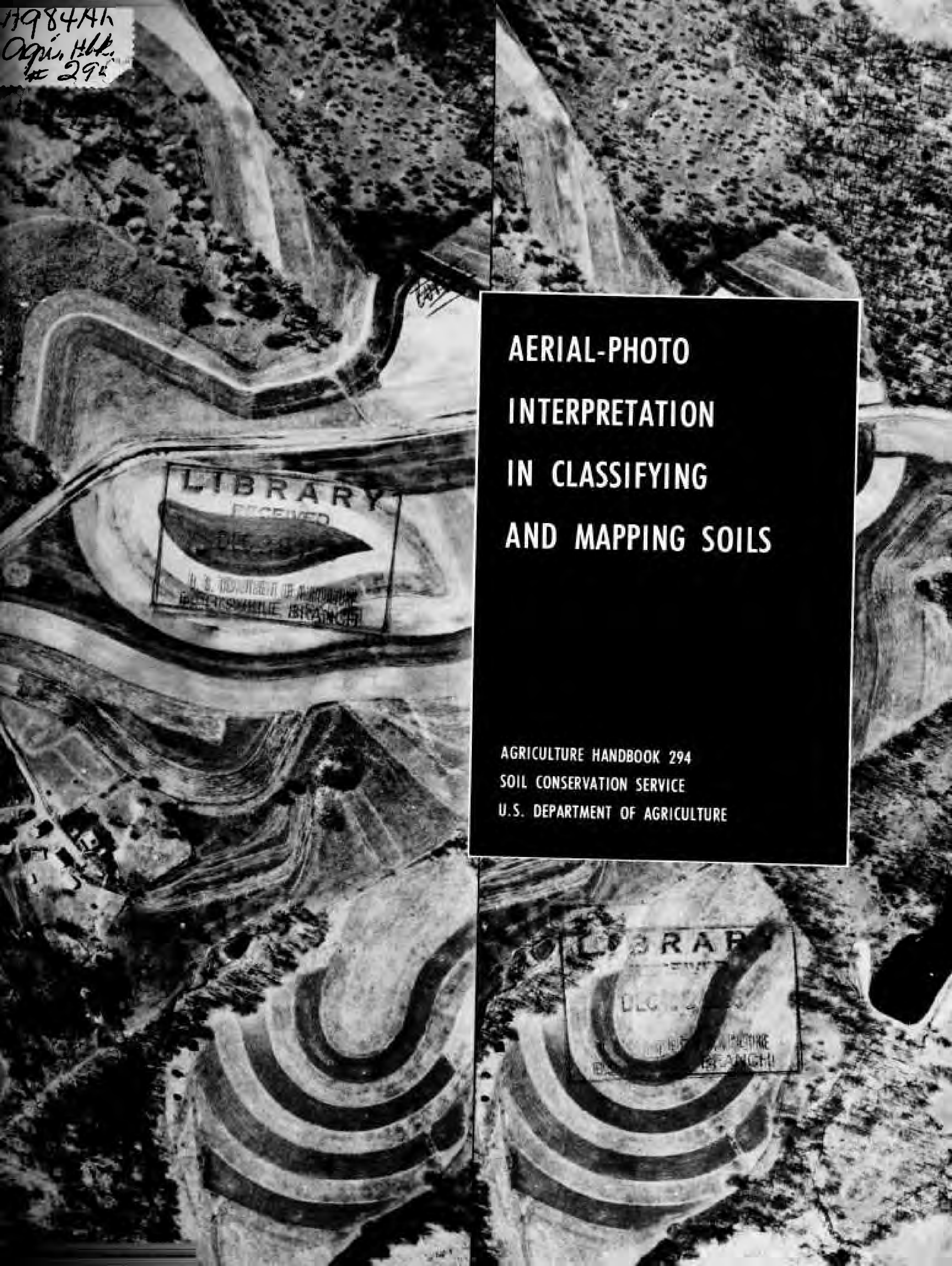

AERIAL-PHOTO INTERPRETATION IN CLASSIFYING AND MAPPING SOILS

AGRICULTURE HANDBOOK 294
SOIL CONSERVATION SERVICE
U.S. DEPARTMENT OF AGRICULTURE

Aerial-Photo Interpretation

in Classifying and Mapping Soils

Prepared by
SOIL SCIENTISTS AND CARTOGRAPHERS
Soil Survey Staff
Soil Conservation Service

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FOREWORD

This manual has been prepared by staff cartographers and soil scientists primarily for soil scientists and others directly engaged in the national cooperative soil survey of the United States. Many of the principles may be helpful to others.

Perhaps the first use of aerial photographs for soil surveying of a whole county was in the soil survey of Jennings County, Indiana, about 1929. Since the middle 1930's soil surveying in the United States has been done on aerial photographs. This technique became available about the same time that the concept of a soil as a profile was extended to the concept of a soil as an individual, three-dimensional body on the surface of the earth.

The use of aerial photographs, first of all, makes possible increased accuracy in plotting the soil boundaries. Since the photographs show many more landscape features than ordinary planimetric maps or planetable sheets, the soil scientists have abundant control for plotting boundaries between soils identified in the field. The field soil scientist is also relieved of a large part of the job of plotting houses, roads, and other features required for users of soil maps. In fact, the features that can be seen clearly on the ground and on the photos serve as control, both for the soil scientist in the field and for the user of the soil maps.

Besides using photographs as a base on which to plot results of their field examinations, soil scientists have developed skill in interpreting photographs for clues to the kinds of soil and to the location of soil boundaries both before and during the field mapping. In low-intensity soil surveys they can make reasonable estimates of soil boundaries in areas between those examined in the field. The best reconnaissance soil surveys are made with aerial photographs. Such soil maps guide the establishment of priorities for the detailed soil surveys needed for operational planning. All these uses require high-quality photographs.

The replacement of planetable sheets by photographs as field sheets also increased the requirements of cartographic engineering skill for accurate compilation. The greater accuracy and the saving of the time of soil scientists more than compensate for the exacting job of map assembly. Published soil maps on controlled photographic mosaics help the user locate himself on the map and thus improve his accuracy of reading the kinds of soil on specific tracts of land.

Great progress has been made in soil mapping by photo interpretation accompanied by full examination of the soils at frequent intervals. While mapping soils, the soil scientist has two immediate problems: (1) With what kind of soil does this individual soil belong? (2) Where are its boundaries?

The photographs can be interpreted more accurately on the location of soil boundaries than they can on the exact classification of the soil. After close field study, however, a highly skilled soil scientist can identify kinds of soil in several kinds of landscape.

Soil scientists must always recall that soils have depth. Many aerial photographs do not show the surface of the soil itself, let alone the several horizons beneath it. Accurate soil maps cannot be made without deep examination of the soils.

Similar patterns on aerial photographs can be misleading. A combination of landform and vegetation that can give accurate clues to kinds of soil can suddenly fail elsewhere because of undetected changes in one or more aspects of climate, lithology, or land use history. What are indicator plants for one kind of soil only a few miles away can be indicator plants for a different kind of soil that is highly contrasting in terms of its use potential. But with a few examinations of soils in depth, the relations can be clarified and aerial photographs can be used for accurate interpretation.

Variations among the lower soil horizons, or among layers just beneath the soil, may have no associated surface indication under wild vegetation or extensive use. Yet these features are highly significant under more intensive use. In deserts, for example, salt-rich layers and impermeable layers deep within the soil—which have no influence on native plants—can be of the utmost significance if the soils are irrigated. Thus soil surveys of arid land to guide irrigation require many field examinations in depth.

As the purposes of the soil survey require increasing detail and accuracy of interpretations influenced by lower horizons, relatively more dependence must be placed on field examination and less on aerial-photo interpretations. To be satisfactory, the highly detailed soil maps needed for consolidating fragmented holdings and for planning extensive irrigation works, must be developed with many field examinations. Yet in all soil surveys advanced aerial interpretation is extremely helpful for planning and for anticipating the kinds of problems to be dealt with. Experienced soil scientists use photo interpretation a great deal both for estimating soil boundaries and for identifying kinds of soil for low-intensity surveys of rangeland where the mapping units commonly are soil associations.

This manual is based mainly on experience in the national cooperative soil survey during the last 30 years. The highly technical aspects of photogrammetric engineering have been avoided, but references are cited to fuller discussions.

Several illustrations show how keys for correlating photographic images and kinds of soil can be prepared and used in the field.

Although many helped prepare this manual, special credit should be given to F. M. Orsini and C. W. Koechley, who directed its preparation, and to the following, who made major contributions and helped in its organization: M. E. Austin, J. L. Bryson, D. K. Crook, C. M. Ellerbe, R. M. Hooper, B. L. Matzek, A. C. Orvedal, J. D. Rourke, and W. E. White.

CHARLES E. KELLOGG,
Deputy Administrator for Soil Survey.

CONTENTS

Explanation of abbreviations in negative numbers—National Archives and Records Service, NA; Geological Survey, USGS; Agricultural Stabilization and Conservation Service, ASCS; Soil Conservation Service, SCS; and Department of the Air Force, USAF.

AERIAL PHOTOGRAPHY

An aerial photograph is today's most complete and informative, yet most economical, representation of the earth's surface. Aerial photographs give perspective views of the terrain. They reveal hill and dale, soil and water patterns, wonders and ravages of nature, and works of man. The Soil Conservation Service (SCS) was an early pioneer in recognizing the merits of making use of aerial surveying when, in 1934, it contracted for more than 100,000 square miles of photography.

Aerial photographs are widely used in soil surveying, farm and ranch planning, soil and forest conservation, irrigation and flood-prevention studies, timber estimates, crop-area measurement, highway planning, railroad and power-transmission location, geological research, and municipal planning. Through the science of photogrammetry, they are used as the basis for constructing precise topographic, planimetric, and controlled aerial mosaic maps.

No single combination of survey scale and lens focal length can be applied to all situations; many types and scales of aerial surveys are continually being made. In many instances aerial photographs can be used economically only when the survey is flown at or near a given scale. Accuracy in compiling large-scale maps requires a large-scale aerial survey, whereas economical production of small-scale maps requires smaller scale survey. Also, most stereoscopic plotting instruments require surveys flown with 9- x 9-inch cameras equipped with 6-inch-focal-length lenses. Other plotting instruments require camera lenses with focal lengths of 3.5 to 12 inches, depending upon plotter design and aerial negative format. The longer 8¼-inch-focal-length lenses produce photographs that are best for direct use for soil surveys and photo interpretation as used in SCS.

In addition to various scales and lenses, aerial surveys are flown with various cameras and camera angles. Single-lens or multiple-lens cameras can be used. Also, multiple cameras can be mounted with the axes of the lenses inclined to the surface of the earth to obtain converse or convergent low-oblique photography. A vertical aerial photograph, however, is the best base for soil mapping and photo interpretation, and nearly all aerial photographs for soil surveys are made with vertically mounted single-lens cameras that expose a 9- x 9-inch image area.

AERIAL SURVEYS

In the 1930's there were wide differences among surveys being flown by the various agencies of the U.S. Department of Agriculture (USDA). To provide aerial surveys that would suit most needs in agriculture, USDA agencies, in 1937, agreed to adopt a standard scale of 1:20,000 for these surveys. They were to be flown with a vertical camera equipped with an 8¼-inch-focal-length lens, which would expose a 7- x 9-inch image area.

To establish conformity among aerial surveys made by these agencies, Standard Specifications for Aerial Photography for General Map Work and Land Studies were developed. Since that time, nearly all of the United States has been flown at the scale of 1:20,000 under these "standard" specifications. Special surveys, however, are flown at 1:40,000, 1:31,680, 1:15,840, 1:10,000, 1:5,000, and other scales.

SCS modifies specifications for aerial surveys to meet requirements of a particular job and revises them to take advantage of developments in technology and improvements in materials and equipment. Specifications are revised in coordination with other USDA agencies. A summary of the latest specifications follows.

FACTORS TO BE CONSIDERED

Many geographic, physical, technical, and economic factors must be considered before a schedule of advertisement can be prepared for aerial surveys. The ultimate use or objective of the survey must be known: Is it to be of general use, for which 1:20,000 standard flying is required; or is it to be used primarily for topographic mapping at a larger scale? Does the elevation or the type of photography require special flying equipment? Nearby surveys should be investigated to eliminate small gaps between surveys that would be expensive to fill in later. In addition, Government agencies coordinate their activities to prevent duplication. These factors help determine the survey boundary, scale of photography, and focal length of the camera lens.

TIME FOR FLYING

Contracts that enable contractors to keep their plants and personnel busy throughout the year and to to take optimum advantage of favorable seasonal conditions have a direct bearing on the cost of surveys. Therefore, economical planning requires close study of such regional weather characteristics as the anticipated number of "photographic days" for each month for each survey area.[1] Such factors as geographic latitude and solar altitude must be considered to reduce or eliminate objectionable shadows in rugged areas. Generally, photography is undertaken only during that part of the day when the sun is 4 hours or more above the horizon. But in areas of little relief that have only slight differences in tone, the position of the sun may be used to emphasize landforms by introducing shadow patterns.

Most aerial surveys must be flown when the ground is free from snow. This limits the flying season in colder sections.

To show the earth's surface, photographs should be taken when trees are free of leaves and other vegetation is minimal. This limits the flying season to a few weeks in early spring and late fall. Since atmospheric conditions further limit the flying time, restricting flying to seasons when trees are free of leaves is impractical except for projects that require only a few weeks. A large project flown under such limitations would require excessive equipment to complete the job in a reasonable time. In SCS, aerial surveys made specifically for large-scale topographic mapping by stereo-plotting equipment are usually flown when deciduous trees are bare. Most of these special projects are small.

CAMERAS AND LENSES

Precision 9- x 9-inch cameras and appropriate lenses are specified so the photography will meet minimum requirements and be widely useful. The cameras must be constructed to withstand vibration and temperature changes. Collimation or fiducial markers must be built into the plane of the film and secured to the magazine or to the inner cone of the camera so that negatives will reproduce the markers in each exposure. Fiducial marks are midway on each of the four edges of the photographs. Lines joining opposite members of the two pairs of markers will intersect at the optical center (principal point) of the exposure. Specifications also require a camera that is designed to permit testing procedures. The lens must have high resolving power to provide sharply defined images. Low distortion is required to maintain true perspective. For general use 1:20,000 surveys, the focal length is about 8¼ inches (210±4 mm). For topographic mapping surveys, the focal length generally used is about 6 inches (152±3 mm).

Test reports of the camera and lens must be prepared by a testing organization or Government unit approved by SCS. Reports must be submitted before the contract is awarded. These tests determine whether the camera and lens meet accuracy requirements. Test reports include the resolving power, the distortion pattern, the equivalent[2] and calibrated[3] focal lengths of the lens, and the value of distances separating opposite fiducial markers. These fiducial measurements can be used to determine the dimensional stability of exposed negatives and of reproductions processed from them. Also, when compared to corresponding measurements on a reproduction, these distances can be used to determine the precise degree of enlargement.

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[1] A photographic day is one during which there is no more than 10 percent cloud cover.

[2] The equivalent focal length is the distance measured along the lens axis from the rear nodal point to the plane of best average definition over the entire field used in the aerial camera.

[3] The calibrated focal length is an adjusted value of the equivalent focal length computed to distribute the effect of lens distortion over the entire field used in the aerial camera.

FILM

The specifications require fine-grained, high-speed, polyester base, panchromatic film, or its equivalent. This type of film gives a good range of densities from black to white of all the colors. Panchromatic film is used for most surveys because of its all-round adaptability and low cost. Polyester base is exceptionally stable and eliminates any problem of dimensional changes caused by the film.

Since color aerial surveys for general use in SCS are not yet practical, the specifications do not list this type of film. Color aerial photography is especially limited because of processing difficulties. The cost for making color prints is now considerably more than that for making black-and-white prints. Color aerial photography has improved the accuracy of certain kinds of photo interpretations, however, especially for the military, for geologic investigations, and for forest-disease studies.

Similarly, infrared aerial photography in SCS is limited, and specifications do not mention this type of film. Infrared aerial film is sensitive to a portion of the infrared spectrum, which is not visible to the human eye. Since the film is also sensitive to a portion of the visible spectrum, true infrared photography is obtained by exposing the film through a deep red filter, which permits recording only the infrared rays. Thus, reproductions from true infrared aerial photography have a distortion of density values of the various reflected color tones. For example, green foliage of deciduous plants appears very light, as though covered by heavy frost. Differences between tones of certain species of trees and vegetation are more pronounced. Bodies of water and areas in shadow appear black. The more drastic effects of true infrared photography may be modified with a minus blue (yellow) filter, which permits recording a portion of the visible spectrum as well as the infrared portion. Modified infrared photography has many of the characteristics of true infrared photography, but it also retains some of the characteristics of panchromatic photography. In USDA, modified infrared photography is used principally by the Forest Service to distinguish between tree species.

ALTITUDE FOR FLYING AND SCALE OF NEGATIVES

The scale of an aerial survey is generally given in terms of a representative fraction or "ratio scale"; for example, 1:20,000. The ratio scale S is determined by the lens focal length f and by the altitude or flight height H above the ground as follows:

$$S=\frac{f}{H}$$

where both f and H are in the same units of measurement. Thus, general-use, 1: 20,000 surveys may be flown with an 8¼-inch (0.6875-foot) lens at an altitude of 13,750 feet above ground level. Figure 1 gives the relationship between various lens focal lengths, flight altitudes, ratio scales, and scales in terms of feet-per-inch.

The schedule of advertisement for aerial surveys for SCS specifies the focal length of the lens, the altitudes for flying, and the ratio scale of negatives. The specifications require that flight altitudes do not exceed more than plus or minus 5 percent of specified values. In flat areas the scale of the negatives will vary generally within plus or minus 3 percent but will seldom vary more than plus or minus 5 percent of true scale. In mountainous areas the scale of individual exposures of a flight can range from plus 10 percent to minus 20 percent of the specified ratio scale. Such variances are primarily due to the rise and fall of ground elevation along the flight strip. Higher ground, which is closer to the camera, produces larger scale negatives. It also produces less overlap between exposures and less sidelap between flight lines. Conversely, lower ground produces smaller scale negatives, increased overlap between exposures, and increased sidelap between flights. In some areas flight altitude must be increased to maintain satisfactory sidelap over peak elevations. This action decreases the average scale of the flight and, unfortunately, produces even smaller scales through the lower agricultural areas.

FLIGHT LINES AND SIDELAP

The direction of flight lines is north and south unless special conditions make it necessary to orient the flights in another direction. Some flights are planned in an east and west direction to parallel the higher ground elevations

780-309 O—66——2

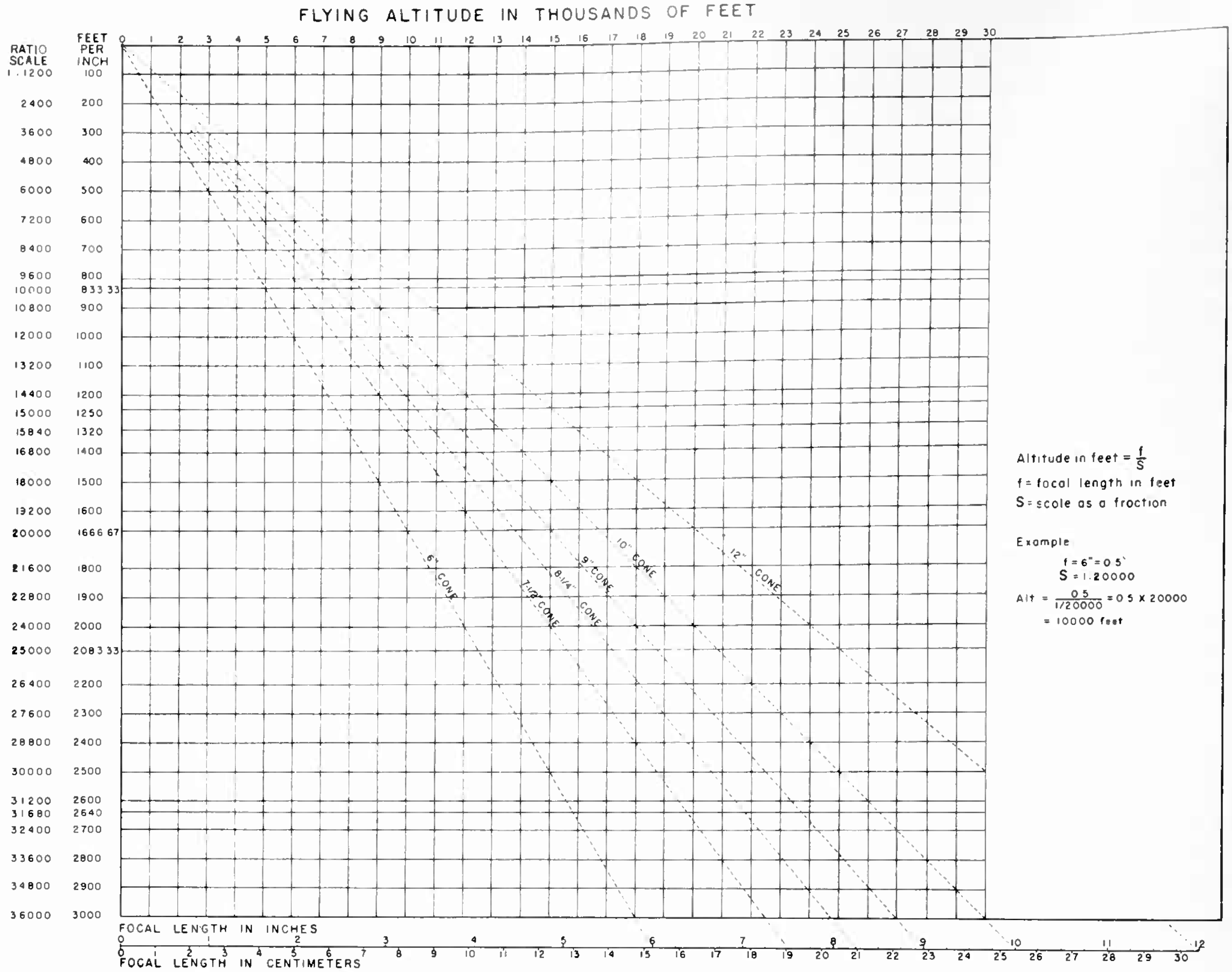

Figure 1.—Altitude chart for aerial surveys.

since flights that parallel the contour direction result in more uniform scale throughout the exposures. East and west flights are also used to parallel the longer dimension of a flight area and thus reduce the number of flights. Flight lines of small areas flown for topographic mapping may be oriented in any direction or combination of directions that will result in photography parallel to the general direction of the streambed.

Spacing and locations of flight lines are also specified. This spacing together with the flight altitudes and the camera and lens combination establishes approximately 30 percent sidelap between flights. Flight lines for general use 1: 20,000 photography are spaced at 2-mile intervals. In sectionized areas flight lines are over alternate section lines. Flight-line locations depend upon analysis of such factors as the location of former flight lines of the area and adjoining areas; exposure locations of new surveys that duplicate exposure locations of former surveys are generally desired. In addition, the location of particular sites of interest may dictate flight-line locations. With proper planning, these sites may fall entirely within a single photograph or within a single flight line. The minimum and maximum sidelap are specified at 15 percent and 45 percent, respectively. Some deviation from these values is permitted: for instance, within an area where there is extreme variation in elevation.

Flight lines are usually required to be continuous across the length of the area to be photographed. Breaks in flight lines are permitted when clouds, insufficient overlap or sidelap, or other conditions require reflying a portion of a flight line.

OVERLAP

Exposures are made at intervals that result in an average overlap of about 60 percent with the preceding photograph in the flight. A minimum of 55 percent and a maximum of 65 percent overlap is specified. Overlap of 60 percent provides systematic coverage that is adequate for stereoscopic viewing of any point. Greater overlap than necessary increases the number of exposures required and therefore increases the cost. Average overlap of less than 60 percent increases the possibility of stereoscopic gaps. Such gaps cause a loss of steroscopic views of the areas which eliminates or lessens the value of the survey for mapping. Wherever breaks in flight occur, reflights are necessary and should cover at least 100 percent overlap of end exposures at the break in flight to assure stereoscopic pairs through the "break" area.

BOUNDARY COVERAGE

Where the boundary of an area is perpendicular to the flight lines, the first and last photograph on each flight line will fall outside the project boundary. When the boundary is at an angle with flight lines, exposures at the ends of flight lines will provide stereoscopic coverage to a point at least 1 mile beyond the boundary.

Where the boundary of the area is parallel to the flight lines, the sidelap beyond the boundary will not be less than 15 percent.

CRAB

Crab of an aerial photograph is caused by failure to orient the camera with respect to the ground track of the airplane. As a result, sides of the photographs are not parallel to the line of flight. For general use photography, any two or more consecutive photographs may not be crabbed more than 10 degrees as measured from the plotted flight line. For mapping photography, any two or more consecutive photographs may not be crabbed more than 5 degrees. Within these limits, crab alone does not cause problems in the use of photographs.

TILT

Specifications limit the tilt of any negative to no more than 4 degrees. Tilt may not average more than 2 degrees in any 6-mile section or more than 1 degree for the entire unit.[4] Relative tilt between any two successive negatives may not exceed 6 degrees.

Image displacements due to tilt are generally negligible compared to displacements due to ground relief. Tilt of a photograph may cause image displacements that produce scaling errors of as much as 1 or 2 percent; ground relief could cause displacements that produce scaling errors 10 percent or more, depending on the ruggedness of terrain. In an area of flat terrain, displacement caused by tilt can be the principal cause of a small error in scale.

IDENTIFICATION OF EXPOSURES

Each aerial negative is marked with the date of exposure, an alphabetical symbol, the serial number and letters of the roll, and the serial number of the exposure on the roll. For example:

10–8–62 ABC–12DD–112

In addition, the abbreviation of the standard civil time of day of the exposure, the agency initials, and the approximate scale of the negatives are marked on the first and last negatives of each flight line and at each break in a flight line. For example:

10–8–62 12:15 SCS 1:20,000 ABC–12DD–112

The identification is marked within the exposure area along the northern side of the negative for north and south flights and along the western side for east and west flights.

In most exposures the alphabetical symbol alone will identify the county. In some the symbol identifies only the aerial survey project. Further investigation is required to ascertain the county within the project.

Each roll of aerial film exposed in a unified block of flying is numbered in an unbroken series beginning with number 1. A suffix of alphabetical letters is made to the roll numbers to differentiate between multiple surveys of the same county. Each exposure within a roll is also numbered in an unbroken series beginning with number 1. Exposures and rolls are thus numbered in the sequence in which they are flown. Because of weather, rejections, and

[4] "Unit" means a county, counties, or parts thereof having the same designating symbol.

other factors, flight lines are seldom flown entirely in consecutive order. Therefore, there is no particular pattern to the roll numbers or to the direction of exposure numbers that make up the final coverage.

PHOTOINDEX

Photoindex sheets of each county or area are prepared by photographing an assembly of contact prints from the aerial negatives. Photographs in the assembly are laid so that corresponding images match reasonably well and the numbered edges are exposed to show the identity of each print. This assembly is copied on 20- x 24-inch negatives at a scale of 1: 63,360. Each sheet is identified by a title, which shows the county or area name, sheet number, alphabetical symbol, agency and contractor credit lines, graphic scale, and other data such as survey scale and year of flying. County and unit boundaries are then delineated on the index negatives.

Although the individual contact prints are not precisely matched, a photoindex is a fair mosaic and can be used for advance planning and broad reconnaissance surveys in many fields. But an understanding of its accuracy is essential to apraise the results that may be expected if the index is used directly as a map base.

Since indexes are a compilation of contact prints, there may be considerable difference between prints of one flight line compared to prints of an adjoining one. Consequently, mismatches and scale differences may be expected in the index assembly. Deviation in the scale of aerial negatives is caused primarily by ground relief; therefore, accuracy that can be expected within an index sheet is generally proportional to the amount of ground relief. For example, in nearly flat areas, most mismatches between prints used in the index assembly should be within 0.10 inch on the final index and no mismatch should exceed 0.15 inch plus that caused by ground relief. For rugged terrain, mismatch between prints used in the assembly may amount to 0.50 inch or more.

PHOTOGRAPHIC REPRODUCTIONS

SCALE OF REPRODUCTIONS

Contact prints, since they are made at the same scale as the negatives, retain all scale deviations of the negatives. Within limitations, enlargements can be made to any desired scale if enlargement factors are computed. To compute an accurate enlargement factor, the scale of the negative must be determined. This scale is usually preferred in terms of feet-per-inch and is determined by the following relationship between horizontal ground distance *GD* and photograph distance *pd*, measured between the same two identifiable points:

$$\text{Scale in feet-per-inch} = \frac{GD}{pd}$$

where ground distance *GD* is in feet and photograph distance *pd* is in inches. The enlargement factor can now be computed simply by dividing the feet-per-inch scale of negative by the feet-per-inch scale of enlargement desired. A common, though less accurate, way to obtain a ground measurement is to scale the distance from a map. Where accurate scales are required for many reproductions covering a unified area, a slotted-templet radial-control net may be established. Most aerial surveys flown for general use by USDA agencies have been scaled from radial-control nets. Where control nets have not been established, however, "theoretical" enlargement factors may be used. Theoretical factors are determined by dividing the ratio scale of enlargement desired by the ratio scale planned for the aerial survey. Enlargements made with a theoretical factor have the same percentage of scale deviations inherent in the original negatives. For example, if the scale of the original negative is 5 percent large, the scale of enlargement will also be 5 percent large.

Enlargements projected up to four or more diameters may be made. Film emulsion grain and other conditions cause some loss of sharpness of detail. Therefore, enlargements in excess of this magnitude are not recommended. Table 1 gives average image size of enlargements from the more common survey scales. Although a smaller scale aerial survey will result in fewer photographs for coverage of a given area, a greater enlargement is required to produce a photograph of a given scale when com-

TABLE 1.—*Average image size of enlargements*

[Approximate quantities of stereoscopic reproductions required to cover an area of 1,000 square miles are indicated within parentheses]

Ratio scale of survey	Scale of enlargement					
	1 inch=400 feet	1 inch=660 feet	1 inch=1,320 feet	1 inch=1,667 feet	1 inch=2,640 feet	1 inch=3,333 feet
1:10, 000	19 x 19 inches (2,600).	12 x 12 inches (2,600).	(1)	(1)	(1)	(1).
1:15, 840	16 x 16 inches (2,060).[2] 30 x 30 inches (1,030).	18 x 18 inches (1,030).	9 x 9 inches (1,030).	(1)	(1)	(1).
1:20, 000	20 x 20 inches (1,300).[2] 38 x 38 inches (650).	23 x 23 inches (650).	12 x 12 inches (650).	9 x 9 inches (650).	(1)	(1).
1:31, 680	31 x 31 inches[3] (520).[2]	19 x 19 inches (520).[2] 36 x 36 inches (260).	18 x 18 inches (260).	14 x 14 inches (260).	9 x 9 inches (260).	(1).
1:40, 000	(4)	24 x 24 inches[3] (320).[2]	23 x 23 inches (160).	18 x 18 inches (160).	12 x 12 inches (160).	9 x 9 inches (160).
1:50, 000	(4)	30 x 30 inches[3] (200).[2]	15 x 15 inches (200).[2] 29 x 29 inches (100).	23 x 23 inches (100).	14 x 14 inches (100).	11 x 11 inches (100).
1:60, 000	(4)	35 x 35 inches[3] (140).[2]	18 x 18 inches (140).[2] 34 x 34 inches (70).	15 x 15 inches (140).[2] 27 x 27 inches (70).	17 x 17 inches (70).	14 x 14 inches (70).

1 Reduction; less than 9 x 9 inches.
2 Only physical coverage (nonstereoscopic) in the image size shown. Enlargements are processed in sections by the method given in figure 2.
3 Enlargements in excess of 4.3 diameters.
4 Not available.

pared to enlargements made from larger scale aerial surveys.

Where enlargements will produce photographs too large to be handled conveniently and economically, reproductions may be made from sections of each negative (fig. 2). Two sectional enlargements are made from each succeeding negative, namely, a "right-center area" and a "left-center area." The principal advantage of this system is that complete physical coverage is processed from only the more accurate portions of the aerial negatives. Right-center and left-center reproductions are identified merely by adding an R or an L, respectively, to the exposure number. For example, ABC-12DD-112R and ABC-12DD-112L.

The comparison of ratio scales to other equivalents is given in table 2. Equivalents for additional ratio scales may be computed as follows:

Feet-per-inch $= \frac{D}{12}$

Inches-per-1,000 feet $= \frac{12{,}000}{D}$

Inches-per-mile $= \frac{63{,}360}{D}$

Miles-per-inch $= \frac{D}{63{,}360}$

Meters-per-inch $=$ Feet-per-inch x 0.3048006

Acres-per-square-inch $= \frac{D^2}{43{,}560 \times 144}$

Square-inches-per-acre $= \frac{43{,}560 \times 144}{D^2}$

Square-miles-per-square-inch $= \frac{(\text{Feet-per-inch})^2}{(5{,}280)^2}$

with D the denominator of the ratio scale.

TABLE 2.—*Map scales and equivalents*

Ratio scale	Feet per inch	Inches per 1,000 feet	Inches per mile	Miles per inch	Meters per inch	Acres per square inch	Square inches per acre	Square miles per square inch
1: 500	41. 667	24. 00	126. 72	0. 008	12. 700	0. 0399	25. 091	0. 00006
1: 600	50. 00	20. 00	105. 60	. 009	15. 240	. 0574	17. 424	. 00009
1: 1, 000	83. 333	12. 00	63. 36	. 016	25. 400	. 1594	6. 273	. 00025
1: 1, 200	100. 00	10. 00	52. 80	. 019	30. 480	. 2296	4. 356	. 00036
1: 1, 500	125. 00	8. 00	42. 24	. 024	38. 100	. 3587	2. 788	. 00056
1: 2, 000	166. 667	6. 00	31. 68	. 032	50. 800	. 6377	1. 568	. 00100
1: 2, 400	200. 00	5. 00	26. 40	. 038	60. 960	. 9183	1. 089	. 0014
1: 2, 500	208. 333	4. 80	25. 344	. 039	63. 500	. 9964	1. 004	. 0016
1: 3, 000	250. 00	4. 00	21. 12	. 047	76. 200	1. 4348	. 697	. 0022
1: 3, 600	300. 00	3. 333	17. 60	. 057	91. 440	2. 0661	. 484	. 0032
1: 4, 000	333. 333	3. 00	15. 84	. 063	101. 600	2. 5508	. 392	. 0040
1: 4, 800	400. 00	2. 50	13. 20	. 076	121. 920	3. 6731	. 272	. 0057
1: 5, 000	416. 667	2. 40	12. 672	. 079	127. 000	3. 9856	. 251	. 0062
1: 6, 000	500. 00	2. 00	10. 56	. 095	152. 400	5. 7392	. 174	. 0090
1: 7, 000	583. 333	1. 714	9. 051	. 110	177. 800	7. 8117	. 128	. 0122
1: 7, 200	600. 00	1. 667	8. 80	. 114	182. 880	8. 2645	. 121	. 0129
1: 7, 920	660. 00	1. 515	8. 00	. 125	201. 168	10. 00	. 100	. 0156
1: 8, 000	666. 667	1. 500	7. 92	. 126	203. 200	10. 203	. 098	. 0159
1: 8, 400	700. 00	1. 429	7. 543	. 133	213. 360	11. 249	. 089	. 0176
1: 9, 000	750. 00	1. 333	7. 041	. 142	228. 600	12. 913	. 077	. 0202
1: 9, 600	800. 00	1. 250	6. 60	. 152	243. 840	14. 692	. 068	. 0230
1: 10, 000	833. 333	1. 200	6. 336	. 158	254. 000	15. 942	. 063	. 0249
1: 10, 800	900. 00	1. 111	5. 867	. 170	274. 321	18. 595	. 054	. 0291
1: 12, 000	1, 000. 00	1. 0	5. 280	. 189	304. 801	22. 957	. 044	. 0359
1: 13, 200	1, 100. 00	. 909	4. 800	. 208	335. 281	27. 778	. 036	. 0434
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1: 16, 000	1, 333. 333	. 750	3. 96	. 253	406. 400	40. 812	. 024	. 0638
1: 16, 800	1, 400. 00	. 714	3. 771	. 265	426. 721	44. 995	. 022	. 0703
1: 18, 000	1, 500. 00	. 667	3. 52	. 284	457. 201	51. 653	. 019	. 0807
1: 19, 200	1, 600. 00	. 625	3. 30	. 303	487. 681	58. 770	. 017	. 0918
1: 20, 000	1, 666. 667	. 60	3. 168	. 316	508. 002	63. 769	. 016	. 0996
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PAPER AND PAPER FINISHES

Aerial photographs are printed on single- or double-weight paper with glossary or semimatte surface. Single-weight paper is useful where photographs are mounted, as in mosaic assembly, or where prints must be rolled. When photographs must be folded, a special single-weight folding stock generally is used. Double-weight paper can be handled repeatedly and still remain more nearly flat and, therefore, is the paper favored for general use. Glossy finishes are usually reserved for illustrations or for mounted photographs. The semimatte surface is designed to take colored or lead pencil notations and is favored for general use.

