appearance.

7. Direction of stream flow may be determined by the following:

a. V's formed by meeting of adjacent streams or rivers point down to the direction of flow.

b. Pointed "tear-drop" ends of sand bars go downstream.

c. U's are formed around obstacles in the water with the open end of the U downstream.

d. Streams are wider at the downstream end.

e. Bridge abutments on the upstream side usually catch driftwood or have sand bars built against them.

f. Boats on the water that are moored to shore, point the stern end downstream.

8. Vegetation usually grows thickest along river or stream banks, so that the outline of water coursing through dense vegetation can be picked out on the photos.

9. The current is more swift when the stream is straight.

EXAMPLES

Lake.

Note how the streams join in V's and point down to the lower elevation of the lake. The light tone of the water would denote shallow, muddy conditions.



Large river. On the next page we have a vertical photo of a large river near Gettysburg, Pennsylvania (1: 10,000). It is very easy to pick out because of its winding course, dense growth of vegetation all along the banks, and constant tone. The direction of flow from bottom to top (viewed horizontally) is easily determined by the V's of the streams joining the main branch and pointing downstream.

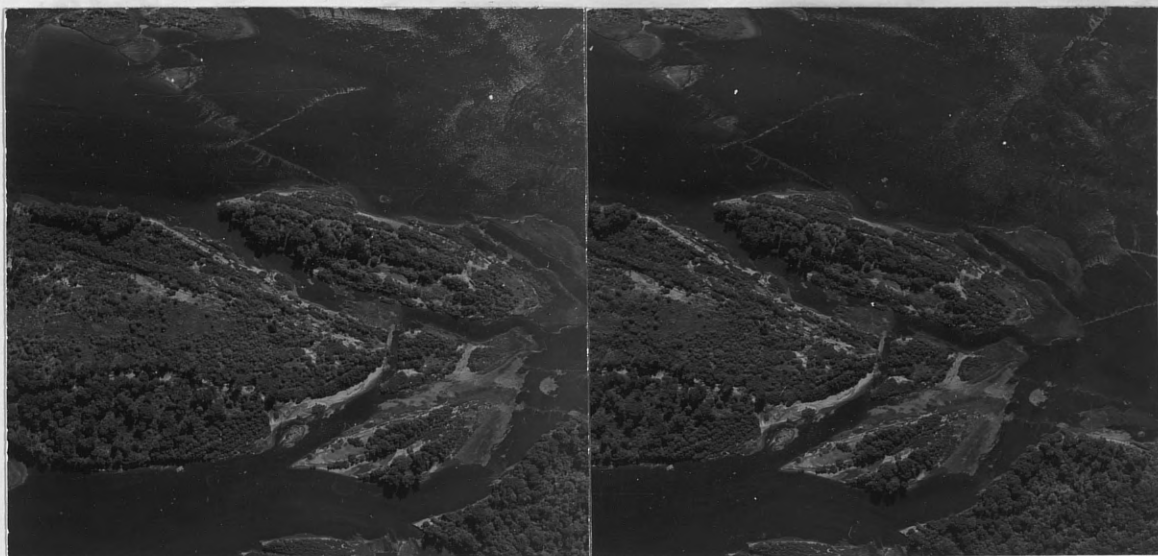


Meandering stream.



Often times the meandering nature of a stream can be easily seen as it winds through vegetation growing along its banks. Sand bars and shadows of the undercut banks help locate its channel. Direction of flow can be determined by the streams joining the main one in a V.

Islands.



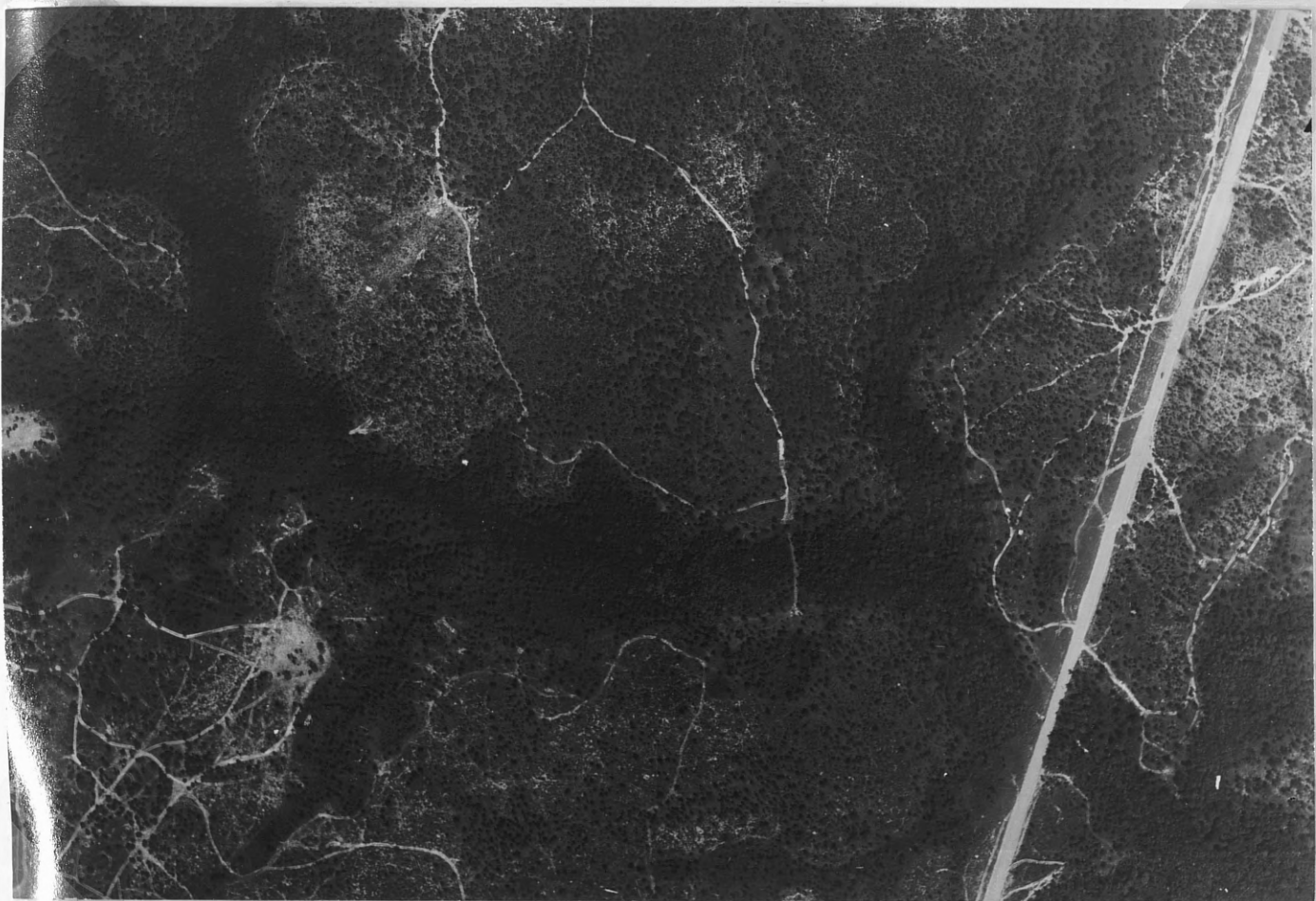
A group of islands on the Susquehanna River (1: 7500) illustrate how the pointed tear drop shape of the sand bars gives the direction of stream flow. In the stereo-pair above the river travels from right to left.

Swamp.



A swamp normally is darker than surrounding vegetation. When drainage ditches are dug, water drains off, the vegetation changes to a drier species, soil dries out, and since it now reflects more light, the area now is lighter in tone.

