FSTC-HT-23-732-68

US ARMY FOREIGN SCIENCE AND TECHNOLOGY CENTER

MANUAL FOR USING AERIAL PHOTOGRAPHS IN SOIL MAPPING

by

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COUNTRY: USSR

This document is a rendition of the original foreign text without any analytical or editorial comment.

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TECHNICAL TRANSLATION

FSTC-HT-23- 732-68

ENGLISH TITLE: MANUAL FOR USING AERIAL PHOTOGRAPHS IN SOIL MAPPING

FOREIGN TITLE: METODICHESKOYE RUKOVODSTVO PO ISPOL'ZOVANIYU MATERIALOV AEROFOTOS'YEMKI PRI POCHVENNOM KARTIROVANII

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SOURCE: SEL'SKOKHOZYAYSTVENNAYA AKADEMIYA
Moscow, 1964
pp 1-64

Translated for FSTC by ACSI

NOTICE

FOREWORD

(pp 3-5)

I. P. Grechin

The increased demands of kolkhozes and sovkhozes with respect to the accuracy and details of soil maps make it acutely necessary to employ new progressive methods in the field and laboratory studies and mapping of soils. The utilization of materials of aerial photography is one of such methods.

Materials of aerial photography (aeromethods) are widely used in various branches of national economy connected with the study of natural landscapes. At the present time aeromethods are used in compiling maps of various content -- topographical, geomorphological, geological, forest management and others.

The first experimental works on mapping soils with the application of materials of aerial photography were done in our country and in the USA in the twenties of this century. In 1925-1930, in our country, the societies "Dobrolet" and "Ukrvozdukhput'" conducted the first operation in aerial photography for the purpose of forest management and land management. These materials were also used by soil scientists.

The introduction of aeromethods into the practice of soil mapping was greatly facilitated by prominent scientists A. Ye. Fersman (1928) and L. I. Prasolov (1931). At first the materials of aerial photography were used by soil scientists chiefly as a topographic basis. When aerial photographic operations expanded in the country, aerial photos started to be used in soil mapping for a direct identification of soil varieties and their boundaries.

Aerial photographs were used for the first time for a direct study of soils by A. N. Levengaupt in 1931.

At the present time in our country, the Dokuchayev Soil Institute, the Laboratory of Aeromethods of the USSR, Academy of Sciences, Moscow and Leningrad Universities and other organizations are working on methods for the application of aerial photographic materials in various geographical regions of the country.

In the works of recent years, much attention has been given to the methods of interpreting soils by aerial photographs and to the study of interpreting characteristics of soils of various zones and provinces. M. S. Simakova has a good description of special characteristics for interpreting the soils of Northern Caspian region. She describes in detail the basic peculiarities of the representation in aerial photographs of alkali, saline, chestnut and meadow-chestnut soils. Special characteristics of interpreting the soils of the forest-steppe zone were described by V. A. Andronnikov and those of the forest and the tundra zones by Yu. A. Liverovskiy and T. V. Afanas'yeva. The study of the soils of Northern Kazakhstan is treated in the works of Yu. S. Tolchel'nikov, A. S. Preobrazhenskiy and N. N. Semencva. The work by Ye. A. Galkina contains data on the interpretation of various types of swamp soils. However, unfortunately, all these data are scattered in various sources and are not too accessible for the purpose of teaching. The existing textbooks on soil sciences do not treat the problems of the application of aeromethods in the practice of field and laboratory work on compiling soil maps. On the other hand, the study of the application of aeromethods in the practice of large-scale soil mapping in our country and abroad indicates that the use of materials from aerial survey increases considerably the accuracy of soil mapping, reduces the volume of the field work, cuts down its cost and increases the practical value of soil maps.

The use of survey materials in large-scale mapping of soils increases every year. However, aeromethods are used very little in the practice of soil research for agricultural purpose. This situation is explained, first of all, by the fact that the principles and methods of interpreting soils from aerial photographs have not yet been sufficiently developed as well as by the fact that soil specialists are not familiar with aeromethods. This is also characteristic of soil agrochemists trained by our Academy. Therefore, in 1961 the Department of Soil Science of the K. A. Timiryazev Russian Agricultural Academy (TSKhA) introduced a special section of the "Application of Aeromethods in Large-Scale Soil Research" in the course of soil science for the students of the Department of Soil Science and Agrochemistry.

The present guide on methods was compiled in accordance with the program of this section and is intended to aid the students in using soils as materials of aerial survey in the study of soils both in the process of laboratory work and during the period of their theoretical and practical work in soil science.

The present guide on methods presents brief information on the aerial survey methods and on the characteristics of aerial photographs in large-scale soil mapping. It consists of three sections:

1) types of aerial survey and the characteristics of aerial photographs;

2) general principles of interpreting soils from aerial photographs;

3) special characteristics of the organization of soil mapping with the use of aerial photographs.

We hope that the guide on methods for the application of materials of aerial survey in soil mapping prepared by Docent A. P. Mershin for the purpose of his course of lectures and practical work with third-year students of the Department of Soil Science and Agrochemistry of the TSKhA will be of practical use in the process of field soil studies and preparation of soil maps with the application of aeromethods.

(pp 7-25)

I. TYPES OF AERIAL PHOTOGRAPHIC SURVEY AND PROPERTIES OF AERIAL PHOTOGRAPHS

Aerial Photographic Survey and Its Types

Aerial photographic survey is a very complex process consisting of: photographing the terrain from a plane with a special camera; treatment and preparation of exposed aerial film and the preparation of prints; establishing plane and altitude points on the terrain which are necessary for correcting the distortions in the aerial photographs and their fixation; grammetric processing of aerial photographs which is necessary for the compilation of plans and maps of the terrain. As a result of this, a reduced picture of the terrain is obtained in light-sensitive film which is constructed according to definite geometrical and physico-optical laws. The use of aerial photographs requires a special recognition of their content, i.e., an interpretation, for which it is necessary to know the process of aerial photography and its geometric and physico-chemical laws according to which the photograph image is registered.

According to the amount of deflection of the optical axis of the aerial camera from the vertical line at the moment of photographing, two types of photographs are distinguished: the plane or horizontal and perspective or oblique. For plane photographing, the main optical axis of the aerial camera is in a vertical position and the plane of the negative is strictly horizontal in relation to the photographed surface (Figure 1). For such exposure, the permissible deviations of the main optical axis of the aerial camera from the vertical line are not more than 3-5°, while for the perspective photography the angle of deflection (α) is always more than 10°. For a plane photograph, the terrain is photographed in the form of a square and for a perspective photograph -- in the form of a trapezium. A plane aerial photograph resembles a topographic map of the terrain of equal scale throughout the picture. A perspective picture resembles more a panoramic view and its scale is not the same in various parts of the picture and depends on the size of the angle (α): the greater the angle (α), the greater are the differences in the scales of the pictures. These differences in the scales of perspective aerial pictures complicate the work with them. Therefore, soil scientists prefer to use the plane aerial pictures.

According to the nature of the assignment and the extent to which the terrain is covered by the pictures, aerial photographic survey can be selective, route or solid. For a selective aerial survey, individual sections of a terrain or objects are photographed. One or several pictures will suffice in this case. For a route survey, the terrain is photographed along an assigned route: surveying land-protective forest belts, river valleys, routes, etc. Survey routes can be rectilinear or curvilinear. The course of a route is photographed by a series of consecutive pictures. Solid aerial survey has a wide application. Soil scientists use solid aerial survey in their work. It is accomplished by parallel mutually overlapping routes (Figure 2). Overlapping is necessary for eliminating gaps in the territory being surveyed. Overlapping can be of two kinds: longitudinal and transverse. In the case of a longitudinal overlapping, aerial photographs of one route overlap

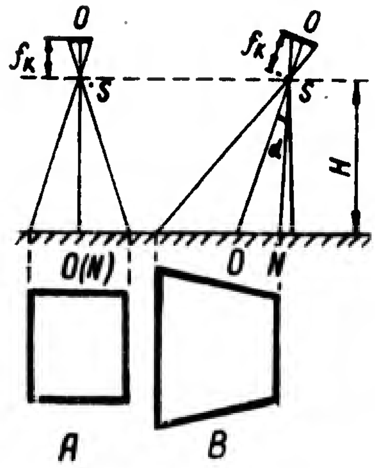

Figure 1. Plane and Perspective Aerial Photographic Survey.
A -- section of terrain photographed in plane survey;
B -- section of terrain photographed in perspective survey;
fk -- focal length of the camera;
OO -- optical axis (in plane exposure coincides with the plumb line);
H -- height of photographing;
α -- angle of deflection of the optical axis of the aerial camera from the plumb line.

one another, and in the case of a transverse overlapping, pictures of adjacent routes overlap one another. Transverse overlapping constitutes 30-40% and longitudinal overlapping -- 55-60%. Longitudinal overlapping is also necessary for having a stereoscopic effect when aerial pictures are used to study natural or artificial landscapes of a locality.

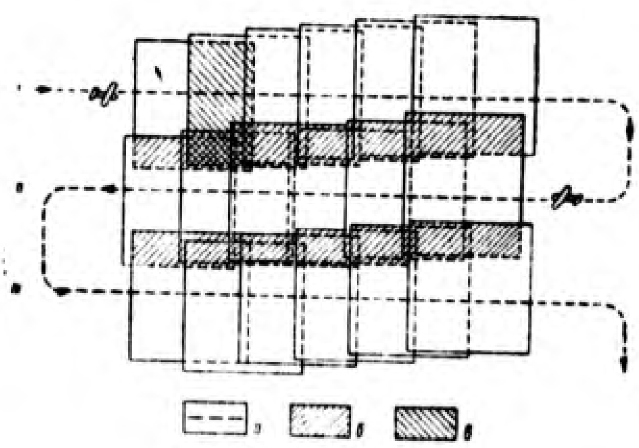

Figure 2. Scheme of Solid-Area Aerial Photography;
I -- aerial survey of the first flight;
II -- aerial survey of the second flight;
III -- aerial survey of the third flight;

Figure 2. (Continued)
a -- routes of the plane, б -- transverse overlap,
В -- longitudinal overlap.