Except for special types, photographic paper presents a minor problem of distortion. The paper is fairly stable in one direction; however, atmospheric conditions can cause distortion to 0.5 percent or more across the grain of the paper. This distortion is usually shrinkage.

When dimensional stability of the reproduction is important as in slotted-templet assemblies, photographs may be printed on water-resistant paper or on white semiopaque polyester base material. Polyester base is more stable than water-resistant paper and lies perfectly flat. Because costs are about 30 percent higher for reproductions processed on water-resistant paper and about 90 percent higher for reproductions processed on polyester base materials, reproductions other than contact prints are seldom processed on stable-base material.

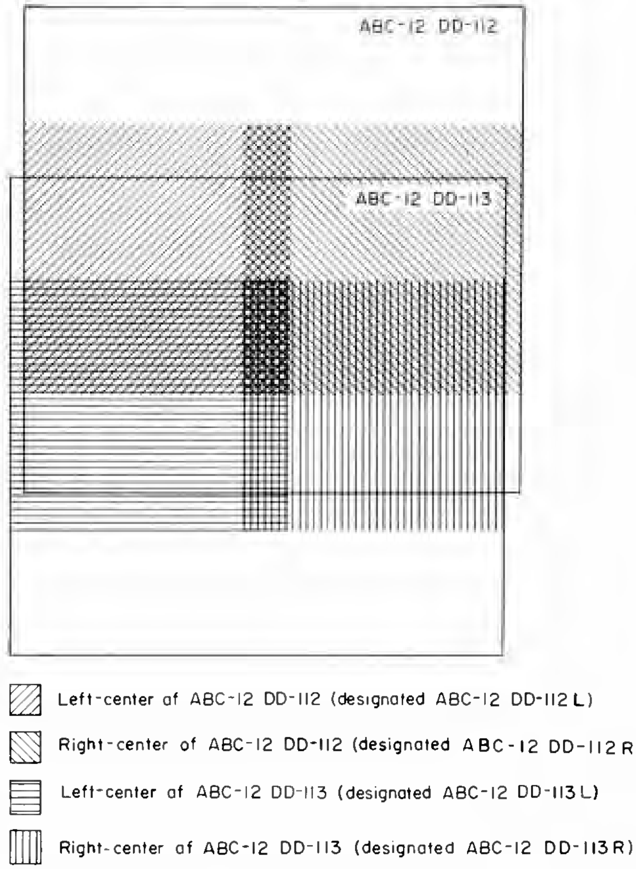


Figure 2.—Method for making sectional enlargements.

SELECTION OF COVERAGE

Either alternate or stereoscopic coverage may be selected for any portion of the surveyed area. Since each exposure within a flight line is made to provide at least 55 percent overlap with the preceding exposure, every part of the surveyed area is covered by at least two overlapping photographs. Thus, a set of alternately numbered photographs will cover every part of the surveyed area. Reproductions from consecutive exposures are referred to as "stereoscopic coverage," whereas reproductions from alternate exposures are sometimes referred to as "nonstereoscopic coverage," "physical coverage," or "alternate coverage."

Stereoscopic coverage is required for three-dimensional viewing and for reproductions to be used for photogrammetric mapping. Since the center areas of photographs are more nearly like a true map, stereoscopic coverage should also be selected where there are considerable differences between ground elevations. Where the terrain is nearly flat, however, alternate coverage may be selected for general use. Alternate coverage is more economical since only half as many photographs must be processed and used.

As has been stated, an aerial photograph is a perspective picture and does not show all objects in their true positions. Today's precision lenses and stable-base negatives do not cause significant distortion of images in photographs for general use; but photographic papers may. Varying ground elevation within a picture is, however, a major factor of image displacement.

In flat country, image displacement is negligible. In rolling terrain, it is negligible only near the center of the photograph. Change in ground elevation within the photograph area causes continuous change in the scale of the photograph. The tops of the hills are nearer the camera than are the valleys. Because of this, the photographic scale of hills is larger than the scale of valleys. Except in rugged areas, scale variances may not be serious; but to make effective use of photography of rugged areas, the perspective characteristics of the image must be fully understood.

Figure 3 represents image displacement caused by elevation of the ground. The datum plane shown in the diagram is the level of ground elevation that produces the planned aerial-negative scale. Points A, P, X, B and C, are ground positions. The distortion- and displacement-free (orthongonal) locations of these points are shown at A', P', X, B', and C'. The aerial photograph, however, shows these ground positions at locations a, p, x, b and c, which are displaced in a radial direction from the nadir point.[5] In a true vertical photograph, the nadir point coincides with the principal point,[6] or picture center, which is indicated as point p.

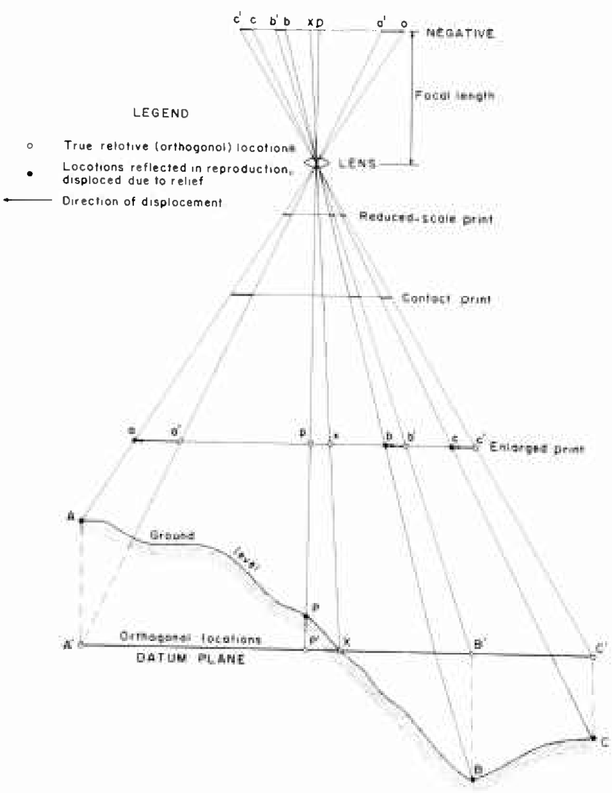


Figure 3.—Displacement due to elevation of the ground.

The radial displacement of any image point may be computed from the following formula:

$$d=\frac{nh}{H}$$

where d = the amount of displacement measured on the photograph

n = the distance measured from the photograph nadir to the image point

h = the difference in elevation between the ground point and the datum plane (positive if ground point is above datum, negative if below)

H = the height (flight altitude, fig. 1) of the camera above the datum plane

and where d and n are in the same units of measurement, as in inches, and h and H are in the same units, as in feet.

From the formula, ground elevations above the datum plane, such as at A, are displaced outward (positive) from the nadir; but ground elevations below the datum plane, such as at B, are displaced inward (negative). Ground elevations that coincide with the datum plane, such as at X, and ground points directly below the camera, such as at P, are not displaced. The formula also discloses that displacement varies jointly as distance n and difference in elevation h, and inversely as height H.

The net displacement caused by a difference in elevation measured from the ground to the

[5] The nadir point, or plumb point, is the point on the ground vertically beneath the camera lens.

[6] The principal point is the optical center of the photograph.

top of an object, such as a silo or tree, also may be computed with the above formula if H is defined as the height of the camera above the base of the object and h is defined as the height of the object.

Because the flight altitude H is equal to the lens focal length divided by the ratio scale of the survey (fig. 1), a longer focal length requires a higher flight altitude to maintain a specified ratio scale. From the displacement formula, a higher flight altitude reduces displacement caused by ground elevation. The $8\frac{1}{4}$-inch focal-length lens used for 1:20,000 photography for USDA is a compromise based on such factors as the amount of image displacement and estimated cost of surveys.

STEREOSCOPY

Stereoscopy is the science of producing three-dimensional effects from two-dimensional pictures of subjects having three dimensions and the methods by which these effects are produced. In normal vision, each eye focuses on an object from a different position and transmits a slightly different image to the brain. In the mind's eye, the two transmitted images are combined into a single three-dimensional counterpart of the original object. If one eye is closed and the object is viewed with only the open eye, however, no more than a two-dimensional image is achieved. For all practical purposes, depth or distance factors are lost and actual distances can only be judged by the comparative size of the viewed object or by the relative positions of familiar objects.

This stereoscopic principle is used to produce a three-dimensional image of the earth's surface with pairs of vertical aerial photographs. The opportunity to study vegetation, culture, drainage, and other features of the land in three dimensions gives greater value to aerial photography.

Almost anyone with good sight in both eyes, or whose eyesight can be corrected, can acquire the ability to view pairs of aerial photographs steroscopically. Skill in stereoscopic study is gained only through practice. Initial attempts may be frustrating, but as facility in the procedures increases the stereoscopic examination of aerial photographs becomes routine.

PARALLAX

Parallax is defined as any apparent displacement of an object due to a change in position from which the object is observed. The eyes view an object from two slightly different positions because they are separated. This separation is called the interpupillary distance and is about $2\frac{1}{4}$ inches for most people but ranges from 1.97 inches to 2.85 inches for different persons. Parts of a three-dimensional object seen by one eye are not seen by the other. Furthermore, the image of near objects seen by each eye alternately appears displaced or removed laterally in relation to background objects. This lateral displacement is "parallax." Parallax is an important factor in determining the relative distances of objects in a scene. When the eyes scan a solid object the different planes of the object are separated through parallactic displacement and the impression of relief is obtained.

BINOCULAR VISION

Most people can distinguish between well-defined vertical lines if the distance between the lines subtends a convergence angle of at least 1 minute of arc (fig. 4). A highly trained observer, however, may distinguish between lines that subtend an angle as small as 15 to 20 seconds of arc.

A person with an interpupillary distance of 1.97 inches may perceive depth in an object up to a distance of about 570 feet; a person with an interpupillary distance of 2.85 inches may see depth in objects up to a distance of about 800 feet. The highly trained observer could perceive depth to about 1,700 feet if he had an interpupillary distance of 1.97 inches, or to a little over 2,400 feet if he had an interpupillary

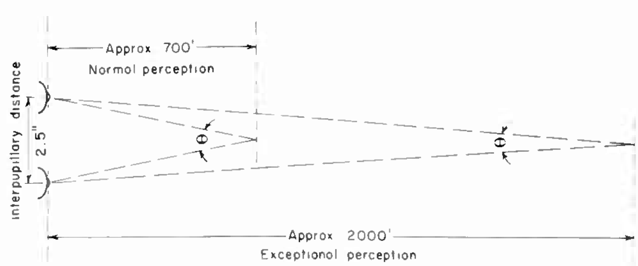


Figure 4.—Interpupillary distance and depth perception.

distance of 2.85 inches. Beyond this even the trained observer is unable to perceive depth or see relief. For this reason mountainous or rough terrain looks nearly flat when flying at a considerable altitude.

The following relationship between interpupillary distance PD and angle of convergence θ may be used to approximate large distances R to viewed objects:

$$R=\frac{PD}{\theta}$$

where R and PD are in the same unit of measurement, as in feet, and θ is expressed in radians.[7]

SEEING STEREOSCOPICALLY

Anyone with normal eyesight in both eyes or with corrected vision can see three dimensions, or see stereoscopically. This ability may be tested by looking at a small object at eye level about 20 feet away. Extend the forefinger of each hand and raise each to eye level. Without changing the focus of the eyes on the distant object, bring the fingertips together slowly on the line of sight. If you see an "ocular weinerwurst" between the fingertips (fig. 5), you can learn to use a stereoscope successfully.

Many persons are able to experience three-dimensional impressions while viewing pairs of aerial photographs without benefit of lenses, prisms, or mirrors, but simply with the eyes alone. This ability is acquired only by special effort and continued practice. While this ability is sometimes helpful, use of a stereoscope is more satisfactory.

Ordinarily, the eyes converge on the subject being viewed. To view a stereoscopic pair of photographs, however, the lines of sight must be about parallel so that the right eye views the right-hand photograph and the left eye the left-hand one. At times a three-dimensional image is inverted. This inverted or pseudoscopic effect is caused by viewing the right-hand photograph with the left eye and the left-hand photograph with the right eye. The condition may be corrected by reversing the photographs to their proper positions or, if the effect is caused by looking cross-eyed, by making sure that the lines of sight do not cross.

KINDS OF STEREOSCOPES

There are several kinds of stereoscopes made by a number of optical and photogrammetric equipment manufacturers. The principal difference between stereoscopes is the optical method used to prevent lines of sight from converging at the focal plane or point of focus. The basic types are: *prism* stereoscope, *lensatic* stereoscope, reflecting or *mirror* stereoscope, or a combination of these. Some mirror stereoscopes are equipped with binoculars which magnify the image. This attachment is considered unsatisfactory for general use because the field of vision is reduced drastically. Binocular attachments, however, help to identify land survey stations and other minute detail.

The old-fashioned parlor stereoscope (fig. 6) is probably the best known prism stereoscope. It has thin wedge-shaped prisms that spread the lines of sight, slight magnification with a limited field of vision, and a critical focal distance.

A simple folding, pocket-sized, lens stereoscope (fig. 7) extends the focal length of the eyes and helps overcome normal convergence. Figure 8 illustrates the difference in the lines of sight between the spherical lens and the pris-

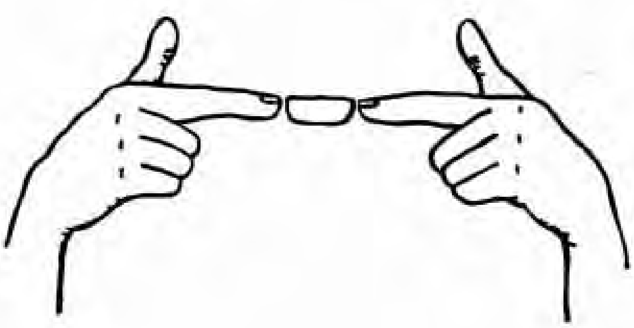


Figure 5.—Ocular wienerwurst.

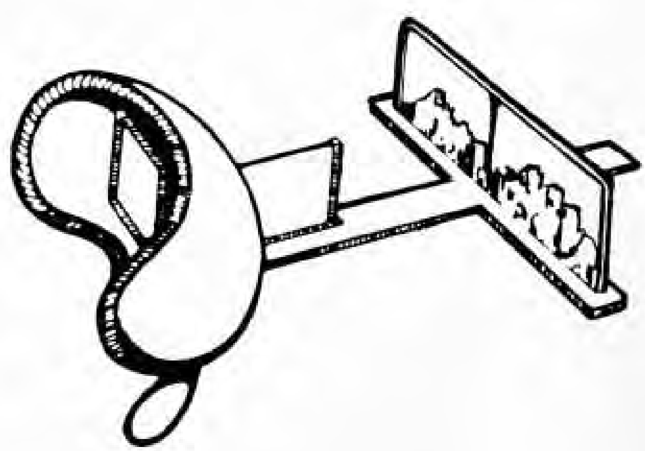


Figure 6.—Prism stereoscope.

[7] 20 seconds of arc is 0.0000965 radians.

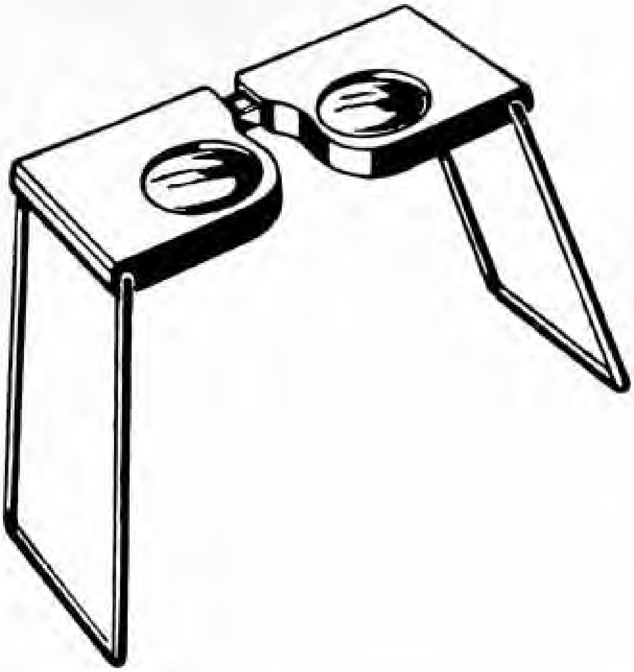


Figure 7.—Lens stereoscope.

Figure 9.—Mirror stereoscope.

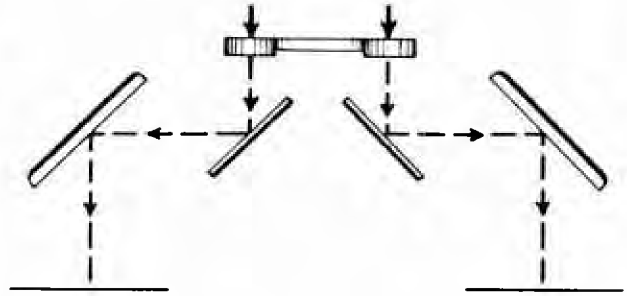


Figure 10.—Lines of sight through a mirror stereoscope.

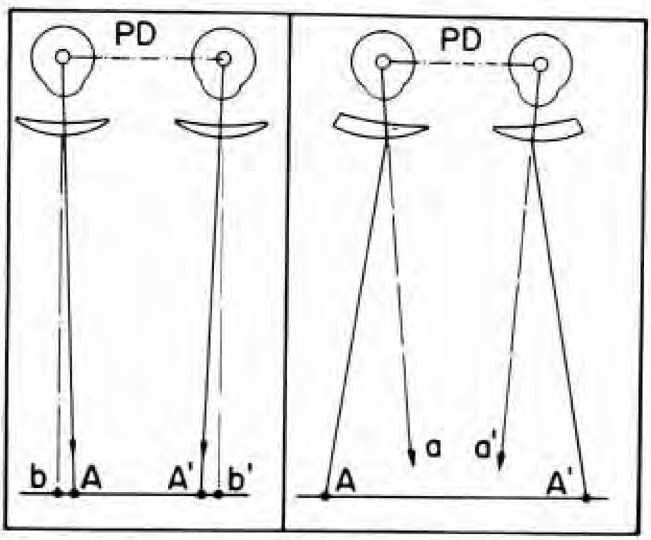


Figure 8.—Line of sight through lens stereoscopes: Left, through simple spherical lenses the distance between image points (A and A′) is usually less than pupillary distance (PD)—maximum separation does not exceed bb′=PD. Right, prismatic lenses permit the distance between image points (A and A′) to be greater than pupillary distance (PD)—prismatic deviation causes A and A′ to be seen in the directions a and a′.

matic lens stereoscope. The photographs are placed at a distance from the lens equal to the focal length of the lens. Since this is much like placing the photographs at or near optical infinity of the eye, the lines of sight are nearly parallel. Most lens stereoscopes are inexpensive. They can be used effectively with 9- by 9-inch contact prints and 4-inches-equal-1-mile enlargements from 1:20,000 aerial surveys. They magnify the image about 1½ to 2 times and are convenient for general use.

The mirror stereoscope (figs. 9 and 10) has prisms or mirrors, or both, to spread the lines of sight. The lens-mirror assembly usually can be raised or lowered until the photographic image is focused sharply. The lines of sight at the point of focus are usually about 9 inches apart. Because of this a much larger photographic area may be examined without moving the photograph or the stereoscope. Reflecting or mirror stereoscopes may be used to view 9- by 9-inch contact prints and enlargements.

OTHER WAYS TO PRODUCE A STEREOSCOPIC EFFECT

In addition to stereoscopes and pairs of overlapping photographs, anaglyphs or vectographs give a three-dimensional impression.

An anaglyph is a composite of superimposed stereoscopic images in complementary colors. This kind of composite is used to obtain the three-dimensional view in most stereo photogrammetric plotters such as the Multiplex and the Kelsh. The overlapping portion of one aerial exposure of a stereoscopic pair is projected or printed in a color such as blue. The overlapping portion of the adjacent aerial exposure is projected or printed in a complementary color such as red which is superimposed over the blue image. Usually the image of one color is slightly offset from the image of the other color. The composite image is then viewed through a pair of spectacles which has one red lens and one blue lens. One eye sees only the blue image because the red lens neutralizes the red image; the other eye sees only the red image because the blue lens neutralizes the blue image. Thus, a three-dimensional view is achieved.

A vectograph uses polarized light rays to achieve image separation. Polarized light, the basis for the process, vibrates in only one direction within a plane, whereas ordinary light vibrates in all crosswise directions. A composite of superimposed images is prepared by transferring dyed images of the aerial exposures to a sheet of polaroid vectograph film. One side of the vectograph film polarizes light in one direction; the other polarizes light in the opposite direction. The overlapping image of one aerial exposure is dye-transferred to one side of the vectograph film; a reversed, overlapping image of the adjacent aerial exposure is dye-transferred to the other side of the vectograph film. The composite image is viewed through a pair of polarized spectacles, which has the axis of one lens at right angles to the axis of the other; one eye sees the image of only one of the pictures of the overprinted pair; the other eye sees only the other. The mental fusion of the two images forms a three-dimensional view.

STEREOSCOPIC VIEW FROM AERIAL PHOTOGRAPHS

For general use 1: 20,000 surveys, exposures within the line of flight are made about 1 mile apart. In effect, the eye base is enlarged to 1 mile from the normal between-the-pupils distance of 2¼ inches. This makes possible a three-dimensional view even though the photographs were taken from a height of more than 2½ miles. When viewing a stereoscopic pair each eye assumes a position of the camera station at the instant of exposure and the impression of slope is greatly exaggerated (fig. 11).

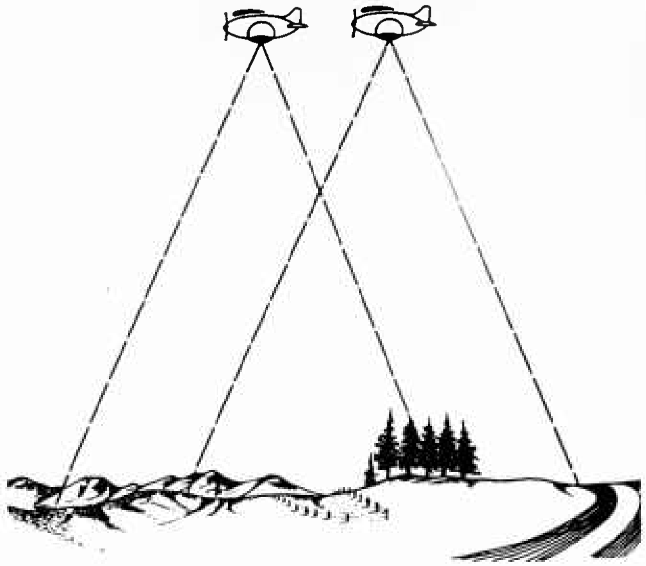


Figure 11.—Camera station and eye position.

This exaggeration increases as the distance between the two camera stations increases. It can be of considerable benefit when interpreting ground slope from photographs.

SELF-TRAINING

The lenses of a stereoscope must be accurately spaced and adjusted for each individual's eyes if he is to see a stereo model properly. If the lenses are spaced too far apart, the model appears concave or saucer shaped. If they are spaced too close, they give a convex or mound appearance. Either improper spacing can lead to mistakes in delineation of drainage or in other interpretations.

To adjust the stereoscope lenses, place two identical prints under the lenses of a stereoscope so that the same area can be viewed on both photographs, like a regular stereoscopic pair. Both photographs must be flat. The concave or convex effect can be noted readily by moving the lenses to the extremes, wide apart or close together, and adjusting the duplicate photographs accordingly. When the lenses and photographs are moved back and forth until an area of about 4 square inches directly under the stereoscope appears to be perfectly flat, the lenses are properly spaced for viewing stereoscopically. Mark the stereoscope so that the lenses can be set to this spacing without testing each time the instrument is used. A stereoscope with adjustable lenses that can be spaced to each individual's eyes should be used for photo interpretation rather than one with fixed lenses.

To see stereoscopically, some control of the eyes not exercised in ordinary vision is essential. One of the simpler ways to develop this control requires but two sheets of paper with a horizontal line drawn on one and a vertical line on the other. Place one sheet below the left-hand lens of a stereoscope and the other below the right-hand lens. Focus each eye on the line appearing directly below. Hold the left-hand sheet in place and move the right-hand sheet slowly to the left or right (fig. 12). When the horizontal and vertical lines appear in the form of a cross rather than as two separate lines, the view is stereoscopic. Blinking first one eye and then the other while bringing the two images into focus may help.

A piece of cardboard placed perpendicularly between the stereoscope lenses may help keep the lines of sight parallel and help train each eye to focus separately on its subject. This exercise may tire eye muscles but will not harm them.

To practice, after the cross appears move the left-hand sheet until the vertical and horizontal lines again separate. Then, shift the sheets until the lines join once more in a cross. Repeat until "fusing" is done rapidly. Note the location of each sheet with reference to the stereoscope lenses when the lines are fused into a cross.

The centers of the lines should be 2 to 3 inches apart under the pocket stereoscope and about 9 inches apart under the usual mirror stereoscope.

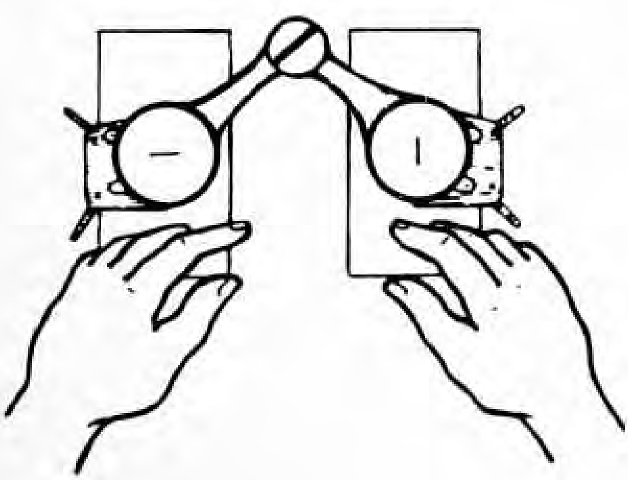


Figure 12.—Location of sheets under stereoscope.

Removing and replacing the sheets trains the eyes to focus on the lines. When the lines can be rapidly fused into a cross, stereoscopic viewing of aerial photographs may be started.

Mounted pairs of stereoscopic pictures are helpful to practice viewing aerial photographs. They can be made by cutting 2-inch-wide strips covering the same ground area from adjoining aerial photographs. The strips are cut perpendicular to the line of flight. They are mounted on stiff paper so that images of identical ground points are opposite one another and about 2 inches apart. (See figures 20, 21, and 22.) Of course, the strip from the left photograph must be mounted on the left side. Mounted pairs that show particularly interesting terrain are especially helpful.

Stereoscopic pairs showing land with moderate relief and a distinct pattern of surface features should be selected for practice. The photographs should have equal tone and identical ratio scale. The optical center of each photograph is marked with a small cross (P_1 and P_2, fig. 13). Next, the optical center of each photograph is transferred to the other (P_1' and P_2'), and a straight line is drawn between the two crosses of each photograph. This line very closely represents the flight path of the aircraft. Because of crab, the lines may not be perpendicular to the photograph edges they intersect. The pair of photographs is now placed under the stereoscope so that the center-to-center line on one photograph is a continuation of the line on the other, and the photographs are overlapped so that the center of one photograph as at P_1 and its transferred location on the other photograph as at P_1' are separated by about 2 inches. Also, these lines must be parallel with an imaginary line drawn through the centers of the stereoscope lenses.

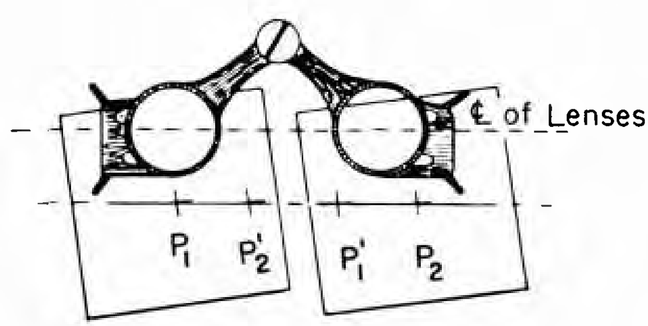


Figure 13.—Orientation of photographs for viewing.

The photographs should be moved toward or away from one another until the crosses and connecting lines are fused under the stereoscope. As soon as this occurs one of the photographs should be shifted until fusion is lost and then moved again until fusion is recovered. This should be practiced until many of the more prominent features can also be fused rapidly. One of the more difficult and most important steps is placing the two photographs in the proper position relative to one another and to the stereoscope. Even a slight twist from parallel creates additional distortion and causes eyestrain. Viewing at an oblique angle also increases the distortion. As skill develops, however, images are fused by observing the physical features rather than by matching the crosses and lines, and photographs without such lines can be used.

OTHER PROCEDURES AND DEVICES

Many details and devices will be discovered and developed as proficiency in stereoscopic work is increased. For example, each photograph should be equally illuminated without glare, and the light should be behind the stereoscope. Photographs should be oriented so that shadows extend toward the viewer and away from the light. Shadows extending away from the viewer may invert the stereoscopic image.

The inside edge of the top photograph is frequently lifted or rolled upward to view stereoscopically part of the bottom photograph otherwise obscured by the top photograph. Figure 14 shows a convenient holder for stereoscopic pairs which systematically bends upward the overlapping portion of the top photograph. When prints are too large to bend all the excessive overlap upward, a slot may be made in a table top or supporting base, through which the excess parts may be inserted and bent downward. Or this slot may be an inch gap between two tables. Except to provide the stereoscopic view, photographs should be kept flat.

Several devices for supporting the stereoscope over the photographs have been proposed. One device mounts a vertical rod at the rear of a table and has a horizontal arm to support and swing the stereoscope over the work surface (fig. 15, top). Another attaches the stereoscope to the flexible standard of a gooseneck lamp. A third uses an accordion telephone extension unit that has a terminal support with casters at the stereoscope end. Still another method attaches the stereoscope to a storm sash friction adjuster (fig. 15, bottom); the friction disks at the three hinge points eliminate wobble but allow horizontal movement of the stereoscope over the photographs.

A very handy method of supporting a stereoscope is shown in figure 16. Simple stereoscope lenses are mounted on a drafting lamp. The stereoscope may be moved over the photographs and the light is always in proper position for excellent illumination.

A desk stand for mounting a simple pocket stereoscope may be constructed as shown in figure 17. The legs of this support occupy positions beyond the stereoscopic working area.

For field use, a shelf has been designed for attachment inside the right-hand door of a pickup truck. The surveyor raises the shelf and puts photographs in position for stereoscopic study (fig. 18). Excess parts of the photographs are bent downward through a 1-inch slot. With this shelf a stereoscope may be used conveniently; the shelf is easily raised or lowered, and the car door can be opened or closed at any time; aerial photographs can be carried in place while the shelf is either up or down; the entire unit can be installed or removed without marring any part of the vehicle.

Figure 19 gives details for making an easy-to-use stereogram for field use.

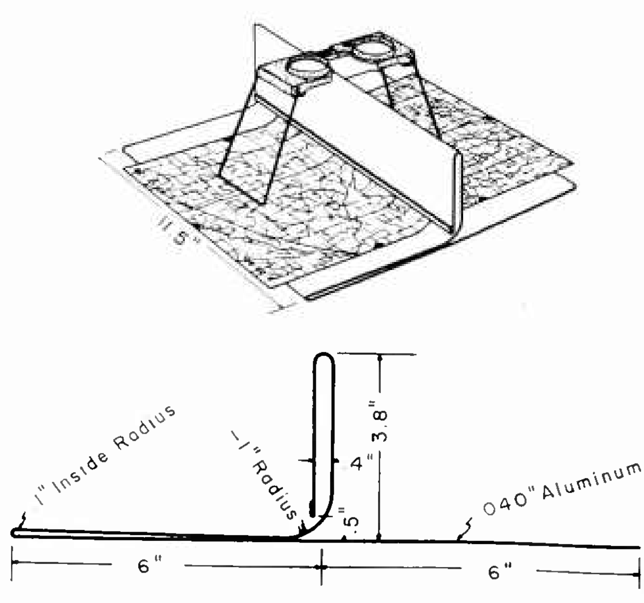


Figure 14.—Holder for stereoscopic pairs.

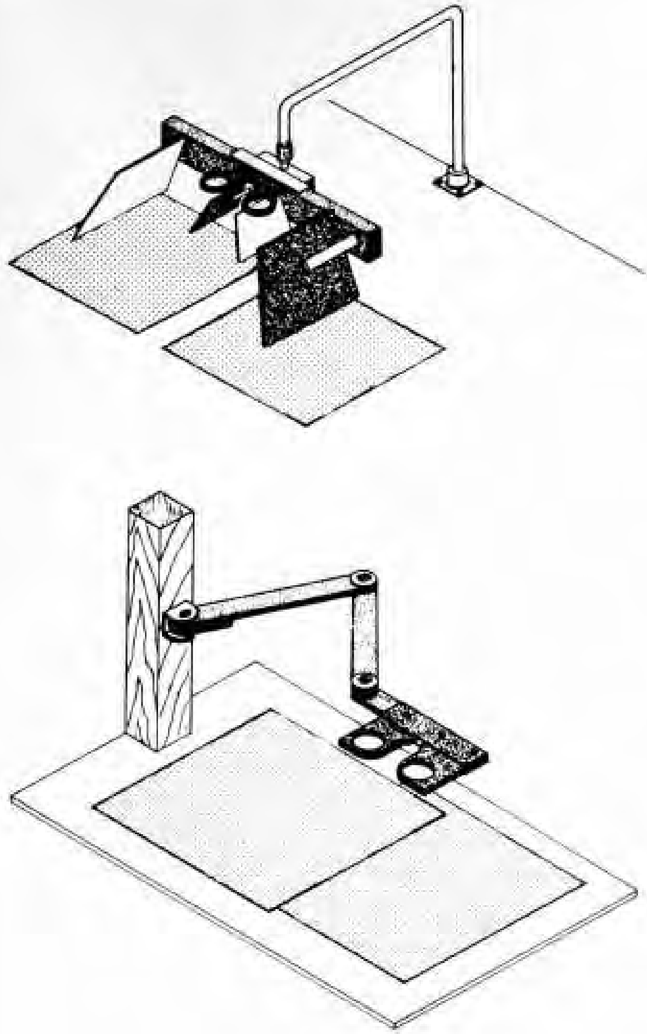


Figure 15.—Top, rod support for stereoscope. Bottom, friction sash adjuster as a support for stereoscope.