Marsh.



This low swampy area is near Fort Bragg, North Carolina. It is identified by the dark tone outlining the course of the stream through the wet ground. Note how the roads parallel the swamp and outline the wet area.

C. Vegetation.

Of all the influences of nature that affect terrain and topography, the most important to the forester is the various types of vegetation growing on it. Identification and interpretation of the plants and trees on the ground as seen from the photograph will be the main problem confronting people using aerial photographs for a forestry undertaking. Therefore, it is paramount that emphasis and training be placed on this problem.

Starting at page 23 and through page 48, we have gone through the basic steps of identification and interpretation, and can now apply these to trying to determine what kind of vegetation there is on the ground as interpreted from our photos.

In our first stereo-pair below, we have a simple type of vegetation pattern. After glancing quickly over the area, one

can readily interpret what is seen as the outskirts of a small town with tiny patches of



gardens alongside and behind the houses. A fairly large piece

of corn field is on the left of the photo. By applying common sense judgement and by remembering the everyday scenes, it is not too difficult to interpret vegetation. By means of the stereoscope, the relative heights of the different plants can be approximated; and when compared with known objects, identity should be a matter of elimination.



Another common pattern dotting the countryside in our eastern states especially, is shown above. Stereovision is not necessary to identify the vegetation. The farm buildings, numerous roads, and the row upon row of neatly layed out trees tell us without much trouble that we are looking at an orchard. On this particular photo, the scale is 1: 8,000, and naturally

identification is easier because of the large scale. On the accompanying small scale photo the main characteristics will show to advantage, for the rows of evenly spaced fruit trees still stand out clearly. The white lines of cultivation between trees make the dark-toned trees stand out even more.



Another example of a typical vegetation pattern is the numerous fencerows that are so evident on photos that cover agricultural land where fences are used extensively. Weeds, brush, and various species of



trees grow up along the fences, and since they are rarely cut down, they soon grow quite large. On the stereo-pair above



the many fencerows are much in evidence and can be identified by their straight lines and very narrow width. The arrow points toward a fence row that was photographed on the ground. The ground

view enables us to identify the main species making up the row as red cedar and fire cherry with some sumac on the edges.



Old fields or pastures that have been abandoned very often seen in with red cedar and other species of wind-blown or bird-dropped trees. Such a field takes on a speckled appearance where the "bush size" trees are coming in well interspersed throughout the field. Grasses and weeds usually grow quite profusely in the same area until the trees grow large enough to close up their crowns and shade out the grasses. Near Gettysburg, Pennsylvania, there are numerous such abandoned

pastures that have become quite heavily stocked with red cedar. Such an area is covered in the stereo-pair above. Note how old fence rows can still be discerned amidst the heavy growth of cedar. A ground view that



shows the appearance of the pasture at the time the photo was taken. Red cedar, fire cherry, and sumac were the main species.



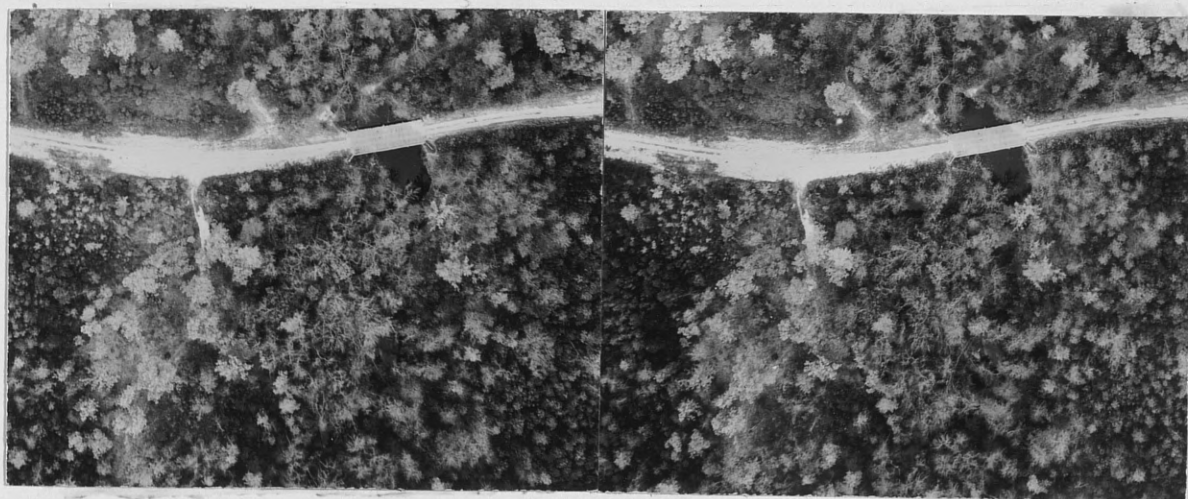
A small scale photograph will cover quite an extensive area. If agriculture is carried on, the landscape shows a cut up pattern of fields, fence rows, orchards, farm woodlots, large areas of forests, and many man-made improvements of roads and houses. The accompanying stereo-pair taken near Fairfield, Pennsylvania, scale 1: 10,000, covers such a pattern. By viewing it through the stereoscope, the various types of vegetation can be outlined and labeled. The long diagonal streak going through the forest is a cleared right of way for a power line. Brush and grass have come in quickly and show

up as a distinct demarkation line between the tones of the dark forest on either side. A closer examination of the forest will reveal the presence of darker patches of trees. Undoubtedly they are pine or large growth hardwoods.

AFFECT OF SEASONAL VARIATION ON VEGETATION

Season of Photography. The best all around time for taking photos for forestry use should be taken when the foliage is still on the trees. However, photographs taken in other seasons of the year have advantages that should not be overlooked.

1. Winter. In climates where deciduous trees lose their leaves in Fall and the country usually experiences varying degrees of snowfall, the combination of these two seasonal changes has a marked effect on aerial photos of forests.



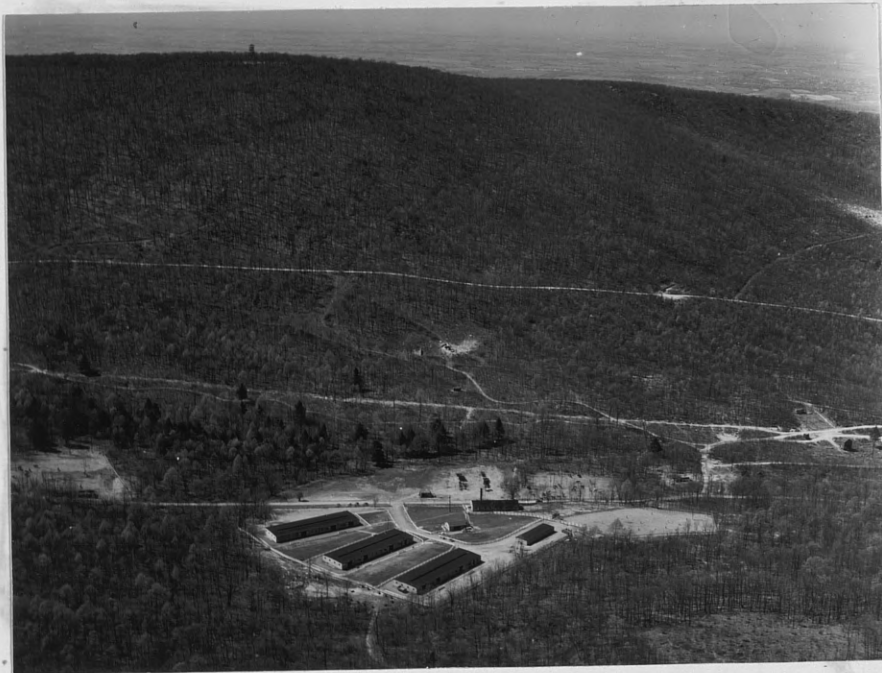
When the leaves are off, the hardwoods resemble masses of scraggly feathers; and because of the branches in the crown which are all exposed to the camera, interpretation of species is difficult (see the above stereo-pair).