With respect to the scale, aerial photographic mapping can be of two types: large-scale ones (from 1:50,000 to 1:10,000) and small-scale ones (<1:50,000).

Air Cameras and Aerofilms

The photographing of a locality from an airplane is done with special air cameras. In the aerial photographic survey operations, automatic cameras are used. With respect to their focal length, they are divided into three groups: short focus (focal length from 50 to 150 mm), medium-focus (150-300 mm) and long-focus (> 300 mm).

Aerial photography is done on a celluloid film covered with a photosensitive emulsion. There are several grades of emulsions: ordinary, orthochromatic and infrachromatic. They differ in their sensitivity to various rays of the spectrum. The ordinary emulsion is most sensitive to blue and violet rays of the spectrum with wave lengths of 400-510 mμ (millimicrons).

The orthochromatic emulsion is most sensitive to yellow, yellow-green and green rays with wave lengths of from 400 to 580 mμ and is less sensitive to blue-azure rays.

The iso-orthochromatic emulsion is sensitive to all rays of the spectrum from 400 to 640 mu, and particularly to green rays.

The panchromatic emulsion has a still larger sensitivity range. It registers all visible rays from 400 to 700 mμ, including the red rays. Its lower sensitivity is registered in the zone of green rays with wave lengths of 490-540 mμ.

A characteristic feature of the infrared emulsion is the fact that it is sensitive not only to all visible rays but also to the invisible ones, i.e., infrared.

Moreover, various color films are now being introduced into aerial photography. These films have two layers: the first layer is sensitive to all visible rays and the second registers the invisible infrared rays. The layers of the film are colored, due to which they produce a colored image.

Almost all of the above-mentioned emulsions have a high sensitivity to azure rays. In these rays, the brightness and contrasts of the objects are the highest and, therefore, light filters are employed to block the blue-azure rays.

Selection of an aerofilm sensitive to particular rays and appropriate filters make it possible to photograph a locality in most contrasting expression.

Aerofilms are of various lengths. Films of 35 and 60 m in length are used most frequently, which makes it possible to take 200-250 aerial pictures of the generally accepted sizes (18 X 18, 24 X 24, 30 X 30) with one roll of film.

The time of the year is of importance for the quality of aerial pictures. The most contrasting pictures are taken in the spring when the soil surface is covered with vegetation and the soils on various elements of the relief differ sharply in the amount of moisture. Aerial photographic survey is usually done on bright, sunny, cloudless days. High cloudiness does not prevent aerial survey. However, if cumulus clouds get into the field of vision of the lens, they appear in the photographs as white spots and their shadows show as dark spots. Such pictures are not suitable for interpreting.

Weather conditions also affect the quality of the pictures. In the steppe, dry-steppe and desert zones, good contrasts in the pictures are achieved after the rain because of the uneven drying of the soils. Poorly contrasting images are obtained after strong winds and dust storms when a layer of settled dust disguises the color contrasts not only in the soils but also in the vegetation. Daily variations reflect on the photographic images chiefly in the changes in the sun's altitude. The most contrasting aerial pictures are obtained under the conditions of the plains when the position of the sun is the lowest. In this case, the sharpest contrasts in the aerial pictures are those between plant associations and the soils. In the areas of split-up relief and those covered by forests, the best images in aerial pictures are obtained in the middle of the day when the position of the sun is the highest.

Geometrical Characteristics and Scales of Aerial Photographs

The surface of the earth is represented in aerial photographs according to definite geometrical laws in a central projection. Natural and man-made elements of a landscape are projected in the pictures by rectilinear rays emerging from the camera -- the projection center (Figure 3). In such photography, flat objects in a plane picture have similar images. Vertical objects produce images similar in form to their top part. Aerial photographs make it possible not only to examine the objects which are in these pictures but also to take various measurements (determine the heights of trees, depths of gulches, etc.). But for this it is necessary to be able to orient the photograph in relation to the projection center (internal orientation) and in relation to the terrain (external orientation). The elements of internal orientation are the focal length of the camera (f_M) and the principal point of the picture (O). The focal length is the length of the perpendicular sO lowered from the center of the projection onto the plane of the picture. These elements are known with a high degree of accuracy. The focal length is shown in the specifications of the camera. The main point of the picture is determined by crossing the straight lines connecting the opposite coordinate markers which are printed on aerial pictures. The elements of external orientation include the altitude of exposure (H), angle of deflection of the optical axis of the camera from the plumb line (α) and the tilt angle of the picture ($\varkappa$) (of the camera) (Figure 4). The elements of the external orientation are determined in flight with a low degree of accuracy, therefore, they are determined during the laboratory processing of aerial pictures by means of photogrammetry.

Commencing the work with aerial photographs, first of all one should determine their scale. The scale of a plane aerial photograph is equal to the ratio of the focal length of the camera to

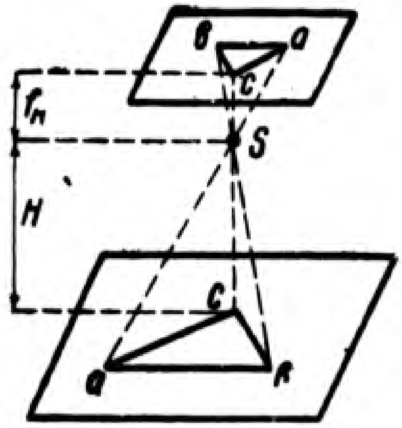

Figure 3. Central Projection:
S -- projection center (lens of the camera);
f_H -- focal length of the camera;
ACB -- the object in the locality being photographed;
acb -- image of the object of the locality in the aerial picture and the map.

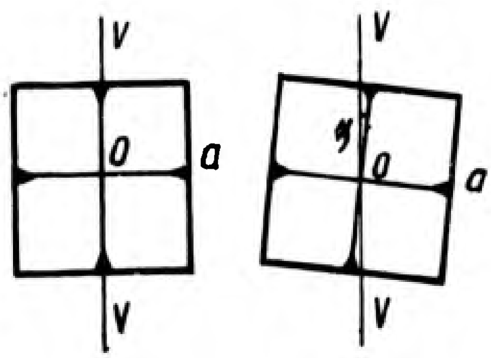

Figure 4. Plane Aerial Photographs:
α -- coordinate markers;
o -- principal point of the aerial photograph;
k -- tilt angle;
Vv -- main vertical of the aerial photograph (projection of the lines of the exposure direction.

the altitude of exposure, i.e., 1/m = fr/H (m is the scale denominator), or, in a different way, the ratio of the length of a line segment in the picture to the length of the corresponding segment in the locality. This can easily be proven by the above example (see Figure 3). It is known that the survey scale is the ratio of the image size of a certain segment to the value of the corresponding segment in nature, then the ratio of segment ac to AC is the scale value, i.e. AC/ac = 1/m = M. In similar triangles, which are the triangles acS and ACS, the ratio AC/ac = fr/H. Consequently, 1/m = fr/H.

Let us assume that an aerial survey was done with a camera with focal length (fr) of 200 mm and the survey altitude (H) was 2000 m. In this case, the survey scale will be 200/2,000,000 = 1/10,000.

It can be seen from this example that the smaller the focal length of the picture at the same survey altitude, the smaller is the scale of the picture, and vice versa, the smaller the survey altitude at the same focal length of the aerial camera, the larger is the scale of the aerial picture; the greater the survey altitude, the larger area will be photographed in the picture, and vice versa, the lower the altitude, the smaller area will show in the picture.

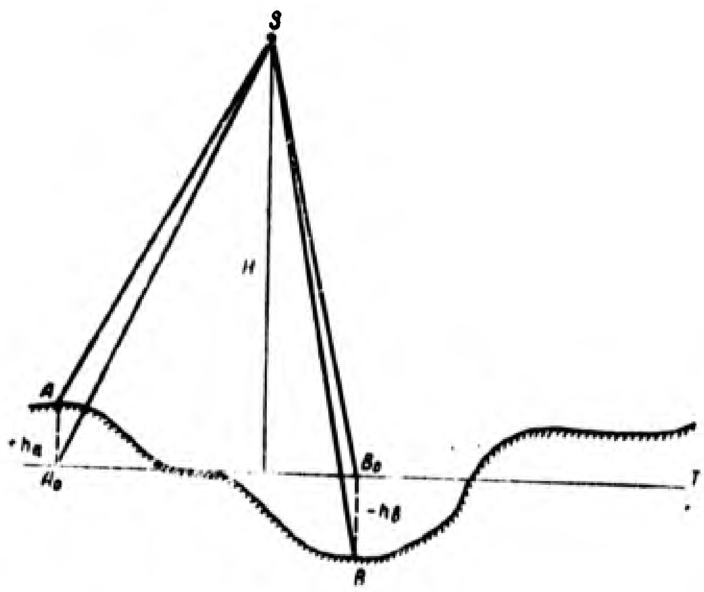

Figure 5. The Effect of the Relief on the Position of the Points of the Area Shown in the Aerial Picture:

AB -- points of the area being photographed;
T -- line of horizontal plane;
A_oB_o -- points leveled with respect to the horizontal plane;
h_{α} -- height of the point;
h -- lowering of the point in relation to the leveled horizontal plane;
H -- survey altitude (leveled in relation to the horizontal plane);
S -- projection center.