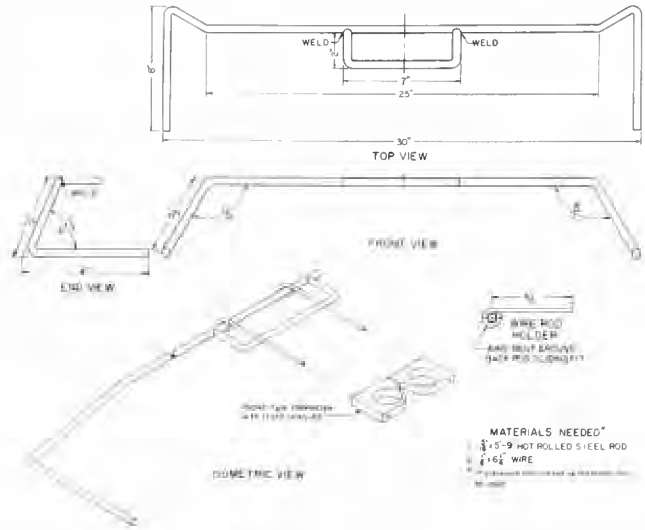


Figure 17.—Desk stand for pocket stereoscope.

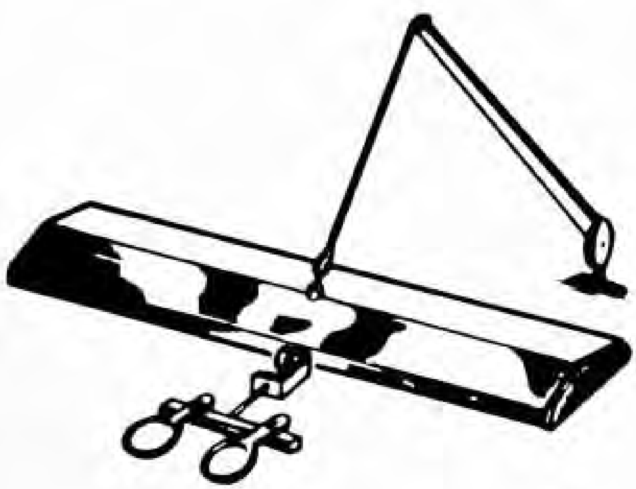


Figure 16.—Stereoscope mounted on drafting lamp.

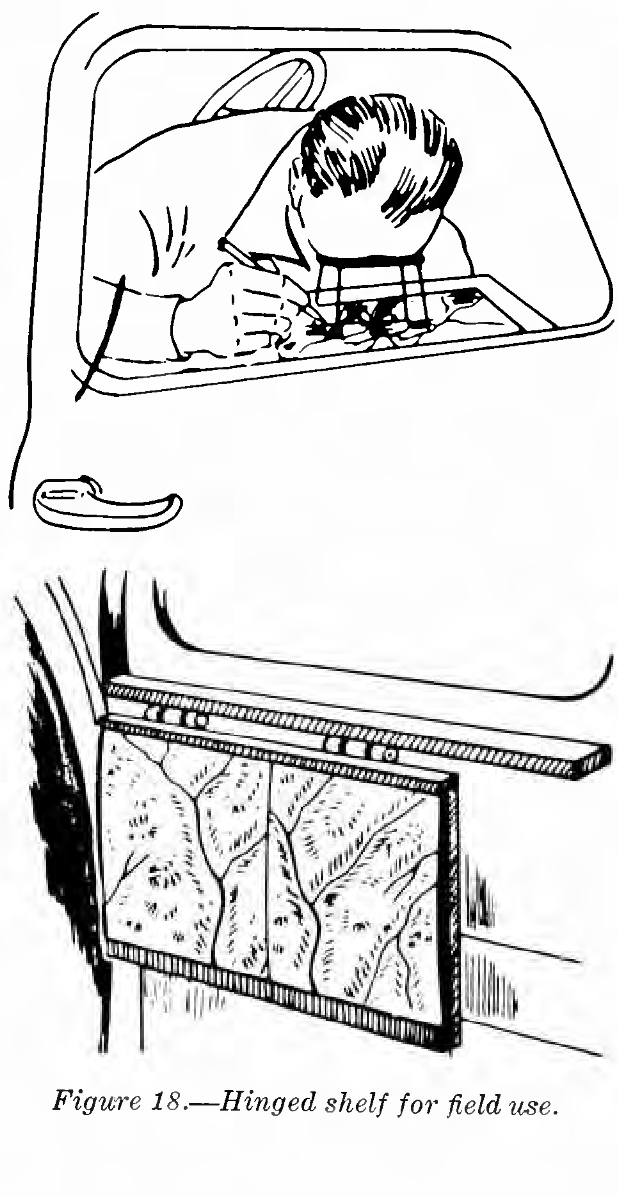


Figure 18.—Hinged shelf for field use.

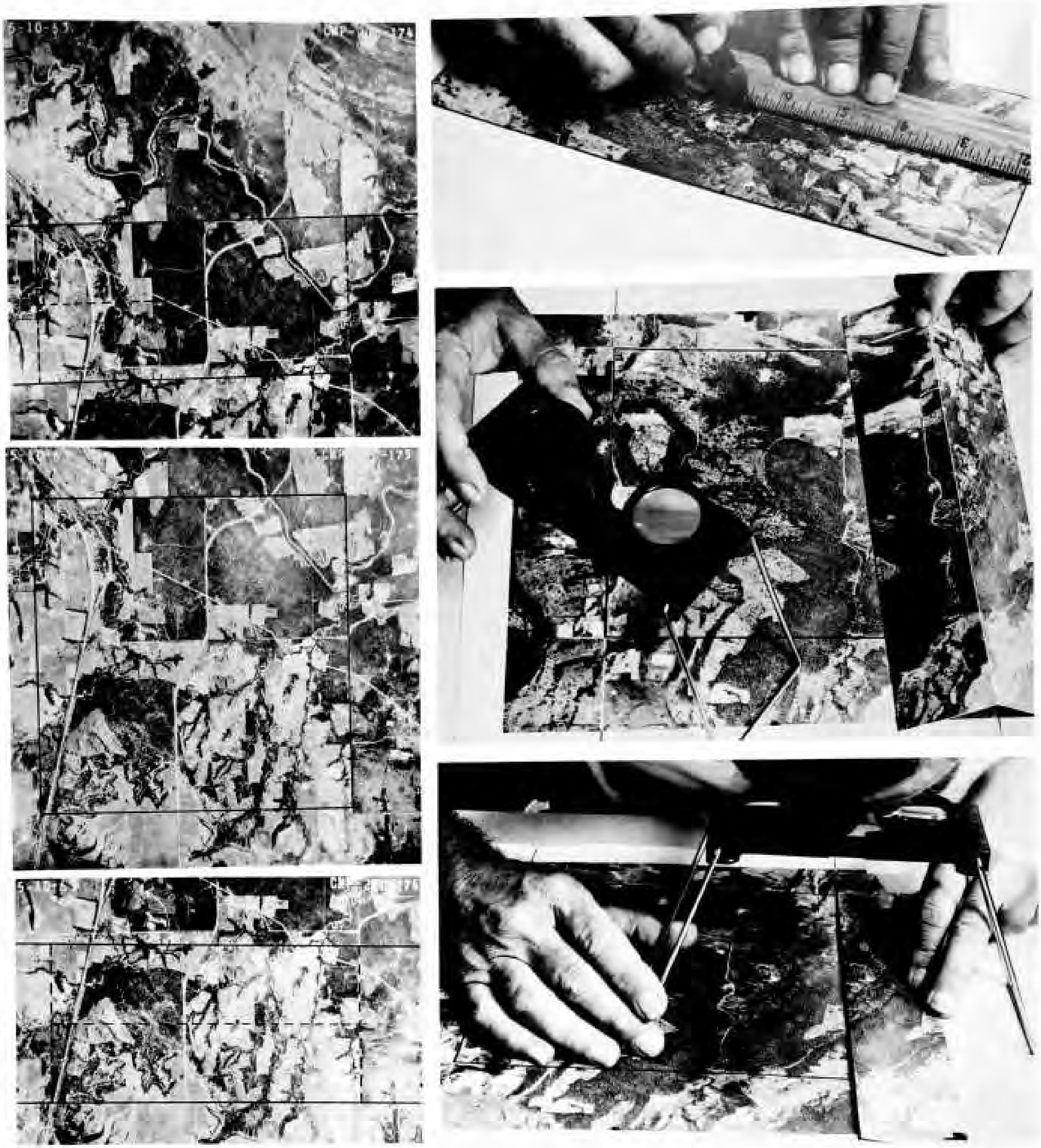


Figure 19.—Steps in preparing aerial photographs for easy stereoscopic viewing in the field: Mark match lines on mapping photograph (left center). On alternate adjacent photographs sketch exactly half of the mapping area (left top and bottom). With a sharp instrument, trim upper and lower lines on alternate photographs. Cut through the emulsion only across the center of each trimmed section (dashed lines, left top and bottom) and fold along the cut line with the emulsion side out. Position the trimmed sections for stereoscopic viewing (right center) and tape them outside the viewing area (right bottom). Fold under for viewing the edge of the mapping photograph (right bottom) and out for viewing the center.

SOIL INTERPRETATION FROM AERIAL PHOTOGRAPHS

Aerial photographs are widely used as a base on which to plot data about soils and to draw boundaries between kinds of soil with or without the aid of a stereoscope. Stereoscopic interpretation of aerial photographs gives a soil scientist additional clues about the kinds of soil he is likely to find and especially about where the soil boundaries lie. There are of course limitations. No one can "see" a soil on an aerial photograph. A soil is a three-dimensional unit of the landscape. It has depth. From the picture the soil scientist can see only the surface—and that imperfectly. He can see the third dimension only by digging a pit.

Yet the study of aerial photographs gives important clues about the shape of surfaces, the vegetation, and the soil color. Often these patterns are repeated over large areas. By studying examples of landscapes that make up patterns along with excavations and borings, and supplementing these with laboratory data, the soil scientist can learn the local relationships between specific kinds of soil and patterns in the photographs. This helps him in plotting soil boundaries more accurately and rapidly. It helps him with exploratory or reconnaissance soil surveys that are often made before detailed soil surveys of specific parts of a large area or region. Even so, limitations in such observations can only suggest soil identification in detailed surveys. Many soil surveys are used as a basis for predicting the systems of soil and crop, range, or forest management that can be carried economically on a sustained basis. This involves specific predictions about adapted crops and the yields that may be expected of these crops by kinds of soil under alternative systems of management. To be reliable, the kinds of soil and the soil mapping units must be identified from ground observations. The principle here is not one of "either-or." Even though we cannot make a reliable soil map from examining aerial photographs alone, the photographs should not be ignored; soil maps can be made more accurately and more rapidly with good photo interpretation than without it.

Exploratory or reconnaissance soil surveys have an important place in areas having little soil suitable for cropping or in areas where the proportion of soils suitable for cropping is unknown. If sizable areas of soils suitable for intensive use are discovered by these surveys, they can be covered by detailed soil surveys for planning such use. Approximate identification of the kinds of soil can be made by interpretation of aerial photographs, and a suitable soil map can be produced provided that adequate examples of each kind of soil have been studied on the ground.

It is extremely important that the limitations of photo interpretation in soil mapping be understood. Some so-called "soil maps" have been made with little or no groundwork by soil scientists. Since soil maps made in this way are bound to be misleading if used for giving the definite recommendations that land users require, such work discredits both soil science and photo interpretation of aerial photographs.

There are several reasons why one cannot expect to produce accurate soil maps from aerial photographs alone. For example, certain kinds of trees and other native plants in one combination of climate and landform indicate a soil suitable for agriculture; in another combination of climate and landform the same or similar plants are not reliable guides. Man has played an important role in altering the relationships of vegetation, climate, and landform. He has removed or drastically altered the original vegetation in many places. Even though wild plants have been allowed to return, they may not be the same kind of plants as were there earlier. The soils in the northern Lake States illustrate how misleading vegetation can be. If the soils have been cut over and not burned, one type of forest comes back. If they have been cut over and burned, another type appears. If the burning continues for many years, still another type will occupy the soil for some time. Other areas of these soils may have been cultivated a while and then abandoned to wild plants of still a different association. Some places take 200 to 300 years for anything like the original vegetation to return. Unless these matters are made clear through ground study and unless the interpreter is familiar with this detailed knowledge the chances for error are great.

Most soil maps are made for giving information to land users about how the soils respond to management that involves substantial changes in the soil. On the whole, crop plants require a considerably higher nutrient status of soil

780-309 O—66——4

than do wild plants. Many soils that appear to be infertile in a wild landscape can be made productive through the use of chemicals, water-control practices, and proper plant species. Other soils that look the same to a casual observer cannot yet be made productive perhaps because of certain characteristics beneath the surface or perhaps because science has not yet found out how.

All soil scientists and students of plant geography are familiar with the close relationship in many places between kinds of soil and nature of the parent material, relief, climate, vegetation, and age of the landform. Thus broad soil zones do correspond roughly to broad climatic and vegetation zones. Yet near the margins between these zones some small factor such as wind velocity or amount of calcium carbonate in the parent rock may throw the soil along one course of development or another. In large parts of western Alaska for example wind velocity has probably kept the trees much farther east than they would otherwise have been. And in the Mediterranean region, differences in hardness of the calcareous rock cause sharp contrasts in soils lying side-by-side.

IDENTIFICATION ON AERIAL PHOTOGRAPHS

Before aerial photographs can be interpreted, the ground features on the photographs must be identified. Identification is by direct recognition or deduction or a combination of the two.

Objects that make well-defined or familiar images can be identified by their shape, size, and tone on single photographs or on stereoscopic pairs. Road networks, farm buildings, fields, vegetation, and bodies of water can be identified on a single photograph by shape and variation in tone. Position of objects in relation to other features helps identify the objects. Information about land use and management practices also can be learned from single photographs. Additional features are likely to be identified if stereoscopic pairs are viewed through a stereoscope.

VARIATION IN TONE

The tone of an image on a photograph depends on the amount of light reflected by the object that forms the image. Objects that reflect most of the light striking them appear light on a photograph; those that reflect a small amount of light appear dark. On photographs the tones are mainly shades of gray, but they may cover the complete range from black to white.

The amount of light reflected from an object depends on the nature and color of the surface of the object, the degree to which the object is exposed to the sun, and the angle of reflection from the object to the camera. The smooth surfaces of roads and of dry, bare soil photograph almost white from a wide range of camera positions because they reflect much light in many directions (fig. 20). Bare, moist soils photograph darker than do bare, dry soils. Mirror-smooth bodies of water reflect a high proportion of light in a single direction and photograph white if the light is reflected directly into the camera (fig. 21). They may appear very dark or black on aerial photographs (fig. 22) if the camera lens is moved out of the line of reflected light. Most objects in the landscape, however, reflect at least a small amount of light.

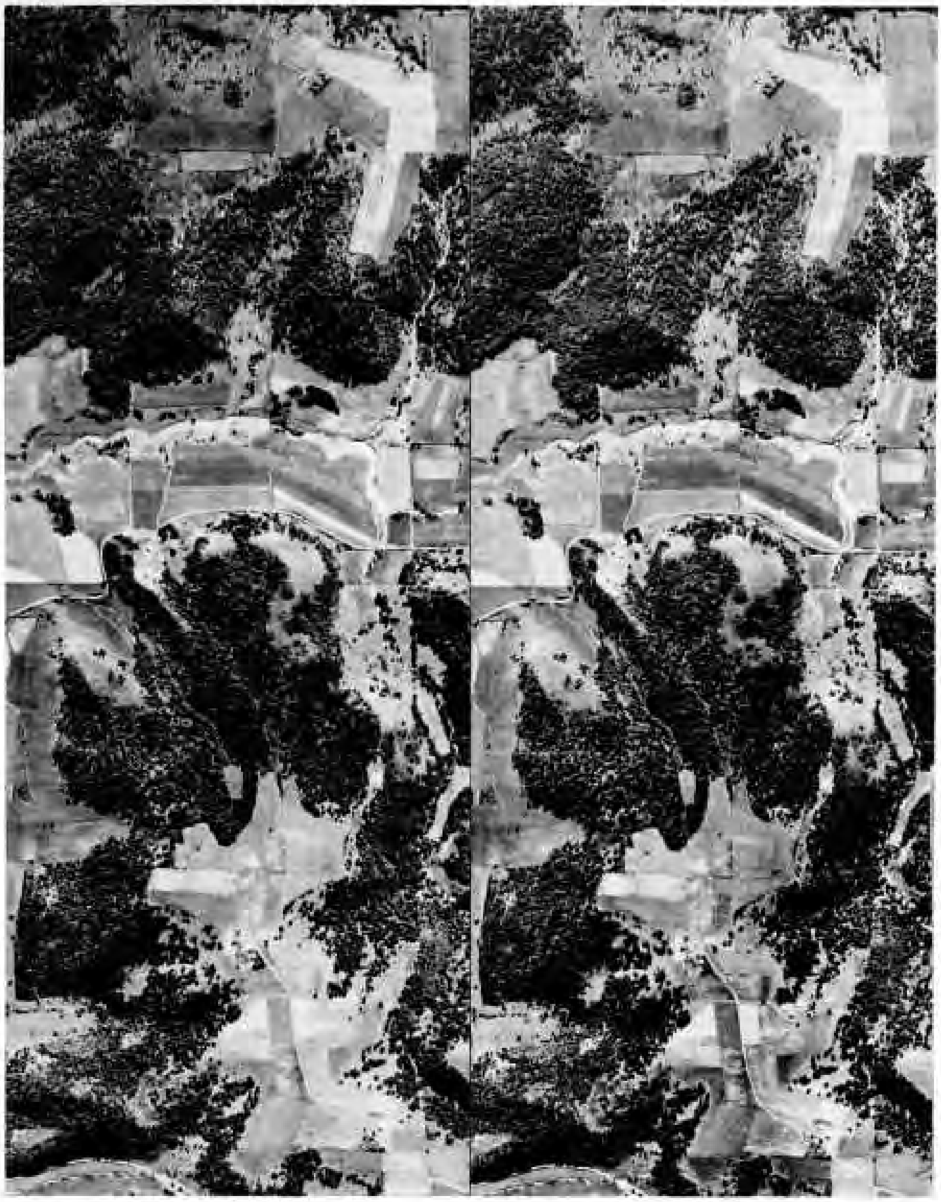
EVIDENCE OF SLOPE

A surface reflects the greatest amount of light when its slope reflects the sun's rays directly into the camera and photographs lightest at this time. Thus, in any single photograph, if differences in slope of the landscape are sufficient, these differences cause variations in tone on the photograph. From the difference in tone, slope can be inferred. Frequently differences in slope not disclosed by inspection of a single photograph can be discerned by comparing two photographs of the same area taken at different times. The change in position of the sun changes the angle of reflection and shows evidence of slope.

Evidence of slope derived by comparison of tone is particularly useful in forested areas where minor variations are obscured by trees and do not show in stereoscopic observation. Trees appear lighter in areas sloping toward the sun than in areas sloping away from the sun.

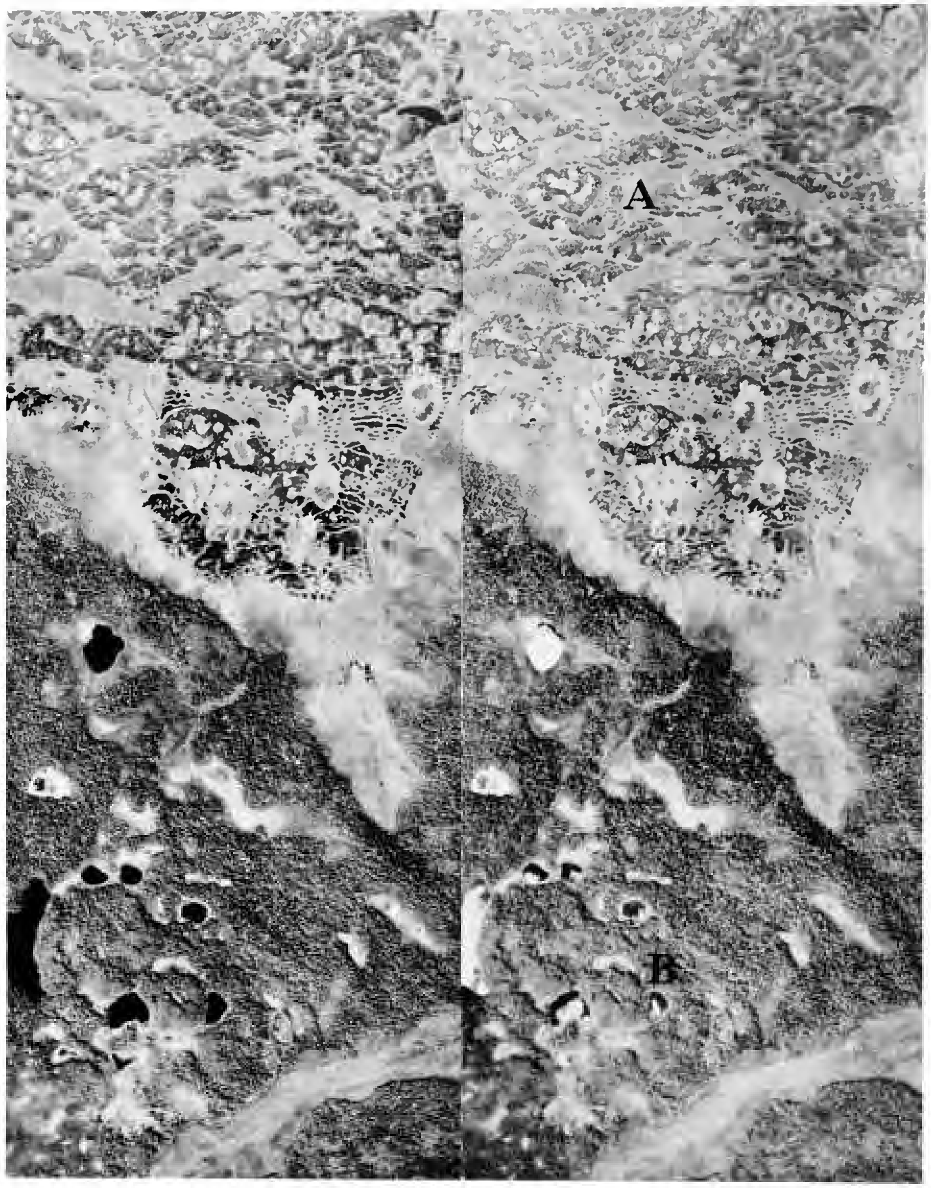
SHADOWS

Shadows covering relatively large areas suggest that the landscape has steep slopes and high landforms (figs. 23 and 24). The length of shadows varies with season of year as well



SCALE 1: 20,000 NA—SP-1A-36; SP-1A-37

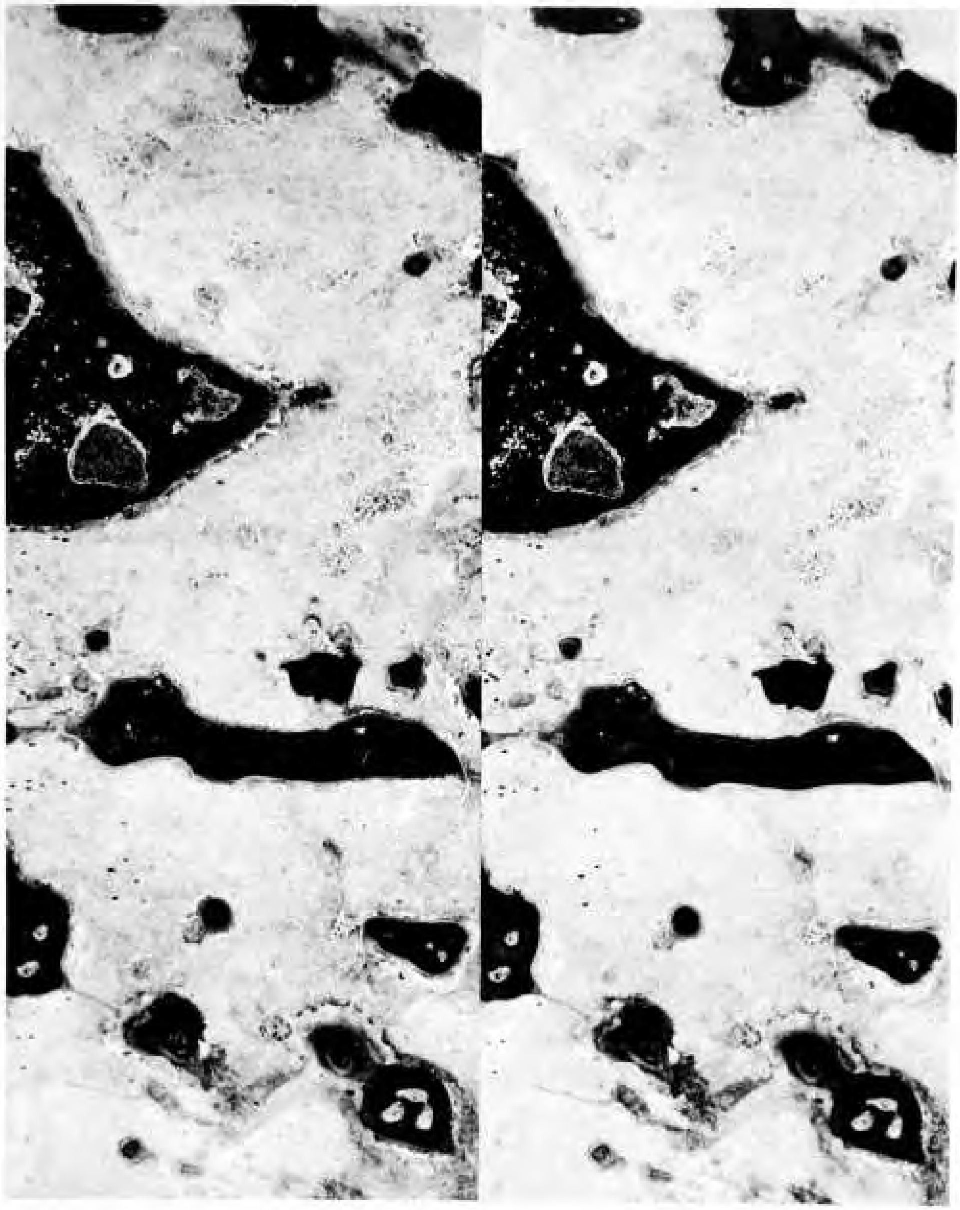
Figure 20.—Roads photograph as narrow white lines with sharp boundaries. Light tones of unforested uplands and stream terraces represent Gray-Brown Podzolic soils. The mottled dark tones represent forested areas mainly of rough stony land or limestone outcrop land.



SCALE 1:40,000

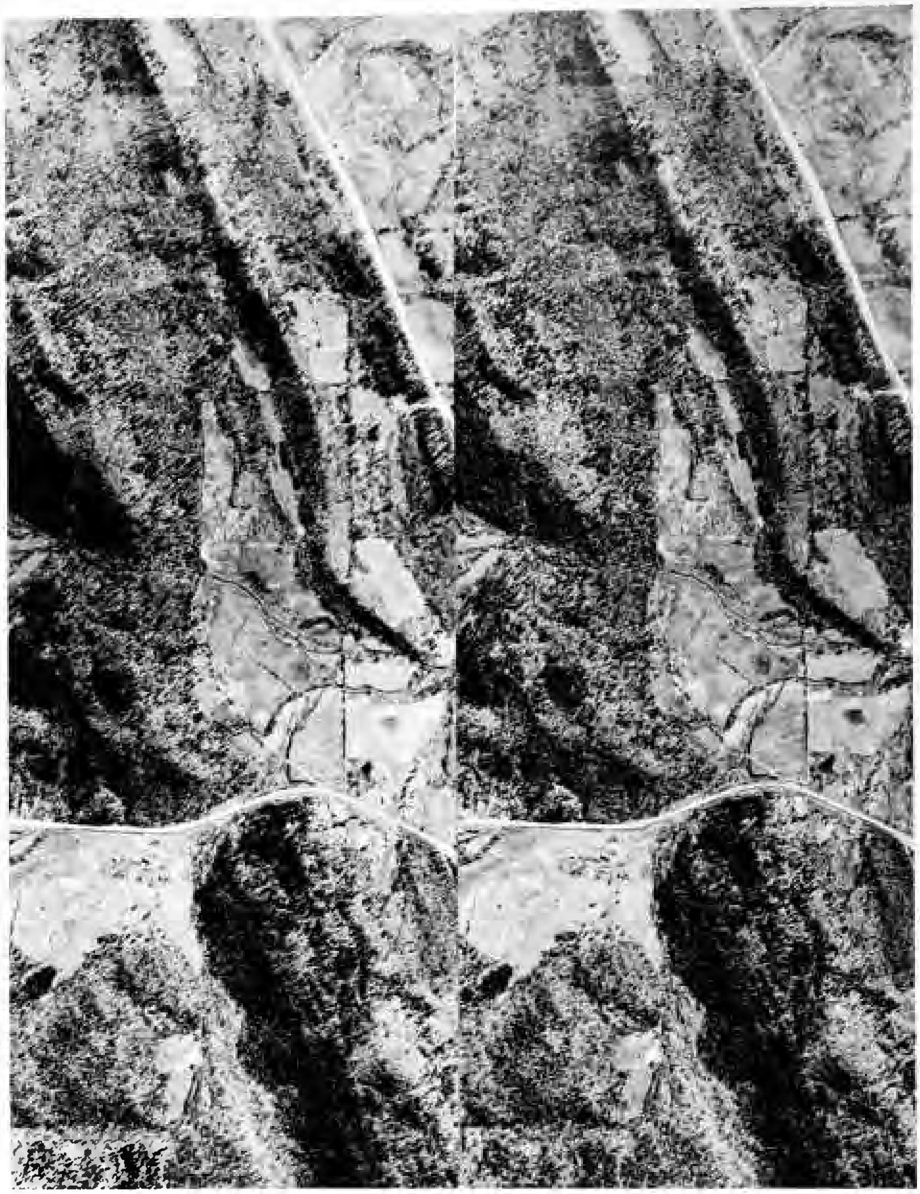
USGS—M-351-88; M-351-87

Figure 21.—Contrasting tones of two images of the same body of water in Alaska, one white and one very dark gray, show the effect of shift in camera position. In the upper part, labeled A, is the typical mottled image that represents sphagnum peat (muskeg) without permafrost. The part labeled B represents hilly glacial moraine with lakes and smaller muskegs.



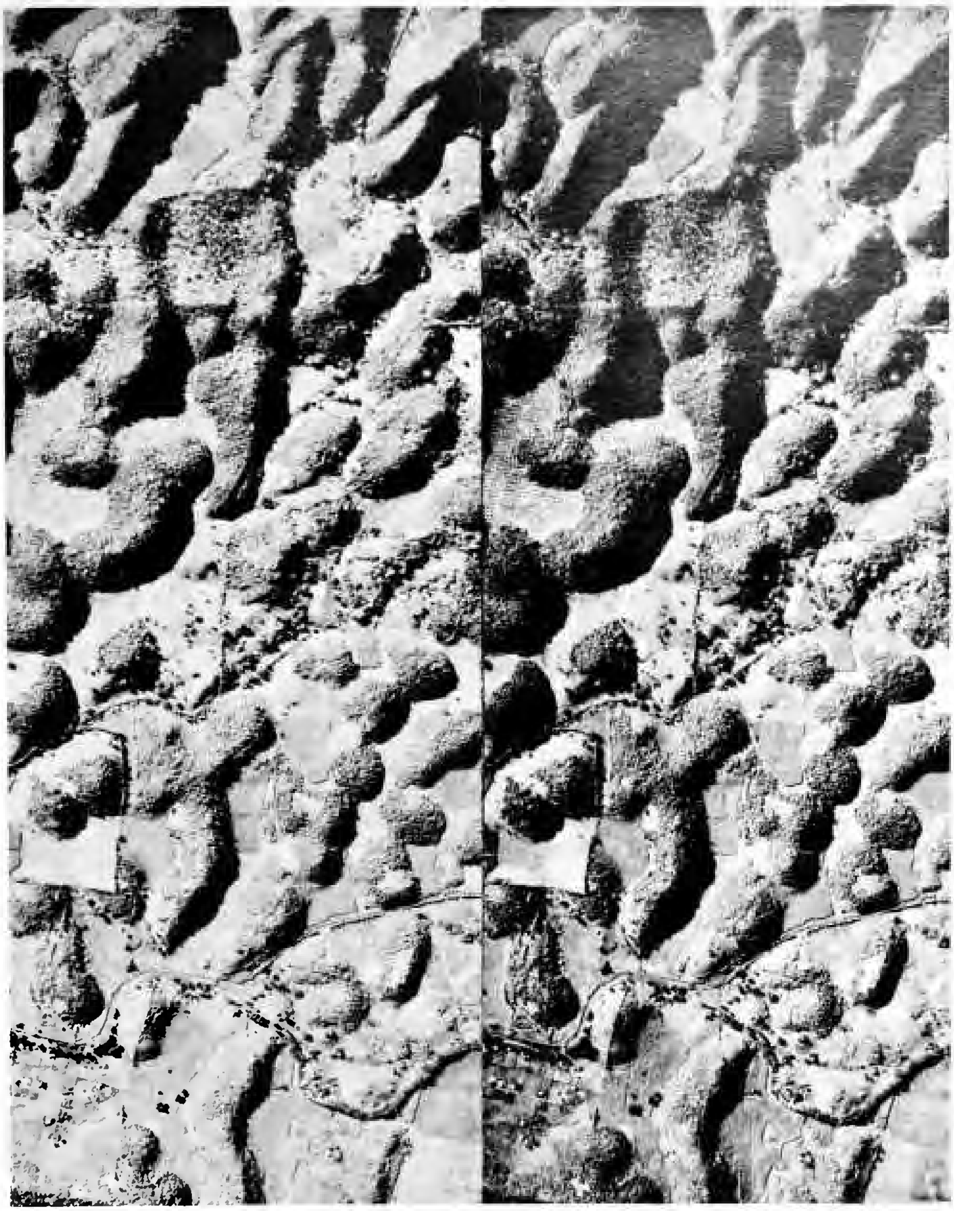
SCALE 1:20,000 ASCS—CYW-4H-90; CYW-4H-89

Figure 22.—The light and dark tones on these photographs of acid sandy flatwoods in southern Florida indicate soil differences and bodies of water. The large black areas are images of water. The mottled, very dark, small, rounded spots represent basins of Low-Humic Gley soils and the light-gray background, Ground-Water Podzols between the depressions.



SCALE 1:20,000 ASCS—BPV-3G-80; BPV-3G-79

Figure 23.—Shadows in dark tones on northwest slopes (north is to the left) suggest steep slopes and high landforms in an area of shale and sandstone in Arkansas. Knowledge of the soils on opposite slopes, which differ in lithology, permits a soil scientist to make reasonable deductions about the soils photographed.



SCALE 1:15,000

DEPT. OF PUB. WORKS, SANTURCE, P.R.
GS-LR-5-20; GS-LR-5-21

Figure 24.—The pronounced relief of this area in north-central Puerto Rico is apparent from the shadows of the forested hills and the topographic contrast is striking even without a stereoscope. Most of these extremely steep hills have rounded tops; a few are somewhat elongated.

as with time of day. The forms of shadows can be used to identify some structures and certain other cultural and natural features. For example, the image of a bridge may not show whether the bridge is supported by a trestle or an arch, but the shadow cast by the bridge may.

CONTRAST

Contrast refers to distinctness of tones as opposed to gradations in tones. Black and white are the extremes of contrast. Photographs with very dark and very light tones and only a few middle tones have high contrast.

The amount of contrast is determined partly by variations in the capacity of objects to reflect light and partly by the clearness of the atmosphere and by the photographic techniques used. Atmospheric haze scatters light and reduces contrast. The contrast in photographs taken on bright days is greater than in photographs taken on dull days. Soil when wet absorbs light and photographs darker than when it is dry. Contrast changes from season to season but not uniformly from region to region.

A land surface broken by variations in kinds of slope, by differences in soil, vegetation, and land use, and by manmade objects will have more contrast than a land surface fairly uniform in topography, soil, and land use. A hilly landscape in the Southeast that is marked by forests, fields in crops, freshly plowed land, and severely eroded patches produces a photograph with more contrast than a smooth area of rangeland or desert in the Southwest.

Contrast can be increased or decreased by varying the exposure time or the time for developing film and by the paper used for making prints.