Winter photography does have a number of advantages such as the following:

- a. There is usually much more good flying weather.
- b. Pines, hardwoods, and mixedwoods are easily discernible.
- c. Ground conditions are exposed, and evidences of rock and fallen trees can be seen through the bare branches.
- d. General density of the stand and height measurements can be made more easily, especially if the ground is covered with snow as in the oblique below.



2. Fall and Spring. Standish (3) mentions that theoretically the best pictures for differentiation of timber types is when the hardwood foliage is turning in the fall, or when it is coming out in the spring, so that the many



variations in tone between the major species are apparent. The big disadvantage in this type of photography is that they are too difficult

to get and difficult to use. It is almost impossible to photograph extensive areas at just the right stage of coloring. For practical purposes, fall or spring photography is not ~~too~~ reliable, but if photos can be taken especially of a relatively small area, fall photography is preferable to spring. A Fall picture is shown above and illustrates the advantages that such pictures have in differentiation of types, density, and height classes of timber.

3. Summer. Aerial photos taken in late spring or summer are the best for identification and interpretation.

On the following page there are two sets of photos over the same area and are given as good examples of how the appearance of various types of vegetation is affected by seasonal variation. One is taken during the Winter with snow on the ground, and the other at the height of the summer season. Notice how revealing the snow photos are, but from the standpoint of timber typing they would be good only to determine conifers from hardwoods and heights from shadow measurements on the edges of the stands. However, the intermingling of the branches by their shadows is very confusing; therefore, the limited use of snow photography is apparent. On the Summer picture, the crowns of the individual trees, its apparent height over other objects and trees, tone, and shape are much more in evidence; and it is not too hard to compare them and list their advantages and limitations.





HEIGHT FINDING

There are two general methods for determining heights from aerial photos: Parallax and Shadow. The former requires stereo-pairs with a minimum of tilt, while the latter can be accomplished with a single photo if the shadow falls on level ground and if accurate marginal information about date, time and geographical coordinates is available.

Each of the two methods have variations within themselves that will be discussed below.

A. Parallax height finding with an interpreters scale.

1. Preparation of photographs.

- a. Pick stereo-pairs containing trees to be measured.
- b. Accurately determine the center of each photograph by the use of collinating marks. Transfer these centers stereoscopically or by inspection to their proper location on the adjacent photo.
- c. Join the centers on each photo with a straight line. This represents the line of flight of the photographic plane.
- d. Overlap the photos in the normal manner for viewing stereoscopically; then separate along the line of flight.
- e. Fasten the left photo with masking tape or thumb tacks.

f. Place a straight edge along the flight line as plotted on the left photo and bring the flight line of the right photo into place under the straight edge. This is an important adjustment and all four centers must be exactly aligned. Leave a gap of one-half to one inch between the two photos. Now tape or tack down the right photo.

2. Measuring the difference of parallax.

a. To determine the difference in elevation between the bottom and top of a tree, accurately measure the distance between the two tops and between the two bottoms.

b. Subtract, and the difference is the difference in parallax.

3. Determination of the elevation factor.

a. The elevation factor is the ratio of the altitude of the camera (H) above the ground to the photo distance of the flight base.

$$\text{Elevation Factor } E = \frac{H}{b}$$

Where: E - Elevation Factor
 H - Altitude of camera above ground.
 b - Average photo distance of flight base of both photos.

If for example, H = 5,000'

B (left photo) is .304'

b (right photo) is .306'

Average = .305'

$$E \text{ is equal to: } \frac{5,000'}{.305'} \text{ equals } 16065$$

b. This signifies that for every 16065' difference in elevation on the ground there will be a 1' difference in parallax on the photos.

4. Calculation of difference in elevation.

a. Multiplying the elevation factor by the difference in parallax will give the difference in elevation between the top and bottom of a tree.

$$H = P \times E$$

Where: E - Elevation Factor
P - Difference in Parallax
H - Difference in height between top and bottom of object measured.

If for example, E equals 1413

P equals .03

Then H is equal to $1413 \times .03 = 42.31$

The tree or object then is 42' high.

B. Parallax height finding from one photograph.

An expedient method of determining the height of an object on a single photo can be used if the photograph is relatively free from tilt.

1. Mark the center of the photograph and measure from this point to the top of the object whose height is to be determined. This distance is "D".

2. Measure from the center of the photo to the base of the object and subtract this value from D. The difference is distance "d".

3. The height of the object (H_0) is obtained by use of the formula: $H_0 = \frac{Hd}{D}$ Where H is the height of the plane over the ground.

Example: On the following page there is a single photo of the campus at Michigan State College, East Lansing, Michigan. It shows the chimney of the power plant and the enormous shadow it casts. The R.F. is 1: 4,000. The photo shows our "D" measurement to be .285', while our measurement to the bottom is .269'. The difference "d" is .016'.

Applying the formula we get:

$$H_0 = \frac{4,000 \times .016}{.285} = 225' \text{ Ht. of chimney.}$$

C. Parallax wedge measuring device (4).

Mr. Stephen H. Spurr of the Harvard Forest, Harvard University, Cambridge, Massachusetts, has devised an inexpensive device that permits rapid and precise measuring of parallax. The device is a wedge consisting of two rows of dots which when fused stereoscopically and superimposed over a stereoscopic aerial view, appear as a single row of dots slanting downwards or upwards through the stereoscopic model. The dots provide a sequence of reference marks of fixed vertical intervals which may be shifted about in the model, and against which objects may be compared in elevation. For instance the height of a tree



would be determined by noting the difference in reading between the image dot that lay on the ground at the base of the tree and the image dot that was level with the top of the tree.

The readings obtained are differences in parallax and are converted into height by this parallax formula:

$$\text{Height} = \frac{f \times P}{\text{R.F.} (W + P)}$$

Where: f = focal length of the camera.

OR

P = differential parallax.

$$\text{Height} = \frac{H \times P}{W + P}$$

R.F.= Representative fraction.

W = Photo distance between the centers of the stereo-pair in the line of flight.

H = Height of the camera above ground.

D. Height finding by shadow:

This method provides a rapid means for height determination. Perhaps the outstanding man in this field is Mr. H.C. Seeley of the Canadian Department of Lands and Forest (5), to whom much credit must be given for initial research and results using this method.

For precise measurements, this method requires the use of complicated formulas and charts. It does not replace the parallax method, for its use is restricted to determining the heights of objects perpendicular to the ground such as smoke

stacks, buildings, trees, walls, poles, etc. It is further limited by the slope of the ground containing the shadow. If the ground is horizontal or approximately so, the shadow measurements may be considered accurate. But if it slopes at a perceptible angle, the results are inaccurate; and this method cannot be used.

The basis of the shadow method is the relation of the height of the plane to the length of the shadow cast or

$\frac{H}{S} = \tan x$ "Shadow Factor". Height then will be $S \times \tan x$.

To find $\tan x$ we must make use of the following formula:

$$\sin x = \cos (a) \cos (b) \cos (c) \pm \sin (a) \sin (b)$$

Where: x - angle of elevation of the sun.

a - declination of the sun on day of photography.

b - latitude of the photo within one-half degree.

c - local hour angle.

It is + if the photo was taken between March 20th and the 21st of September.

It is - if the photo was taken between September 23rd and the 19th of March.