Since in the plane survey pictures there are some deflections from the vertical axis, small changes in the picture's scale may occur. Changes in the picture's scale may also occur because of an unevenness in the relief of the area being photographed. An aircraft flying at a constant altitude turns out to be at very different altitudes of a broken terrain. This is clearly illustrated by Figure 5. In this case, the scale of point A = $H-h_{\alpha}/fr$, and the scale of its projection on the leveled surface = fr/H. Thus, the scale of point A is larger than the scale of its projection.

Differences in the scales of aerial photographs due to the relief in flat and hilly regions are small, therefore they have little effect on the accuracy of the image of the area surveyed. Considerable differences in the scales due to the terrain's relief occur in mountain regions. In these cases, the scale differences are reduced by transforming the aerial pictures, i.e. their scales are leveled, or they are either increased or reduced in relation to the average leveled plane. Aerial photographs are transformed under laboratory conditions by aerial photography specialists.

The value of aerial pictures is also in the fact that they make it possible to obtain not only the spatial but also a volume representation of the object: the depth and width of river valleys, ravines, steepness of slopes, height of buildings and trees, etc. This is achieved by viewing the object from two different points. In a human being such points are the left and the right eyes. Stereoscopic effect (the volume preception) may be achieved by viewing two mutually overlapping aerial pictures of the object (stereo-pair). For this purpose to align each picture of the stereo-pair in relation to each other in such a way that they would assume the same position which they did during the time of the exposure so that the outlines of the overlapping part would coincide. The left picture should be viewed with the left eye and the right one with the right eye. Such viewing reveals stereoscopic effect, i. e. the observer sees the photographed area such as it is in reality. If the aerial photographs are switched around (if we look at the left picture with the right eye and the right one with the left eye) a reverse stereoeffect is achieved (lower parts of the terrain appear as elevations and vice versa). However, it is difficult to achieve stereoeffect with a naked eye. For this purpose various instruments have been developed which not only make it easier to obtain a spatial image of the photographed terrain but also enlarge the image of the object. One of the simplest instruments of this type is a mirror-lens stereoscope (Figure 6). It consists of two small mirrors and two large ones arranged in such a way as to enlarge the ocular basis. Two lenses placed between them are intended to enlarge the image. This is a portable instrument and can be used for laboratory and field work.

It is simple and convenient to work with it. Before starting the work, the stereoscope is unfolded and set for work. Then, two mutually oriented aerial pictures (stereo-pairs) are placed under the stereoscope: the left picture on the left side and right picture on the right side. Looking into the stereoscope the viewer gradually moves the pictures apart to a distance of about 65-70 mm (the size of the ocular basis) until he obtains a stereoeffect. The simplest way to achieve stereoscopic effect is as follows. Two identical points are selected in each picture of the stereo-pair (crossroad, a corner of a field, edge of a forest, river bend, etc.). The selected points are covered with the index finger of the left hand in the left picture and with the right index finger in the right picture.

While looking through the stereoscope, the pictures are moved apart until both fingers coincide and form one image. As soon as This is achieved, we get a stereoeffect, i.e., the terrain acquires a spatial image. After this is possible to start the interpretation or measuring the elevational differences of the terrain in the aerial photograph.

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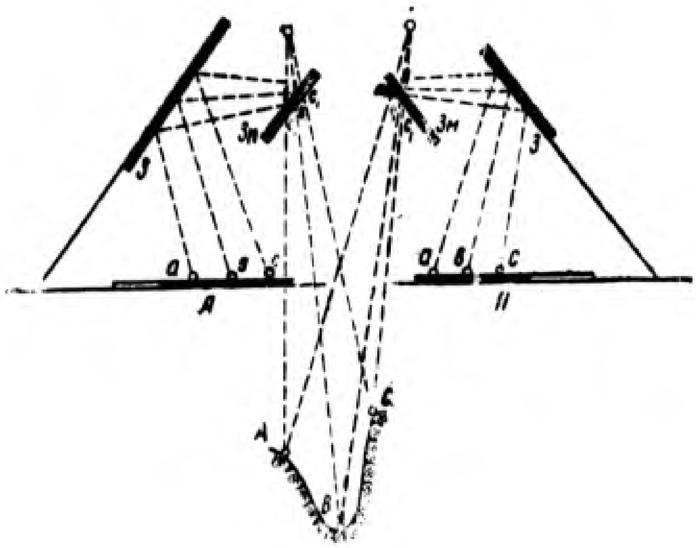

Figure 6. Design Diagram of a Mirror-Lens Stereoscope and the Principle of the Formation of a Photographic Image:

З -- large mirrors of the stereoscope;
$З_М$ -- small mirrors of the stereoscope;
Л, П -- left and right aerial pictures (stereo-pairs);
a,b,c -- points in the zone of the longitudinal overlap of the stereo-pairs;
o,o -- position of the observer's eyes;
a_1, b_1, c_1 -- position of the points in the small mirrors of the stereoscope;
ABC -- spatial image of points abc.

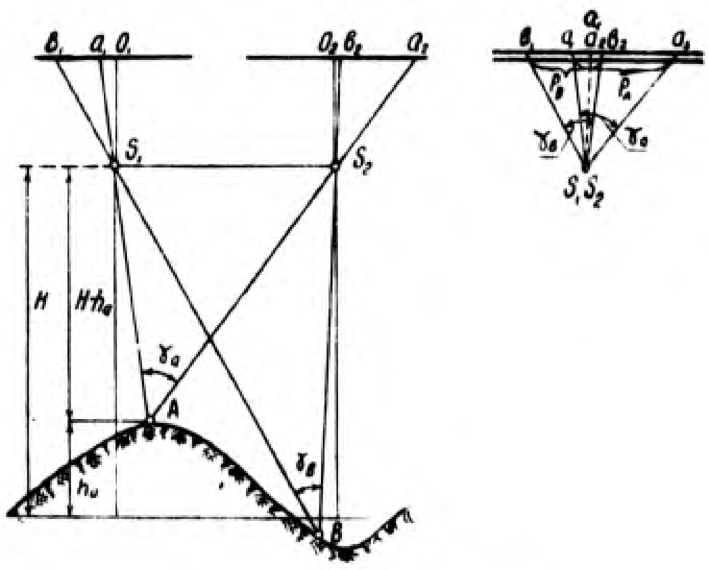

Figure 7. Angular and Longitudinal Parallaxes of Points:
O_1O_2 -- centers of the left and right pictures;
AB -- points of terrain;
A_1B_1 -- image of the points of the terrain in the left picture;

Figure 7. (Continued)
a_2, b_2 -- images of the point of the terrain in the right picture;
S_1, S_2 -- projection centers of the left and the right aerial pictures;
segments o_1, o_2 and o_1b_1 -- abscissas of the points in the right picture;
P_A and P_B -- longitudinal parallaxes of points A and B;
$H-h_\alpha$ -- height of exposure in relation to point A;
H -- height of exposure in relation to the level surface.

It is known that when a point is moved away from the observer, the angle at which he views the terrain becomes smaller. Thus, the greater the difference in the elevations of two points, the greater is the difference in the parallactic angles. This dependence is the basis for measuring elevational differences in a terrain by aerial photographs. This is illustrated in Figure 7.

Calculations are made with longitudinal parallaxes and not with angular ones. The dependence of the longitudinal parallaxes on the elevation of the terrain is expressed by the following formula,

$$h = \frac{H}{\sigma + \Delta P} \Delta P, \text{ where}$$

h -- elevation of the unknown point over the initial point;
H -- height of exposure;
σ -- photo base;
ΔP -- differences of longitudinal parallaxes between the unknown and initial points.

The initial point is some point in the aerial photograph whose absolute mark is known. It may be taken from a topographic map or determined in the field by leveling (barometric, trigometric, geometric). Altitude of exposure (H) is considered in relation to the initial point. The photobase is measured directly in the aerial pictures.

Thus, in order to determine the elevational differences in the terrain or objects, it is necessary to know three magnitudes: the altitude of exposure, photo base and the difference of longitudinal parallaxes.

The principle of determining relative elevational differences on a terrain in aerial photographs is based on the measurement of longitudinal parallaxes. Longitudinal parallaxes are determined in the following way. First of all the principal point is determined in the right aerial picture O_2 (Figure 8); it is identified and pinned on the left aerial picture (O_2). The principal point O_1 of the left picture is pinned on the right one (O_1). The directions O_1O_2 and O_2O_1 are called initial directions or the X-axes through the principal points are the Y-axes of the pictures.

GRAPHICS NOT REPRODUCIBLE

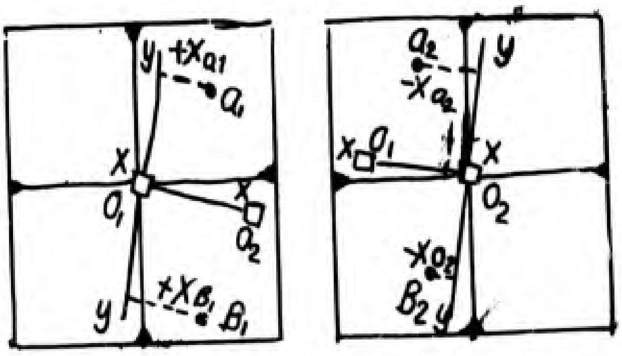

Figure 8. Measuring the Abscissas of the Points in Aerial Photographs:
o_1o_2 -- photo base at the picture scale;
xx and yy -- X-axes and Y-axes;
a_1, a_2 -- image of point A in the left and right pictures;
b_1, b_2 -- image of point B in the left and right pictures;
xb_1, xb_2 -- abscissas of point B;
xa_1, xa_2 -- abscissas of point B in the left and right picture.