SHARPNESS OF BOUNDARIES

The sharpness of boundaries between tones is affected somewhat by the photographic techniques used, but the distinctness of boundaries will differ for different objects. Boundaries of forests, wet areas, and topographic features are generally diffused; boundaries of fields, bodies of water, highways, and railroads are usually sharp.

TONE PATTERNS

Certain landforms and culture have characteristic tone patterns on aerial photographs. Forests, fields, crops, and orchards frequently show distinguishing patterns as do networks of streams, roads, or ditches. The photo interpreter learns the characteristic patterns of the area—for example, dendritic or parallel patterns of drainageways—and uses these to help him identify objects. Figures 25–34, 39, 45, 46, and 56 illustrate various tone patterns.

PERCEPTION OF DEPTH

Some topography difficult to deduce on a single photograph may be seen readily by viewing stereoscopic pairs (figs. 32, 33, 34, and 35). Many items not identified readily on a single photograph are easily recognized; items distinct on a single photograph can be observed in greater detail. Everything that reveals itself by shape and even slight differences in tone generally can be identified with greater certainty.

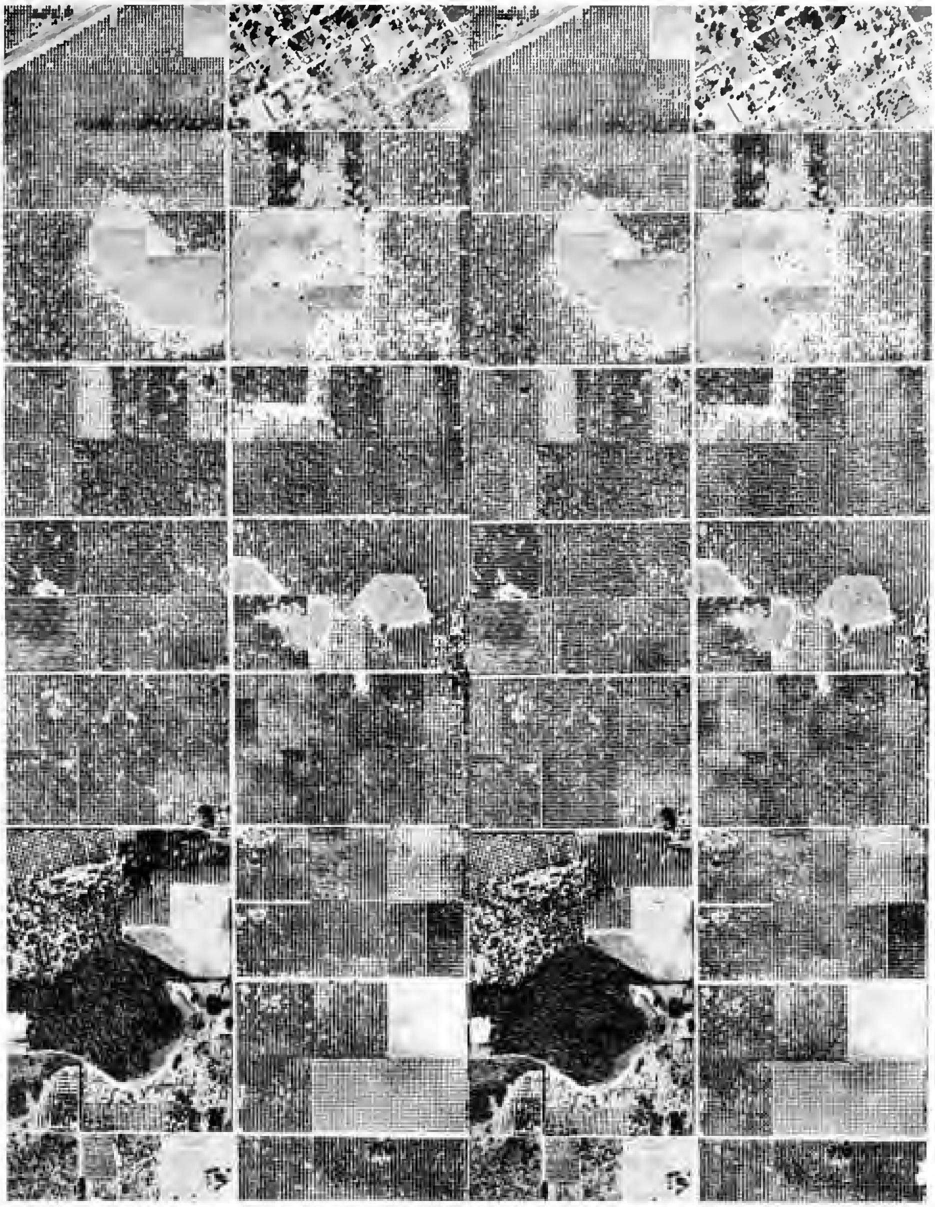
With depth perception to aid him, the soil scientist needs only a little practice to distinguish rough mountains and steep, hilly, rolling, or level areas. He can improve his ability to recognize certain landscapes by frequently comparing the topography as it appears on stereoscopic pairs with its appearance on the ground.

IDENTIFICATION OF LANDFORMS AND OTHER NATURAL FEATURES

Natural features are generally more difficult to detect than are manmade objects or cultivated fields and other areas where man has disturbed the native cover. Low natural hills, for example, generally are more difficult to detect than are embankments because embankments have steeper slopes and more regular lines.

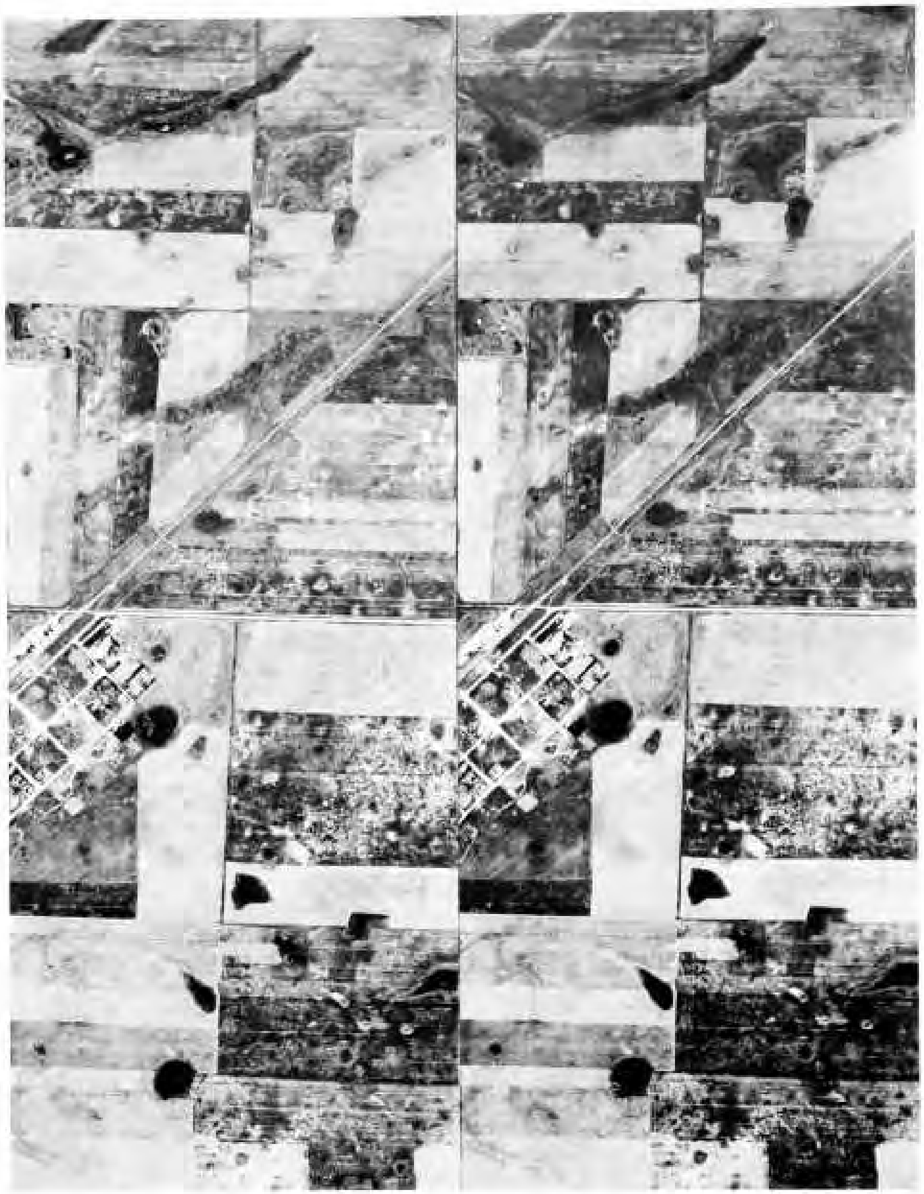
Some simple landforms such as terraces, flood plains, and sand dunes (fig. 36) can be identified by their shape, relative height, slope, and drainage pattern. Identification of features such as ground moraines, shale plains, and limestone uplands is difficult and can be inferred only in part by studying aerial photographs.

Ground Moraines.—Ground moraines in many places produce contrasty photographs because they have many small, shallow, irregularly shaped depressions and intervening gentle slopes. The slight difference in elevation between depressions and intervening slopes can be discerned on a stereoscopic pair. Soils in the depressions photograph dark; others photograph light. (See figure 45.) If there is a



SCALE 1:20,000 ASCS—CTU-13H-55; CTU-13H-56

Figure 25.—These photographs show the characteristic field patterns of Florida citrus orchards on acid, coarse-textured soils. The citrus trees photograph as black dots within the rectangular fields.

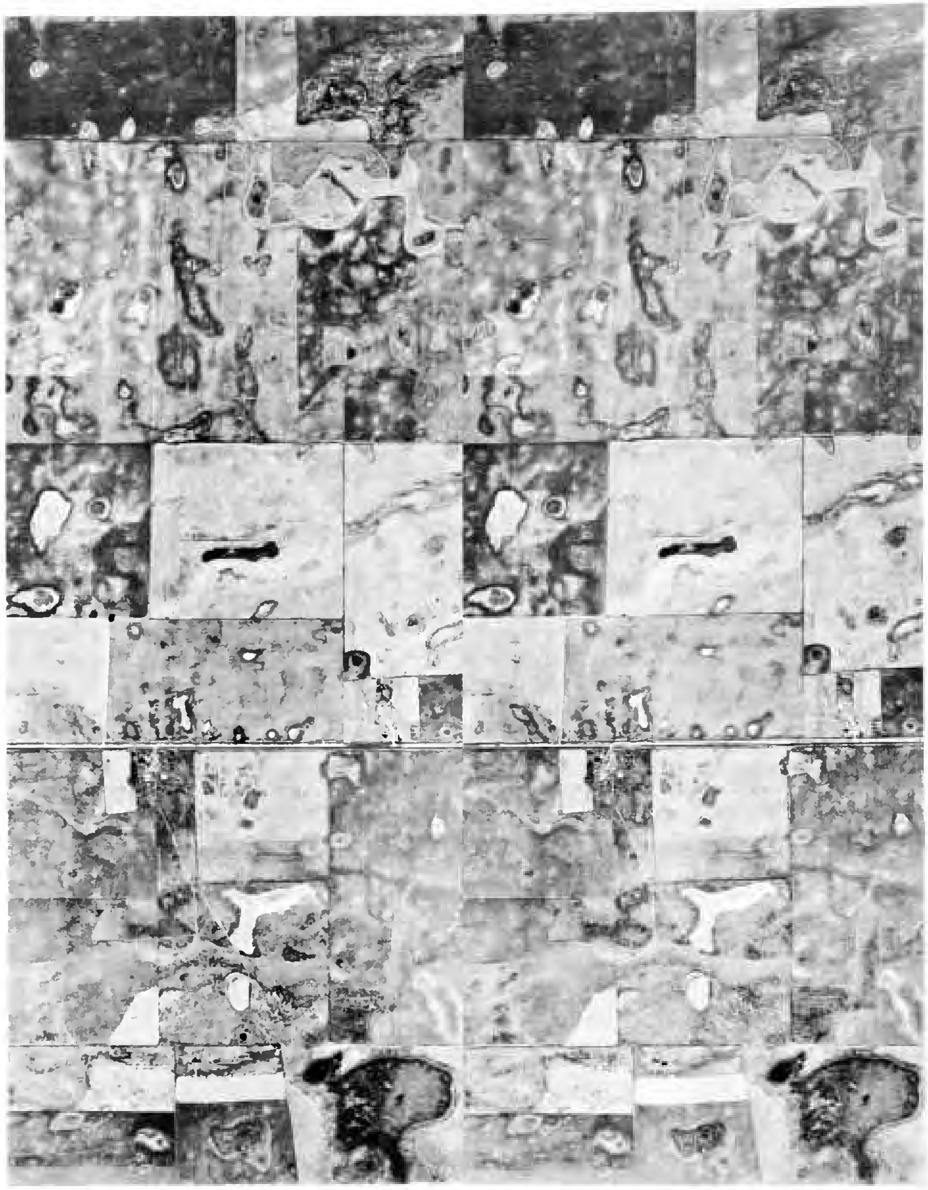


SCALE 1:20,000 ASCS—BAM-9M-136; BAM-9M-135

Figure 26.—In these large rectangular fields in North Dakota the speckled pattern of very light tones against a darker background shows a complex association of Solonetz soils (light tones) and Chernozems (gray background). Where the speckled pattern is absent the soils are mainly Chernozems. The isolated, very dark spots indicate somewhat poorly drained to poorly drained Planosols in depressions. The cluster of small rectangles in the center represents a small town.

SCALE 1:20,000 NA—BCM–1–47; BCM–1–46

Figure 27.—In this area of uniform lithology in Ohio, distinctions between soils are closely related to topographic variations readily recognized under a stereoscope. Soils on flood plains, on drainage divides, and on steep valley sides can be easily delineated. White streaks with feathered edges and orientation with slope are likely to indicate eroded areas. White streaks oriented laterally on steep valley sides may indicate rock ledges.



SCALE 1:20,000 ASCS—CWM-3K-183; CWM-3K-182

Figure 28.—The mottled pattern of light and very dark tones on a gray background represents an association of calcium-carbonate Solonchak soils, Humic Gley soils, and Chernozem soils on the till plain in North Dakota. The Solonchak soils photograph light. Those somewhat poorly or poorly drained have a finely mottled appearance and are within or adjacent to kettles. Humic Gley soils, which usually register dark, occupy the deepest parts of the kettles. Kettles are small subrounded spots with sharp boundaries. The moderately well drained Solonchak soils have a patchy appearance and are in with Chernozem soils, the gray background in the photograph; the lightest shades indicate tops of low knolls or undulations. Compare the sharp outlines of the roads, fields, and images of buildings with the diffuse soil boundaries.

SCALE 1:20,000 ASCS—1Z-5G-181; 1Z-5G-182

Figure 29.—This pair of photographs of an area in Georgia illustrates differences in topography, land use, and drainage pattern between soils in limestone valleys and on adjacent ridges of metamorphic rocks. At B are Lithosols in residuum from schist. They are strongly sloping to steep and are forest covered; the drainage pattern is dendritic. Light areas marked **L** *are mainly Red-Yellow Podzolic soils and Alluvial soils. The Red-Yellow Podzolic soils, mainly on uplands, are in limestone residuum and are gently sloping to hilly. The Alluvial soils, on bottom lands along streams, are nearly level; the drainage pattern, modified by local sinkholes, is indefinite except along large streams.*

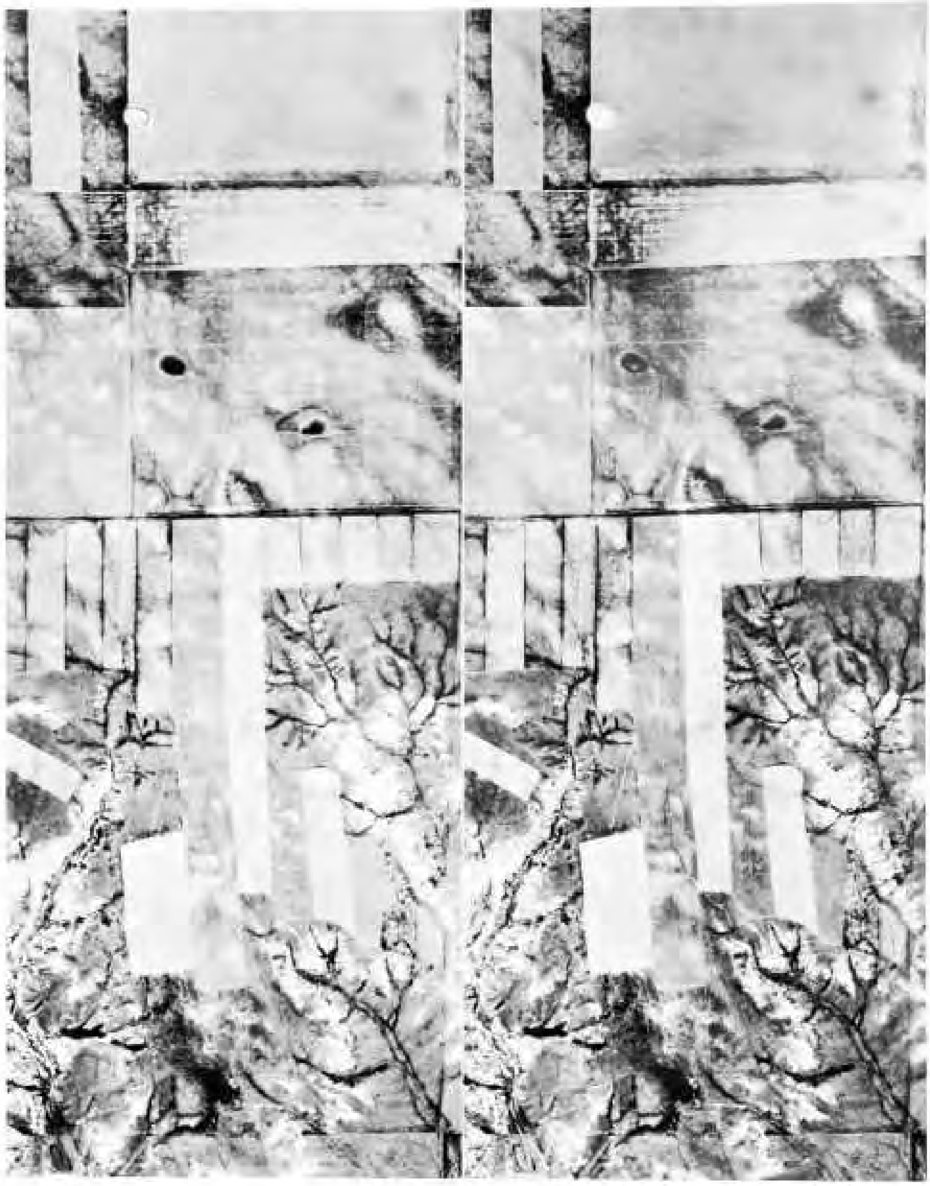
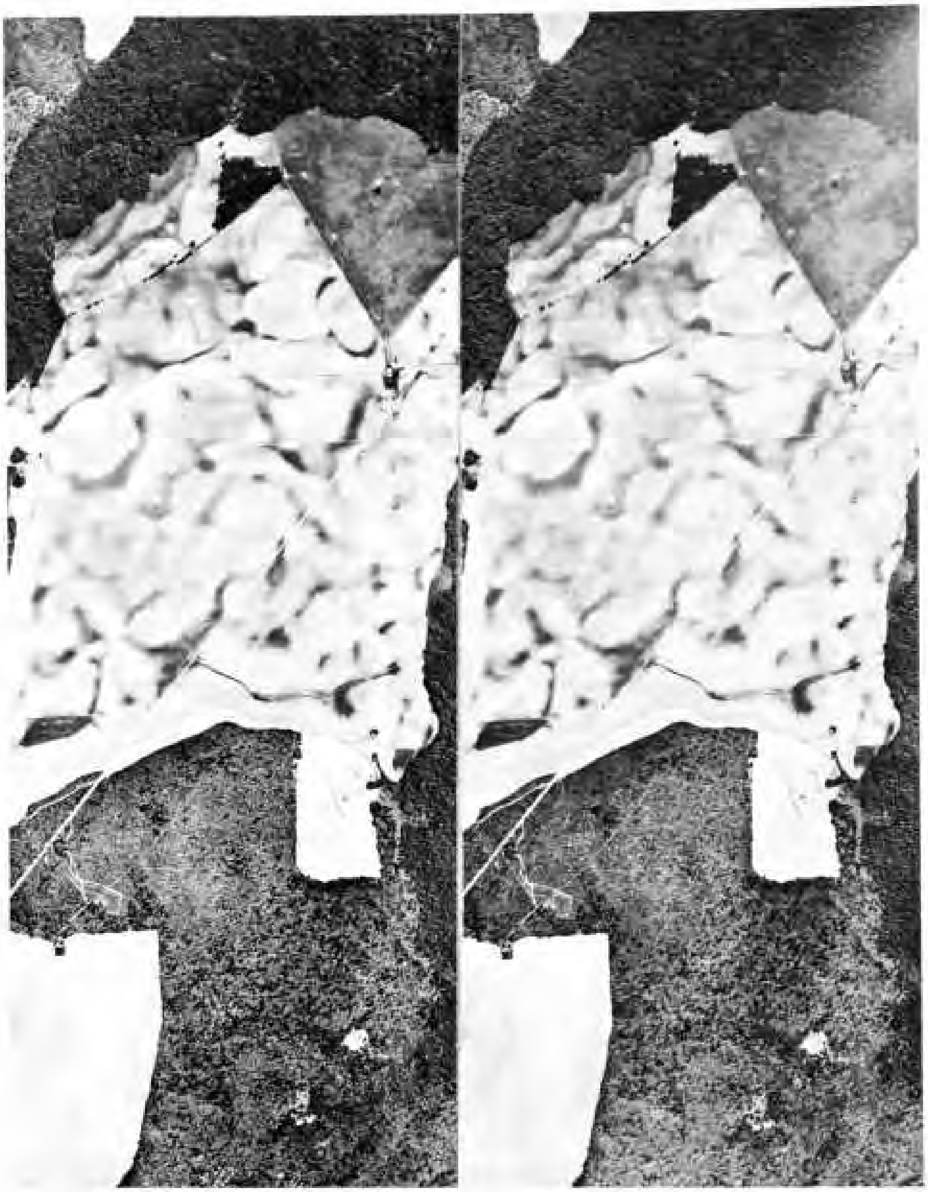


Figure 30.—The gray tone in most of these photographs represents moderately dark-colored Chestnut soils in thick deposits of loess in western Nebraska. The intensely mottled light-colored pattern in the lower part represents Lithosols, exposed residual parent materials, and rock ledges on the walls of narrow, steep-sided valleys. Narrow stream bottoms form a dark skeletal network. A gorgelike cross section is easily distinguished under a stereoscope as are hard rock ledges on the valley sides.

SCALE 1:20,000 ASCS—EK-2F-79, EK-2F-80

Figure 31.—The intricate pattern of light and dark tones shows a complex pattern of rapidly drained very sandy soils and poorly drained soils in Arkansas. The sandy soils register light and the poorly drained soils, occurring in flat or slightly depressed areas, register dark.



SCALE 1:20,000 ASCS—KM-JE-13F-12; KM-JE-13F-11

Figure 32.—The relationship of microrelief to soils on sandy terraces in parts of the Coastal Plain of the Southeast is apparent from the marbled pattern of these photographs. Well-drained soils that have fine-textured subsoils and raised flat to slightly convex surfaces are represented by the light tones, and poorly drained Low-Humic Gley soils in the slight depressions by the dark streaks. The microrelief cannot be seen without a stereoscope.

Figure 33.—As in figure 32, the marbled pattern illustrates the relationship of microrelief to soils on sandy terraces in parts of the Coastal Plain of the Southeast. These soils, however, are sandy throughout and lack the fine-textured subsoil of those in figure 32.

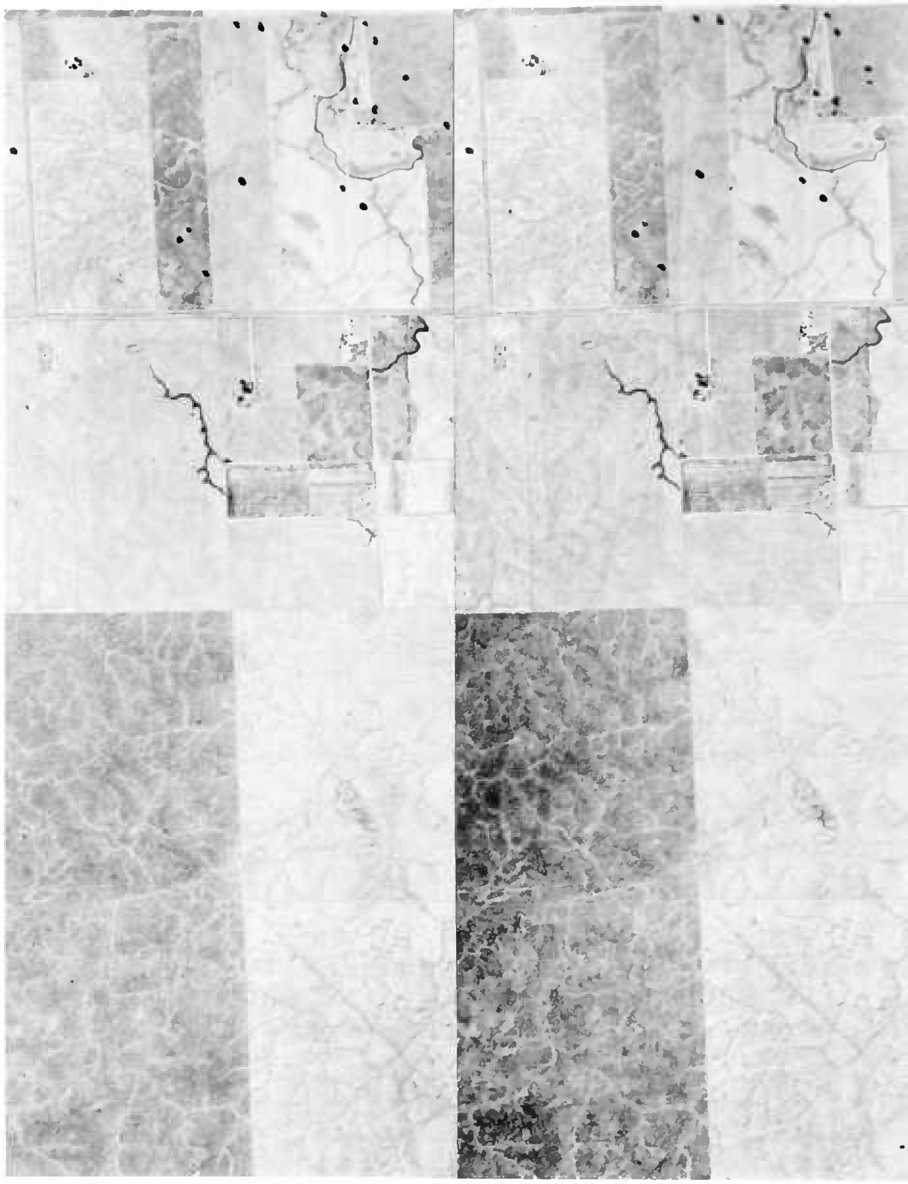
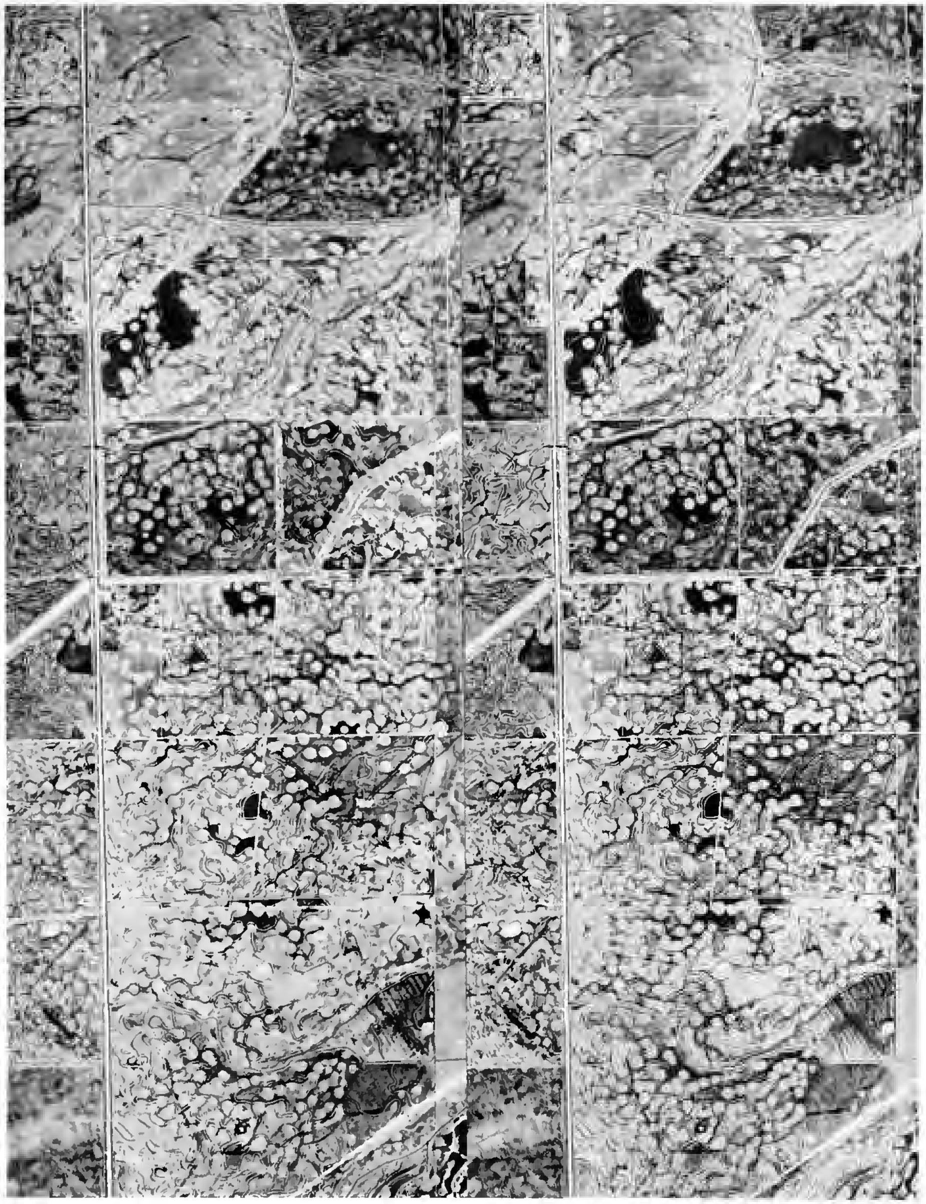


Figure 34.—The reticulate pattern of small drainageways and intervening low mounds in these photographs of an area in California illustrate soils with hardpans at depths of $1\frac{1}{2}$ to $2\frac{1}{2}$ feet.



SCALE 1:20,000 ASCS—CJY-1H-200, CJY-1H-201

Figure 35.—The mottles on these Louisiana photographs identify mounds 30 to 75 feet in diameter and 1 to 5 feet high. Most of the soils are medium textured; those in the mounds are sandier than those between mounds. The vertical shape of the mounds show under a stereoscope.

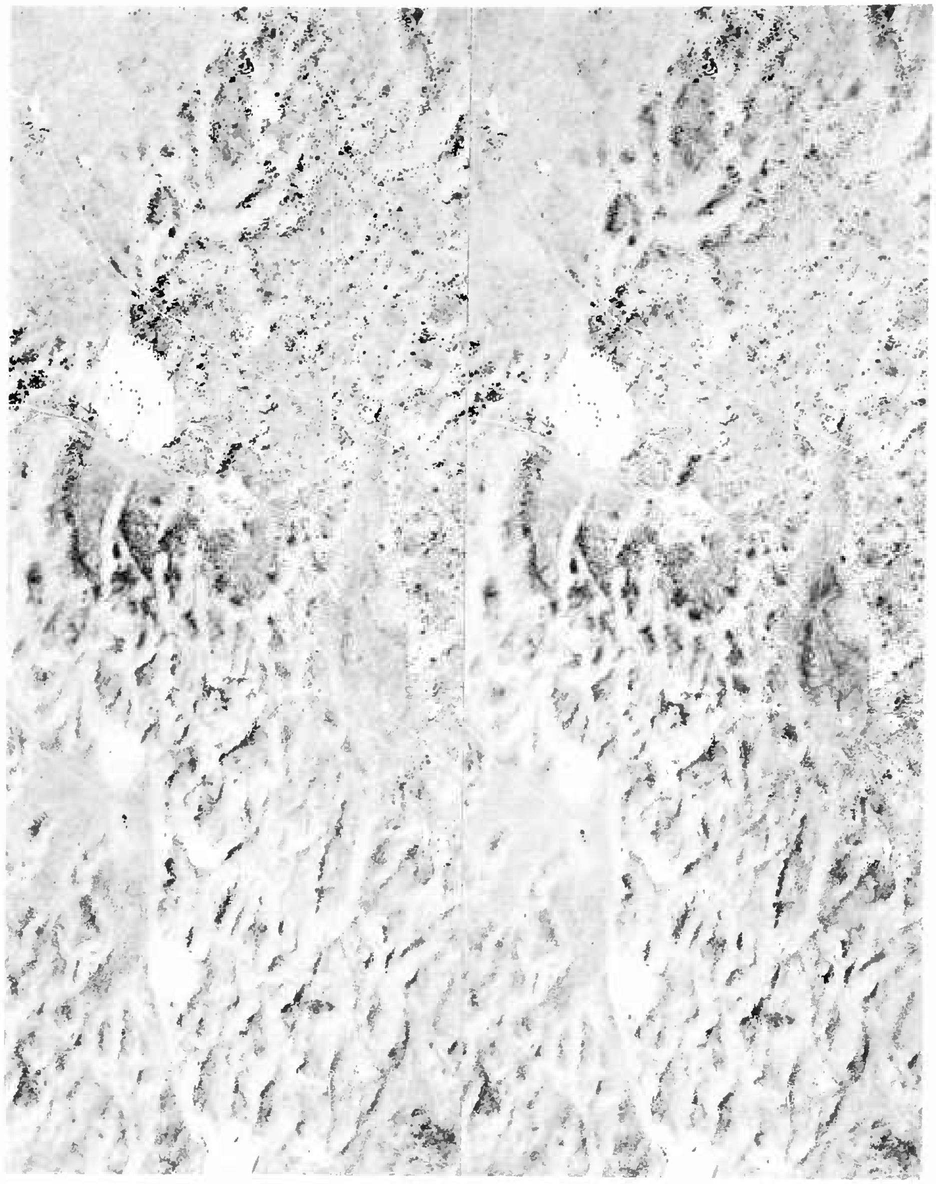


Figure 36.—This pair of aerial photographs taken in eastern New Mexico provides a striking example of how dune topography is revealed with stereoscopic viewing. The soils are sandy Regosols.

drainage pattern, it is weakly expressed and generally coarsely dendritic. Ground moraines that have few depressions and soils that photograph mostly in gray shades do not produce contrasty photographs. Instead of having many irregular depressions they have a dendritic drainage that is not strongly expressed.

Shale Plains.—Shale plains appear more rugged and dissected in a photograph than do ground moraines. Where shale is level bedded the drainage pattern is dendritic. Valleys are steep sided, and all except those of many major streams are V-shaped. Slopes of valleys, hills, and divides are influenced by climate and relative hardness of the shale. In arid areas, where rainfall quickly runs off and vegetation is sparse, soft or clayey shale carves into badlands that have angular valley walls. In humid areas, the hills in shale have rounded tops and the divides are narrow and winding. Hills are lower and more rounded in soft shale than in hard shale.

Limestone Uplands.—Limestone uplands produce a different picture than do shale plains. The differences are most apparent on stereoscopic pairs. Most landforms underlain by limestone with little siliceous material have many sinkholes. Hills are more rounded than in shale plains, streams are fewer and more widely spaced, and stream valleys are more U-shaped. In siliceous limestone there are fewer sinkholes and more tributaries to main streams, and valleys—except those of major streams—tend to be narrower and more steep sided than those in pure limestone.