The resulting answer multiplied by the shadow length equals the length of the object measured.

This method is known as the "correct method", and because of it's ease in application, it is quite popular among forester's. When the shadow factor for each photo has been calculated, it is

written on the back of the photo; and henceforth, any height calculations to be made will simply require the shadow measurement of the object multiplied by the H/S factor on the back of that particular photo.

In any shadow measurements of trees on photographs, the following points must be taken into consideration:

1. Try to get the shadow measured on level ground or on the contour.
2. Be sure of the tree base.
3. Interference from other trees.
4. Shadows falling on ground vegetation reduces the length, therefore, an estimated length must be added to the first answer to compensate for depth of ground cover or snow.
5. Round topped trees give shadows that are too long. Shadow may come off the side and not the tip.
6. Leaning trees give shadows that are long or short depending on the direction of lean.
7. Growth since pictures were taken.
8. Lack of resolution--what is there that cannot be seen. This usually causes underestimates. 3-10' has to be added on the final answer.

E. Height finding from length of shadow--proportion method.

Another practical use of shadows for height determination

can be made if (1) we have a known height or previously measured height of some object on the photo, and (2) if we have the shadow falling on level ground.

Height is found by simple proportion:

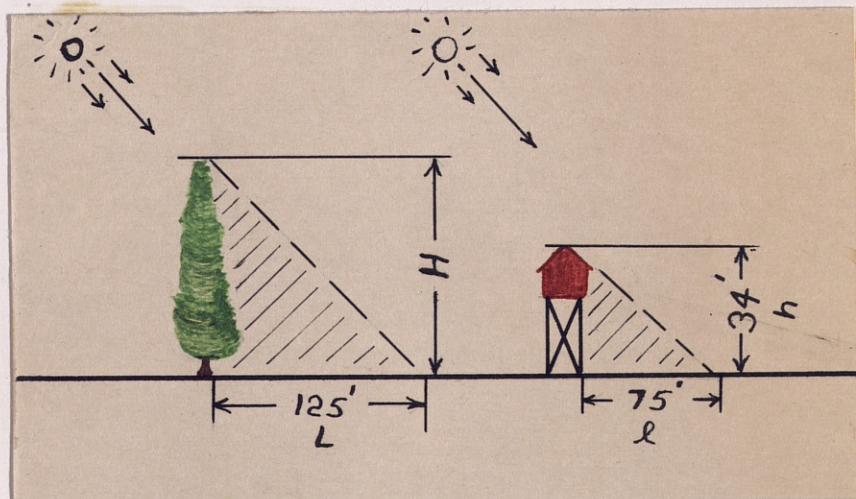
$$\frac{H}{L} = \frac{h}{l} \quad \text{Where: } H - \text{height of the object being measured.}$$

L - length of shadow of object being measured.

h - known height of object on photo.

l - shadow cast by known object on photo.

Example: A spruce tree on an aerial photo casts a shadow of 125' (L);, and on the same photo, we recognize a water tank that is 34' high (h). The shadow cast by the



tower is 75' (l). Using our simple proportion we can set up our formula:

$$\frac{H}{125'} = \frac{34'}{75'}$$

$$75H = 4250$$

$$H = 56.6' \quad \text{Therefore, our spruce tree is 56.6' tall.}$$

TIMBER TYPING FROM AERIAL PHOTOGRAPHS

Perhaps the biggest advantage that aerial photos have for use in forestry work is that the major timber types and land classifications may be delineated when seen in three dimension. By eliminating non-forest and non-commercial forest land on a tract to be cruised, more intensive cruise data can be collected from the more valuable forest which is to be cut or used in a management plan. To do this satisfactorily requires an interpreter who is familiar with ground and timber conditions of areas that appear on the photos he is going to timber type. Photo interpreters should be trained for one particular geographical location so that timber type determination will be restricted to the species occurring in that area under study. Often a rapid ground check can be made by traveling with a car or truck along the main roads and sketching directly on the photos as the various types occur. Later, when interpretation is carried out in the office, simply by referring to the areas typed while on the ground will serve as a means of comparison between untyped areas over the rest of the photos.

A. Type of film to be used in forest interpretation work.

1. Panchromatic. Generally speaking, tree heights and other detail can be measured with ease, but the major

forest types are not always easy to separate. Tone also is not a reliable means of identifying and classifying timber species on panchromatic film. To distinguish major forest types, it is necessary for the interpreter to use a combination of tone, texture, and shape of crown.

2. Infrared. It has been found by Spurr (6) that infrared film with a yellow filter (minus blue) is the best combination for timber typing purposes. On experiments conducted by him in northern forests, he was able to distinguish species by their characteristic tones as follows:

Very dark: black spruce, red spruce.
Dark: gray balsam fir, jack pine, red pine.
Medium gray: white pine, white spruce.
Light gray: tamarack.
Very light: paper birch, yellow birch, aspen, sugar maple.

Trees which generally occur in mixed stands could not be recognized except on relatively large scale photographs.

3. Color. To date the kodachrome and kodacolor film used has not proven to be even comparable to infrared for forest type differentiation. Consequently, it is rarely used in interpretation work.

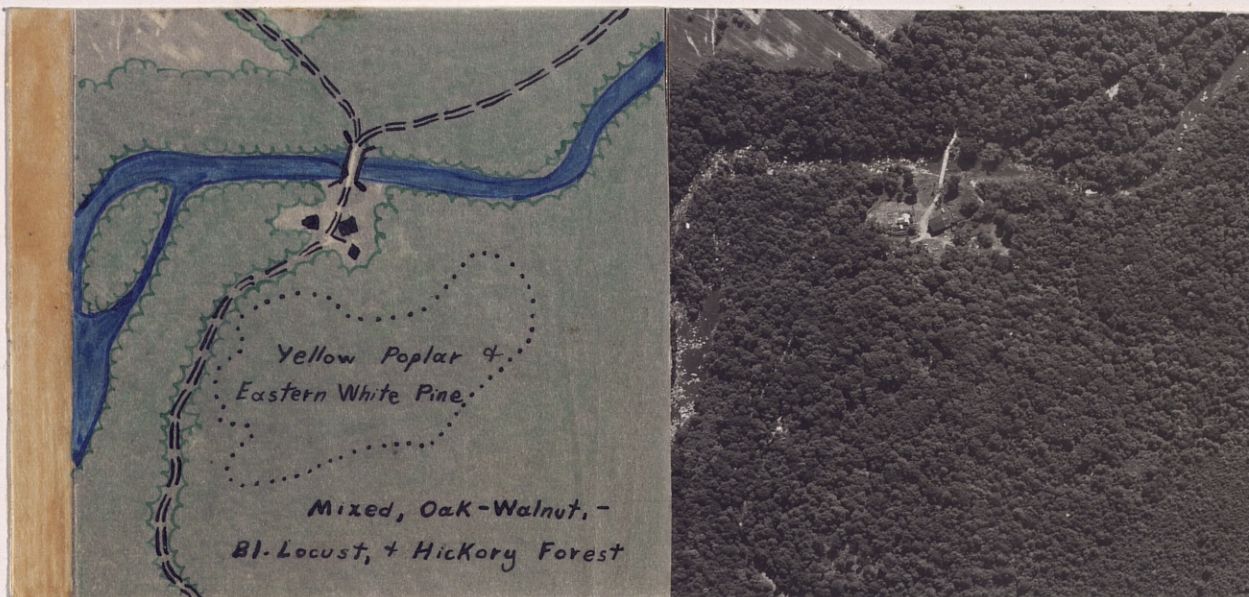
B. Aids for timber typing.