The distance between the principal points is called photo base (Figure 8). In determining the photo base, the scale of the aerial picture is taken into consideration. In our example, the photo base for the left picture will be segment O_1O_2, and for the right one -- O_2O_1. The bases are measured with accuracy of 0.2 mm.

After plotting the Y-axis on the aerial photographs, the elevational differences are determined from the aerial photographs by measuring longitudinal parallaxes.

Longitudinal parallaxes (P) are determined as algebraic differences of the abscissas (X) of the corresponding points measured in the left ($X_{Л}$) and the right ($X_{П}$) pictures.

For example: the abscissa of point M($X_{mЛ}$) in the left picture is equal to +20.0 mm* and in the right picture ($X_{mП}$) -- 51.4 mm. Hence, the difference of the longitudinal parallaxes of point M(P_M) will be

$$P_M = 20.0-(-51.4) - 71.4 \text{ mm.}$$

Further measurements of the absicissas of points BK yielded the following values:

$$X_{BЛ} = -20.5 \text{ MM}, \quad X_{BП} = -88.6 \text{ MM}$$

$$X_{KЛ} = +89.8 \text{ MM}, \quad X_{KM} = +21.0 \text{ MM}$$

$$P_B = -20.5 - (-88.6) = 68.1 \text{ MM}; \quad P_k = +89.8 - (+21.0) = 68.8 \text{ MM}$$

The difference of longitudinal parallaxes of the two points is determined by formula

$$\Delta P_{MB} = P_M - P_B$$

*The signs should be observed strictly. All values of the abscissas on the right hand side of the Y-axis will have the + sign and those on the left side will have the - sign.

For our example, the difference of the longitudinal parallaxes will be

$$\Delta P_{MB} = 71.4 - 68.1 = 3.3 \text{ мм};$$
$$\Delta P_{BK} = 71.4 - 68.8 = 2.6 \text{ мм};$$
$$\Delta P_{BK} = 68.1 - 68.8 = -0.7 \text{ мм}.$$

Having determined the difference of the longitudinal parallaxes it is possible to compute the elevational differences of the terrain points by the aerial photographs. In our example, the survey was done at a scale of 1:10,000 at an altitude of 750 m. The photo base was 6 cm. Consequently, the difference of the elevations (H) between the points M and B will be

$$H = \frac{750X33}{600+33} = 31.4 \text{ m}$$

i.e. point B is higher than point M by 31.4 m.

N o t e. The value of the photo base and the difference of longitudinal parallaxes are substituted in the formula with consideration for the scale.

A more rapid determination of the elevational differences of a turrain by aerial photographs is done with a special instrument, a stereoaltimeter.

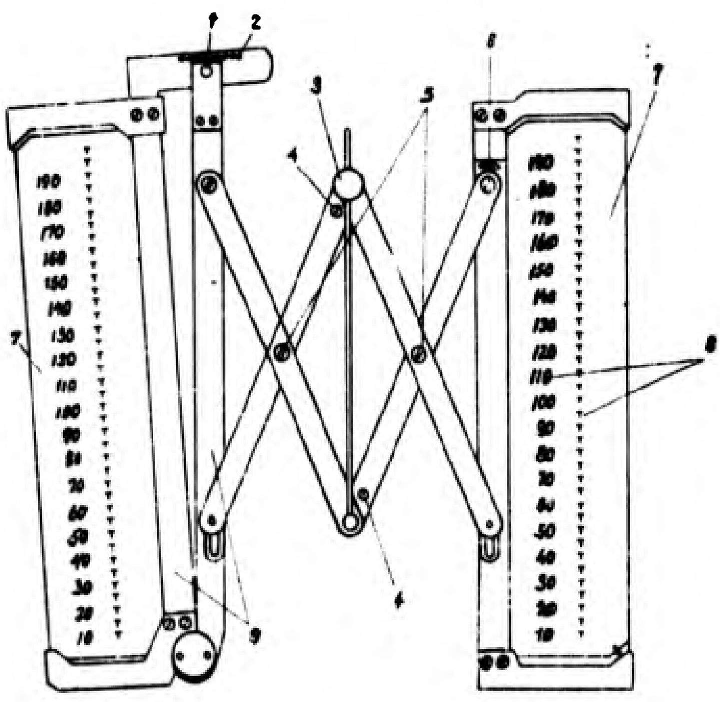

Figure 9. Design Diagram of a Stereoaltimeter.

Before starting the measurement of elevational differences of a terrain in aerial photographs with a stereoaltimeter, it is necessary:

1. To plot points on one of the aerial photographs of the stereo-pair between which elevational differences are to be determined, draw initial directions on them, orient the pictures under a stereoscope along these directions and fasten them with tacks.

2. To set up the stereoaltimeter in working condition. To establish the parallactic coefficient scale of sector (4) of the instrument and to secure it with the screw. Compute the coefficient by formula K=H/P, where: H is the survey altitude and P is the value of the longitudinal parallax. If the value of the parallactic coefficient K is greater or smaller than the final scale divisions of the sector, then the value of K is reduced or increased accordingly by two times. In this case, the measured values of the elevational differences should be also increased or reduced by two times.

3. To place the stereoaltimeter on the aerial photographs. Changing the position of the instrument to establish its axis perpendicular to the initial direction. The control of the correctness of the instrument's position is the absence of the doubling of the markings along the vertical. Having unfastened the adjusting screw of the mechanism of parallel movement, to move the places apart in such a way that one of the marks with a reading of about 100 would stereoscopically touch the initial point in the aerial picture. (It should be average in elevation). To secure the adjusting screw. Now the instrument is ready to operate.

In order to determine the elevational differences in an aerial picture, it is necessary to set the marks of the stereoaltimeter on each of the p l o t t e d points and to take the readings from the elevation scale.

Let us assume that a is average in its elevation (initial point) and has markings 98 on the scale of the stereoaltimeter, point б -- 107, point в -- 114, and point г -- 91.

Thus, the elevational differences in meters will be: for point б = +9, for point в = +16, and point г = -7.

The following assignments are done with students in the laboratory in connection with the section "Types of Aerial Photographic Survey and Properties of Aerial Photographs."

Practical Work on the First Section

Assignment 1. Determine the scale of a plane aerial photograph.

In order to fulfill this assignment it is necessary to have: aerial photographs, topographic maps of the area for which aerial photographic survey was done, a measuring scale and a divider.

The scale of a plane aerial photograph can be calculated by the formula:

$$1/m = f/H,$$

where: f -- focal length of the aerial camera;
H -- altitude of exposure
or m = b/B,
where; b -- section in the picture between two points;
B -- corresponding section on the map between the same points;
m -- scale denominator.

Let us assume that aerial survey was done with an aerial camera with a focal length of 100 mm and the altitude of exposure was 1000 m above the terrain. Then the scale of the aerial photograph 1/m will be 1:10,000 (100/1,000,000).

If the focal length or the altitude of exposure are unknown, then the scale of the aerial photograph is determined by comparing the segments measured on the aerial photograph and on the map or on the terrain. For this purpose it is necessary to find some outlines or local objects (crossroads, fields, cultivated fields, water reservoirs, etc.) which are clear in the aerial photograph. Measurements are taken between these objects (with dividers on the map and the aerial photograph, with measuring tape on the terrain). For determining the scale, segments in different parts of the aerial photograph are selected. The scale of the aerial photograph is computed as an arithmetic mean.

Let us assume that on a map of a 1:10,000 scale three segments A, B, C were measured and were found to be 12.4 mm, 16,5 mm and 8.8 mm. On the aerial photograph the same segments were: a -- 12.1 mm, b -- 15.6 mm and c -- 8.9 mm. Consequently, segment A has a length on the terrain of 12.4X10,000 = 124,000 mm = 124 m, segment B = 18 mm X 10,000 = 165,000 mm = 165 m, segment C = 8.8 mm X 10,000 = 88,000 mm = 88 m.

In order to determine the scale, we divide respectively:

$$\frac{12400 \text{ mm}}{12.1 \text{ mm}} = 10.248; \qquad \frac{165,000 \text{ mm}}{16.6 \text{ m}} = 9940; \qquad \frac{8.9 \text{ mm}}{88000 \text{ mm}} = 9888.$$

Taking an arithmetic mean from the three definitions, we obtain the mean scale of the aerial photograph:

$$\frac{10248+9940+9888}{3} = 10028, \text{ or } \frac{1}{10028}$$

During their laboratory work, students determine the scales of two or three aerial photographs and record the results according to the following form:

No. of aerial photographs	No. of segment	Size of Segment: On map, mm	Size of Segment: On aerial photographs, mm	Size of Segment: On terrain, mm	Survey scale
440	1	12.4	12.1	124	1:10248
	2	16.5	16.6	165	1:9940
	3	8.8	8.9	88	1:9880
		Mean scale			1:10028

It should be kept in mind that in this way it is possible only to determine the scale of a plane aerial photograph of a flat terrain. In the aerial photographs of mountain areas, scales of various terrain elevations have to be determined.