Rock Outcrops.—Rock outcrops, except those of very dark color, appear as light spots. A shadow is often a clue to an escarpment; on a stereoscopic pair escarpments show as abrupt changes in elevation. Stone fences are clues to stoniness, but on aerial photographs they are difficult to distinguish from other fence rows or field boundaries.

Alluvial Fans.—Alluvial fans may photograph lighter than do adjoining flood plains. But the fans will appear darker if they contain more moisture than adjacent areas. If the outer rim of the fan is wet by seepage, it will appear darker than the inner part.

Alkali and Saline Patches.—Alkali and saline patches in arid regions appear as light spots when dry and as dark spots with white rims when wet. Where there is no white encrustation or other direct evidence of alkali or salts, the salinity of the area may be inferred from the absence of vegetation or from change in appearance of vegetation. Greasewood, for example, is a large shrub that grows in saline areas where other native plants may not survive.

Drainage Patterns.—In a single photograph, main streams ordinarily can be identified easily, but the irregular curved line of tributary drains are more difficult to recognize. Success in identifying the drainage pattern depends on the relief of the area, the number of tributaries, how easily they can be seen on the photograph, and their orientation to the main stream. Tributaries can be recognized by depth and shape of valleys and slope of valley sides. Figure 37 illustrates drainage patterns.

Under the stereoscope, stream courses in heavily forested areas can be located from the topography of the valley (fig. 38). Where the gradient is steep the direction of flow can be determined stereoscopically by noting vertical differences along the stream. If a single photograph is used, direction of flow has to be deduced from studying other evidence. The width, depth, and shape of a stream channel are best observed by stereo (fig. 39). Drainage patterns are more easily detected stereoscopically even in areas of weak dissection or otherwise subdued relief. Where there are no shadows in such areas, only the larger streams can be recognized in single photographs.

Eroded Soils.—A knowledge of local climate, topography, and soils aids in recognizing sheet erosion and gullying on aerial photographs.

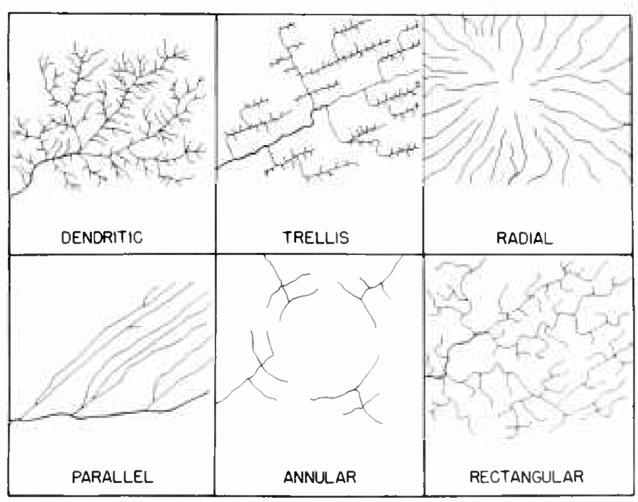


Figure 37.—Six drainage patterns.

Figure 38.—These Arkansas photographs illustrate how a stereoscope helps in delineating soils whose differences are related to topography. Red-Yellow Podzolic soils occupy the smooth upland, Regosols the forested steep valley sides, and Alluvial soils the flood plains of major streams.

SCALE 1:20,000 ASCS—BRG–1E–184; BRG–1E–185

Figure 39.—This stereoscopic pair of an area in Texas provide an excellent example of how erosion appears on photographs. Sheet erosion registers as light and very light areas with diffuse edges and gullies as white networks of long scars with irregular borders. Gullies and stream channels from weakly developed to deep and U*-shaped are readily recognized under a stereoscope.*

SCALE 1:20,000 NA—CCO–203–42; CCO–203–43

Figure 40.—These photographs show eroded soils and complexes of solodized-Solonetz soils and Chestnut soils from shales in southwestern North Dakota. Light tones that have diffuse borders represent eroded Lithosols or thin weakly developed Chestnut soils. The complex shows a reticulate pattern of light and dark, particularly in the upper parts of the photographs.

Sheet erosion may register in tonal differences and light patches. Seriously eroded areas not covered by vegetation photograph light (figs. 39 and 55). Light tones, however, are not always indications of sheet erosion. The soil scientist takes into account that steeply sloping soils are more likely to erode than those gently sloping, that in areas of subdued relief erosion is likely to occur at the crests of low ridges, and that eroded areas may be covered by crops or native vegetation. He applies his knowledge of plant succession and his ability to recognize different kinds of vegetation on aerial photographs. For example, where the climax vegetation is hardwoods, patches of young pines may mark eroded areas that have been abandoned and are revegetating.

Gullies appear as long scars with definite irregular borders (fig. 39); they contrast with sheet-eroded areas, which have more diffuse and smoother outlines (fig. 27). Gullies are common in natural drainageways and at the boundaries of fields.

Certain characteristics of gullies are related to soils (fig. 41). The gradient and cross section may indicate the kind of parent rock and the soil texture.

Gullies in well-drained sandy soils are V-shaped in cross section and have steep gradients; those in poorly drained fine-textured soils are apt to be saucer shaped in cross section and to have gentle gradients. Gullies in stratified soils have irregular side slopes and abrupt changes in gradient.

Vegetation.—Vegetation is identified on a single photograph mostly by tone, but some that cannot be distinguished by tone alone can be through a stereoscope. Prairies, forests, and cultivated fields are distinct on single photographs (fig. 42). Forest and nonforest, deciduous and coniferous trees, and young and mature growth generally can be distinguished by tone. Many foresters can identify dominant species in forest types by comparing heights of trees and sizes and shapes of crowns. By comparing the image of trees on the photograph with trees in the forest, the soil scientist improves his ability to identify kinds of tree cover.

The appearance of vegetation changes with the season. Deciduous trees photographed in winter have a lacey appearance and a lighter tone than that of coniferous trees.

Tall, short, and mixed grasses are difficult to distinguish from each other even in large areas of native vegetation. Sparse desert vegetation is easier to recognize.

To identify vegetation, the soil scientist should be familiar with plants in the area and their relation to the environment. A knowledge of plant succession furnishes clues helpful in identifying soils.

IDENTIFICATION OF MANMADE OBJECTS

Since manmade objects have sharp boundaries they are generally easier to recognize on aerial photographs than are natural features, and they are also more emphasized than natural features on stereoscopic pairs.

Farm Forests, Fields, and Orchards.—From manifestations of tone, the photo interpreter can tell how land is used. Forested areas appear mottled (fig. 20). Fields can be identified by their distinct boundaries and their patterns of dark and light (fig. 43). Harvested crops of hay, small grains, and corn in shocks can be identified by regularly spaced dark spots. Orchards have a more open pattern of larger spots. Terraced fields and stripcropping have alternate light and dark strips.

The arrangement, size, and shape of fields vary according to the type of agriculture. Fields are larger and more uniformly spaced in dry-farming areas than in humid areas. Field boundaries may appear as straight lines between patches of contrasting tone. The dark tones of hedgerows and other vegetation often

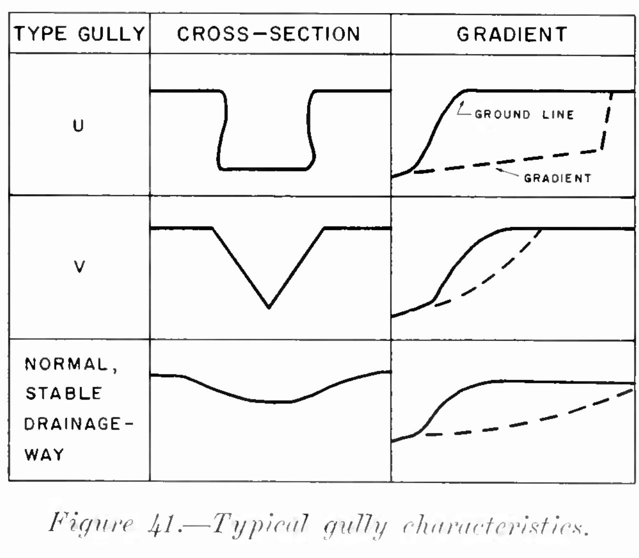
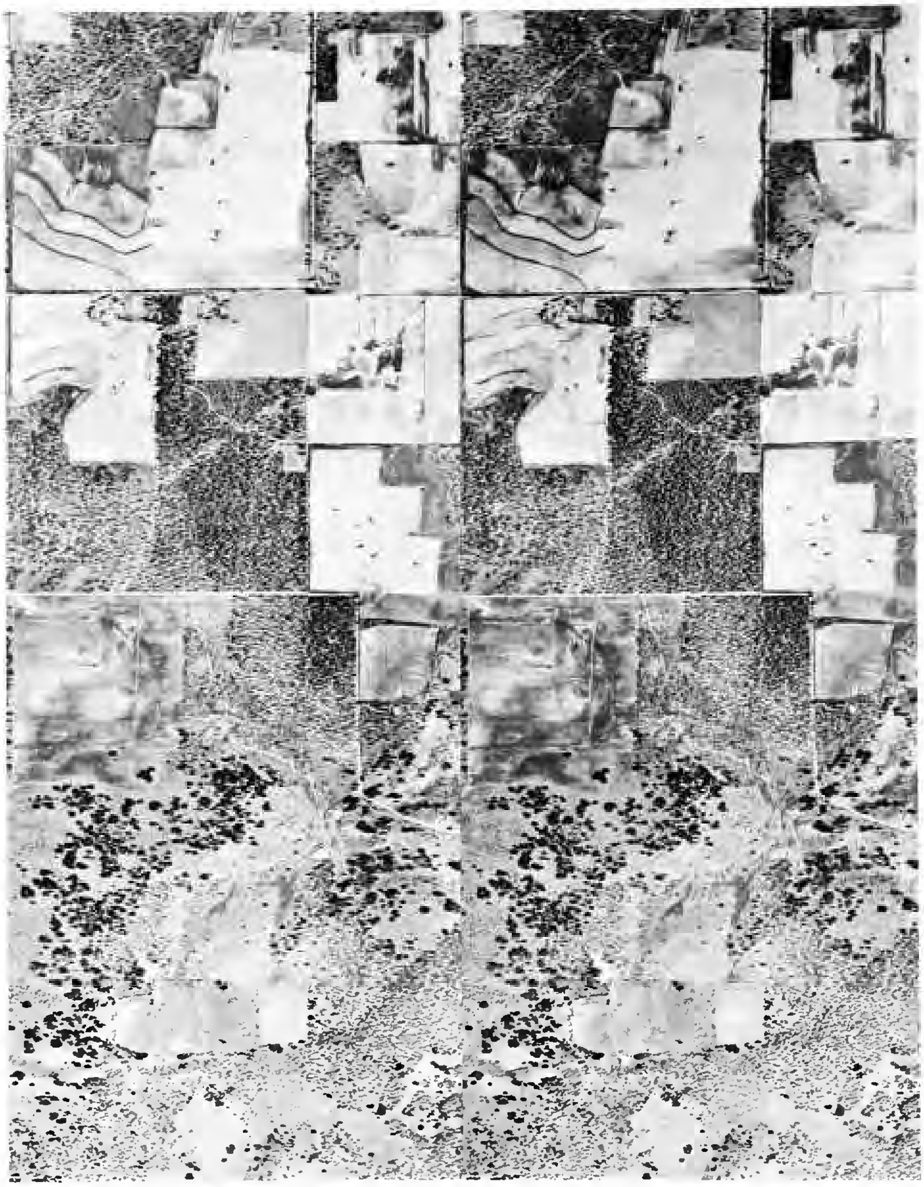


Figure 41.—Typical gully characteristics.



SCALE 1:20,000 ASCS—BRG-1E-94, BRG-1E-93

Figure 42.—In these photographs of north-central Texas forested areas produce a speckled light and dark pattern; coniferous trees appear as dark specks; the gray faintly mottled background represents native prairie vegetation; and cultivated fields produce light areas with sharp boundaries (upper part). Reddish prairie soils are under native grasses and Red-Yellow Podzolic soils under decidous forest that has scattered coniferous trees.

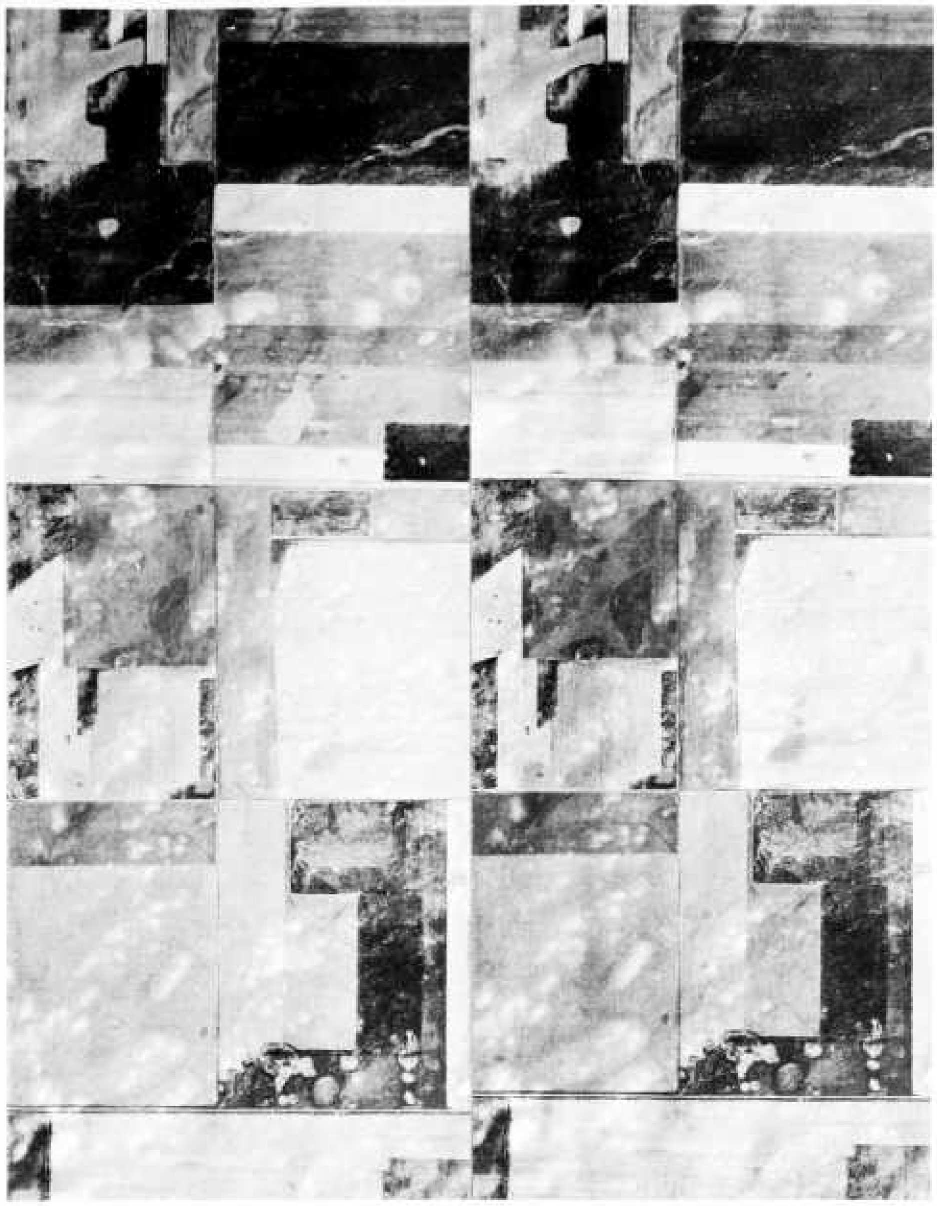


Figure 43.—The scattered light spots on these photographs of dry-farmed tablelands in Nebraska represent thin soils in residuum from siltstone and sandstone; the dark background represents deep and moderately deep Chestnut soils in loess. Outlining the bases of the low ridges or knobs under a stereoscope shows the abrupt and wavy boundary between the soils in loess and those in residuum.

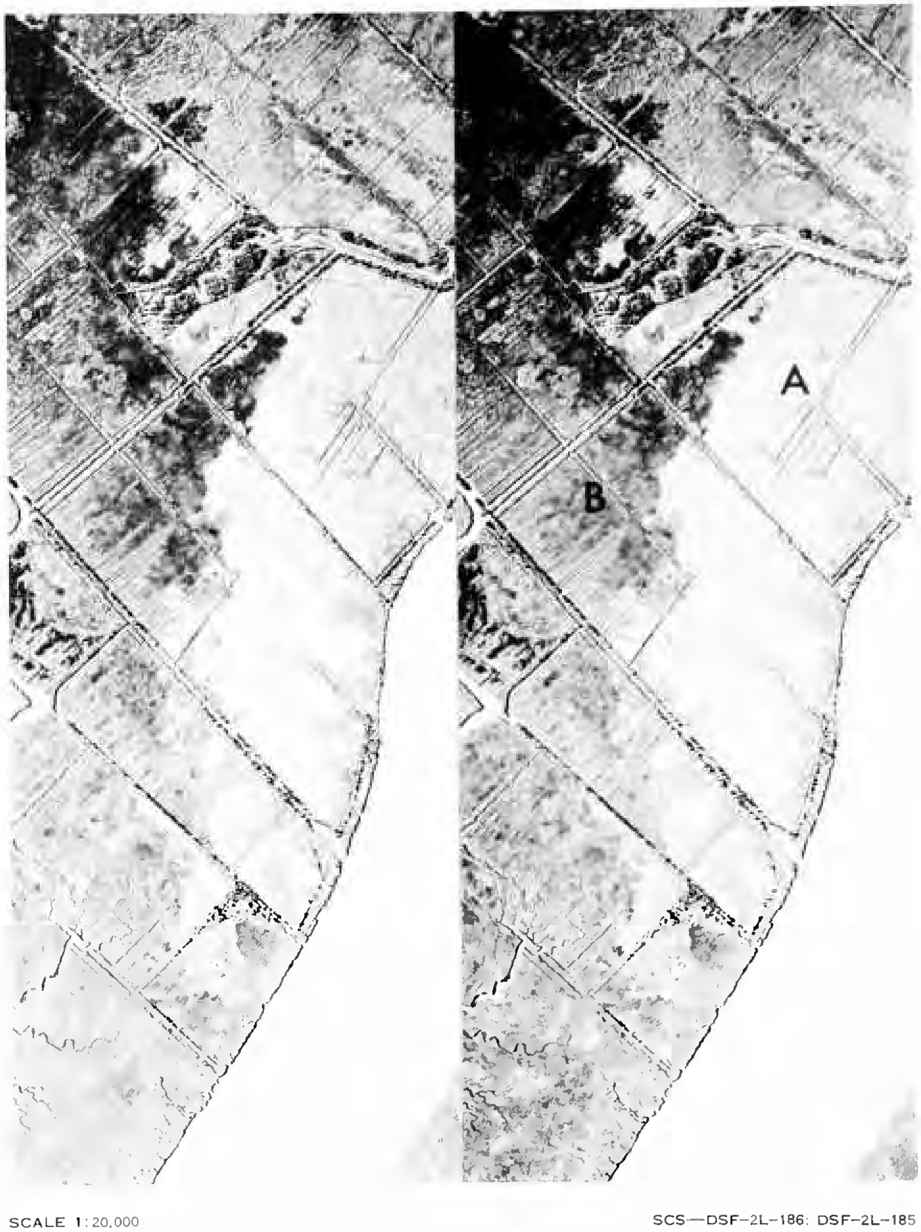


Figure 44.—These photographs of an area in Georgia illustrate the contrast in appearance of mineral soils and organic soils under cultivation. The very light gray areas marked A represent Low-Humic Gley soils intergrading to young marine clays of the salt-water marsh. The dark-gray or black areas marked B suggest organic soils. Hedgerows produce the very dark irregular lines along field boundaries.

mark boundaries and fences (fig. 44), but generally the photographic scale is too small to show fences.

Buildings.—Buildings can be recognized by their angular shapes and contrasting tones. The part of the roof directly exposed to the sun photographs light and contrasts sharply with the shadow cast by the building. Farm buildings are usually in small rectangular groups beside or at the end of roads. In the arid southwest they are isolated; in the Great Plains they may be in groves of trees or among scattered trees; in the dissected or mountainous section of the humid Southeast they may be in cleared patches surrounded by forest.

Roads, Trails, and Streets.—Roads and trails commonly photograph as light lines. Improved roads have uniform width, straight stretches, and smooth, gentle curves; unimproved roads are more irregular in width and have sharper curves. Large uniform squares bounded by roads suggest sectionized rural areas, clusters of small rectangles indicate towns or cities (fig. 26).

Railroads.—Compared to roads, railroads are narrower, have longer and smoother curves, and are darker on aerial photographs. Along the right-of-way large cuts and fills, spurs, stations, and warehouses can be detected.

Bridges.—Bridges can be located by following the course of a road or a railroad until it crosses a stream or by following a stream and noting the interruption of tone caused by the bridge. The kind of bridge can often be identified from its shadow.

Tunnels.—Tunnels can be identified by the dark spots of their portals, by the spoil near the portals, and by the sharp termination of the road, railroad, or canal.

Power Transmission Lines.—Transmission lines are difficult to detect in open areas on some photographs used in soil surveys. On photographs of very large scale, towers or their shadows can be seen. In wooded areas, power lines are long, narrow, cleared stretches that have angular changes in direction rather than curved changes.

IDENTIFICATION ON PHOTOGRAPHS TAKEN AT DIFFERENT TIMES

By comparing photographs of the same area taken several years apart, the extent and rate of erosion, especially gully and streambank erosion, can be estimated. The meandering of streams can be traced, and changes in land use noted. Damage from range and forest fires can be assessed.

Pictures taken before and after floods are often used to appraise flood damage. "Before" and "after" pictures also indicate changes caused by the construction of a large dam and by the filling of the reservoir that is formed. The extent of the encroachment of urban development, highway construction, or powerline installation on agricultural land can be estimated. During periods of drought or drawdown, sedimentation studies can be made.

INFERENCES FROM FEATURES IDENTIFIED

To make reliable inferences the soil scientist must correlate features on the aerial photograph with soil characteristics observed in the field. A knowledge of soil genesis, especially as it relates to geomorphology, assists in understanding correlations made in the field. A person who is well versed in the phases of soil science and who has a good understanding of the soils in the area studied can obtain much more from aerial photographs than one less well versed.

SOIL DIFFERENCES

Some differences among soils can be detected from variations in tone on the aerial photograph; some can be inferred from analysis of surface features that reflect soil differences. Clues to these differences are found in such features as landforms, stream dissection, drainage networks, vegetation, and land use. Combinations of these features may coincide with the morphological characteristics used in separating soil classes such as great soil groups or soil series. Thus, soils on uplands that have distinct horizons may be distinguished from alluvial soils with faint or no horizons on flood plains. Poorly drained soils appearing dark in depressions may be set apart from well-drained soils on convex slopes (fig. 45). Several morphological features and chemical properties are neither expressed nor implied by features apparent on an aerial photograph. These can be

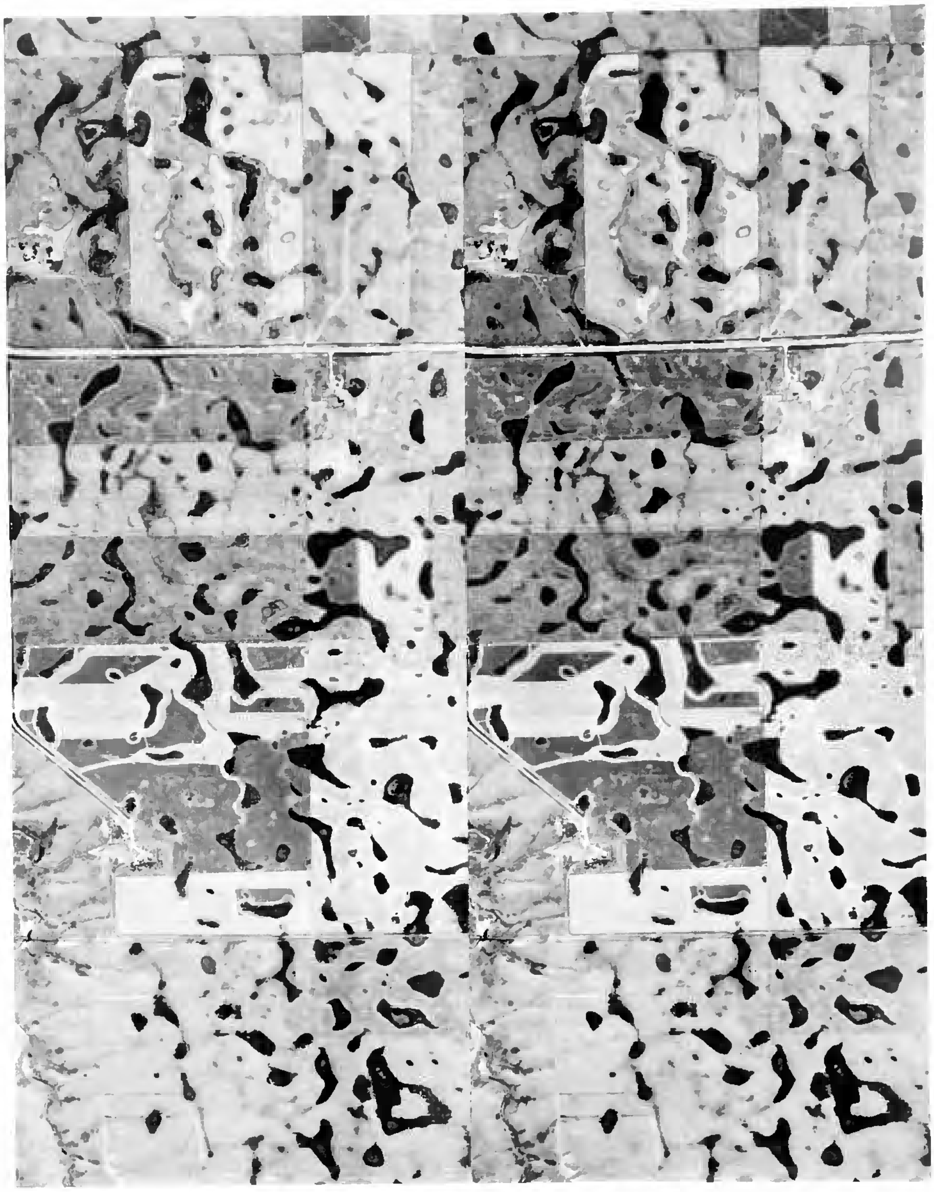


Figure 45.—The mottled dark-gray to black pattern against a lighter background represents an association of Chernozems and Humic-Gley soils on the till plain of North Dakota. Humic-Gley soils, which photograph dark, are in the small closed morainic depressions; Chernozems in the light intervening areas.

distinguished only by field investigation or perhaps laboratory analysis.

Differences in tone that give clues to differences in soil can be seen in figures 32, 46, 47, and 48. Differences in tone, however, do not always indicate significant differences in soil, and differences in soil are not always revealed by differences in tone (fig. 49). The soil scientist must be able to distinguish change in tone caused by the angle of reflected light from that caused by some feature on the ground. The best way for him to prevent errors in identification and inference is to work out the local relationship between the landscape and the patterns on the photograph.

Dark-colored soils are dark toned on the photographs and light-colored soils are light toned (fig. 50). A lightening of tone usually indicates better natural drainage of the soils, stronger slope, more severe erosion, or coarser texture. A light-toned area, however, may be a poorly drained soil covered by a light film of water when photographed. On the other hand, dark-toned areas may be from soil plowed shortly before the photograph was taken.

In many places, differences in landform and drainage patterns indicate broad differences in soils and their parent materials. Experienced field soil scientists recognize bottom lands, terraces, alluvial fans, upland plains, hills, and mountains on aerial photographs of most regions. Generally, soil and slope boundaries coincide with boundaries of landforms and can be accurately located on aerial photographs. The soil scientist must remember, however, that many of the boundaries highly significant to accurate soil classification and mapping are not related to landforms.

Patterns are often misleading, and interpretations are found to be incorrect when the soils are examined in the field (fig. 51). Patterns that appear the same may represent unlike landscapes or associations of soils. Color patterns may be associations of eroded and uneroded soils, coarse- and fine-textured soils, well-drained and imperfectly drained soils, and other combinations. The soil scientist who is aware of these possibilities will determine which are most likely through both field examination and photo interpretation.

If it can be determined from an aerial photograph, the type of vegetation cover may indicate what kind of soil to look for and where to look. In some areas rather consistent correlations of vegetation and soil can be made; in others the probable correlations are few. In a dominantly agricultural area, one would expect soils in a patch of woods to be different from soils that have been cultivated for a long time. But in some areas aerial photographs of vegetation do not reflect soil characteristics that would be important if the soil were cultivated (fig. 52).

Fires modify vegetation without immediately affecting the soil. Also, clues that show on one photograph may be masked by vegetation on another. This makes it necessary to work out the relationship between elements of the landscape and the pattern on the photograph by direct observation in the field.

Different patterns of native vegetation imply differences in soils. For example, concentric rings that progress from grasses and sedges to low bushes and trees as they extend outward from the borders of a pond indicate that the soils are increasingly better drained as the distance from the pond increases.

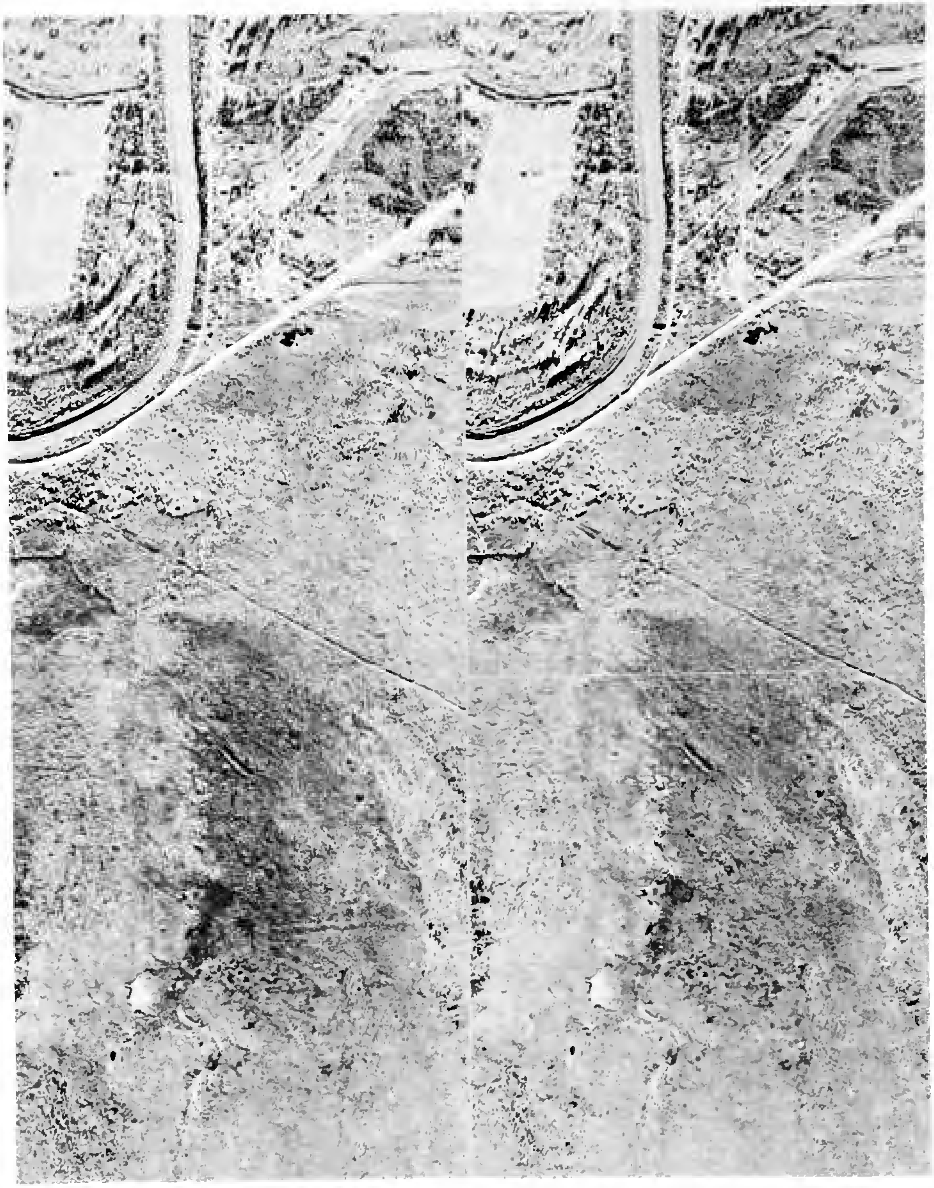
EXPRESSIONS OF FACTORS OF SOIL FORMATION

Relief and vegetation as they were at flight time can of course be seen on an aerial photograph. Preexisting relief and vegetation that had a profound influence on soil formation can only be inferred. This is true also of parent material, climate, and age of landforms.

Relief.—Relief changes slowly, and probably has changed very little from the earliest stages of soil formation up to the time the photograph was taken. Allowance must be made, however, for erosion and other changes brought on partly by the activities of man.

Vegetation.—To evaluate the relationship of vegetation and soil, the soil scientist should become familiar with local ecological environment, including plant succession. He can then compare present with past vegetation and determine whether the vegetation he identifies is representative of earlier types. The soil scientist will be aware, for example, of how the original forest was altered by burning or cutting.

Identification of native vegetation may lead to inferences about soil and soil genesis. Pine forests in Maine, northern New York, and Michigan are clues to Podzols or to the formation of Podzols. Mixed deciduous and pine forests on

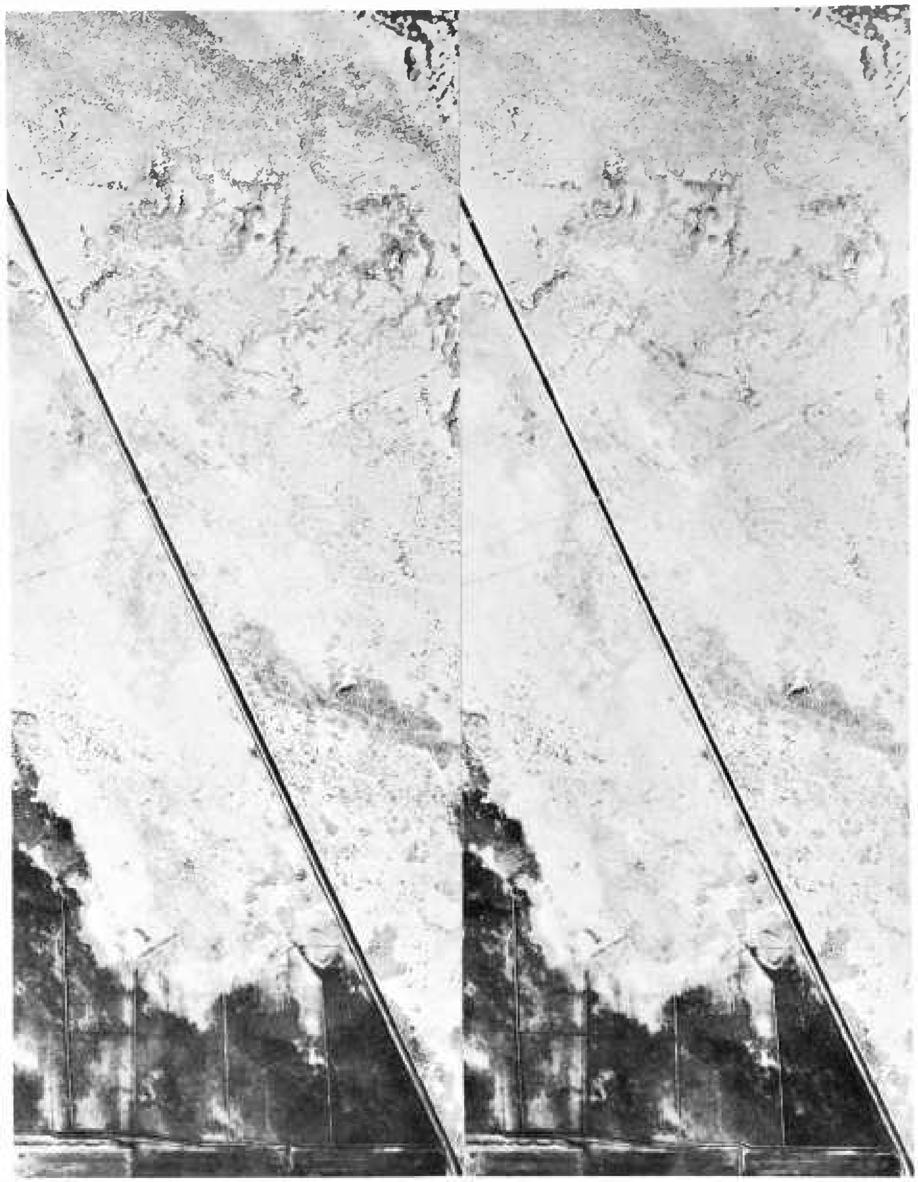


SCALE 1:20,000 USAF—M-878-503, M-878-502

Figure 46.—The slight tonal differences and the polygonal pattern on the lower half of these photographs of river flood plains of interior Alaska indicate soil differences. The darker areas represent Bog soils covered with sphagnum moss; the somewhat lighter areas and the polygonal pattern, Humic Gley soils. Note the indefinite boundaries of areas of sphagnum moss in contrast with the distinct outlines of roads and images of buildings.