1. Tone. The tonal value of a forest usually varies quite considerably with the season, time of day the pictures were taken, type of film used, filters, and photo pro-

cessing. In spite of this, tone still is an important aid to photo interpreters of forest stands on the normally used small scale photos of 1: 20,000. In these photos, individual tree images are so small that the over-all blending of the tree crowns, openings, and shadows in the stand into a tone, give the best clue to interpretation. Again, the best method of applying this is for the interpreter to take photos and visit areas appearing on the photos to get the relationship fixed in his mind.

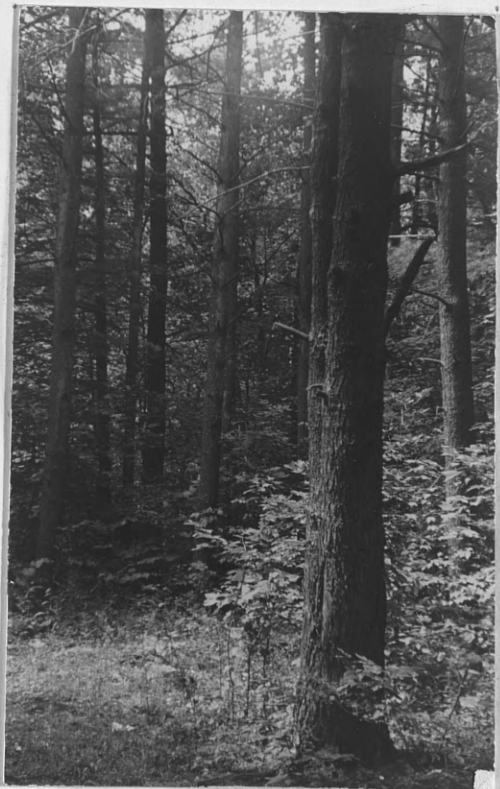
The different types may be outlined with ink directly on the photos, and a number or letter may be placed in the timber type to which it corresponds. Another method which saves the photo for future use is to place vellum paper over the photos, and outline and label the timber types on this.

Below is an example of timber typing on a stereo-



pair taken near Fairplay, Pennsylvania, scale 1: 7500.

It is part of a farmers woodlot composed of a few compact groups of tulip and white pine. The rest is cut over oak, walnut, cherry, and hickory of inferior size and quality. By looking over the area under the stereoscope, we can separate the tulip and white pine from the rest by their darker tone and more compact crowns in the bottom center of the stereo-pair. To distinguish them from the other species present, the tulip and pine have been outlined with black dots on a piece of overlay paper. A ground check was made and photographs were taken to show how the area appears on the ground.



Views in the small groups of eastern white pine that stand out on the photographs can be seen above.



Yellow poplar trees, 8-12 inches D.B.H., that made up the over-story with the white pine. The height range was 75-90'.

If other photos taken in this area would be timber typed, it would be entirely possible to annotate the trees that have the same tone and crown density, and call them tulip and pine. Sample plots



would have to be taken in such areas to determine the percentage of white pine and tulip present in such mixed stands.

A view into the mixed hardwood stand that surrounded the pine and tulip. Ave. D.B.H. 8", and height range was 40-50'.

Differentiation between pine and tulip is almost impossible unless interpreted from fall or winter photos.

A large scale photo (1: 20,000) timber typed and classified directly on the photo would appear similar to the one on the following page, which is an area near Blue Ridge Summit, Pennsylvania. The symbols and timber types were chosen at random; but in actual practice, each letter and number refers to a definite classification of land and timber on the basis of density, species, and height.

2. Density. This is one of the easiest factors to estimate consistently. The U.S. Forest Service, Survey Division, suggests the following useful groupings of density based on percent of tree crown closure over an area: (Southern Appalachian Region)

Very poor density	- - - - -	5 to 19%
Poor density	- - - - -	20 to 39%
Medium density	- - - - -	40 to 69%
Good density	- - - - -	70 to 100%

To determine density accurately requires constant checking with ground conditions. The Pacific Northwest Forest and Range Experiment Station at Portland, Oregon, has issued a helpful aid for it's photo interpreters for checking density. It consists of a series of seven rectangles representing crown density on an aerial photo



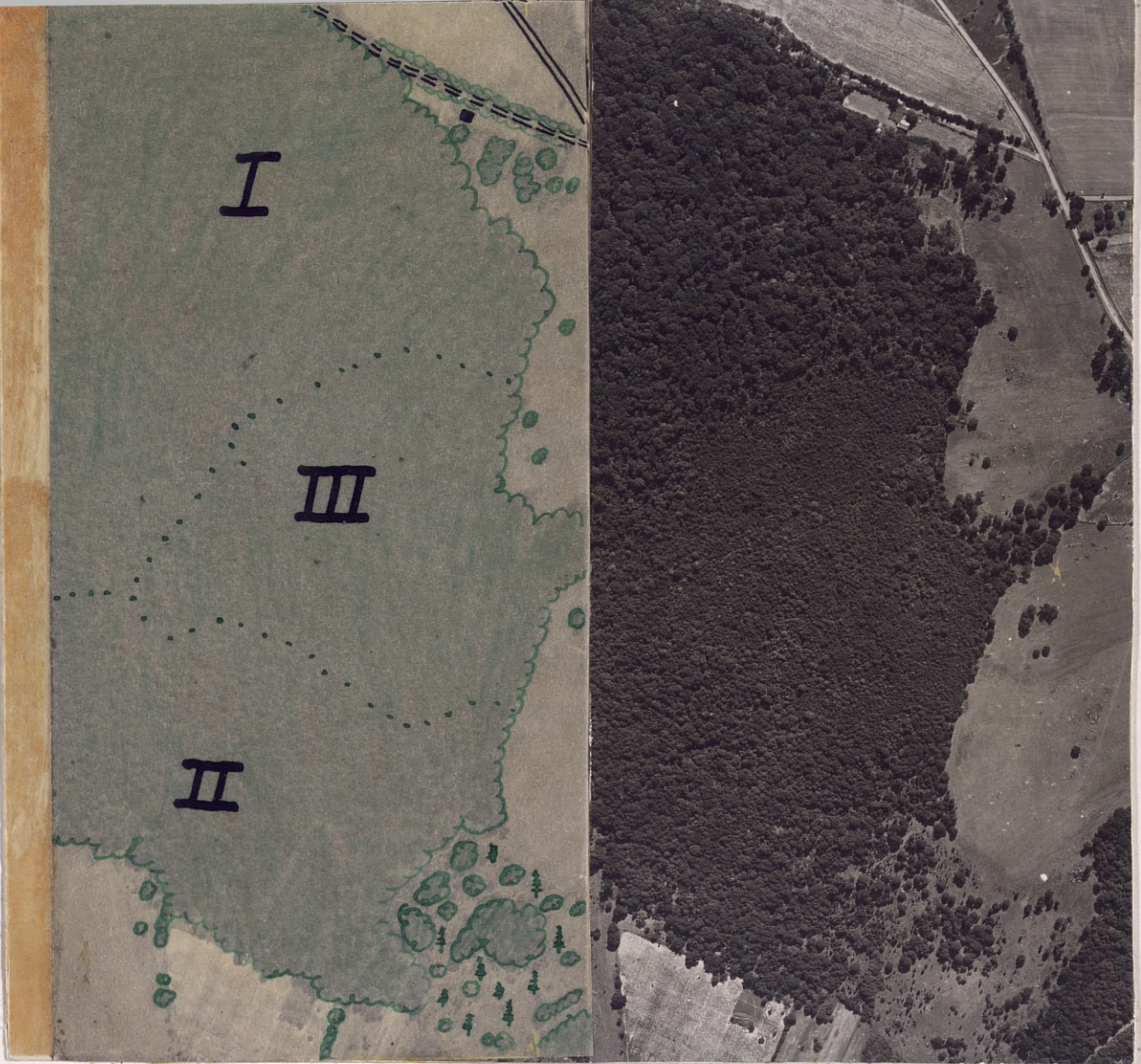
of timber. Each rectangle has a certain amount of space dotted and stipled to represent poor (10-40%), medium (40-70%), and well (70-100%) stocked areas. Thus, by comparing the rectangles to areas of forest, the interpreter can check density quite rapidly.