Assignment 2. To plot X-axes and Y-axes on the aerial photographs. To determine principal points, initial direction and photo base on 1-2 stereo-pairs and record them in the following form

Number of Picture	Position of Picture in Stereo-pair	Photo Base, cm
6600	Left	6.00
6601	Right	6.00

Assignment 3. To determine elevation differences of three or four points in the picture by measuring longitudinal parallaxes. Record the results according to the following form:

No. of Aerial Photograph	No. of Point	Survey Altitude (H), m	Abscissa, mm	Difference of Longitudinal Parallaxes, mm	Difference of Longitudinal Parallaxes between points	Photo Base, mm	Elevational Differences (h), m
6600	1	750	+20.0		71.4- -68.1=	60	750X33 / 600+33
				71.4		60	
6601	1	750	-51.4			60	
6600	2	750	+20.5			60	=31.4
				68.1	=3.3		
6601	2	750	-88.6				

Assignment 4. To determine the elevational differences of a terrain in an aerial photograph by means of a stereoaltimeter.

To carry out this assignment, it is necessary to have: two or three stereo-pairs of aerial photographs with different reliefs, ruler, tacks and notebook. The work with a stereoaltimeter should be performed on a level desk or on a drawing board.

On one of the aerial photographs of a stereo-pair, the points between which elevational differences have to be determined are plotted and numbered. The aerial pictures are arranged under the stereoscope, oriented along the initial directions and fastened with tacks.

The parallactic coefficient is established by formula K=H/b, where H is the survey altitude; b is the photobasis.

No of Stereo-pair	Photo Base	Reading on Altitude scale	No. of Observation Point	Elevational Difference, m	Remarks
347-348	Left-70.0	120	1	+14	2nd point over 1st point
	Right-68.4	134	2	+11	3rd point over 2nd point
Middle	Middle-69.2	145	3	-55	4th point over 3rd point
		90		4	

In our example, the aerial survey was done at an altitude of 1900 m. The photo base was 69.2 mm. Consequently, the parallactic coefficient = 1900/69.2 = 27.5.

The results of measuring the elevational differences are recorded. The difference of the readings on the scale is the elevational difference between the points.

(pp 25-57)

II. GENERAL PRINCIPLES OF SOIL INTERPRETATION FROM AERIAL PHOTOGRAPHS

The Concept of Interpretation

Interpretation of aerial photographs is a process of identification and determination of qualitative and quantitative characteristics of various objects and phenomena by their photographic images.

The process of interpreting aerial photographs is based on revealing special characteristics of the photographed objects reflected in the picture. Depending on the type of objects being identified by their photographic images, i.e., depending on the purpose, interpretation can be: topographical, agricultural, forestry, geological, geobotanical, soil, hydrographic, etc. Each type of interpretation reveals in the aerial photographs only those characteristics of objects in the area which are required for solving special assigned problems.

Soil interpretation has two goals: to reveal by aerial photographs the boundaries of soil varieties and complexes and to study the properties of the soil. In fulfilling the first goal, interpretation of the contour is performed. It has become widespread in the soil practice because this method determines more accurately and considerably more rapidly the boundaries of soil contours than the usual methods using topographic maps as a basis. Fulfillment of the second goal requires the most complicated diagnostic interpretation of soil. Its methods have not been as yet sufficiently developed.

A special characteristic of soil interpretation is in the fact that soils are often covered by vegetation which often hides the coloration of the upper horizons of the soil. Even in the absence of vegetation, aerial photographs reflect the coloration and structure of the soil surface. Therefore, soil interpretation is based on establishing the regular relationships between soil and the conditions of their formation and development.

Soil interpretation is one of the most important methods of field and laboratory investigations of the soil which permits to perform soil mapping most accurately and less expensively. With respect to the conditions of interpreting, it is subdivided into laboratory and field interpretation.

Laboratory interpretation is carried out under laboratory conditions and is based on the establishment of the regularities of photographic images. This interpretation employs special standards, published descriptions of soils, cartographic materials, etc. Field interpretation is based on comparing natural objects with their photographic images in aerial pictures. Soil interpretation utilizes both methods; laboratory and field. Inasmuch as the properties of soils and their occurrences are closely connected with the conditions under which they are formed, soil interpretation must be accompanied by the interpretation of vegetation, relief, geological structure of the area, etc. Moreover, the soil scientist must be able to distinguish, in an aerial photograph, roads, populated areas, hydrographic network, etc. Consequently, soil interpretation is also accompanied by simultaneous topographic interpretation. Various methods are employed for interpreting: visual (by sight), when the shapes, dimensions and properties of the object are evaluated by sight, instrumental, when objects are identified by means of various devices and instruments, and, finally, instrument-visual, when certain instruments are used in order to identify more accurately the indexes of visual interpretation (scale rulers and magnifying glass, proportional compasses, magnifying lenses, stereoscopes, etc.). At the present time soil interpretation of aerial photographs is carried out by the visual and instrument-visual methods by using magnifying glasses, measuring instruments and stereoscopes.

Interpretation Criteria

The completeness, reliability, and accuracy of interpretation depend on the ability of the soil scientist to "read" the rich content of the aerial photograph and on his experience in working with survey materials. The recognition in aerial photographs of various elements of the landscape is carried out according to definite criteria; the size, shape, brightness, color, etc., i.e. by the same characteristics which help us to distinguish the objects which we see in nature. When we interpret natural objects we should also take into consideration their position in the environment and their mutual connection with it. In soil interpretation, direct and indirect interpretation criteria are distinbuished. The direct criteria are those which are responsible for the details of the photographic image in the aerial pictures due to the properties of the soils (tint, color, pattern of the image). The indirect criteria are the vegetation, relief, geological structure, etc.

In the process of interpretation, all these criteria are used in combination and interrelation. This makes it possible to determine the presence of natural objects which are not reflected directly in the picture (for example, soil, if it is not covered by vegetation) and to describe them. In this case, the data on soils are established by indirect criteria.

Soils, just as other natural objects, show in aerial photographs due to their different ability to reflect solar light which, passing through the lens of the camera, acts upon the emulsion of the film.

Differences in the composition of the reflected light are perceived by us as the photic differences of the soils, due to which soils are reflected in aerial pictures by various shades of light. Differences in the color are shown only by color photography. Black and white pictures, which are most widely used in aerial photographic surveys, show the image of natural objects and soils by means of different shades. Shades (brightness of coloration) are evaluated visually. The human eye discerns the differences in brightness of 2-3%. Differences in brightness of 5-10% are readily discernable. Therefore, the interpreter distinguishes the following seven shades: white, light, light-grey, grey, dark-grey, dark, black. It should be taken into consideration that the shades of the image of the same natural object, as well as soil, may differ in aerial pictures of different flights because they depend on many factors (degree of illumination of the surface, photosensitivity of the negative material, degree of moisture in the soil, etc.). Within one flight, when identical photographing conditions are maintained, the shade of the image renders the coloration of the soil surface and its ability to absorb or reflect the rays of solar radiation (spectral reflecting power). In analyzing the shades of photographic images, it is necessary to consider the type of the aerofilm used, because different films react differently to various rays of the spectrum and, therefore, the same natural objects will be reflected differently on aerofilms of different quality.

The color of the soil surface is affected by humus, iron content, moisture, mineralogical and mechanical composition, and the amount and quality of salts in the soil.

Humus gives the soil dark and grey shades. When the amount of humus increases, the reflecting power of the soils decreases, as a result of which the shades in the aerial pictures intensify. The more humus in the soil, the darker is the coloration of the emulsion of the aerofilm. Moreover, the reflecting power of humus depends on its composition. With the same amount of humus in the soil, the soils with a high content of humic acids will show darker in the photographs because their reflecting power is very low and approaches zero.

The reflecting power of fulvic acids is considerably higher -- about 20%. Therefore, soils whose humus contains a large amount of fulvic acids have a lighter color in photographs. In part, this explains why the solonetz and solonetzic soils among chernozemic and chestnut soils stand out as light colored spots, although they contain much less humus.

It was shown by Yu. S. Tolchel'nikov's studies that ferric iron has a low reflecting ability. Similarly to humus, when its content increases in the soil, the intensity of dark coloration in the pictures also increases. Therefore, the blackening of aerial photographs depends on the total content of humus and iron in the soil.

The experience of soil interpretation indicates that it is simple to establish differences in the coloration of photographs under the conditions of a dry steppe and a semidesert when the difference in the humus content is 0.5-1.0%, i.e., by the shades of photographic images of soils it is possible to establish differences only between types and subtypes of soils. In the soils of the steppe zone containing over 3% of humus, the differences in the images of soils in aerial photographs are established when the differences in the humus content are not less than 2%. Without much difficulty it is possible to isolate subtypes of chernozem, chestnut and other soils. However, it is necessary to take into consideration that the brightness of soil images in photographs changes with their moisture content. Dry soils are represented in pictures by lighter shades than the moist soils. Differences in the moisture of soils creates contrasts in their images in the pictures, which has found practical application in aerial survey. Aerial surveys for the purpose of soil mapping are usually timed for such periods when the differences in the moisture content of various soils are most expressed. For example, during spring, watershed areas dry rapidly while the soils in the negative elements of a relief have excessive moisture for a long time.

Mechanical composition of a soil also affects the brightness of its image in aerial photographs. When the size of soil particles is small, the brightness of the soil increases. This explains that sandy soils have a darker coloration in photographs than clay and loamy soil when the humus content is the same.

Soil minerals have different degrees of reflecting power. For example, quartz reflects 54% of the solar radiation rays, orthoclase -- 44%, muscovite -- 24%, and biotite -- 5%. Therefore, soils which developed on the rocks of different mineral composition appear in aerial photographs in the form of a striped and spotted design. Moreover, the coloration of the aerial photographs depends on the structure of the soil surface. A rough surface of a soil is represented by a darker shade than a smooth surface.