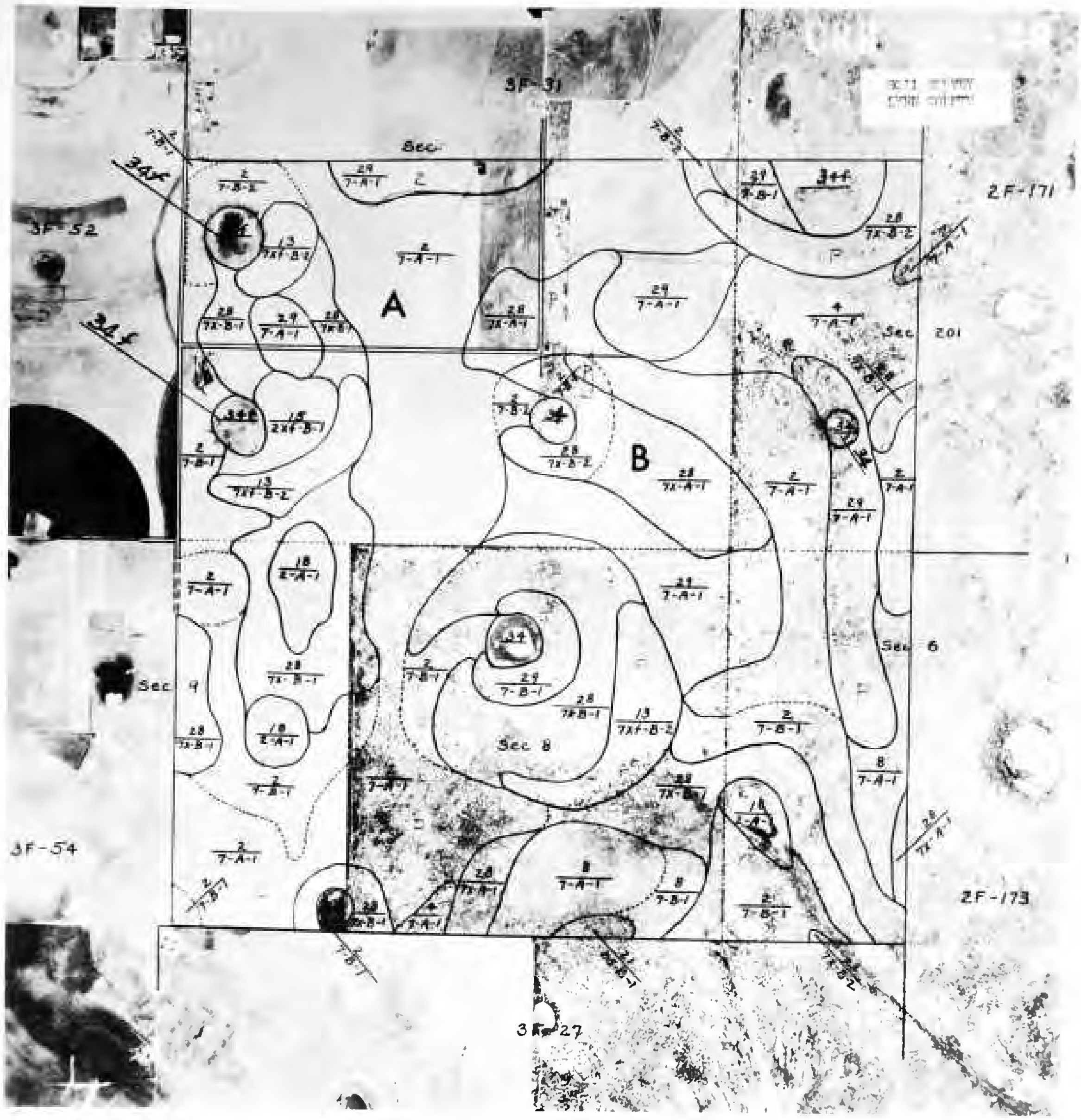
SCALE 1:20,000 ASCS—OV-3E-83; OV-3E-82

Figure 47.—Tone variations with gradual boundaries often are clues to differences in soil drainage, most commonly in humid areas. Sharp boundaries are due to vegetation or land use. The lightest tones in these photographs of sandy soils on the Atlantic Coastal Plain represent somewhat excessively drained Regosols; the intermediate ones well-drained and moderately well-drained Red-Yellow Podzolic soils; and the darkest, somewhat poorly or poorly drained Low-Humic Gley or Humic-Gley soils.



SCALE 1:20,000 SCS—DOP-1T-71; DOP-1T-72

Figure 48.—These photographs of an area in Nevada show the highly contrasting tones registered by sandy Regosols, the light tones, and by somewhat poorly drained Alluvial soils, the dark area in the lower part of the photographs.



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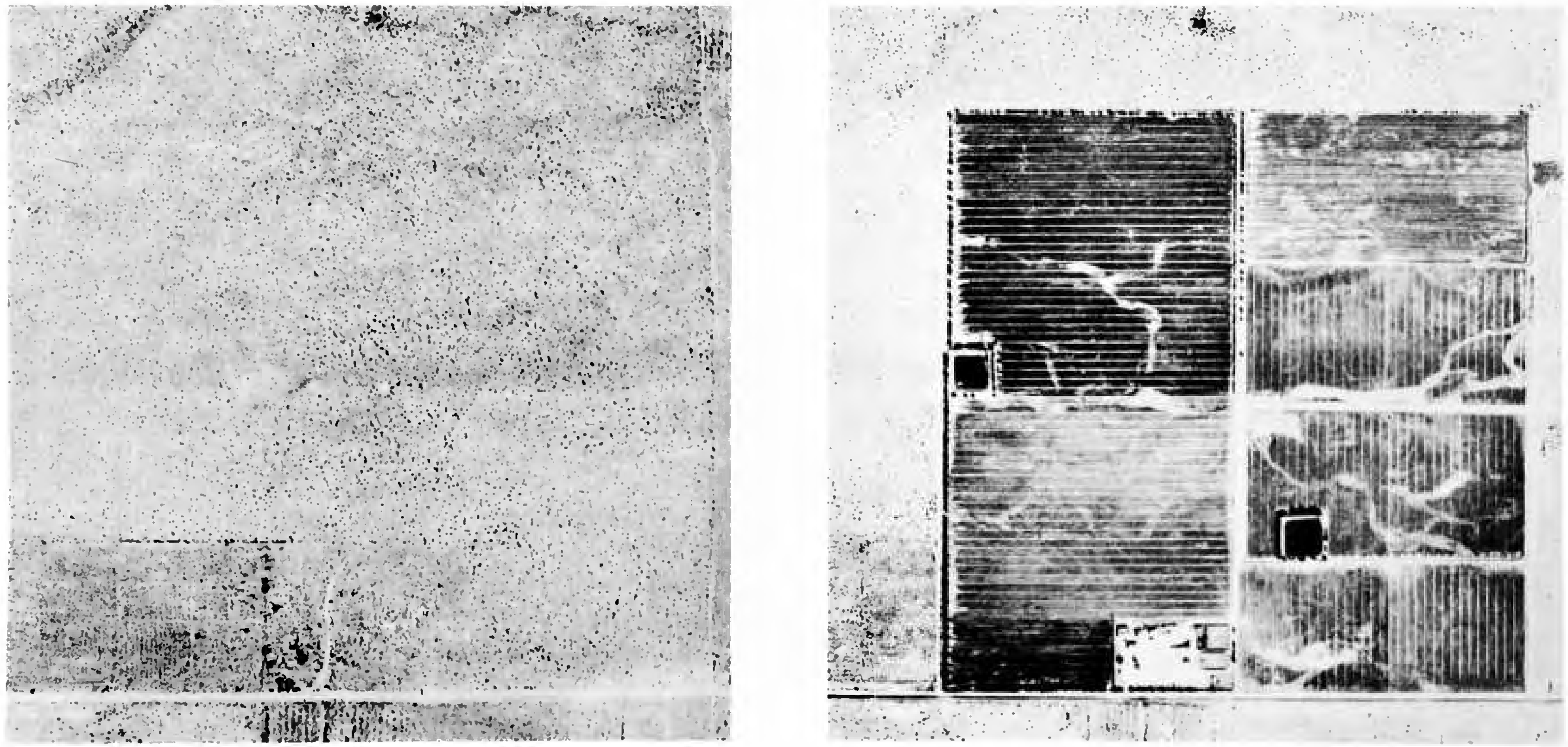
ASCS—CRH-3F-29

Figure 49.—Quite different soils may photograph in similar tones. Here a Reddish Chestnut soil in Texas in area A appears in light-gray tone like that of the Calcisol in area B. The darker tones of soil 34f, also a Calcisol, are as dark as those of soil 34, which is a Grumusol.

SCALE 1:20,000 NA—AWW-7-84; AWW-7-85

Figure 50.—These photographs of an area underlain by chalk in Texas illustrate the relationship of light and dark tones to differences in color among soils. Dark tones represent nearly level or gently sloping Grumusols, which have thick dark surface horizons. Light tones portray more strongly sloping and light-colored Lithosols formed in residuum from very light gray or white chalk. The topographic expression, though moderate, is easily noted under a stereoscope.

Figure 51.—In this photograph of an area in New Mexico the pattern suggests a rough, choppy, complex landscape with no agricultural potential except for range. Field examination, however, showed a succession of miniature escarpments 6 inches to 3 feet high on an alluvial fan; the escarpments are topped by ridges of sandy Regosols in eolian deposits 6 to 24 inches thick. Regosols are moderately fine-textured soils formed in alluvium.



SCALE 1:13,000 LEFT. USAF—4M741-4V-25, RIGHT: ASCS—AXL-44K-7

Figure 52.—These photographs of an area in the Mojave Desert, Calif., show vegetation that fails to reveal important differences in soil characteristics. The uniform cover in the left photograph consists chiefly of creosotebush and bursage. The same 160-acre field is shown on the right after leveling and planting to alfalfa. The light streaks represent narrow beds of gravel or cobbles, which affect the efficiency of irrigation but have no apparent effect on native vegetation.

rolling or hilly uplands in the Southeast are related to the formation of Red-Yellow Podzolic soils. In the northern Great Plains tall grass was the native cover over Chernozems when they were forming.

Parent Material.—Parent material can be inferred from the aerial photograph after considering the landforms and, in some areas, the vegetation. But such inferences may be unreliable because no specific kind of parent material can be correlated exclusively with a specific kind of landform or vegetation. Rock structure, climate, and other factors affect the relationship.

In some areas, however, relationship can be found between topography shown on the photograph and parent material. In the Appalachian Highland, for example, rolling limestone valleys and ridges are distinct from steeply dissected shale plains; these in turn are unlike mountainous areas of crystalline rocks. In central United States, rolling areas of thick deposits may be separated from adjacent driftless plateaus that are more dissected.

Climate.—The climate of an area is reflected in the shape of landforms and in stream patterns, but the most reliable key to climate is vegetation. The effect of climate on vegetation can be seen by comparing vegetation across the United States; vegetative zones correspond to broad climatic belts.

The relationship of soils, climate, and vegetation in the western part of the Central Lowlands is also striking. Gray-Brown Podzolic soils occur in the humid, forested valleys; Brunizems are on the less humid grassland divides that intervene.

Age of Landforms.—Inferences concerning the age of landforms of an area, at best very general, are based mostly on deductions made after studying the physiographic expressions and acquiring some knowledge of the geology. Young soils are likely to occur on steep hillsides and flat flood plains. On strong slopes, horizon differentiation hardly keeps pace with geologic erosion. On alluvial plains, continued accretion of fresh materials keeps the soils young.

PLANNING FOR THE DETAILED SOIL SURVEY

Aerial photographs are used in both detailed and reconnaissance soil surveys. The principles of photo interpretation are the same for both although applications of them differ somewhat. More reliance is placed on clues offered by the photographs in reconnaissance than in detailed soil surveys. This is true of both determinations of kinds of soil and placement of soil boundaries. In detailed soil surveys, field examinations are made at frequent intervals and boundaries are observed throughout their entire course. In reconnaissance soil surveys, field examinations are widely spaced and parts of soil boundaries are projected.

Most soil surveys are detailed and procedures have been developed for the use of aerial photographs in such surveys. These procedures are outlined in this section. They include evaluations of existing aerial photographs, judgments of the need for procuring new ones, day-to-day operations, and determinations of the relationships of photographic features to elements of the local landscape.

PROCUREMENT OF AERIAL PHOTOGRAPHS

Plans for procuring aerial photographs should be made about 2 years before the start of a soil survey.

The SCS Cartographic Division prepares a report of existing aerial photography, which includes other agencies' plans to fly the survey area in the immediate future. On the basis of the report, and on knowledge of the physiographic changes since the last aerial survey, the SCS State Conservationist through his soil scientist decides whether a new aerial survey is needed.

If it is needed, arrangements to initiate flight operations must be made at least 1 year before the photographs are needed in the field. Aerial surveys are made by commercial aerial photographers under contract. About 6 weeks should be allowed to develop the specifications and schedule of advertisement, prepare flight maps, solicit bids, and award the contract.

If the State Conservationist decides that the existing aerial survey is adequate, photographs are obtained through the Cartographic Division. Most soil surveys are made on photographs enlarged to scale 1 inch=1,320 feet (4 inches=1 mile). Where large-scale irrigation or land leveling developments are contemplated, more detailed soils information may be needed than can be shown at a scale of 1 inch=1,320 feet, and larger scale photographs are required. Contact prints, being of smaller scale, often are helpful in making a stereoscopic study of the area because a larger area can be viewed at one setting. Also, the smaller scale concentrates the detail, and broad associations of features can be studied.

Unless an older survey is specified the Cartographic Division furnishes photographs from the most recent adequate aerial survey. Photographs should be examined immediately to see that they are good quality prints and that all prints needed have been received. Images on the photographs should be sharp to permit study of small details. Prints should be of normal contrast with shadows and highlights printed so that details of the negatives reproduce to maximum advantage.

SELECTION OF PHOTOGRAPHS

Ordinarily, soil-survey data are recorded on alternate photographs since this reduces matching delineations of soils and other features from one photograph to the next. It also reduces costs of reproducing the completed soil-survey field sheets since only half as many sheets are required. But for areas of rough terrain, where the difference in ground elevation exceeds 750 feet on a large part of the survey area, soil-survey data are recorded on every photograph. Where there are large blocks of different terrain every photograph is used for the mountainous part and alternate photographs for the less rugged terrain.

COLLECTION OF REFERENCE MATERIAL

In addition to aerial photographs, existing maps and reports of the survey area should be studied. Photoindex, topographic, geologic, and forest-type maps, old soil maps and reports, and planning board maps and reports are helpful.

PROCEDURES FOR USING PHOTO INTERPRETATION IN MAKING SOIL SURVEYS

USE OF PHOTOINDEX SHEETS

Photoindex sheets are generally at a scale of 1:63,360 (1 inch=1 mile). Since each sheet covers a large area, they may show overall geologic and soils relationships not readily seen on individual photographs. Photoindex sheets are also useful as a base for the preparation of a preliminary soil-association map. Such a map is helpful in setting up the standard soil survey legend.

Photographs of representative sections of the areas should be selected from the index sheets. These should be studied stereoscopically to acquaint one with general topography, landforms, erosion, drainage patterns, land use, and general appearance of vegetation. Later, they should be checked in the field to determine the range and meaning of tone and to learn the local causes of differences in tone, such as wetness, soil texture, vegetation, bedrock, and outcrops.

MATCH LINES

Before the soil survey is started, match lines are drawn on every photograph selected for delineation of soils data. These lines are boundaries of the area to be mapped on the photograph. They can be drawn with or without the aid of a stereoscope. In using the stereoscopic method, a straight line is drawn midway through the overlap area parallel with the photograph edge. The straight line is then stereoscopically transferred to the adjoining photograph (fig. 53). In rough or mountainous terrain this line is usually transferred by marking its location on the high points, or ridges, and on the low points, or bottom drainage, and connecting these points by a series of straight lines. In areas of rough terrain, a straight match line on one photograph will be a very irregular one when transferred to the adjacent photograph.

Straight match lines can be transferred without using a stereoscope by sketching the line where it seems to curve over high spots and through low spots. On flat land the match lines may be transferred by connecting the same points of detail with a straight line.

In both methods, the process is continued throughout the survey area by transferring the match lines to the next photograph in the flight line and to adjacent photographs in the adjoining flight lines.

Match lines may follow prominent ground features, such as roads, railroads, rivers, or land lines. If cultural and physical features are concentrated along the road, the match line should be drawn where it would be less difficult to match delineations of soils and other features. Match lines are usually drawn with green pencil.

STEREOSCOPIC REVIEW

A careful stereoscopic review should be made each day before starting work. First, the area to be surveyed should be determined. If this is a farm or ranch its boundaries should be delineated on the photographs. With a stereoscope, the area is scanned to make a brief mental review of significant conditions such as type of farming, topography, geology, landforms, soils to be expected, drainage conditions; and farming practices.

PRELIMINARY DELINEATION OF FEATURES

Before field work begins all important features that can be accurately identified in the office should be delineated on the photographs. Some can be determined with more certainty than others, depending on one's familiarity with local conditions and skill with a stereoscope. Features easily identified should be delineated first. Then features that relate to and help identify obscure features should be studied. The following is an outline of steps for this preliminary stereoscopic delineation:

1. Major drains, smaller drains, intermittent streams, and drainage heads and ponds should be tentatively delineated before going to the field. This should be done in blue pencil so needed changes can be made after field checking.

2. If soil surveys have been made on adjacent photographs, all soil and mapped features should be transferred stereoscopically to the outside edge of the match lines. Many boundaries between kinds of soils, including slope and erosion phases, can be tentatively extended or closed. If

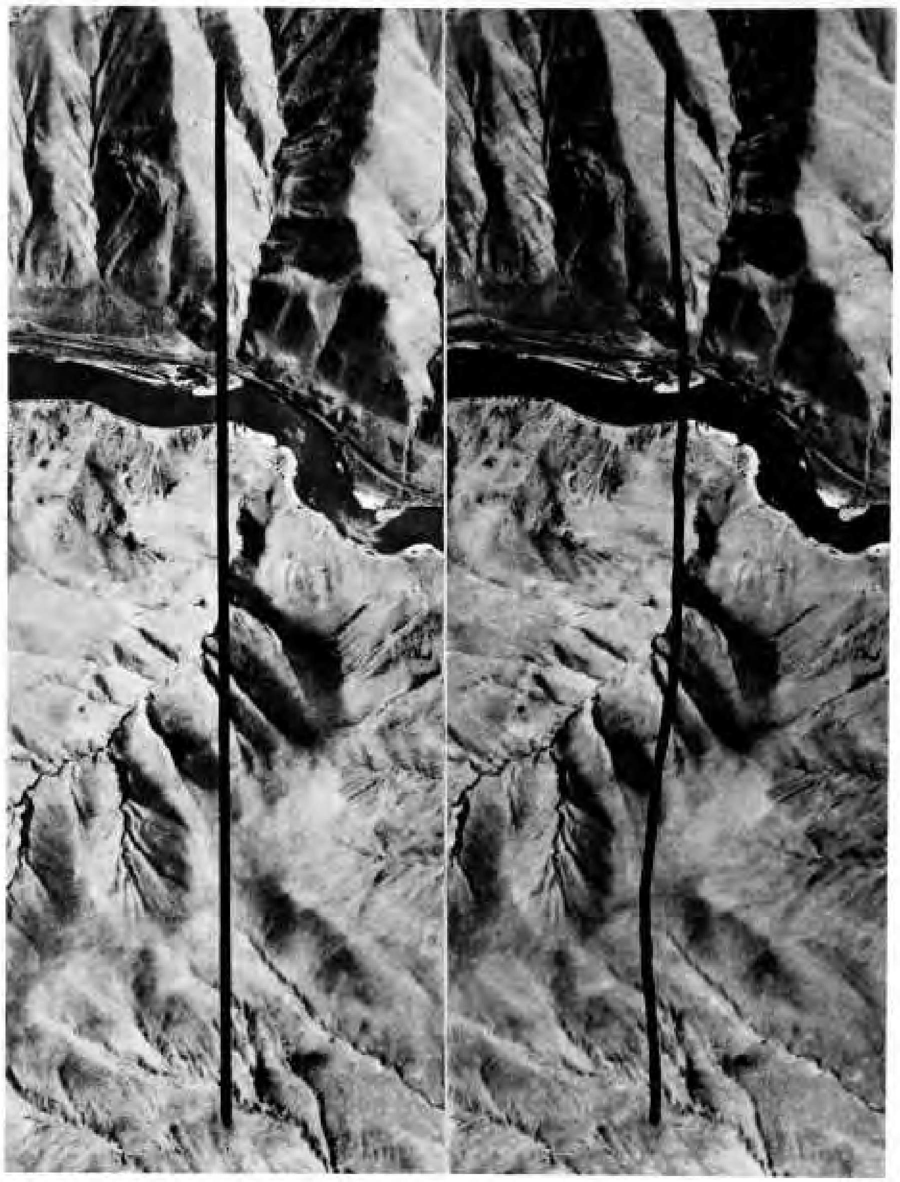


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Figure 53.—Transferred match line.

possible, lines should not be closed off directly on the match line. Careful selection of match lines minimizes the need for this.

3. Roads may be inked and classified on the basis of knowledge of the area and the latest county highway maps. According to some State policies, highways prominent and readily identified on a photograph need not be inked.

4. Whenever they can be identified, dwellings and other pertinent buildings outside of built-up areas may be inked on the photographs. In built-up areas, only public buildings important to farmers or farm programs such as courthouses and schools should be indicated

5. The following should be tentatively delineated in pencil:
   - Bottom land and flood deposits
   - Stream terraces
   - Gravel and borrow pits
   - Ridge lines
   - Sinkholes and wet spots
   - Swamp or marsh boundaries
   - Other significant landforms such as escarpments and rock outcrops.

6. All slopes that are clearly seen and appear to correspond with the slope phases in the legend should be delineated, and the estimated slope groups given. In many soil survey areas, the definitions of slope phases vary among kinds of soil. Beginners may have difficulty delineating slope groups with reasonable accuracy. Regardless of the lack of success, this should be done and checked in the field each day, for this skill can be developed only through continual practice and field comparisons.

7. Gullied and severely eroded areas should be delineated and an estimated-erosion symbol placed in the delineation.

8. Soil series or types that can be differentiated may be tentatively delineated and indicated by symbols.

9. Routes for traversing the area most efficiently should be planned. This should insure sufficient field checking and, at the same time, reduce the number of unnecessary traverses.

DETERMINATION OF GUIDES AND RELATIONSHIPS

Stereoscopic interpretations made in the office should be reviewed in the field and verified or revised as necessary. Areas not correctly identified in the office should be restudied. Valuable experience is gained by making notes on the relation of soil to the photographic features that are indicators of the particular soil. Accuracy in making estimates increases, and the soil scientist learns which delineations he can make with suitable accuracy.

For each slope group or major landform, slope can be established with an Abney level and areas delineated in the field. These delineated areas serve as references to compare with similar-appearing areas delineated with a stereoscope.

Soils tend to occur in systematic patterns. Assistance in determining local patterns may be obtained from the study of topographic and geological maps and reports. Block diagrams showing the relationship between local soil types and phases need to be prepared. (See figures 59 and 62.) These diagrams help to visualize the relationships between kinds of soil areas and factors that pertain to the development and occurrence of soils in the landscape.

CORRELATING AERIAL PHOTOGRAPHIC IMAGES WITH SOILS IN SPECIFIC AREAS

In many places soil scientists have learned how to recognize distinctive soil landscapes or soil associations on aerial photographs. Though within a given landscape the boundaries between soils of strongly contrasting texture, drainage, or depth can be readily recognized, this is not true of finer distinctions among these features. The soil scientist needs to be thoroughly familiar with soil landscapes on the ground before he attempts to interpret soils from the aerial photographs.

Up to now, no systematic key correlating aerial photographic images and soils has been issued. But soil scientists have used photographic tone, pattern and kinds of vegetation expressed in photographic tone, and physiography as interpreted from tone, detail, patterns, and shadows to make their own correlations.

The following extracts of local correlations are mainly from the humid East. With them as guides to things to look for in aerial photographs, each soil scientist should develop his own local key. Using such keys can significantly accelerate soil-survey field work.

CORRELATIONS IN THE NORTHEAST

Connecticut.—Landforms such as traprock ridges, drumlins, ground moraines, glaciofluvial or outwash terraces, kame and kettle topography, eskers, lacustrine terraces, flood plains, and bogs are features that can be identified with a stereoscope. Soil associations with well-defined features are associated with each of these landforms. Soil features such as drainage, texture, degrees of stoniness, and kind of vegetation can also be interpreted to a certain degree with a stereoscope.

Shallow to bedrock soils are common on traprock ridges in the Connecticut Valley of Connecticut. The principal indications of traprock ridges are steep western slopes that have dark tones due to shadows and linear crests that are jagged, irregular, and sharply outlined. The adjacent areas to the east have uniform decreasing slopes. There are more hemlock trees, recognizable by dark images, than on adjacent associated shallow soils. Presence of hemlock itself, however, does not indicate traprock ridges.

Shallow soils on granite, gneiss, and schist, usually appear as large domelike rounded hills irregular in topographic features. The drainage pattern is dendritic; typical curved lines emerge from the base of the hills. Scattered light patches indicate exposed bedrock and a surrounding mantle of shallow soils. Darker tones are more difficult to interpret because of the nature of the topography, vegetation, and bedrock reflections. Extensive dark tones on either side of streams suggest soils with restricted drainage. Natural vegetation—mainly oak, maple, and beech and scattered white pine and hemlock—appears medium gray with some dark spots.

Drainage patterns of moraines, which have irregular slopes in contrast to the long, uniform, contoured slopes of drumlins, lack uniformity because of the irregular topography. There are many small individual drainage patterns that do not combine to form a well-defined drainage system. Individual streams are not long but are well defined. Generally they empty into peat bogs, swamps, and ponds in the low points of the landscape.

Light gray tones of moraines usually indicate shallow soils on steep valley walls or hillsides. Medium gray tones are confined to 3- to 8-percent slopes, which generally are moderately well drained. Darker tones on 2- to 3-percent slopes are evidence of poorly or very poorly drained soils. In general, all cultivated areas have the same tone. Oak, maple, and beech, the principal tree species of a mixed hardwood cover, appear in fairly uniform gray tones.

Drumlins, generally oriented in a northwest to southeast direction in Connecticut, are smooth, oval, cigar-shaped hills. A few, which are broad, flat surfaced, short sloped, and less elongated than typical, appear semicircular to semioval. Though defined drainage patterns are lacking, they do control the drainage in many adjacent till-covered areas. Those with broad tops or semioval shapes usually bear intermittent streams that flow southeast, that is, with the long axis.

Since many drumlins have soils with impervious subsurface layers that restrict vertical movement of water, lateral movement of water on the long slopes results in occasional seepage spots and these are conspicuous by their darker tone. A uniform gray tone indicates moderate drainage and darker grays poor drainge. Clean-tilled land is usually lighter toned than old pastures and hayfields, but in both differences in soil drainage are reflected by tone.

Glaciofluvial and outwash terraces, generally nearly level to undulating, in places occur as a series of benches with intervening short terrace escarpments. Lack of surface drainage patterns show that the subsoil and substratum are permeable. Rapid permeability also accounts for the typical, but occasional, V-shaped short steep gullies. Light to bright overall tones are characteristic of terraces. The lightest tones indicate well-drained coarse-textured soils; darker tones indicate somewhat poorly drained or poorly drained finer textured soils.

Eskers, which are long narrow steep winding ridges consisting of sorted gravel and sand deposited by glacial-melt waters flowing in ice-walled tunnels or channels, appear superimposed upon surrounding landforms. Photographic tone as such is not diagnostic for eskers because gullies are few and the esker tones blend with surrounding landforms. When examined under the stereoscope, however, they stand out as ridges. Some show gravel pits. In many places they are idle or in forest in contrast to adjoining areas of outwash or till in cropland.

Kames and kettles are individual knobs or linked knobs with irregular shapes and haphazard distribution interspersed with random shallow to deep depressions and no definite drainage patterns. Coarse texture accounts for white-toned V-shaped gullies that occur on steep-sloped mounds. Tones range from white to light gray on kame crests and to darker shades toward the slope bases. Intermittent spattering of white to gray photographic tone, coupled with the topographic features, gives a three-dimensional effect on some single photographs. These topographic features are readily recognized under the stereoscope.

Though lacustrine deposits are distinct from the surrounding landforms, the topography may be so similar to adjoining areas of glacial till or outwash that differences are not discernible under the stereoscope.

On undulating topography, silts and clays generally lack well-defined drainage or gully patterns. Bright, dark gray, and random tones within a specific area are typical on these materials. Low mounds of sands are bright and are usually pock marked with black depressions. Clays, moderately well to poorly drained, have uniform light gray to darker gray tones.

Clay and sand over clay in terrace positions commonly have a fine dendritic drainage pattern. The valley walls are V-shaped and steep; interfluves are narrow and rolling. Photographic tones are fairly uniform except for shadows cast by the slopes. Gray tones are typical for the moderately well drained soils. The gray tone and drainage patterns are the principal indications of clay soils on dissected landscapes. In many places, undulating to rolling slopes can be delineated from hilly and steep areas under a stereoscope.

An overall level surface is the most significant feature of flood plains. Along mature rivers this uniform slope may be broken by irregularities which result from local stream cutting and deposition. Sandbars appear as raised areas adjacent to or parallel to rivers. Though uniform drainage systems do not develop on flood plains because of their low position, seasonal flooding, and deposition, streams flowing from the surrounding topography cut across flood plains in some places. Black streaks—curved and generally parallel—are typical of channel scars, oxbows, and abandoned channels. The black tone is accounted for by the fine-textured mineral soils and organic matter that accumulate in these depressed areas. Linear streaks of well-drained sands or loamy sands appear as nearly white. The gray tones represent level areas with a high water table.

Peat bogs usually occur as depressions; streams are very few. Vegetation changes abruptly at the border between the bog and surrounding terrain. Photographic tones are distinctly darker than surrounding areas.

In many places bogs are covered by low brush, sedges, and moss; these areas appear as a smooth gray tone. At higher elevations some bogs covered by spruce forest appear dark gray to nearly black in contrast to the lighter gray of adjacent uplands covered by hardwoods. Some of these bogs have a rim of spruce which diminish in height and give way to brush toward the center. Regardless of kind of vegetation, nearly all bogs are darker toned than adjoining better drained areas.

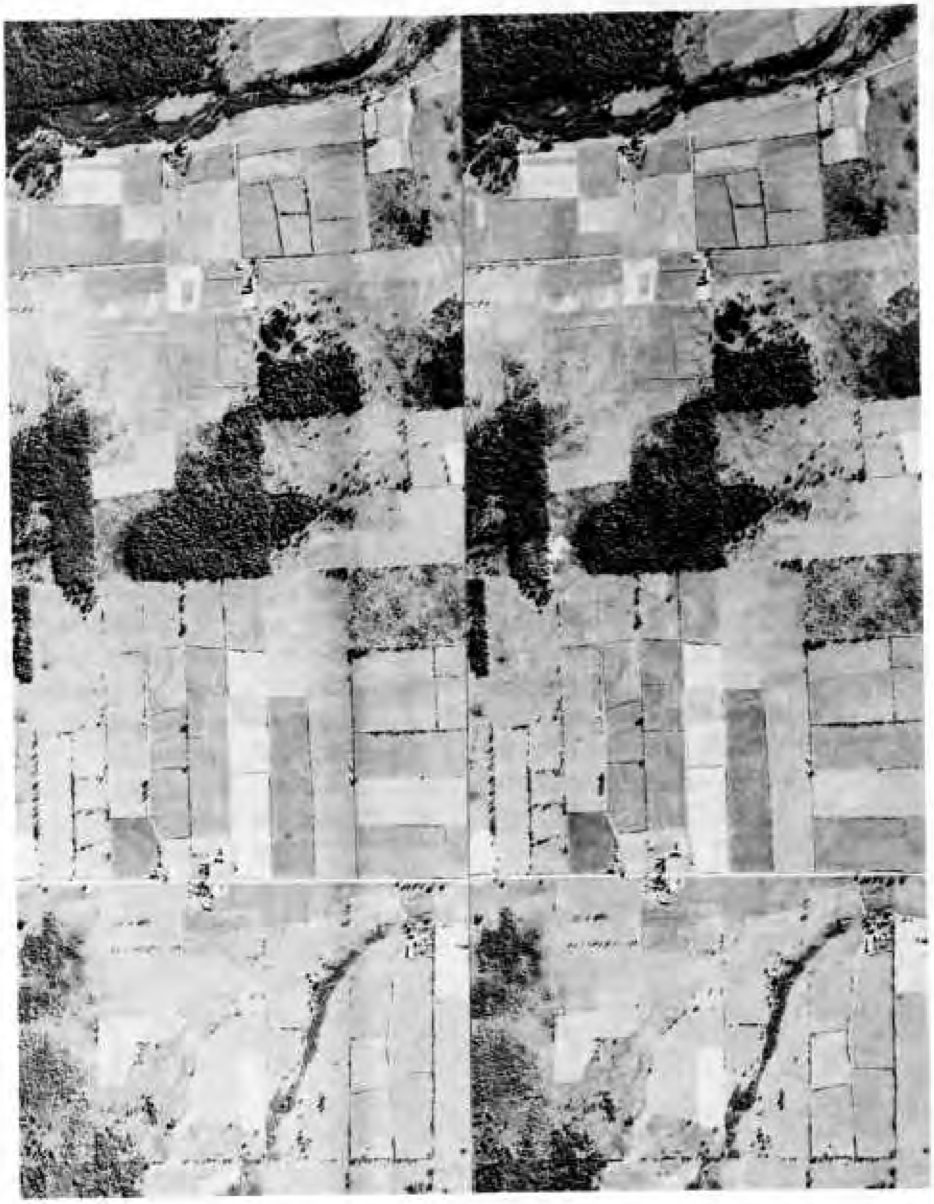

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Figure 54.—These photographs represent the gently to moderately sloping landscape of ground moraines of Wisconsin glaciation in New York. Well-drained Gray-Brown Podzolic soils are on the gentle rises and Planosols and Low-Humic Gley soils on lower slopes and in depressions.

New York.—In New York, main soil associations can be recognized by tone although many associations may have similar patterns. In many places the soils can be picked out by photographic tone, shading, or vegetation.

Large areas of outwash photograph either in light or very light tones on level plains or in the spattered pattern of kame and kettle topography. Sharp slopes breaking to the bottom lands or valley sides usually can be recognized by slightly darker tones but are best identified under a stereoscope. Where frost-moved material covers the outwash, the slope to the valley sides is gentle and difficult to identify except under a stereoscope.