3. Tree heights. By applying shadow or parallax methods of height finding to our trees on the photo, the forest can be broken down into appropriate height groups for use in logging and management plans. The ^{Forest} Survey Division of the U.S. Forest Service recommended the following classification for the southeastern forest region:

- Reproduction and saplings - - - 15' tall
- Poles - - - - - 15-50' tall
- Small saw timber - - - - - 50-70'
- Intermediate - - - - - 70-90'
- Large - - - - - 90+

It should be noted that with such a tree height classification, the shadow or parallax methods of height finding would be very satisfactory.

On the following page is an example of how a woodlot can be divided into height groupings. It is of a farm woodlot near Fairfield, Pennsylvania, with a scale of 1:7500. It has three distinct blocks of timber that are easily picked out when viewing it stereoscopically. Roman numerals one through three have been inked on the



overlay paper to show the three classes of height. I is the highest, and III the lowest.

4. Crown diameter. A very useful method for determining stand size classes in uneven-age stands is to get a table made up of crown diameters, heights, and D.B.H.'s from a good representative number of trees measured in the field where conditions are similar to what will appear on the photos. Then by plotting, curving, and tabulating the data, we can get a table that will be fairly accurate

for height and D.B.H. By using the table, we can make our crown diameter measurement, and check it with the table to see what the height and D.B.H. of the trees on our sample plots will be. In a small area, this method may be used quite satisfactorily, but it is thought by many interpreters that it is not too reliable because of frequent variations due to species and age-class compositions of various stands.

5. Profile. On page 34 we have seen how the profile of shadows cast by various trees will aid in determining the species of timber on the photo. It would be restricted to edges of stands or along roads where shadows could fall on bare ground.

6. Topographic location. By applying our knowledge of forest ecology to our interpretation it is often helpful in determining species of trees on the basis of their topographic location. We could differentiate the upland types and swamp species from each other. Knowing certain trees are growing in a low, marshy area, we would be more inclined to call it black spruce or tamarack than red or white pine.

C. Forest area determination. To make a timber cruise for any good sized area of forest land, it is necessary to have the total number of acres to which cruise data can be applied in order

to determine volume per acre by species. There a number of methods, but to the forester the following methods are the most commonly used:

1. Traverse. This method is probably more accurate, but because of the length of time that must be spent in the field surveying the boundaries of each tract it is being replaced by quicker methods.
2. Dot count. In large areas of township and county size, this method is very quick and accurate for all practical purposes. It consists of making a dot count of forest areas on each print. Total the forest dots for all prints and divide by the total dots (forest + non-forest) to obtain the proportion of forest land. This percentage is then applied to the township or county land areas as given in the United States census and the acreage of forest land determined.
3. Acreage grids and scales. For areas below a township in size, a reliable method is the use of transparent grids or scales that are marked off in squares or dots. Each of the dots or squares represents a converting factor in acres for various scale photos. By counting the full squares or the number of dots falling on forests and multiplying by the acreage of a single square or dot, the

total acreage is found.

Examples of grids and scales:

- a. Bryan Modified Acreage Grid. This is based on a grid of 64 dots per square inch, and was designed by Mr. Milton M. Bryan.(7)
- b. Acreage Measurement Scale. This is based on the system of squares, and was prepared by the Soil Conservation Service, Cartographic Division, Region 5, Milwaukee, Wisconsin. (ibid)

VOLUME DETERMINATION FROM AERIAL PHOTOGRAPHS.

We have seen how it is possible to determine acreage, timber types, heights, and density with our photographs. By combining all this information and supplementing it with sample plots, we can get fairly accurate volume figures per acre by species.

A. There are two general methods that may be followed.

1. Aerial photos plus sample plots.

- a. Procure coverage for the area to be cruised.
- b. Outline boundary of the area.
- c. Delineate timber types by inked line on the photos.
- d. Calculate acreage of each timber type by acreage grid or acreage measurement scale.
- e. Determine the number of sample plots necessary to keep within the accuracy desired.

- f. Mark the section lines and corners where known.
 - g. Lay off cruise or plot lines in each type so that total number of samples to be taken will be proportioned evenly in each type.
 - h. Take the photos in the field for orientation, and cruise the sample plots in the conventional manner.
 - i. Apply cruise data to acreage figures to determine volume per acre.
2. Aerial photos only.
- a. Repeat all steps from "a" through "f".
 - g. Ink on photos the circles corresponding to the sample plots which are scattered proportionally over each type.
 - h. Calculate the height of trees in the sample plots. Apply a stand volume table based on height, species, and crown closure percent. OR,
 - i. Count the tree crowns, their width, height of the trees, and apply a volume table based on crown width and height classification.
 - k. Calculate volume per acre.

FLOATING LINE VISIBILITY (8)

During the war the photo interpretation section of the Military Intelligence Training Center at Camp Ritchie, Maryland, used an instructional aid to determine limits of visibility on aerial photographs. It is called floating line visibility. I believe that this technique, with particular stress on locating "dead space" in panoramas from fire lookouts, and checking relative heights on terrain for form lining or contouring, has valuable possibilities in application to Forestry problems.

A. Limitations of the map profile method of determining visibility.

1. Contours represent ground elevations only; therefore, woods and buildings will not appear as obstructions on a map profile. When actually observing from one point to another, these features may completely block visibility.
2. Contour lines on maps are usually put on by interpolation and inspection and are, therefore, not too accurate in detail.

B. Floating line method.

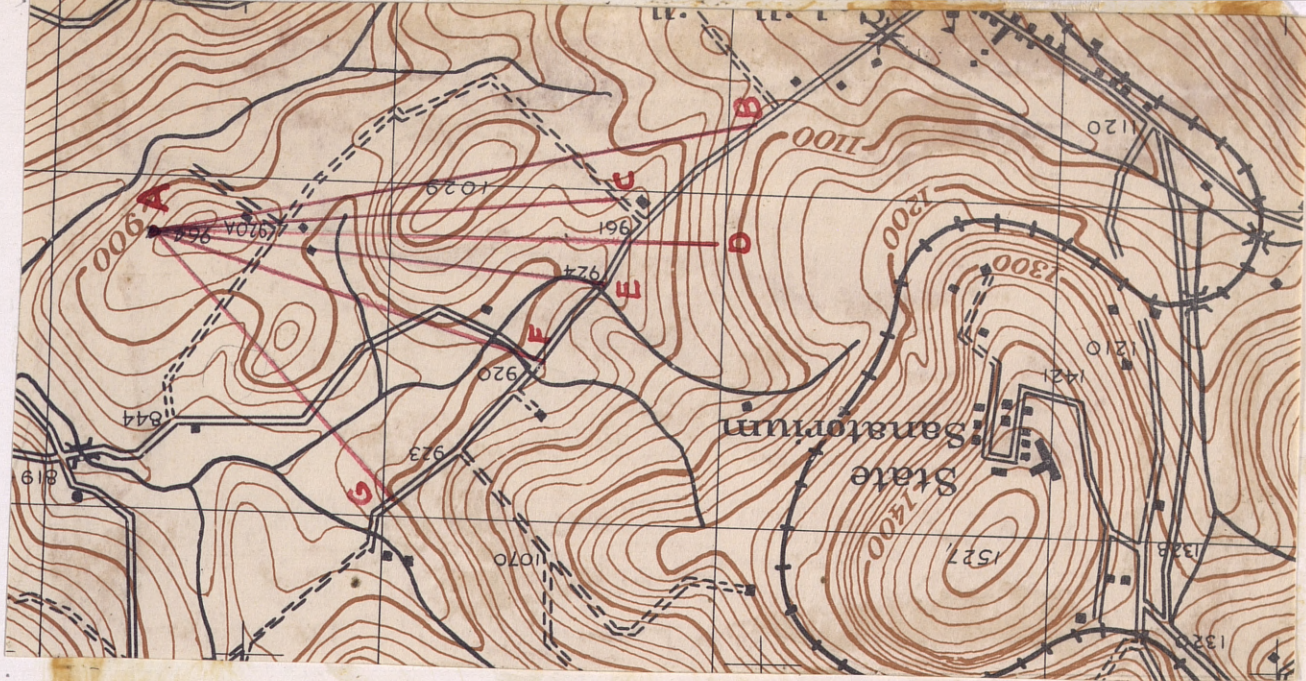
1. The following are steps in preparing photos for floating lines:
 - a. Obtain two photographs with overlapping area that contains points of doubtful visibility and proposed tower sight.