The fact is that when the surface is lumpy, there appear individual sections covered by microshadows whose brightness is 9-10 times lesser as compared to the sections which are illuminated by direct solar radiation. As a result of this, shadows produce a darker general background. Therefore, a plowed field is refleted in a picture by a darker shade and roads by a lighter one. The difference is the same between a harrowed field and an non-harrowed field.

The presence of such salts as Na_2CO_3, NaCl, $CaCO_3$, $Ca(HCO_3)_2$, $CaSO_4$ and others gives lighter shades to the soils. Therefore, all of them are characterized by a high degree of almost identical brightness over the entire spectrum, due to which the solonchak and saliniferous soils are reflected in aerial photographs by light shades and standout well among other soils.

The pattern of the surface in the image is one of the most important criteria for interpreting aerial photographs, particularly natural objects in black and white pictures. This criterion is more stable than the shade and the color. The shape of the image in a p l a n e aerial photograph is similar to the shape of the photographed object. In aerial photographs, there are noticeable differences between natural objects and objects which are a result of human activity which usually have geometrically regular shapes (plowed field contours, forest strips, gardens, etc.). The forest has its own pecular image design. Gardens are also represented in areal photographs by a grainy design, but trees in gardens are arranged in regular rows. Flood plains of large rivers stand out clearly in photographs. They have a specific "striped" design which is formed by the unevenness of the relief, cut-off lakes, channels, etc. (Figure 10).

Swamps almost always have a variegated design in the pictures where dark spots (surface water) alternates with lighter spots of vegetation. The soil surface of the dry steppe appears in a characteristic variegated design which is created by a complex vegetative cover and a bare soil. Moreover, the design of the surface differs in different vegetation types of complexes. It depends on the composition and the ratio of the components in the complex. Thus, by the pattern of the image it is possible to judge the composition of the vegetation and the soils which are characteristic of this vegetation. Variegated patterns of the soil cover of plowed areas stand out just as clearly in aerial photographs. Plowing even contributes to a more contrasting image. This is particularly noticeable in regions which are subjected to erosion and with a

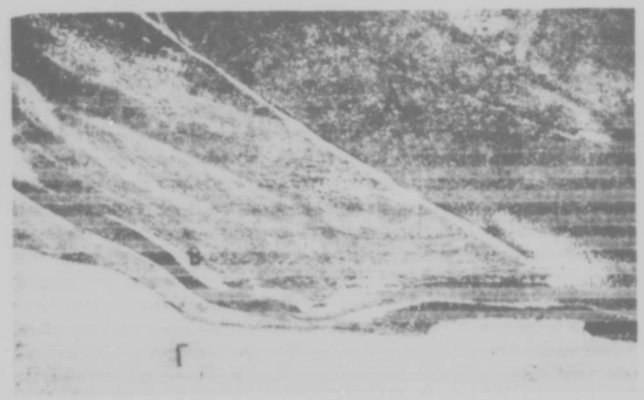

Figure 10. Fragment of a Pancromatic Aerial Photograph of an Approximate Scale of 1:10,000 of a River: a -- river bed, б -- channel, в -- dune near the river (river bank); г -- plowed field; д -- brushwood; e -- depression.

complex soil cover whose variegated pattern is a result of differences in the coloration of various soils belonging to the complex.

When interpreting soils, it is necessary to consider the interrelation between the soil, relief, geological structure of the territory and the vegetation. Simultaneous interpretation of soils and conditions of soil formation makes it possible to give a more complete description of the genetic properties of soils and establish their connection with definite elements of the relief.

Interpretation of Relief

Relief is one of the most important factors of soil formation. It is reflected clearly in aerial photographs. Therefore, its interpretation must be carried out without fail in compiling soil maps from aerial photographs. It is expedient to study the forms of relief with mirror-lens stereoscopes which are used by soil scientists in compiling geomorphologic schemes of terrain. Having the scheme of the terrain, the soil scientists isolates soil contours of a definite content. Investigations of microforms of the relief are particularly important because they are not reflected in topographical maps but have a great effect on the formation of soils. It is necessary to note that aerial photographs are the only material capable of rendering various forms of microrelief. Microrelief depressions stand out clearly in aerial photographs. They are represented by a darker shade in comparison with "zonal" soils, which is connected with increased humus content in these depressions of "zonal" soils or formation of another soil differing sharply from the "zonal" soil.

Areas of a terrain with a well-developed microrelief (with a complex soil cover) have a heterogeneous image in photographs. The elements of a microrelief are readily recognized by their horizontal dimensions and shapes. In dry steppe regions, small dark spots several millimeters in size which correspond in nature to several meters in diameter are depressions surrounded by solonetz or alkaline soils which are represented by a lighter shade in the photographs. The dark strips stretching along the slopes correspond to erosions, gullies, etc. Branchy structure is characteristic of regions subjected to erosion by water. In interpreting the relief, differences in the illumination of the slopes should be taken into consideration because different slopes reflect different amounts of solar rays from the surface, which reflects in the shades of their images in aerial photographs. Different shading in the images of illuminated and shaded slopes gives a clear idea of the forms of the relief. The forms of relief are closely connected with the geological structure of the terrain. Areas of a terrain composed of rocks of different strength and susceptibility to erosion create specific relief forms. Glacial forms of relief, the relief of the tundra zone, particularly hilly and polygonal tundra, are also readily recognizable in aerial photographs. The shapes and sizes of various alluvial and diluvial formation, as well as their position in the environment are almost always connected with their lithological and mechanical composition. Thus, in interpreting the relief, geological structure of the locality is revealed to a certain degree.

Interpretation of Vegetative Cover

Vegetation is the leading factor in the soil formation. In nature, direct dependence is observed between vegetation and the properties of soils. Therefore, we can form an idea about soils by the vegetation. It is easier to interpret soils on which there is virgin ligneous and herbaceous vegetation. Because of this, when we interpret the vegetative cover, we must divide it into a natural vegetative cover and ligneous growths and field crops cultivated by man. Among these categories it is possible to isolate various vegetation formations, communities, associations of virgin vegetation and types of agricultural crops which are reflected and interpreted in aerial photographs in different ways. Unlike other elements of the landscape (soil, rock, etc.), vegetation is interpreted directly by its size, shape, shade or color of the image (if colored aerial pictures are interpreted), by the shape of the shadows and other criteria. Depending on the vegetation formation, certain particular interpretation clues are used. For example, shadows can be used for the identification of tall trees and can not be used as an interpretation clue for herbaceous vegetation or shrubs. The same can be said regarding the structure of photographic images in the recognition of a meadow vegetation, while this criterion is one of the most important ones for the interpretation of the swamp vegetation.

Forest vegetation can be interpreted most fully. The following are the basic interpretation clues for the identification of

Shrubs are readily recognizable in aerial photographs. They also have grainy images but of finer grains than forests. There are also other characteristics in which shrubs differ from forests, namely: they do not produce shadows and are associated with particular habitats (swamps, steep slopes, river banks, etc.). The specific composition of shrubbery is difficult to determine by direct indications. For this purpose, indirect methods of interpretation are used, for example, the association of certain species of shrubs with certain habitats (indicator interpretation).

The herbaceous vegetative cover appears in aerial photographs in the form of an amorphous design of the entire association in one or another shade. Individual plants do not stand out in pictures of 1:10,000 or 1:25,000 because of their small size. Moreover, the nature of the image of herbaceous vegetation depends on its density and the moisture of the soil surface. Higher density of the plants and increased moisture in the soil result in darker shades of the photographic image.

Meadow vegetation shows in pancromatic aerial photographs by a uniform grey shade. Interpretation of meadow vegetation is facilitated by the fact that it is associated with definite habitats -- -- river valleys, streams, forest glades, etc.

In the regions with well developed agriculture, where most of the territory is plowed, meadows occupy those sections which are inconvenient for plowing, such as ravines, gullies, depressions, etc., which clearly show in aerial photographs. Under the steppe conditions, where the soil is covered by vegetation to a small degree (70-60% and lower), the general background is a result of a combined effect of soils and vegetations.

Yu. S. Tolchel'nikov pointed out that the brightness of herbaceous vegetation during summer periods is approximately equal to the brightness of soils containing 3-4% of humus. Therefore, during the time of dry weather, bare areas of soils containing less than 3% of humus show in aerial photographs in lighter shades than virgin soils. Greater density of grass cover is represented by darker shades in photographic images. In this case not only the density, but also the shadows are of importance. When plants stand very close to one another, the brightness of their photographic image may increase. The homogeneous composition of sedge meadows will be represented in photographs by a lighter shade than a meadow covered by a variety of grasses. During the dry season, steppe vegetation is represented in aerial photographs by a grey shade. Lower sections which receive additional moisture and are covered by meadow-steppe vegetation appear in photographs as a dark-grey background. In the dry steppe zone, the variety of plant associations increases. Here, the variegated nature of the vegetative and soil covers is clearly expressed and reflects very well in aerial photographs. The vegetation of the dry steppe is reflected in photographs as a grainy-spotty pattern where the grey shade is produced by feather-grass and sheep's fescue associations, the dark-grey and dark shades -- by the meadow-steppe and meadow associations of microdepressions and mesodepressions.