Where present in large blocks soils from lacustrine material usually have recognizable patterns. They have gently undulating to moderately steep topography.

Where the topography is nearly level, tonal value is the most important photographic feature for identifying individual soils that differ in drainage. Light gray tones are registered by Vergennes soils which have the best drainage, intermediate gray by Panton soils, and dark gray to black by Livingston and Covington soils, which have the poorest drainage. Limestone outcrops associated with these soils appear as light toned streaks or spots.

In areas that are dominantly till, the gently to moderately sloping landscape without abrupt slope breaks usually denotes deep, moderately well and somewhat poorly drained soils (fig. 54). Steeper slopes usually include well-drained soils. Darker toned depressions contain poorly and very poorly drained associates.

In the southern tier (Allegheny Plateau) Lordstown soils usually can be identified by step-like relief with short, steep breaks along a general east-west axis. The breaks are interspersed with nearly level to gentle slopes. Where this relief is absent the Lordstown soils may be mistaken for Bath, Mardin, or Volusia soils on photographs. Shallow soils do not give consistent tone values; field examination is necessary to differentiate them.

Shallow and moderately shallow Nassau and Macomber soils on folded rocks along the Hudson Valley are identified by the pattern of short broken slopes along a general north-northeast to south-southwest axis. Deeper Cossayuna and Dutchess soils on drumlins can be distinguished by their long uniform slopes. Poorly and very poorly drained soils of local alluvium in depressions and soils in glacial lacustrine materials appear in darker tones but are difficult to distinguish from each other without field checks.

In Rensselaer County the pattern of complexes of deep and shallow soils over folded bedrock, with occasional rock outcroppings, generally shows up well especially in areas that have been plowed or are in cultivation. On the newly plowed land, the outcrops and shallow areas are darker toned; in areas under cultivation, these same areas may be lighter toned than the surrounding land.

CORRELATIONS IN THE SOUTHEAST

Tennessee.—In Tennessee, most major soil associations in the Red-Yellow Podzolic soil region have slightly different tone patterns. A few, however, appear similar even though the soils of each are different.

The Dandridge-Whitesburg-Lindside soil association presents the most distinct pattern. The deeply entrenched drainways, high dissection, steep relief, and large amount of forest all show clearly on the photograph. Tones and other clues help identify the individual soils within the association. Ordinarily these clues suggest two or three soil series rather than clearly pointing out a specific one. After the soil scientist has identified the soil in the field, he usually can interpret area boundaries from the photograph. For example, Whitesburg soils on local alluvium are dark toned on the photograph because of higher moisture content and dense vegetation. On narrow strips of bottom land, however, Lindside and Melvin soils also photograph as dark areas.

In the Litz-Sequoia-Lindside soil association, also derived from shales, the landscape is dominantly rolling and hilly and streams are not so deeply entrenched. Individual fields are small; many areas are severely eroded and covered with second-growth pine forest. These clues suggest small subsistence farms and soils of low fertility and high susceptibility to erosion. Badly eroded areas within the association suggest either gullied land or severely eroded Litz soils. Where areas are nearly bare of vegetation, erosion can be detected on the photograph by light tones; where areas are covered by pine forest, erosion can be detected by almost black tones. Most soils on local alluvium and narrow bottom land appear in dark tones. Once specifically identified with an auger, most areas can be delineated by differences in tone. Many soils on uplands and old colluvial slopes are similar in photographic tone and little photo interpretation of soils can be made.

In the Dewey-Decatur-Emory soil association, underlain by materials weathered from dolomitic limestone, fields are larger and more regular in outline; more land is in cultivation and crops; and only small areas are severely eroded. These features indicate that soils are higher in fertility. A poorly defined drainage pattern, modified by many sinks and depressions, can be fairly well detected. Small round depressions show as dark areas because alluvium high in organic matter covers the floors of the depressions. Numerous depressions indicate an irregular karst topography.

In many places studying photographs under a stereoscope is the quickest and most accurate means of locating sinkholes, especially in wooded areas. Mottled light and dark tones in this association indicate an uneven erosion pattern; the light spots have lost their original surface layer and the exposed dark red subsoil reflects a light tone on the photograph either because of bright color or sparse vegetation. (Almost all aerial photograph film is highly red sensitive.)

Most local alluvial areas contrast with upland soils by dark tone. Dewey and Decatur soils on the uplands cannot be separated by photo interpretation.

The Muskingum-Jefferson association is characterized by the narrow linear shape of its individual ridges and intervening valleys and the ridges are conspicuous on the photograph. Photo interpretation is of limited value in identifying soils in the intervening valleys; the valley floors are irregularly covered by alluvial and colluvial materials. Local alluvial spots are clearly shown by darker tone.

In East Tennessee, areas of Tellico soils, derived from the Holston formation, stand out in high ridges and are readily distinguished from soils derived from lower lying limestone and shale formations. Also, Lehew soils on the knobby or comby ridges of the Rome formation can be distinguished from lower lying soils on limestone, such as Dewey soils.

In the dissected area adjoining Caney Fork River in DeKalb and Warren Counties, the soil association comprises steep, forested Bodine soils capped by Mountview, Bodine, or Waynesboro soils in open land. Bodine and Mountview soils, which are moderately eroded, appear medium gray. Waynesboro soils, usually severely eroded and often gullied, appear in much lighter tones.

In areas of uniformly dissected landscapes, such as Bodine-Mountview-Lobelville association (fig. 55) or Memphis-Collins association, the soil scientist can make field checks at much wider intervals if he separates ridge tops and bottom lands under a stereoscope before going to the field.

Two landscapes in Tennessee that appear similar on photographs despite major difference in soils are the Highland Rim Plateau (open land Dickson and forested Guthrie soils) and the Inner Basin (open-land Hagerstown and Talbott and forested rockland areas).

Two that appear similar on aerial photographs but have quite different soils are the Highland Rim (open-land Mountview and forested Bodine and Baxter) and the Cumberland Plateau (open-land Hartsells and forested Muskingum).

Well-drained bottom-land soils such as Pope and Huntington appear in light tones; poorly drained Melvin and Atkins appear much darker. The poorly drained soils may also be covered with forest or brush—another clue to their identification. Moderately well drained Lindside and Philo soils are less easily recognized; they may be either dark or light. Areas of sandy soils appear as very light streaks. The first bottoms and low terraces of large stream valleys are commonly separated by short steep escarpments which show plainly on the photograph. Boundaries between soils on terraces are less clear, however, than between those on bottom lands.

In nearly all landscapes, stony and rocky areas appear lighter than the surrounding areas. The strike or banding of the rock is very evident.

Coastal Plains of the Southeast.—Much of the lower Coastal Plain in the Southeast has slight relief. Tone, kind and pattern of vegetation, and pattern of cultural features, however, are useful guides on aerial photographs to soil conditions in this area.

Vegetation does not reveal specifically the

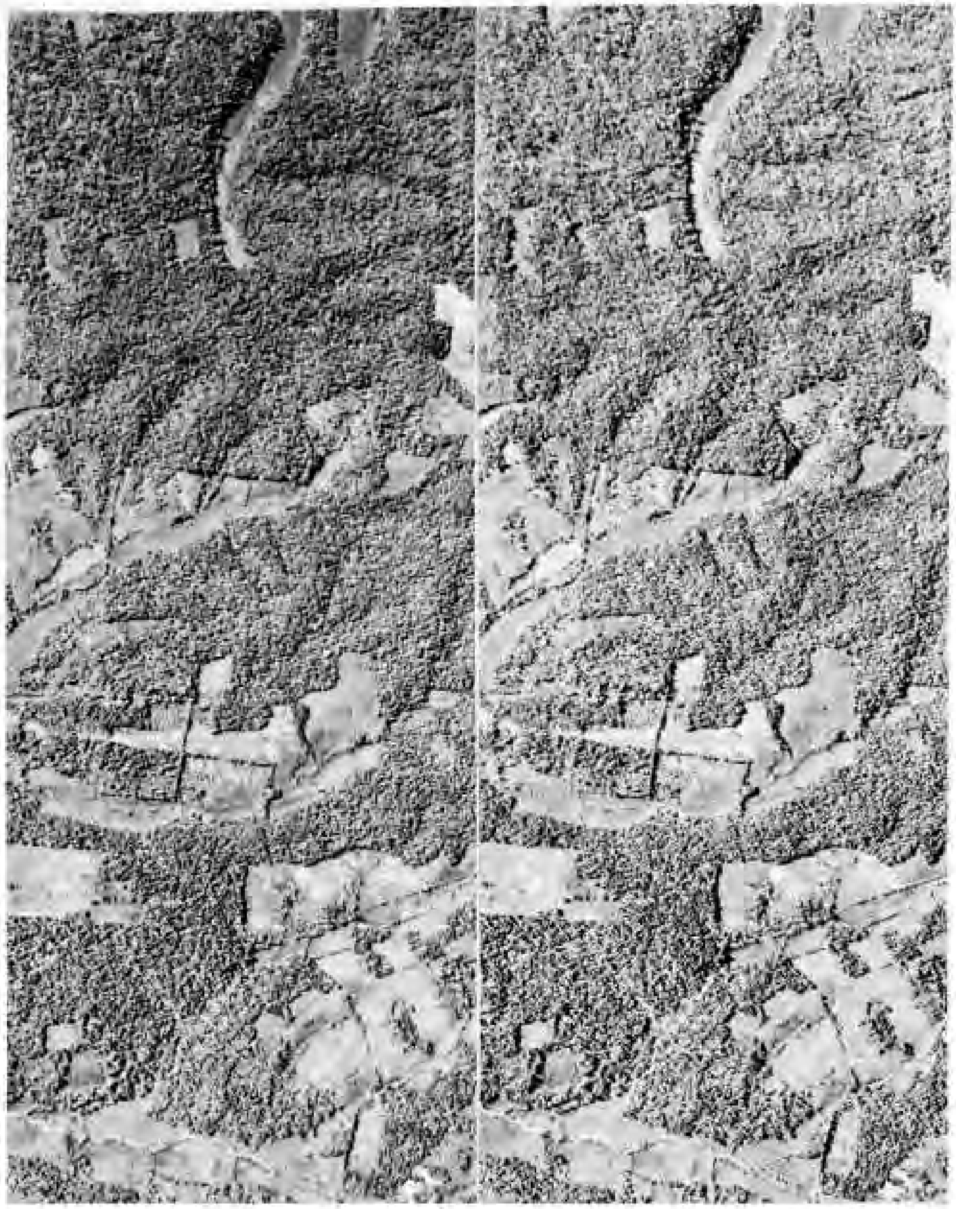

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Figure 55.—These photographs of a dissected limestone plateau in Tennessee illustrate the significance of photo interpretation in dissected areas of uniform bedrock. Regosols are on steep slopes, Red-Yellow Podzolic soils on drainage divides and high terrace benches, and Alluvial soils on flood plains. The white streaks with fuzzy edges in the cleared area represent soil erosion.

kind of soil, but it often gives an indication of what to look for and where to look. For example, in the sandhill section of the Southeast, scrub oak with scattered longleaf pine indicates well-drained deep sand, and pond pines and gallberry indicate wet sand. In the coastal flatwoods section, stunted pine indicates Ground-Water Podzols with hardpans such as Leon and St. Johns soils. In contrast the associated Plummer soils, which have no pan, support much heavier forest. Soil boundaries can often be accurately located by outlining areas of different vegetation on the photographs. In Bladen soils, pure stands of hardwood indicate fine-textured types, whereas mixed stands of pine and hardwood indicate sandy loam types. In poorly drained areas of the middle Coastal Plain, sweetgum is often an indicator of Coxville soils. Black gum is often an indicator of coarse-textured poorly drained soils.

Water-loving vegetation shows dark to very dark gray in tone; its area is irregular. Trees or water-loving vegetation in dark tones appearing as narrow bands with irregular curves are clues to stream channels. Cypress indicates very poorly drained soils; it can readily be distinguished from pines.

In Florida, differences in patterns of vegetation can help the soil scientist separate poorly drained soils on acid sands from those on neutral sands even though the soils are identical in color and are similar in overall tone on the photograph. In many places cabbage palms indicate neutral to slightly acid soils or soils with carbonates at moderate depths since pine trees grow on acid soils. The vegetation alerts soil scientists of the need to examine given sites for possible differences in reaction.

In many areas in the Atlantic Coastal Plain in the Southeast, tone or pattern on the photograph may give a direct clue to soil differences (figs. 22, 32, 33, and 47). For example, cleared well-drained sandy soils appear lighter than cleared well-drained fine-textured soils. In wooded areas the vegetation shows up darker on fine-textured soils. Poorly drained soils show up as dark areas in both wooded and cleared areas. Well-drained clayey soils generally are represented by gray tones on the photograph.

Tones are somewhat misleading, however, since they are influenced by vegetation on the soil. Contrasting shades of light gray indicate coarse-textured somewhat excessively drained soils. Small irregularly shaped light-colored areas within darker areas may indicate severe sheet erosion. A disorderly arrangement of short lines in the direction of the slope represents gullies, which show up clearly under a stereoscope.

A boundary of gray tone against a dark gray tone implies a boundary between well drained and moderately well drained soils. As soil drainage becomes poorer, tones become darker. This suggests that there are two—and possibly three—soil series. In Florida, smooth dark gray tones often suggest Ona, Scranton, Sunniland, or Adamsville soils, whereas black or very dark gray are clues to Rutledge, Portsmouth, Plummer, Delray, Pompano, or Charlotte soils. The first group are moderately well drained and somewhat poorly drained soils, the second poorly drained and very poorly drained. Within the darker tone, areas of light gray sprinkled with black imply the presence of Leon, Pomello, or Immokalee soils, all of which are Ground-Water Podzols.

The boundary lines between better drained and more poorly drained soils on first bottoms can be recognized on aerial photographs because the more poorly drained soils commonly appear darker.

In Florida and Georgia, tone can give an accurate indication of major soil associations within an area. In many areas of Florida, tones give clues to areas having as few as two soil series. Within forested areas gray tones liberally sprinkled with spots of white indicate areas in which acid coarse-textured excessively drained soils predominate.

There is a danger, however, of misinterpreting this feature of a photograph. Coarse-textured excessively drained soils in some parts of Florida appear as dark gray or gray tones intermingled with specks of black that represent pines. This suggests soils that are influenced by limestone or phosphatic materials. In some areas dark-gray or gray tones on photographs represent clay soils. Smooth gray tones within the same area indicate a change in texture or the presence of soils with more restricted drainage. Increasing intensity of tone from gray to very dark gray strongly suggests somewhat

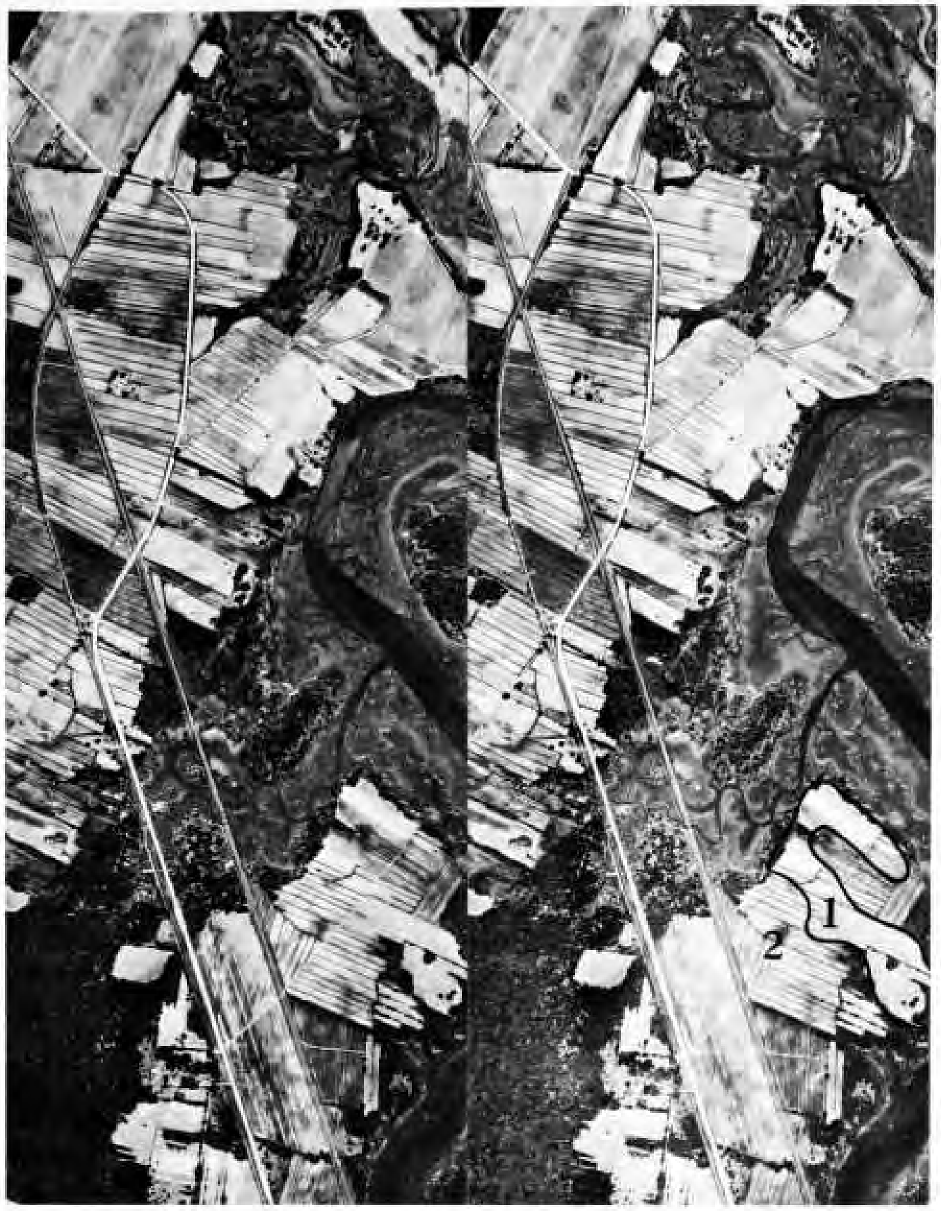

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Figure 56.—Slight differences in tone and the pattern of drainage ditches often indicate differences in soil drainage. These photographs are of a truck-farming area in South Carolina. The light gray area (1) with scattered ditches irregular in length represents well-drained Red-Yellow Podzolic soils. The adjacent darker area (2) with many parallel ditches represents Low-Humic Gley soils.

poorly to very poorly drained mineral soils or soils with surface layers of high organic content (fig. 44).

Cultural and other features such as roads, ditches and canals, terraces, and field patterns may give useful clues to the kinds of soil to expect in some parts of the Coastal Plain (fig. 56).

In nearly level to gently sloping areas, fields are larger, field boundaries are more nearly straight, and secondary roads are straight in many places. Also, in contrast to more sloping areas that have smaller less regular fields and crooked secondary roads that are mainly in valleys or on ridge tops, terraces are lacking. Terraces, which are common on more sloping areas, appear as dark lines on the contour. The spacing of terraces is a clue to steepness of slope. Roads across better drained soils appear as light lines, those across lower more poorly drained areas as dark lines. None of these features by itself is necessarily diagnostic of a soil type, but the combination and patterns may enable the soil scientist familiar with the area to identify the soils.

Spacing of field ditches in truck-crop areas is a clue to the natural drainage and, to a lesser degree, to the subsoil texture of Humic Gley, Low-Humic Gley, and intergrades to Red-Yellow Podzolic soils on the first marine terrace of the Atlantic coast in Charleston County, S.C.

Ditches spaced 60 to 80 feet apart indicate poor to very poor drainage and a subsoil of plastic silty clay. Bladen and Bayboro are the principal soils having this close spacing. Somewhat wider spacing—80 to 120 feet—indicates poorly to somewhat poorly drained soils with subsoil textures ranging from sandy clay loam to sandy loam or loamy fine sand. Weston, Edisto, and Stono soils are the principal soils with these features. Wider spacing—more than 120 feet—and irregularly spaced ditches that are uneven in length indicate moderately well drained soils. These areas are better drained because they have slopes of 1 to 3 percent and are slightly higher than the surrounding soils. Eulonia and Charleston soils with subsoil textures ranging from sandy loam to sandy clay usually occupy these sites.

ACCURACY OF PHOTO INTERPRETATION IN SPECIFIC AREAS

Though photo interpretation is one of the most useful techniques in making soil surveys, too much or too little reliance on photo interpretation can result in inaccurate mapping. The objective is to use photo interpretation to maximum efficiency while keeping the mapping at or above acceptable standards of accuracy.

To obtain a better understanding of the accuracy that could be achieved through photo interpretation in specific areas, selected areas were interpreted and field checked by experienced soil scientists. The following are summaries of the procedures used and results obtained.

COASTAL PLAIN SAND HILLS OF SOUTH CAROLINA

A 640-acre area near Pontiac (Richland County), S.C., was outlined on aerial photographs. A soil scientist who had had 8 years' experience mapping soils in the area and who was thoroughly familiar with its geology and soil associations (fig. 57) and the vegetation that usually grows on the different soils made interpretations by using a stereoscope. He recorded his estimates of soil, slope, and erosion and placed soil boundary lines on the photograph in pencil. An inked tracing of these estimates was made on clear plastic as a permanent record (fig. 58). Then he and another soil scientist also familiar with these soils checked the estimates in the field.

His photo interpretation estimates were compared with the field mapping on the aerial photograph (fig. 59), by placing the inked overlay over the field sheet. The accuracy was determined by measuring the acreage on the overlay that did not correspond with the field mapping.

On 528 acres (82.5 percent), estimates by stereoscope were the same as the field mapping. All streams were accurately identified with the stereoscope. Of the 112 acres (17.5 percent) that were different, 38 acres were in error in designation of soil type or phase. One 12-acre area that was estimated to be Portsmouth sandy loam (53) on field examination was found to be Portsmouth loam (54). Identification of soil series and type was 94.1 percent correct. On 68 acres an error was made in estimating slope with the stereoscope. Two areas, totaling 44 acres, were a low B slope instead of the estimated A slope. Accuracy of estimating slope was 89.5 percent correct. On a 6-acre area class 2 erosion was not recognized.

The soil scientist using the stereoscope was not sure of the correct symbol to put in five delineations totaling 61 acres. He made first and second choices and placed a question mark by his second choice. These were recorded on the overlay before the field check. His first choice proved to be correct in three delineations totaling 36 acres. The second choice was correct on one 21-acre area. On one 4-acre area, the second choice was correct for soil type and erosion but the area was C slope instead of the estimated D slope.

The time required to map the 640 acres was as follows:

- ¾ hour in office making photo interpretation
- 5 hours in field checking the mapping done in the office
- ¼ hour inking time
- 6 hours—total time to map 640 acres (does not include travel time)

The block diagram in figure 57 shows the relation of the major soils to the landscape and drainage. Clues used by the soil scientist in making his interpretations follow.

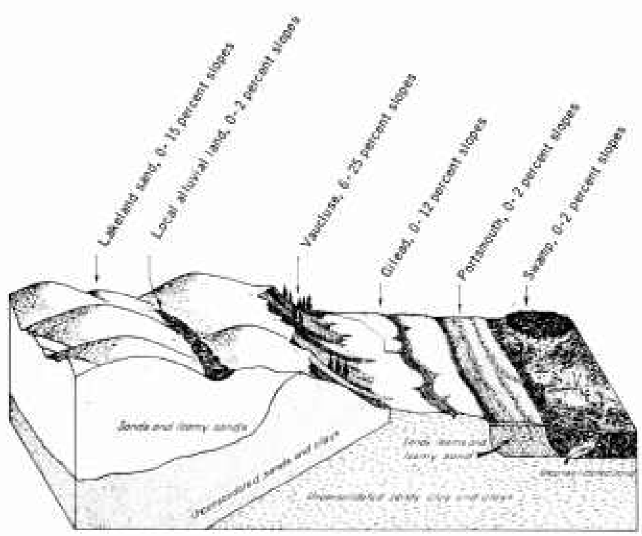

Figure 57.—Relationship of major soils to landscape in Coastal Plain sand hills of South Carolina.

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Figure 58.—Estimates of soil, slope, and erosion delineated by a soil scientist using photo interpretation. Hatching indicates areas for which estimates made in the office were changed in the field. The area is in the Coastal Plain sand hills, Richland County, S.C.

Lakeland sand (18) occurs as dunes or hills on the highest elevation of the soil association. The tone of the photograph is light gray in wooded areas and nearly white in cultivated fields. Cultivated areas reflect so much light that field roads, furrows, and other minor culture tend to be obliterated. The scrub oak of the wooded areas is sparse, and the light gray sand between trees reflects a large amount of light. Minor trails show up very light. Scattered pines show up as dark specks. Under the stereoscope, slopes contrast readily.

Vaucluse sandy loam (96) contrasts markedly under the stereoscope with the associated Lakeland sand by showing a sharp and sudden break in slope. It usually occurs on slopes two or more classes higher and displays some characteristics of an escarpment. Many times it occurs in areas shaped like a horseshoe. The associated thick surface phase (97) generally occurs in broader areas and on somewhat gentler slopes. Tone of Vaucluse sandy loam, thick surface phase, is lighter than Vaucluse sandy loam.

Vegetation on both types is denser and tone is a darker gray than on Lakeland sand. Pine thickets on formerly cleared areas show up black on the photograph. Vaucluse sandy loam often occurs as a narrow band at the highest part of the slope break and on breaks around stream heads. Streams frequently originate at the foot of these breaks.

Gilead sandy loam (115) contrasts with Lakeland and Vaucluse by being at the base of slopes—often in stream heads—and on gentle slopes along the major streams. Few areas are above C slope (6–10 percent). Tone of the pho-

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Figure 59.—The same area as figure 58 with the mapping delineated in the field.

tograph is dark gray due to more dense vegetation and better moisture relations. In cultivated fields the furrows and ridges with relief measured in inches give a marbled appearance of light and dark gray tones.

In both woodland and cultivated fields Gilead sandy loam, thick surface phase (121), shows up lighter than Gilead sandy loam. Through the stereoscope, the thick surface phase often shows up as gentle ridges and mounds. These ridges are lighter than those in Gilead sandy loam.

Local alluvial land (2) contrasts markedly with Lakeland sand by occurring in depressional topography. The tone is darker gray than Lakeland due to slightly denser vegetation. In cultivated areas the more moist, darker surface soil has a light gray tone as contrasted with the white tone of Lakeland.

Portsmouth soils (54) occur in stream heads and along the edges of small streams with a dendritic pattern. Portsmouth soils occur at a slightly higher elevation than swamps and at lower elevations than Gilead soils. The tone is lighter than Swamp (84) and much darker than Gilead. Individual large trees, including scattered pine trees, can be identified. Portsmouth loam has a high water table and a dark surface layer; where cleared, it photographs much darker than the adjacent Gilead soil.

Swamp (84) can generally be accurately delineated by its pattern and the black tone on the photograph. Vegetation consists dominantly of black gum trees that have even crown growth. Tree tops appear in a smooth, even surface and seem to rise up in a block when viewed under a stereoscope. This type of tree growth contrasts sharply with other vegetation and provides distinct boundaries for the delineation of soils.

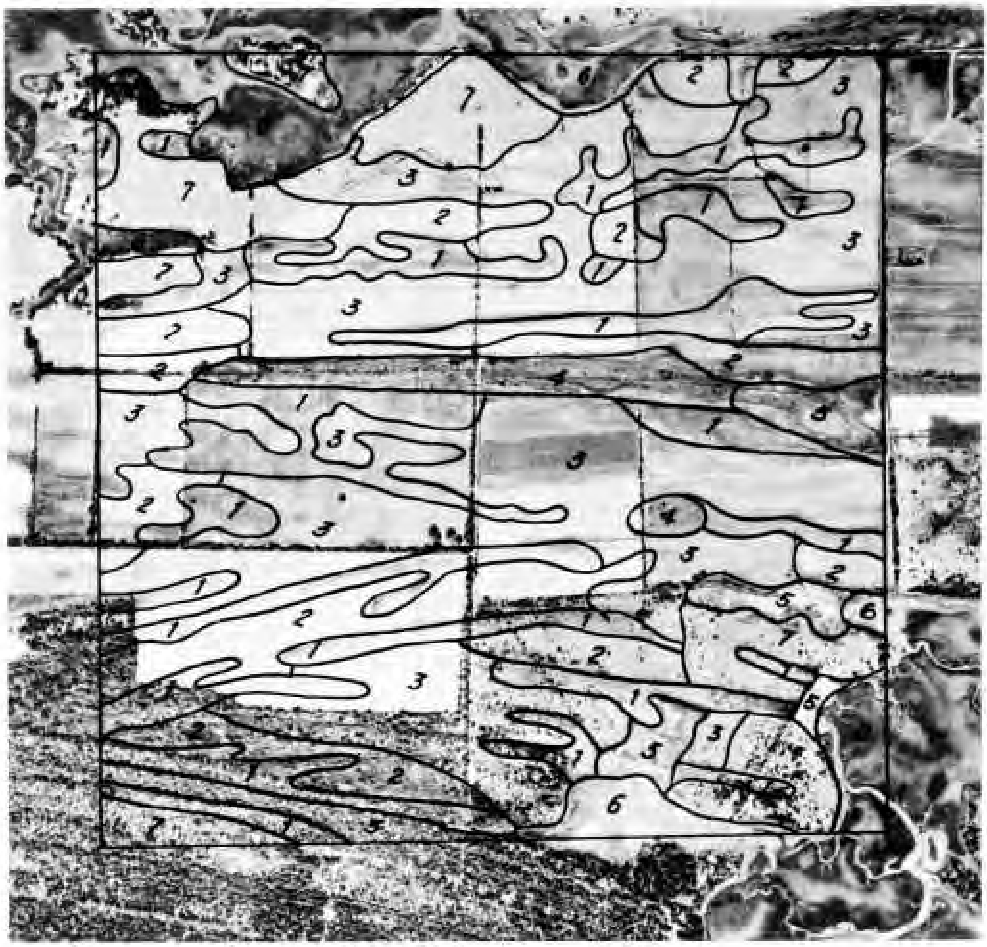

Figure 60.—Delineations resulting from stereoscopic interpretations. The area is in the Atlantic Coastal Plain, Charleston County, S.C.

SOUTHEAST ATLANTIC COASTAL PLAIN OF SOUTH CAROLINA

Interpretations of the photograph of a 640-acre area on a first marine terrace in Charleston County, S.C., were made in the office by a soil scientist who had 12 years' experience mapping in this area. Delineations resulting from stereoscopic interpretations are shown in figure 60 and identified as follows: 1, Rutlege loamy fine sand; 2, Seabrook loamy fine sand; 3, Kiawah loamy fine sand; 4, Stono fine sandy loam; 5, Tidal marsh, high; 6, Tidal marsh; 7, Eustis fine sand.

For comparison, a plain photograph of this area is shown in figure 61. A block diagram of the relationship of major soils to landscape and drainage is shown in figure 62.

Field checking of the mapping done in the office showed that about 95 percent of the interpretation was correct. Interpretations in open areas were accurate where contrasting tones were apparent. A partially wooded area of about 24 acres on the southeast side of the mapped area was judged in the office to be better drained than field examination indicated. Scattered small trees and light gray tone of the photograph on a 12-acre area were interpreted to mean well-drained soils. Field examination showed that this area had been cleared and was being cultivated.

Two areas of 1.3 acres each in the east and northeast parts were better drained than indicated by stereoscopic examination. The lack of contrast in tone did not give the soil scientist the correct clue.

A 0.8-acre area on the northeast was interpreted as part of a 10-acre poorly drained area. Field examination showed that it was poorly drained but was an area of high phase tidal

Figure 61.—Plain photograph for comparison with figure 60.

marsh separated by a farm road from an adjoining area of tidal marsh.

The soils interpretation was based on two factors: (1) *Landform*—parallel bands of old beach ridges and sloughs. (2) *Tone*—white, whitish gray, and dark gray tones indicating good, imperfect, and poor natural soil drainage, respectively.

Landform.—The ridge-slough landform originated as parallel lines of beach dune sands modified by wind and water with time and shoreline recession. The landform in varying stages of development can be traced from the present shoreline beach sand dunes onto tree-covered steep-sided dunes and sloughs and across the broad ridge and slough areas for a distance of about 5 miles. The landform is more extensive and visible on the first (Pamlico) marine terrace than on the second (Talbot) terrace.

A difference in elevation of about 4 to 8 feet between the ridges and sloughs shows on the photograph (fig. 60), but it cannot be readily seen under the stereoscope because the change is gradual. This difference in elevation makes the difference in the drainage class. All the area has A slope (0–2 percent) and class 1 erosion (none to slight). In the entire area of nearly level sand, the water table is high; in low areas it is at the surface where undrained; in higher areas at 4 to 6 feet below. The water table and drainage class affect the amount of vegetation cover that grows and accumulates in the surface soil.

Tone.—Ridge areas grow less vegetation and have less organic matter in the surface soil and therefore show up as white or chalky colored. Low areas having the most organic matter show up dark. Areas intermediate in elevation have an intermediate amount of organic matter and show up as grayish white. The chalky white-

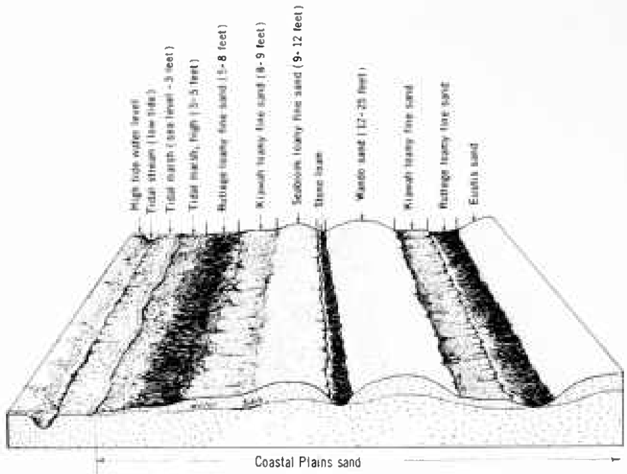

Figure 62.—Relationship of major soils to landscape and drainage in Pamlico Terrace, Coastal Plain of South Carolina. Numbers in parentheses give feet above sea level.

toned ridges are the Eustis soil series, intermediate areas are Seabrook and Kiawah series, and the dark-toned, low areas are the Rutlege series. The problem was to separate Seabrook from Kiawah. The clue was that Seabrook has more white than gray-white tone and that Kiawah has more gray-white than white. In wooded areas the higher well-drained to excessively well drained areas are in pine with about 75 percent crown cover plus some live oak and hickory. Gray areas show up indicating reflection of light from the ground. The pines show up dark. Poorly drained areas in woods are dark indicating a dense stand of pine, black gum, and low-growing shrubs. Intermediately drained areas are gray to dark gray indicating some ground reflection of light with a crown cover between 75 to 100 percent of mostly pine and a few oaks.

On the second marine terrace the sand soils associated with the ridge-slough landform are the Lakeland, Ona, Plummer, St. Johns, and Rutlege series.

The time required to map the 640 acres follows:

- ½ hour in the office making photo interpretation
- 3½ hours in field checking the mapping done in the office
- ½ hour inking time
- 4½ hours—total time to map 640 acres (does not include travel time)

In both of these test areas the high proportion of agreement between photo interpretation and field examination resulted from several factors—the long experience that soil scientists had had in the areas, their intimate knowledge of the soils and of their relationships to landforms, the relatively simple patterns of the soils, and the noninterference of foliage in the interpretations of soils of forested areas. If any of these factors had been lacking, the photo interpretation might have been considerably less accurate.

Even with an intimate knowledge of the soils one would need to field check constantly and continually revise photographic guides because of the close relationships of soils and variations from photograph to photograph and place to place. Areas of such closely related soils as Kiawah and Seabrook are always suspect until examined in the field. Clues change from place to place and may not apply from one photograph to another even if appearances are the same.