- b. Locate points on a single photo radiating from the future firetower location.
- c. With a straight edge and sharp point (pin), scratch a fine line onto the emulsion of the photograph leading from the proposed tower sight to the various points whose visibility is questionable.
- d. Being careful to extend lines to the exact points as located on the first photo, repeat with the overlapping photo.
- e. Fill in the scratches with chalk dust or colored grease pencil (yellow stands out well). Wipe away the excess chalk or grease pencil with tissue paper.

2. Application of the floating line technique: (See page 97)

a. Viewing the prepared photos in three dimension by use of the pocket stereoscope we see the following:

1. If the lines are in proper alignment, they will blend and seem to float straight through the air from point to point if no obstruction intervenes.
2. If there is an obstruction in the form of a hill, forest, or building, the "floating line" appears to cut into it or bend over it.
3. By following each of our lines to the questionable landmark, we can determine visibility from the tower site to each point. (This presupposes that the look-



out is at ground level, or only slightly elevated).

b. On our example we can see that from A to D, F, and G the line "floats", but B, C, and E appear to dig in or bend over hills. The accompanying map on page 97 of the same area bears out this deduction when contours are checked. Photographs were flown over Blue Ridge Summit, Pennsylvania, at a scale of 1: 10,000.

3. It should be pointed out that:

a. The ends of the two lines will fall on identical corresponding points on the two photos.

b. Points along the lines do not fall along corresponding features on the two photos unless the features happen to be on the same horizontal plane as the extremities.

c. As a general rule the lines will not be parallel.

d. Accuracy will be proportional to the R.F. of the photos.

e. The limit of reliability is arbitrarily set at about 20° to the line of flight. This method is not reliable along the line of flight of the stereo-pair.

C. Expedient floating line with acetate strips.

To save the photos from unnecessary scratching, two strips of acetate with fine black lines inked on may be used. Pins are placed at the ends of corresponding lines on each of the two strips and stuck on the point of the photo which represents

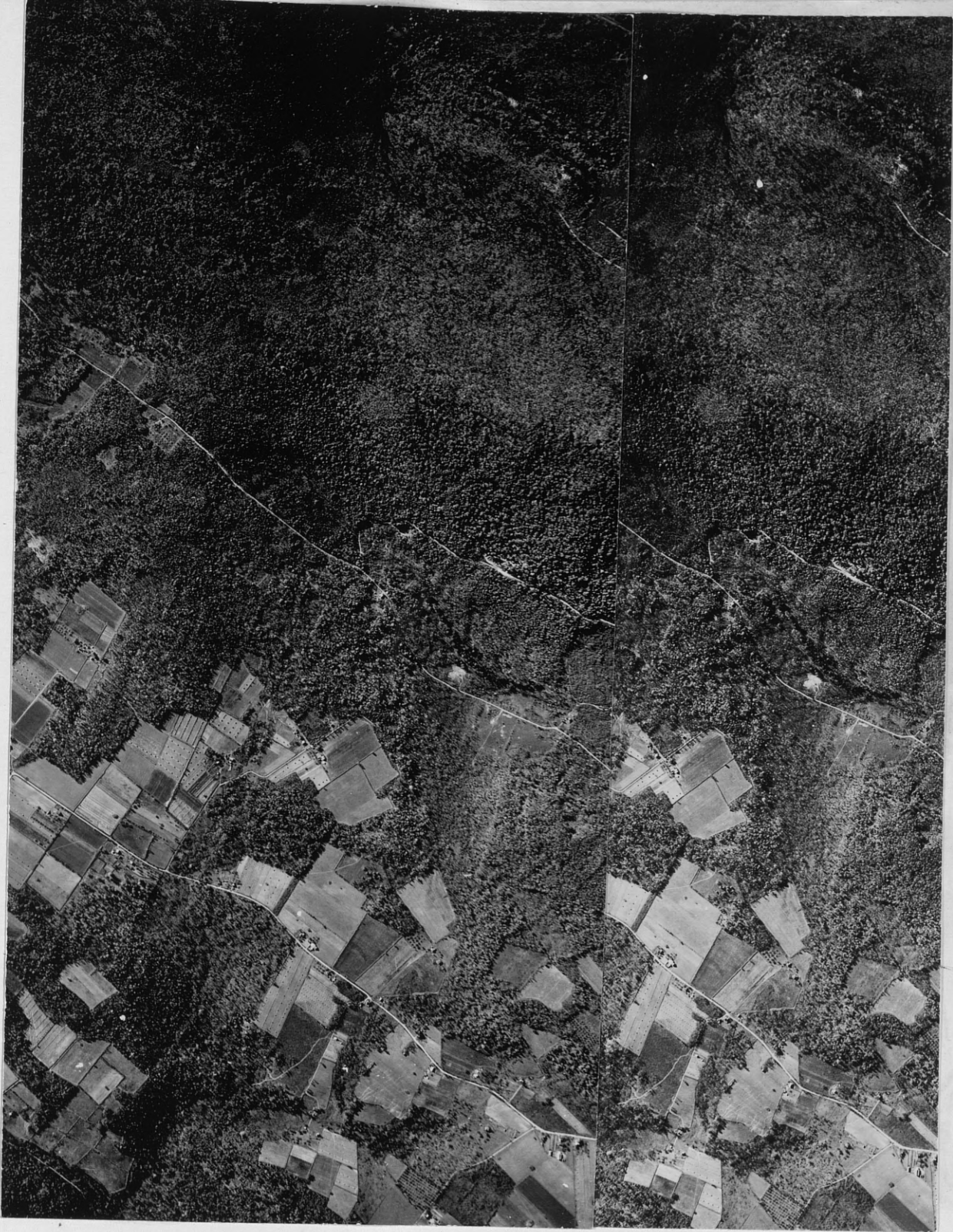
the lookout station. The other ends are swung to any point on the overlapping photos where visibility is to be checked. While being viewed through the stereoscope, they are held down by hand, held by scotch tape or pinned down.

SPECIAL USES

1. Road and trail reconnaissance. (9)

Foresters are often called upon to plan the layout and spacing of new logging roads or trails in which the location is not limited to one certain route. They would have a choice on selecting the best route from the standpoint of accessibility, slope, spacing, amount of work necessary, and ground conditions (swampy, rocky, and down timber). In such an undertaking, aerial photographs, viewed stereoscopically, are invaluable.