The vegetation of the tundra has a specific pattern. L. B. Bogomolov noted that hilly tundra is characterized by a spotted structure of the photographic image where light spots reflect hillocks covered by lichen, cotton grass and sedge; depressions are forests: the pattern of the photographic image, shade or color and the association of the growth with a certain habitat. Forests are recorded in aerial photographs at a scale of 1:10,000-1:25,000 in the form of an unusual "grainy" pattern. The size and shape of these "grains" depends on the shapes and sizes of the crowns of trees of which the forest consists. For example, the oak and the mature birch forests show in aerial photographs as larger grains then the crowns of pines, fir trees and spruce. However, the crowns of trees can change depending on the conditions under which they grow. In a dense forest, the branchy crown of an oak may assume a stretched out and narrow shape. The crown of a pine growing by itself will be different from the crowns of pines growing in a forest. The size of the crown also depends on the age and the bonitet of the tree plantation. Therefore, a young growth of a broad-leaved species shows in an aerial photograph by a pattern similar to the pattern of small-leaved species. However, a young growth does not create shadows, which should be taken into consideration in interpreting. Interpretation is considerably facilitated by shadows at the edge of the forest when their length is equal to or is more than the height of the tree. Each tree has its own shape of the shadow. The crown of the pine has a rounded shadow which lies comparatively far from the tree itself. Due to the fact that its crown is usually raised high, the trunk produces a barely noticeable shadow. The crown of branchy broad-leaved species produce extensive shadows which blend with the image of the tree. The crowns of different trees will also differ in black and white pancromatic aerial photographs in shades. Spruce and fir forests show in a darker shade than deciduous and pine forests. The clearest image of forests is yielded by colored pictures, where different species of trees show in different colors. It is possible to determine the height of a tree or a forest by their shadows. There exist several methods for determining heights of trees. The simplest of them is the visual-stereoscopic method. In this method the height of a tree is compared under a stereoscope with the height of an object known to the soil scientist. This method is widely employed in the work of the interpreters. The most precise measurement of tree heights is done by the formula

$$Hd = lkn,$$

where: Hd -- height of tree;

l -- length of shadow in aerial photograph;

k -- length coefficient of the shadow which is obtained from the appraiser's handbook (State Publishing House for Forest, Paper and Wood Processing Industry, 1962, tables 166-169), length of the shadow is measured in the aerial photograph;

n -- coefficient of the aerial photograph which is determined by the soil scientist in the following way:

if the aerial photograph survey was carried out at a scale of 1:10,000, then n will be equal to 1, at a scale of 1:5,000, n=0.5, 1:15,000 n=1.5; 1:25,000 n=2.5, etc.

Naturally, the soil scientist interpreting photographs must know the scale of the aerial survey and be able to determine it. As it has been said earlier, under the field conditions, the exact scale of the aerial photographic survey is established by measuring definite distances on the ground and in the aerial photograph, while under laboratory conditions this is done by comparing the known distances on a large-scale map and in the aerial photograph.

represented by dark shades. The structure of the polygonal tundra is well depicted in photographs in the form of small polygons. A dotted structure is formed in photographing wooded sections of the tundra, etc. The vegetative cover of the tundra is directly connected with its relief. For example, stony tundra has no flowering vegetation. Sections with a cracked polygonal microrelief are usually covered with sedge and moss, etc.

Swampy complexes are connected with definite elements or relief. They stand out clearly among other natural objects, clearly show in aerial photographs and in most cases can be readily interpreted. It is more difficult to interpret swamps which are solidly covered with herbaceous vegetation or forests. The basic direct interpretation clue is the structure of their photographic image. Swamps are represented in aerial photographs chiefly by heterogeneous variegated pattern, which is connected with a great variety of vegetation, varying quantities of water and the relief of swamps. The shade of a photographic image of swamps may be of any shades of the solar spectrum. Upland moors are most frequently, of light and light-grey shades (light shades predominate). The pattern of upland moors is never monotonous. It can be striped, dotted, polygonal, etc. Flood-plain marshes appear in aerial photographs in dark or dark-grey amorphous patterns. Consequently, by the pattern of the image and the location, it is possible to identify quite reliably the type of a swamp and its economic value. However, in order to establish a series of diagnostic properties of swamps (peat resources, degree of mineralization, botanical composition, etc.), it is necessary to carry out a field identification of the aerial photographs and a laboratory and field study of the peat soils.

Interpretation of Soils from Aerial Photographs

The problems of direct soil interpretation from aerial photographs have not yet been studied sufficiently and very little has been published on the methods of soil interpretation. Until very recently there were no teaching materials on this subject and only in 1962 there appeared "Methods of Compiling Large-Scale Soil Maps with Application of Aerial Survey Materials" edited by Professor Yu. A. Liverovskiy. The book generalizes the experience in interpreting soils in our country and partly abroad, and discusses certain problems of the methods for interpreting the soils of various zones which we used in the present guide. We also took into consideration the works on this subject published by the Laboratory of Aeromethods of the Academy of Sciences USSR (Yu. S. Tol'chenikov and others).

As we have pointed out earlier, soil interpretation has it as its goal to study soil properties from aerial photographs (diagnostic interpretation) and to establish and plot soil boundaries (contour interpretation). The success of the interpretation will depend on the ability of the students and specialists to reveal the rich content of aerial photographs and on their experience necessary for this work.

An aerial photograph is a model of an area of one or another scale which reflects, directly or indirectly, its soil, and certain factors of soil formation. Therefore, soil interpretation will consist of a detailed analysis of aerial photographs of a territory for which it is necessary to know the peculiarities of the territory under study and to know how to use the natural-scientific method of analysis of a photographic image of a natural or cultural landscape.

Soil is a special natural-historical body and the main means of production of agriculture. Therefore, its representation in aerial photographs has its own peculiarities. When soil without vegetation is photographed, the image in the picture represents only the surface of the soil. By the nature of photographic image of the soil surface alone, it is not possible to establish the diagnostic indices (depth of horizons, presence of podzolization, alkalinity, etc.) which are necessary for establishing the belonging of the soil to one or another type, subtype, etc., and for its genetic and agroproductive characteristic. However, by using the method of genetic interrelation of the soils of the top horizons and lower horizons, the soil scientist seems to reconstruct the entire soil profile. The reliability of the genetic identification of soil is established by a comparative analysis of the photographic image of the soil contours in the aerial pictures and their content in the territory under study. It is necessary to consider not only the territory represented in one aerial picture but also in other aerial pictures of the object which is being studied (a kolkhoz, a sovkhoz). Special characteristics of the photographic image of soils in aerial pictures make it possible to interpret the photographs and classify the soils in higher taxonomic categories -- types, sometimes subtypes and, in some instances, kinds. We stress that this can be achieved only if the soil scientist is well familiar with the soils of typical sections of the locality and the special characteristics of their image in aerial photographs. Thus, soil interpretation must be combined with field and laboratory studies. This does not lessen the significance of laboratory soil interpretation from aerial pictures.

Starting his work on the interpretation of aerial pictures, the student must, first of all, determine the scale, since it affects the representation of the details of the natural objects on a plan or a map. The scale of the aerial photographic survey also determines the size of the minimum contour or object which can be represented in the aerial picture. The resolution of aerial photographs is very high (0.03 mm) and, therefore, they reflect the minute details of the terrain. However, the resolution of the human eye is considerably lower (0.08 mm). The human eye is capable of comparing the dimensions of two objects accurate to 0.1 mm when the images of the object are not smaller than 1 mm. The following values correspond to one millimeter in an aerial photograph at different survey scales:

Scales	1:2000	1:5000	1:10,000	1:25,000	1:50,000	1:75000
Size in nature, m	2	5	10	25	50	75

Pictures of 1:2000 show all the details of the microrelief of the area -- hillocks, washed-out hollows, etc., as well as complexes of soils and plants. However, this scale is not convenient for large areas, because they involve a large number of photographs. Pictures of 1:5000 scale also give a rather detailed image of vegetation groupings and microrelief elements 2.5 m in diameter.

Such pictures are not very convenient for large-scale soil mapping because individual photographs cover small areas. Pictures of 1:10,000 and 1:25,000 scales do not reflect small objects, such as rocks, hillocks, etc., but show the details of the relief and the variegation of the soil cover down to individual spots of the solonetz 2-2.5 m in diameter.

The resolution of the human eye can be increased by using magnifying instruments (magnifying glasses, eye-glasses, stereo-scopes), which makes it possible to study smaller details, if necessary. In producing the large-scale soil-cartographic maps of 1:10,000-1:25,000 scales, it is recommended to use photographs of the same scales.

Interpretation of soils by aerial photographs requires their special handling. The primary result of an aerial survey are contact pictures. They are convenient not only for laboratory work, but also for field work because they are small (maximum of 30 X 30 cm). The advantage of contact aerial pictures is in the fact that they reflect all the details of the photographed object. Their non-uniform scale is one of their disadvantages. However, in the center of the picture, the deviations from the scale are slight. Therefore, only the central parts of the pictures are used, i.e. only the working or useful areas are isolated.

The useful area of an aerial photograph is isolated in the following way. Two identical points are marked in the middle of a longitudinal overlap of two pictures from one flight. These points are at the same time in the middle of a transverse overlap of adjoining flights. Thus, the same point is identified and marked in four aerial photographs: two pictures of one flight and two pictures of an adjacent flight. In each picture, four points are marked in the corners, 3-4 cm from the edges. When these four points are connected with a pencil, an area is isolated in the center which is called the useful area of the aerial photograph (Figure 11, shaded part).

In order to reduce the number of aerial pictures used in the work, it is possible to take every other one of them. This is quite permissible, because, if they overlap 60%, each third picture overlaps the first one. Therefore, before starting the work, the pictures are separated into two packs: even and odd ones. One of them (does not matter which) is considered to be the working pack. The working area is isolated in the pictures and soil interpretation is done within it. It should also be considered that contact prints are not oriented (on the terrain) with respect to the geodetic network. For this purpose, the interpreter must have a topographic plan of the terrain and orient the pictures with respect to it. Pictures received for work are accompanied by reproductions for superimposing. In their absence, this work is done by the interpreter himself.