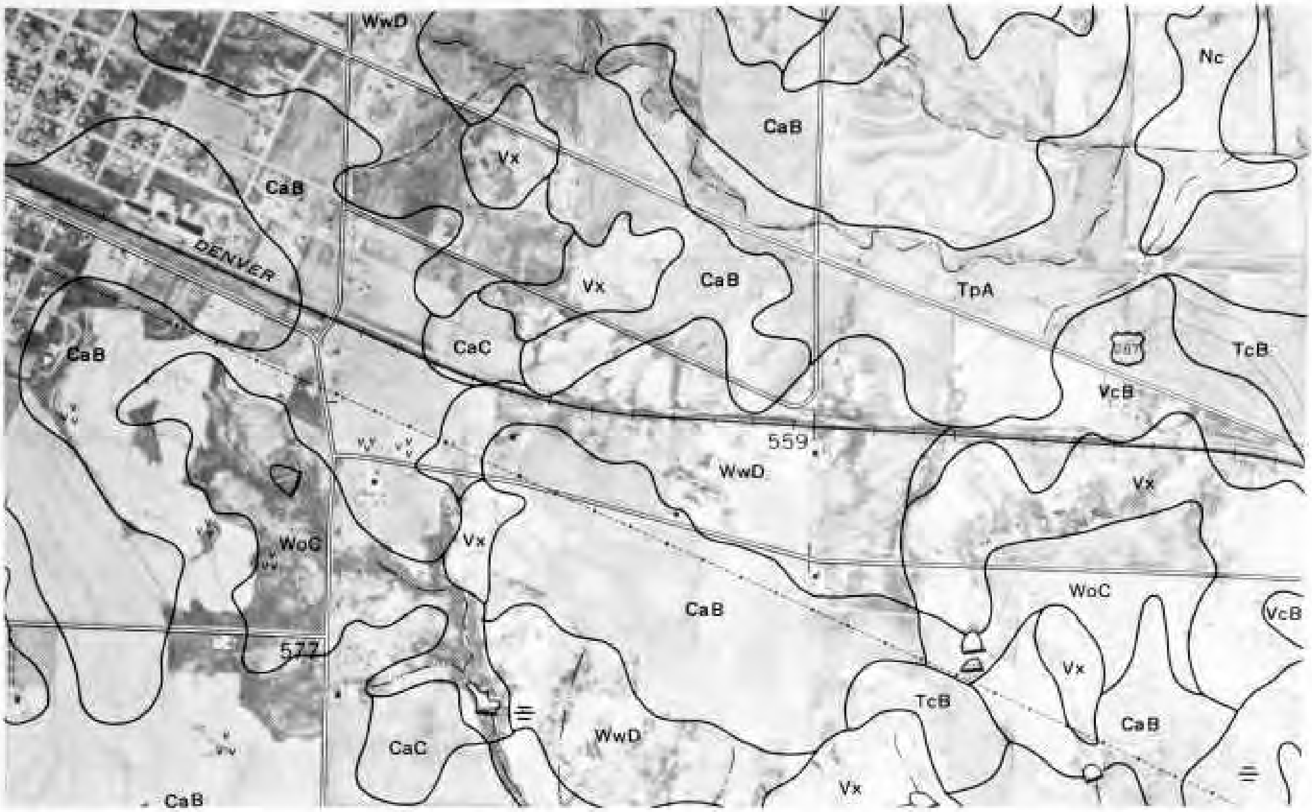

Figure 63.—Section of a soil map compiled on a controlled mosaic base.

Maps systematically compiled from soil-survey data delineated on aerial photographs make up the detailed soil map that is part of every published soil survey. Most of them cover a full county.

Usually the soil-survey data are superimposed on a controlled aerial mosaic base (fig. 63). This base produces uniformity of scale, provides a close match of images between adjoining map sheets, and makes possible the economical production of data on a base that is generally understood and useful.

The published map sheets are 11 x 17 inches in size and usually 1: 20,000 in scale. Some are at scale of 1: 31,680 or 1: 15,840, depending on the complexity of soil delineations and on the intended use of the maps.

Some aerial photographs selected for the mosaic are from the same film used to print the photographs on which soil data were originally plotted. When a more recent aerial survey has been flown, it is used if the photographs have good quality and a satisfactory scale.

The SCS Cartographic Division may begin compiling the mosaic while the soil mapping is being completed in the field.

CONTROL FOR THE MOSAIC

A radial-control network is established for each project. This network provides a pattern of correctly located image points that are identified on the photographs. These provide a basis for rectifying and mounting the individual aerial photographs into a continuous map image.

First, a base grid is constructed at the scale selected for map compilation. The grid, usually constructed on the State rectangular coordinate system, forms a system of spaced lines of reference from which any ground position within the area may be plotted if the coordinates of that position are known. The positions of all geodetic control stations that can be identified and marked on the aerial photographs are then plotted on the base.

Because geodetic control stations are too widely spaced to provide a basis for rectifying and mounting aerial photographs, a system of radial-line triangulation is used to provide accurate locations for additional image points. Since for all practical purposes image displacements caused by relief are radial from the center of the photograph, the true location of an object falls on a line drawn from the center of the photograph through the object. Therefore, the center point of the photograph is a triangulation station from which angles to various objects in the photograph area may be determined accurately.

To provide the triangulation pattern, nine image points are marked on each photograph: the center point, two "conjugate" center points that are transferred from adjacent photographs within the line of flight, two "wing" points on images in the sidelap areas opposite the center point, and four wing points that are transferred from adjacent photographs (fig. 64). Wing points are transferred to adjacent lines of flight much as the center points are transferred from photograph to photograph within a line of flight. Where images of geodetic control stations fall in the sidelap area, they may serve as wing points.

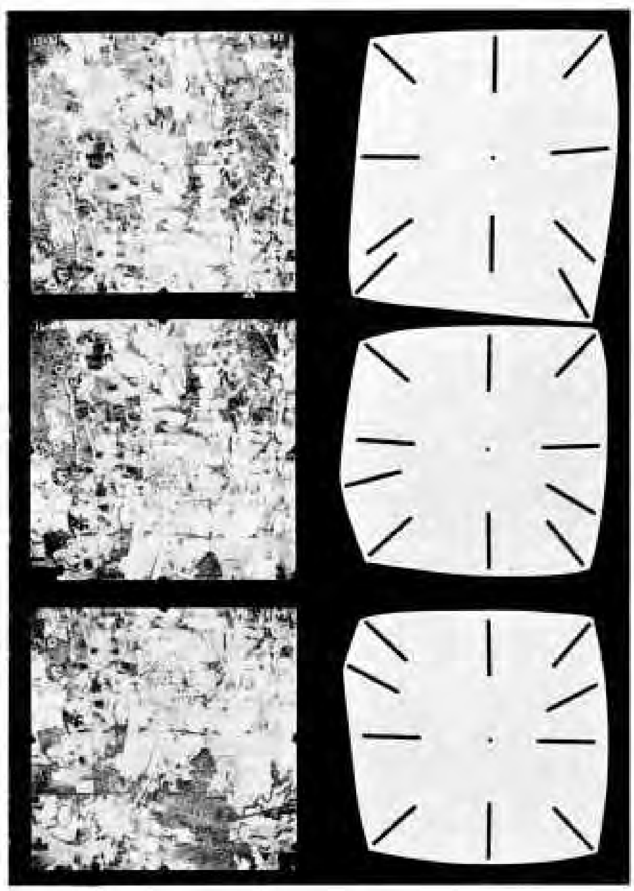

Figure 64.—Typical pattern of center and wing points circled on aerial photographs and corresponding slotted templets.

Where they do not, they are additional points that must be transferred to adjacent photographs within the line of flight. Contact prints are nearly always used to provide radial-line triangulation.

SCS uses the slotted-templet method of assembly to establish the radial-control net. A high-quality cardboard, such as three-ply railroad board or four-ply bristol board in sheets about the size of the aerial photographs, is used for the templets. A templet of the triangulation pattern of each photograph is made by punching a small hole in the center and by punching long, narrow radial slots that accurately reproduce the radial angles established on the photograph (fig. 64). Studs are "anchored" directly on the geodetic control stations plotted on the base, and the templet assembly is jointed by "floating" studs: one stud for each center hole and one for each intersection or radial lines through common wing points. The assembly is expanded or contracted until it fits the anchored studs. Then the locations of all the floating studs, fixed in position, are marked on the base (fig. 65). All radial-control poistions are then transferred to 1/4-inch tempered hardboard sheets on which the mosaic will be compiled.

RECTIFIED PHOTOGRAPHS

On contact prints used to establish the radial-control network, a small dot of black ink is placed on the image points picked for the triangulation pattern; all other notations are removed from the prints. Then a copy negative of each contact print is made. A strip of thin, stable transparent plastic is placed over each flight line pictured on the hardboard control base, and a "strip" templet of each flight line is made by carefully circling on the plastic all control points common to the flight line. The copy negative, which has dotted image points that are displaced, is placed in a rectifying enlarging printer; the strip templet, which has corresponding points that are positioned correctly, is placed on the easel. The dotted points on the negative are projected, ratioed, and rectified until they fit the corresponding points on the strip templet. Then, the templet is removed; photographic paper is placed on the easel; and the rectified image of the copy negative is printed. Great care is taken to expose and develop photographs that will match the tone, contrast, and density of adjoining photographs.

MOSAIC ASSEMBLY AND REPRODUCTION

Because cut lines are less evident along features that have abrupt changes of tone, whenever possible match lines are selected where they can be made along prominent features such as roads, trails, streams, certain landforms, or boundaries of fields, forests, or bodies of water. Since only features that have about the same ground elevation may be precisely matched to adjoining photographs, in areas of moderate to severe relief, cut lines tend to follow a generalized contour line.

Some paper backing is removed along the cut and the remaining paper is sanded to provide a smoothly tapered joint with adjacent photographs. The segment is then positioned on the hardboard base, dotted points are matched to corresponding control points on the base, and photographic detail is matched to detail of adjacent photographs. The photographs are mounted with gum arabic adhesive (fig. 66).

When all photographs are mounted, a transparent dye solution is applied to darken any segment that has a photographic density lighter than that of adjoining photographs. Also, opaque paints in gray tones are applied to correct minor mismatches of prominent features. Finally, corners of individual map sheets are plotted on the mosaic, and each map sheet area is copied through a halftone screen on dimensionally stable film. The halftone negatives are used to print the mosaic images on bases for manuscript compilation and to make press plates for reproducing the photographic background of the map.

To prepare a base—called a greencote—for soil map compilation, dimensionally stable, clear plastic sheets are coated with a white pigment paint developed for scribing.

A green, water-soluble sensitizer is applied over this coating. The sheet is then exposed in contact with the halftone negative to produce a "manuscript base". The greencote reduces the passage of actinic light except through lines where the paint has been removed by scribing. The scribed greencote, therefore, serves as a negative for reproducing the manuscript.

MANUSCRIPT COMPILATION

The map manuscript is compiled by scribing on greencotes the main drainage, roads, soil

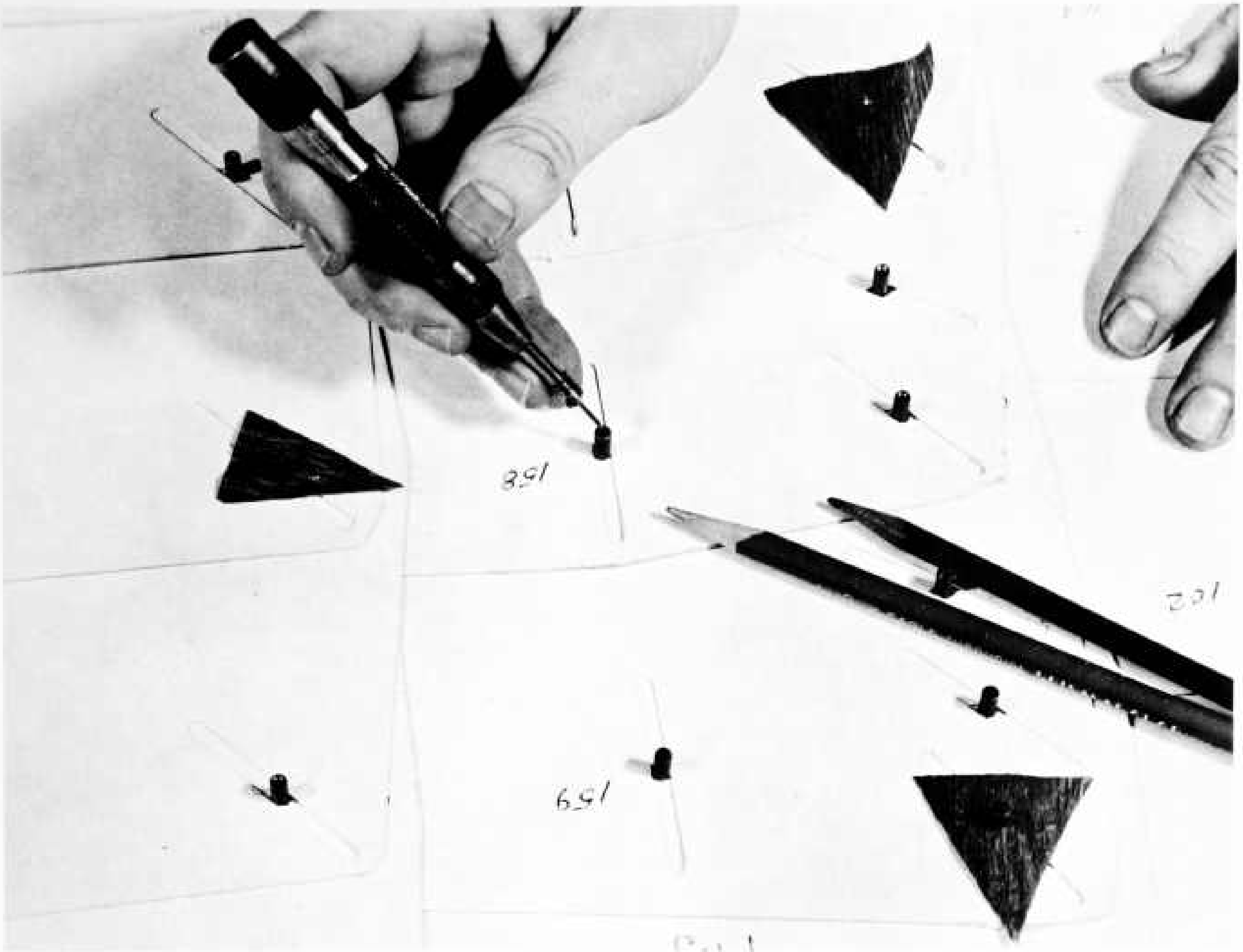

Figure 65.—Portion of a slotted-templet assembly. To mark the locations of studs on the base, a needle is passed through holes drilled through the studs.

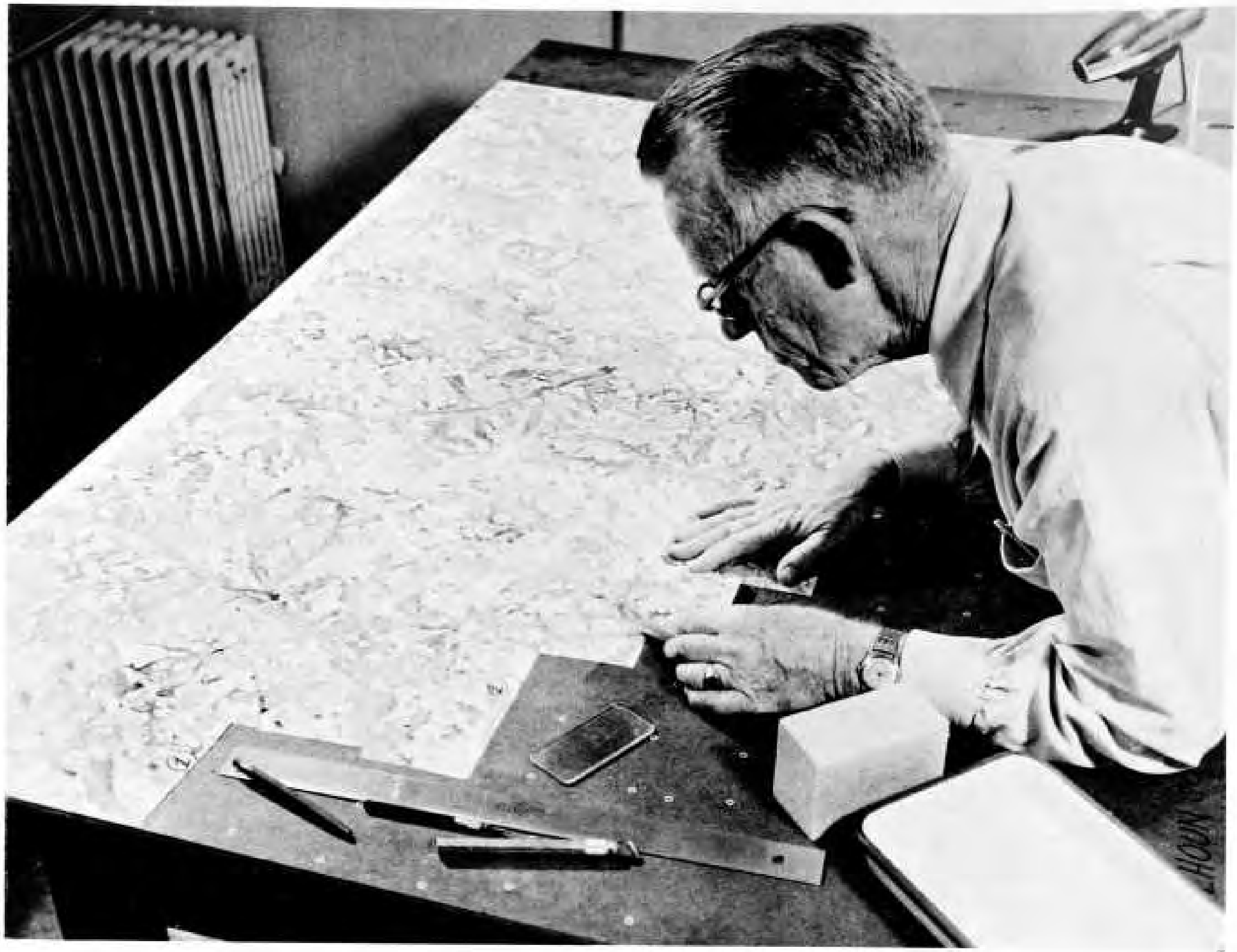

Figure 66.—Mounting aerial photographs to form a controlled mosaic. Note the control points plotted on the hardboard base.

boundaries, soil symbols, and other data shown on field sheets. Main drainage and roads are first traced with a stylus (scribed) as they appear on the mosaic. The greencote is then placed under an overhead reflecting projector, which projects the field sheets to the greencote. The gray-tone image of the field sheet is enlarged or reduced to fit the green-tone image and the scribed drainage and roads on the greencote. The map compiler then scribes soil boundaries and other data that appear on the field sheet. Succeeding field sheets are thus projected until compilation on the greencote is completed.

After soil survey data are scribed on greencotes, identifying soil symbols are scribed in the soil areas (fig. 67). These symbols are taken from a working conversion legend prepared from the correlation and final soil legend. The scribed soil boundaries separating soils that are combined is opaqued out.

When the greencote manuscript is completed, the soil map is edited. Manuscript editors use the original field sheets and the correlation legend to check the accuracy of the soil-survey transfer, adjustment of soil boundaries to the mosaic image, and conversion of field soil symbols to the final map symbols.

COLOR-SEPARATION SCRIBING

Since on final map sheets soils data are printed in red and culture and drainage features in black these features must be separately scribed in negative (left-reading) form. To prepare a base for this scribing, the greencote manuscript is contact printed to a plastic "yellowcote." A yellowcote is similar to a greencote but is coated with yellow pigment paint and sensitized with blue watercote. Since all scribing on the greencote is positive (right-reading), the manuscript is contact-printed emulsion-to-emulsion on the yellowcote to reproduce a left-reading image. Two yellowcotes are printed from each manuscript. Only culture and drainage features to be printed in black are scribed on one yellowcote. Soil boundaries, erosion symbols, and other symbols to be printed in red, such as escarpments, depressions, and rock outcrops, are scribed on the other. Each scribed yellowcote is contact-printed on film to produce a right-reading film positive. Lettering to be printed on the final map sheet is added to these positives.

SCRIBING TOOLS

The scribing tools used are standard throughout the mapping industry. They are ground and adjusted to cut sharp lines of uniform weight and spacing. A tool designed to scribe highways is used to cut a double-line road that will have the specified width and line weight. A rigid scriber is used to scribe soil boundaries and perennial drainage, and a dotting instrument is used to make dots in the symbol that distinguishes intermittent drainage.

MAP LETTERING

To determine the proper position of place names and conventional signs, a lettering guide is first laid out on paper reproductions of the greencote. The size, style and weight of type, and the position of names and signs are shown on this guide. Soil symbols, names, conventional signs, and soil legends are printed on cellophane, the back of which is coated with wax to form a pressure-sensitive adhesive. Next, lettering is cut from the cellophane letterpress sheets and applied to the film positives reproduced from the yellowcotes. Names of roads, drainage, and cultural features are applied to the black plate positive; alphabetical soil symbols are added to the red plate positive after this positive has been placed over and registered with the first one. In this manner the two plates are properly registered, and overprinting of red and black features such as lettering or conventional signs is avoided.

FINAL EDIT

Each completed film positive is contact printed on film to produce a negative, and a composite color proof is made from these negatives. A final edit of the proof is made, and the negatives are corrected before press plates are made.

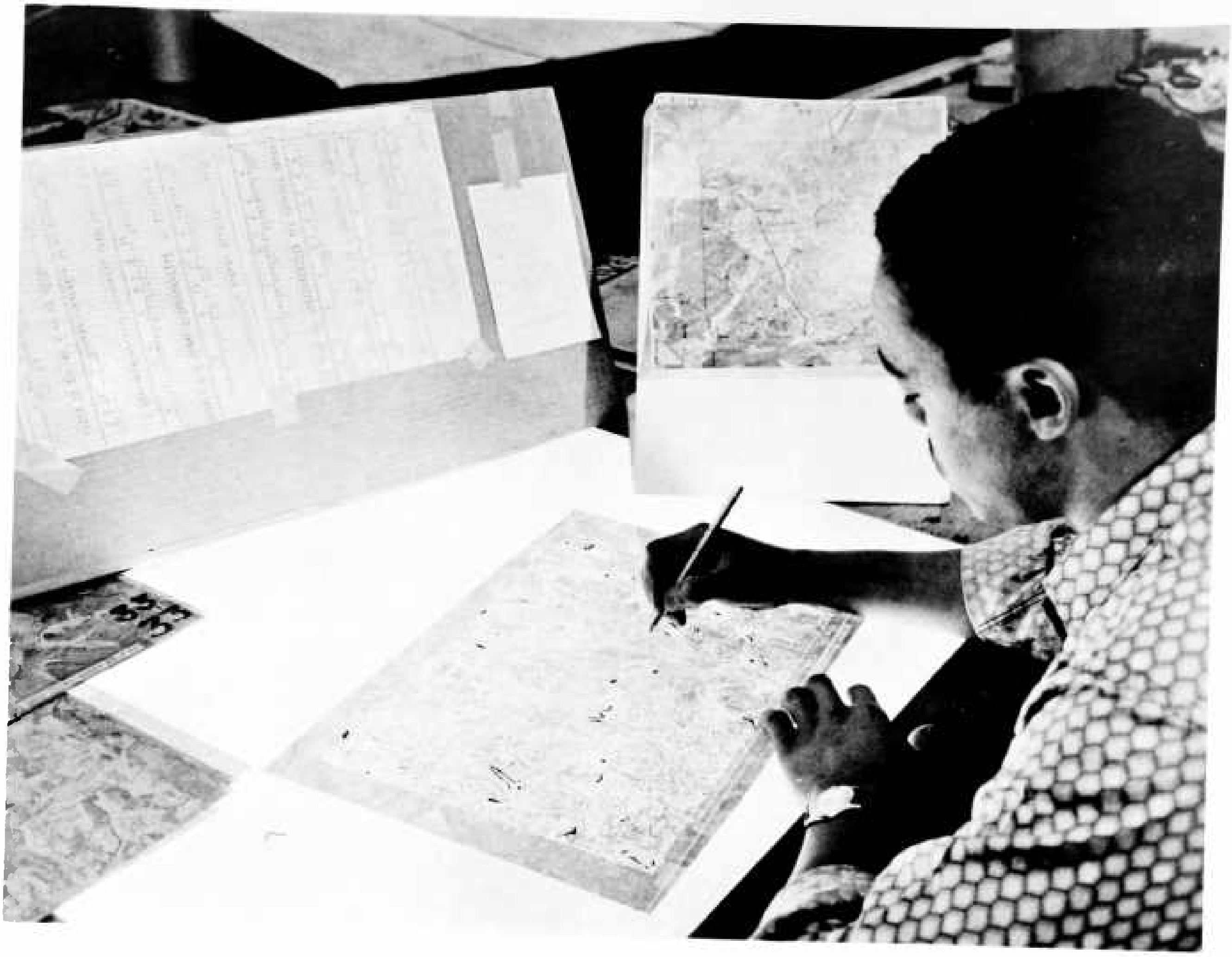

Figure 67.—Scribing soil symbols on greencote manuscript.

PHOTO INTERPRETATION IN WATERSHED-PROTECTION AND FLOOD PREVENTION PROGRAMS

Photo interpretation and related techniques, many of them similar to those used in making soil surveys, are also used to find facts about watersheds. Enough necessary information for watershed planning can be determined by photo interpretation to produce a significant saving in time and cost. A good knowledge of the physical and cultural features of the area being studied increases the accuracy as well as reduces the time required.

Photographs also form the basis for watershed measurements and are used to record information and to make mosaics and maps necessary for planning and working with local watershed sponsoring organizations.

Aerial photographs that have a slightly "flat" finish allow slight tone differences to be distinguished in lighter areas of photographs. These differences may be significant to the soil scientist or geologist. Though 1 : 20,000 is usually a good scale, the physical and cultural characteristics of the watershed could require a different scale. A 60-percent overlap within the flight line and 30-percent sidelap between flight lines give adequate stereoscopic coverage. The most recent aerial survey should be used; a single storm after a survey is flown could cause significant changes in stream channels and erosion conditions.

A folding pocket stereoscope of 2×-power magnification is adequate for studying the pictures, but a stand stereoscope of 2×- or 4×-power is often preferred because the pictures can be moved more easily under it. A pricker or similar instrument is needed for pricking point locations. Also, for close study, a good quality reading-glass magnifier is essential.

Either colored pencils or inks may be used for delineating physical and cultural features. Ink may be better if the pictures will be used several years later or will receive rough field use.

A good color legend for delineation is: Drainage, blue; match lines, green; watershed lines, black; cultural features, red; erosion condition, orange.

All delineation should be made under the stereoscope and should be neat and accurate. All features should be marked clearly.

To avoid duplication there should be a set of match lines on the photographs. Unless the terrain is unusually rough and steep, straight lines can be used for all four match lines.

The interpreter usually is given a county highway or topographic map on which a rough watershed boundary is drawn. But any general map of the county is adequate. The interpreter also has an index map of aerial photographs to be used. A "point of beginning" is set at the lowest level of the watershed before interpretative work is begun. This may be any point on a stream, but normally it is the point where the stream enters a larger stream or lake.

The intepreter locates this point on the photograph by noting on the map features that are near it and finding their images. Under the stereoscope he orients the stereoscopic pair showing the point of beginning and on both photographs pricks and circles this point with a pencil. Starting at the point, under the stereoscope he marks the ridge, or the dividing line from which the ground slopes toward the stream, between match lines on one of the photographs. The procedure is repeated on the succeeding stereoscopic pairs. The completed watershed boundary is a continuous line within which all land drains into one stream.

Next, stream or drainage lines within the watershed are drawn under the stereoscope. Generally stream channels appear as irregular striations and are easily seen. The interpreter overdraws these lines in blue. To keep photographs from becoming cluttered and to show only those drainage lines necessary for further study, the shortest length of stream to be overdrawn is specified before any lines are drawn.

Through stereoscopic study of aerial photographs, the photo interpreter can locate areas that contribute sediment to the stream. Sheet erosion, a major source of sediment, can be marked for field study. If gullies, which appear as irregular striated lines usually sloping toward a stream or drainageway, are in groups the entire area can be marked as a silt-contributing area. For single gullies the gully line is overdrawn.

Streambank erosion, which appears as jagged deep vertical cuts, is delineated by overdrawing the line or outlining the area of cutting. Other sediment-producing areas that must be marked are stream beds clogged with alluvial material; sand or silt bars in streams, which appear as elongated elliptical areas that have a slight mounding or raised surface; and alluvial fans at the mouths of streams or gullies, which appear as triangular areas with the peak or apex of the triangle pointed upstream.

To prepare flood-routing data, planners must know the configuration of the flood plain of a stream. The photo interpreter can assist the planner in this work by delineating the limits of flood plains in the watershed.

Some field work is necessary to locate the highest known water mark along a stream channel. Levels are run to these high-water marks and elevations are transferred by leveling to the opposite bank of the stream. This is repeated throughout each stream for which flood-routing data are required. Each point is marked on a photograph.

In the office the photo interpreter studies the photographs stereoscopically and, using the field-located points, delineates an approximate contour line. It is approximate—not a true contour—because the previous-high-water locations include the hydraulic gradient of the stream.

To help locate economical damsites, the photo interpreter studies the aerial photographs stereoscopically and selects sites where valley walls converge and the valley above is wide and flat. He marks these sites on a photograph for checking in the field. Often he marks the water line as well as the watershed line above each site.

He makes preliminary contour maps of the most desirable sites selected by the field check to determine the approximate storage capacity of each. Field crews may locate elevations along the center line of the proposed dam and upstream along the stream channel to a point higher than any elevation at the center line on the damsite. Points of elevation at intervals of about 10 feet are located on aerial photographs covering each damsite. The photo interpreter views the photographs stereoscopically and draws the approximate contour lines connecting these points. A preliminary estimate of reservoir storage capacity can then be computed by measuring the area of each applicable contour interval.

Land use patterns delineated to help planners estimate runoff should be marked on a separate set of aerial photographs to avoid congestion. If the photo interpreter is familiar with the area under study, he can easily identify almost all land uses. But he must be aware that climatic area affects the interpretations of land use. Land use patterns in arid areas are different from those in humid areas. Even within a climatic area, the tone of the photographic image varies depending on whether the ground surface is wet, moist, or dry.

BASE MAPS FOR WATERSHED PLANNING

All features delineated on aerial photographs are transferred to a base map, which for many areas is an uncontrolled mosaic. One advantage of a mosaic is the ease with which information from individual aerial photographs can be assembled and integrated for the whole watershed. The overall picture a mosaic provides is also often helpful when working with local people.

If a line map is used as the base map, the features on the photographs can be projected onto it with a vertical reflecting projector. A tracing may also be made from the photographs. Appropriate symbols and patterns identify the various features.

If a mosaic is used, it is compiled from a set of contact prints or from reduced-scale prints made by copying the watershed planning party's aerial photographs. Published maps are used to maintain overall scale and alinement. Prints are trimmed as necessary and then taped or pasted together to make the mosaic. Important names, physical and cultural features, and the watershed divide are usually added to the mosaic. Drainage may be delineated in white ink on the aerial photographs before they are copied for mosaicking.

In some areas for which a mosaic is compiled as a base map, a planimetric map of the watershed may also be prepared. Unless the mosaic was compiled from prints made after the drainage had been delineated on individual photographs, drainage is stereoscoped and then delineated on a manuscript overlay of acetate or other plastic placed on the mosaic. Roads and other features taken from the photographs and information from U.S. Geological Survey quadrangles and county maps are also compiled on the manuscript overlay. Map features, including lettering, are cut on scribecoat placed in contact with the manuscript on a light table. A contact film positive made directly from the scribecoat yields diazo reproductions in the original scale. Other sizes can also be made.

TOPOGRAPHIC MAPS OF STRUCTURE SITES

Topographic maps of sites finally chosen for structures are prepared to make the preliminary design for the structure and a storage-data table. These can be made by stereoplotter or conventional survey methods.

For stereoplotting, aerial photographs are studied to select identifiable image points that are suitable for vertical control. They are analyzed stereoscopically to select suitable terminal points for taking measurements to scale the plotter models (areas covered by two overlapping photographs).

Setting up a stereoscopic model in the plotter requires a minimum of horizontal and vertical ground control. A base line, measured on the ground between two clearly identifiable points on the photographs, is required on about every third or fourth model to control horizontal scale. It should be long enough to measure 3 inches or more on the contact photograph and to fall entirely within the model. In addition, four vertical control points, one near each corner, are required for each model. They should have a middle tone on the photograph and be within a flat area about 15 or more feet in radius on the ground.

These control points must be positively identified in the field, positively identified and marked on the photographs, and easily seen in the stereoscopic model. Depending on the accuracy required, differential leveling or trigonometric leveling is used to determine the elevation of the four vertical control points.

The plotter operator should be a member of the field survey party. If this is not possible, the chief of the field survey party should become thoroughly familiar with the operation of the plotter and should know exactly what type of control points to select.

SCS uses Kelsh plotters to produce topographic maps that have fairly large scales and cover areas of 100 acres or more.

The Kelsh plotter provides a maximum of 5× enlargement and forms a single stereoscopic model. This model is produced by two precise projectors that project aerial pictures onto a tracing table. Each projector is provided with a contact glass positive made photographically from original aerial negatives. Each has a colored filter—one blue, the other red. The operator wears glasses with one blue and one red lens.

Once the stereoscopic model is alined with the control points, the operator sets what appears to be a floating dot of light on the elevation to be traced. This light comes through a pinhole in the center of the platen of the tracing table, which is a white disk about 3 inches in diameter. The operator keeps the dot on the ground as he moves the tracing table and an attached pencil traces the contour from below as shown in figure 68.

The Kelsh plotter is economical for preparing topographic maps. For example, from aerial

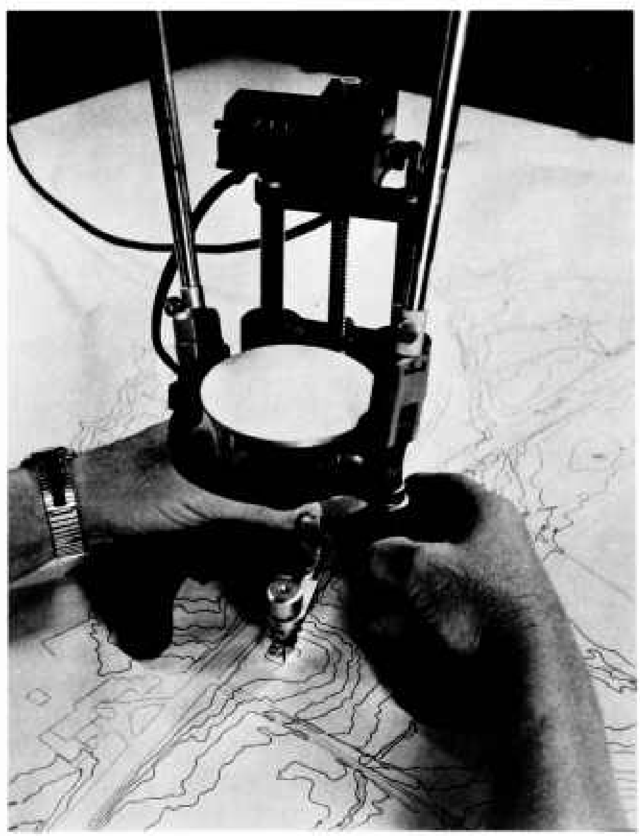

Figure 68.—Tracing contours with a Kelsh plotter.

photographs at a scale of 1: 9,600, 4-foot contours can be plotted using a mapping scale of 1 inch=160 feet; at a scale of 1: 4,800, 2-foot contours can be plotted using a mapping scale of 1 inch=80 feet.

Field time for obtaining the ground control points varies widely. When trigonometric leveling is used on the average site, it should be possible to obtain the four ground control points and the measured distance for scale control in 1 day's time. In rough or brushy country, reconnaissance mapping can be plotted from control elevations obtained by barometric readings from precise altimeters. The accuracy of any topographic map can be no better than the field control on which it is based.

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