The forester, when laying out a road or trail on the ground, may have other alternate routes on either side of him which only time-consuming reconnaissance work will show. With the use of aerial photographs, several possible routes may be chosen before he goes into the field to ground check and decide which route, on the ground, will be the best. He can eliminate the unfavorable routes immediately. With an alternate choice available should ground conditions appear during the field check which would eliminate his first choice, it is not far-fetched to presume he could make his final choice solely from aerial photographs in his office. Occasionally he may be able to locate existing roads not seen on maps that parallel his choice of route and that can be widened and improved to meet his needs. On the following page we have such a road in the stereo-pair. It is just faintly visible through the trees, but it would still serve as a means



of getting to the top of the ridge without the large amount of work necessary to build a new road to serve the same purpose. The road to be improved is shown in red on the overlay.

If he should be called upon to plan such work without being able to cover the entire length of his route on the ground, he could do it with his photos. The stereoscopic view would show slope and limited ground conditions, and he could get a rough estimate on the amount of work required to push the road to completion over his proposed route.

2. Drainage studies.

By using aerial photographs viewed through a stereoscope, accurate mapping and accurate location of a forest for a watershed study can be made more satisfactorily.

In stereo one can study various conditions of the cover or ground that would affect the run-off and the eventual choice on the size of watershed structures to be built. The degree of slope, type of vegetative cover, burnt over and eroded areas can be easily distinguished, and they help one in choosing a final location for the study. This method is of great practical value in areas where accessibility is poor, and money could be saved that otherwise would be spent on long trips to isolated areas for purposes of looking over the possible locations for a watershed study.

3. Fire detection and suppression. (ibid) 9.

"In areas covered by aerial photographs, fire dispatchers' desks may be constructed incorporating the stereoscopic use of aerial pictures. In these cases a set of photographs is

furnished each dispatcher covering his area on which have been delineated the section and township lines and numbers. In unsectionized areas an arbitrary grid may be drawn on the map and transferred to the photographs.

Suitable filing arrangements are made in a specially prepared desk drawer in such a manner that any pertinent stereoscopic pair of photographs may be quickly selected. Other desk drawers contain hazard and fuel type maps illuminated from below. The map of the area on which appear the protractors for the lookouts controlling the area is fixed on the desk top in such a way that intersections may be obtained from the readings of the reporting lookouts. A telephone on an extension arm is provided; also on an extension arm a stereoscope is provided which may be swung into position at a moments notice.

Upon receiving reports of a fire the dispatcher determines the location by cuts from two or more lookouts, considers the dangers by study of the hazard and fuel type maps, selects the appropriate photographs and by use of the stereoscope is provided with a birdseye view of the location of the fire and is so enabled to judge the size of the suppression crew required and to decide upon the best route for approaching the fire as well as to a material degree the plan of attack in suppressing the fire. Availability of the stereoscopic model which may be viewed while in telephone contact with the lookouts permits the dispatcher to outline the progress of the fire, to judge as to the necessity of sending additional men and to some extent direct the suppression activities."

4. Special use permits.

Aerial photos can be a very valuable asset to a forester who received almost daily requests for special use permits. By going to a file of photographic cover on his forest, he can quickly size up the situation of the terrain and vegetative cover in

which the permit is requested, and then pass his judgement accordingly. Examples of permits requested for which photos would be helpful in making decisions: Slash burning, fuel wood cutting, and grazing permits.

5. Insect and disease damage determination.

The United States Forest Service has been using aerial photographs to determine areas of timber infected by various insects and diseases. Usually stands of defoliated and dying trees will appear black on infrared photos and white on panchromatic film. The gypsy moth and spruce bud worm are examples of two insects whose damage to a forest stand can be readily discerned from aerial photos. Another recent application has been in locating the spread of the Dutch Elm Disease on the East Coast and New England States.

6. Locating recreational areas.

Aerial photos are excellent for finding locations that would have the minimum requirements for areas suitable for recreation development as on a large scale program of land purchase. Should a lake or large river surrounded with a certain number of acres of forest be necessary to fit into the recreation plan, the photos could be used to locate the various possibilities. This would eliminate a large amount of unnecessary field work.

7. Mapping.

The advantages and use of timber typed maps has been previously discussed, but it should be mentioned that aerial photos

are used extensively by most forestry agencies; Federal, state, and private organizations, in making large or small scale planimetric and topographical maps. Expensive and intricate machines are used to get accurate ground control and to plot detail from the photos onto a controlled map sheet.⁽¹⁰⁾ Small timber owners usually find these map making methods too expensive and are satisfied with just using the photos to timber type their holdings and perhaps make a mosaic to show the boundary of their timber.

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Glossary of terms used in the thesis

The following are simple definitions of terms commonly used in aerial photograph interpretation. Further explanations of these terms may be found in the U.S. Army Field Manuals 21-25, and 21-26; Training Manuals 5-230, 5-240, and 5-246.

1. Aerial Photo: A picture of the earth's surface taken from above.
2. Vertical Photo: A photograph obtained when the optical axis of the camera is vertical at the time of exposure.
3. Oblique Photo: A photograph obtained when the optical axis of the camera is tilted from the vertical at the time of exposure.
4. Composite: A photograph consisting of one central vertical photo surrounded by four transformed oblique photos. It is taken with a multi-lens camera and has the shape of a Maltese cross.
5. Stereovision: The effect of depth or relief obtained while looking at a stereo-pair.
6. Stereo-Pair: Two vertical photos taken at the same elevation, each with a different camera position and including a part of the area covered by the other.
7. Strip: Successive overlapping vertical photos made from an airplane flying a selected course line or direction.
8. Overlap: Amount by which one photograph overlaps the area covered by another.
9. Mosaic: An assembly of two or more overlapping aerial photographs.
10. Uncontrolled Mosaic: A mosaic in which the vertical photos used vary in scale.
11. Controlled Mosaic: A mosaic in which the vertical photos have been corrected to a constant scale.
12. Photomap: The reproduction of a single photograph, composite or mosaic, complete with grid lines and marginal data.

13. Flight Line: A line drawn on a map or chart to represent the track over which aircraft has flown, or the course over which it will fly.
14. Base Line: The line on a photograph connecting the indicated positions of two camera stations. When applied to a stereo-pair with a small overlap, it is the line connecting the centers of photos when the photos are properly overlapped.
15. Camera Station: The point in space, in the air or on the ground occupied by the camera lens at the moment of exposure.
16. Altitude: Vertical distance from the datum, usually mean sea level, to an object or point in space above the datum.
17. Flight Altitude: The vertical distance above a given datum of aircraft in flight, or during a specified portion of flight. The datum usually means ground elevation.
18. Distortion: The inaccuracy of scale which exists along the edges of a photo due to aberrations of a photographic lens.
19. High Oblique Photograph: An oblique photograph which shows the horizon.
20. Low Oblique Photograph: An oblique photograph with the entire picture below the horizon.
21. Marginal Data: Information in the margin of photos which is of aid in filing, interpreting and determining the accuracy of photos, as well as in obtaining general information therefrom.
22. Focal Length: The perpendicular distance between the film and the lens of a camera.
23. Orientation: A map or photo is oriented when, in a horizontal position, its north arrow points north and all other lines on the map or photo are parallel to the corresponding lines on the ground. A photo reader is oriented when he knows his position on an oriented photo.
24. Representative Fraction: A fraction which expresses the ratio between a given distance on a map or photo and the corresponding distance on the ground.
25. Scale: A fixed relation between the horizontal distance of given points on a map or photo and the same distance on the ground.



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