For this purpose, all pictures for a given area are arranged in order and secured on a sheet of cardboard or plywood. A superimposable reproduction makes it possible to check if the entire area is covered by the pictures. Main populated localities, rivers, lakes, etc. are labeled on the mosaic. Then it is photographed, reduced 4-5 times and prints are made from the negative which serve as an index of the aerial pictures. The necessary pictures can be readily found with its help. It is not possible to carry out measurements by the photographs of a mosaic because the contact prints of which it is composed have different scales.

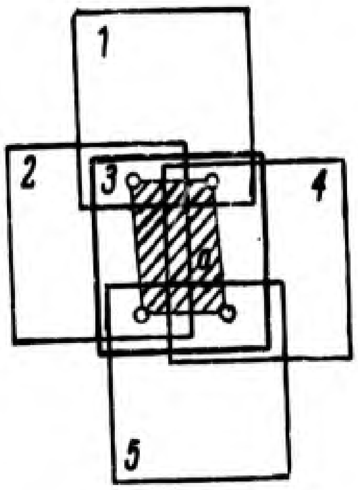

Figure 11. Useful (Working) Area in Aerial Photographs:
1 -- aerial picture of the first flight line.
2,3,4 -- aerial picture of the second flight line.
5 -- aerial picture of the third flight line.
a -- useful area of the aerial picture.

Certain Special Characteristics of Interpreting Soils of Different Zones

Natural landscapes of various soil zones differ noticeably among themselves, which is reflected in aerial photographs. Therefore, in interpreting the soils of different zones, it is necessary to consider, first of all, the specific features of their natural characteristics, because there are frequent cases when soils of different types in different zones have similar or even identical photographic images. In interpreting soils of any zone, we should isolate, first of all, soils which are sharply outlined in aerial photographs. In a forest-grassland zone, M. S. Simakova identifies the following soils: soddy medium and strongly podzolized gley, soddy podzolic gley, soils of the swamp series, soddy meadow soils, etc.

Soddy medium and strongly podzolized gley soils are connected with slight depressions, are subjected to temporary overmoistening and are represented in aerial photographs by a darker background than soils with normal moistening. Soddy podzolic gley soils are subjected to overmoistening for a longer time, have unfavorable agricultural properties, and, therefore, as a rule, are not plowed and are covered by shrubs (birch, willow, alder, etc.). Areas with such soils are represented differently in aerial photographs depending on the vegetation, degree of moisture and relief. If they are covered with shrubs, then they are reflected in a grey small-grain pattern; if they are covered with sedge, they have a light uniform tone, and heavily moistened soils covered by various moisture-loving vegetation assume a dark grey tone. Areas with soddy-meadow soils stand out well in aerial photographs and have a uniform grey tone of the images of herbaceous vegetation reflecting negative forms of the relief (river valleys, ravines, small depressions, etc.). Images of river valleys under a stereoscope make it possible to isolate flood plain soils from watershed soils.

Areas of arable land with its typical soddy-podzolic soils with various degrees of podzolization are reflected clearly in aerial photographs by a grey or a light grey tone with spots or stripes of whitish shades which reflect the emergence to the surface of podzolized or weakly humus-enriched horizons of the soils (Figure 12)

Figure 12. Fragment of a panchromatic aerial photograph at a scale of approximately 1:10,000. Natural landscape of a forest-meadow (soddy-podzolic) zone: A -- arable land, B -- dry river, г -- standing brush along the river banks, д -- standing brush, Л -- meadow, $Л_1$ -- marshy meadow, Ж -- direct shadow of a slope, И -- depression with herbaceous vegetation, M -- road.

A more uniform light-grey tone represents areas of soddy weakly and medium podzolic soils of light mechanical composition. Eroded soils of slopes stand out well in aerial photographs.

The most reliable indication for the identification of eroded soils is the tone of the photographic image, by which soils can be readily distinguished with respect to the degree of erosion, particularly those of a plowed area reflecting directly the top soil horizon. The most contrasting differences in the tones are observed in the aerial photographs of freshly plowed areas which have not yet dried or in the pictures of areas with young sprouts which are not yet shielding the soil. The tone of the photographic image depends on the magnitude of the humus horizon and on its content of humus. Eroded soils always appear in lighter tones in the photographs. Medium and strongly eroded soils stand out clearly. It is difficult to isolate weakly eroded soils in aerial photographs because they have the same tone as the uneroded soils. In this instance a characteristic pattern of branchy tree-like form created by a dense network of small troughs of the drainage in the photographic image is of help.

Strongly eroded soddy-podzolic and podzolic soils, whose illuvial yellow-brown horizons are bare, are reflected in aerial photographs by grey or dark grey colors, which is connected with the presence of large quantities of ferric iron.

Swamp soils stand out clearly in aerial photographs because of a specific form of the vegetation image -- forest, shrub, moss and herbaceous, as well as because of their position within the relief. However, it is not possible to determine by a photograph the magnitude of peat, the degree of its decomposition, etc. Therefore, for this purpose and for the verification of the correctness of the genetic determination (type, subtype, genus),test pits should be made more frequently then in other soils.

Identification of soils by images of forest vegetation has not been developed as yet. However, the identification methods for trees by their images in aerial photographs present no difficulties, which has been mentioned above. Therefore, the determination of larger diagnostic indices (type, subtype and genus) is done on the basis of their connection with the relief and the position occupied by the soil in the system of the natural landscape. For example, on ancient leveled terraces under pine forests where the ground is covered with lichen, there form podzolic soils and podzol; at poorly drained watershed areas under fir tree forests with a thick moss cover there form podzolic gley soils. Thus, by using direct and indirect identification characteristics, it is possible to identify in the forest-meadow zone by aerial photographs not only the soil contours and boundaries of soil divisions, but also to establish certain diagnostic properties of soils in these contours.

The application of aerial photographs in studying and mapping the soils of this zone makes it possible to reveal the great diversity of soils, interpret the mosaic of the soil cover and to represent it more precisely on a soil map. It should be taken into consideration that the time and the scale of the aerial survey are of great importance. The variegated nature of the soil cover is reflected best in black and white aerial photographs taken in the spring or early summer when the fields are not yet covered with crops. The most convenient scale of soil mapping for agricultural purposes is 1:10,000. It is desirable to have aerial survey materials of the same scale. It is possible to use aerial survey materials of scales 1:50,000-1:17,000, because in their identification properties they are almost as good as aerial photographs of 1:10,000 scale. In interpreting the soil cover of a forest-steppe by aerial photographs it should be taken into consideration that a large part of it is plowed, i.e. natural landscapes are created (plowed fields, forest shelter belts, gardens, etc.). Considerably smaller areas are covered with natural vegetation. Special studies by V. A. Andronnikov showed that the soil cover of the territory of a forest-steppe can be interpreted in aerial photographs either directly by the image of the soil surface, or indirectly by the image of the vegetation and by establishing the interrelation of the soil with the relief. In the first case, the direct indications will be: the color, tone and shape of the image of the soil surface; indirect indications are the relief, vegetation, soil-forming rock, etc. In the second case, the soils are identified by the color and tone of the vegetation image and the association of the contour with a definite element of the relief. The basis of the soil cover of the forest-steppe zone are various types of grey forest soils, podzolized and leached chernozems. Against an overall background of grey forest soils, there appear isolated spots of soddy-podzolic, soddy and other soils. Light-grey soils with a clearly expressed podzolic horizon and about 1-1.5% humus content in the cultivated horizon are represented by a general light tone, which is due not only to the low content of humus, but also to the strong podzolization of the soils. Within the contours of these soils, dark spots characteristic of humus-enriched soils are observed.

Plowed areas of these soils are characterized by a fine striped design of the image. This is connected with the fact that the podzol horizon is plowed up to the surface. Light grey forest soils containing 2% of humus are represented by a light grey tone.

Grey forest soils containing about 3% humus are represented by a uniform grey tone in aerial photographs. However, if these soils are formed in relatively flat watershed areas with a noticeable micro-relief, their pattern contains light tone spots characteristic for more podzolized soils.

At spots in the northern regions, in Western and Eastern Siberia, grey forest soils with a second humus horizon are widespread among grey forest soils. In this case, the pattern in the photograph image assumes a darker shade because the second humus horizon which is richer in humus is turned up to the surface.

Dark grey forest soils which are predominantly loamy and clay loamy and contain about 5% humus are represented by a dark grey tone in aerial photographs. They stand out clearly in aerial photographs against a general background of light grey and grey forest soils and because of their position in the relief. These soils are associated with watershed areas or the first parts of slopes. Podzolized and leached chernozems of a predominantly heavy mechanical composition containing about 7-8% humus are represented by the darkest background in aerial photographs. The contours of podzolized chernozems are somewhat lighter then the contours of leached chernozems. They also differ in their location within the relief: leached chernozems are associated mainly with watershed areas, while podzolized chernozems are distributed mainly in the lower parts of slopes. Against the general background of grey and dark grey forest soils, there occur spots of podzolized chernozems also at watersheds.

V. L. Andronnikov mentions that soddy gley-containing and gley soils, as well as the soddy-meadow soils of river valleys are not directly reflected in aerial photographs and, therefore, their identification must be done by indirect indications. The gley and soddy-gley containing soils are identified by their location within a relief. They are associated with the ravine-gully network, because of which their contours are characterized by a elongated shape along ravines and gullies. In aerial photographs they are represented by a grey or dark grey background depending on the moisture in the soil and the density of the meadow vegetation.

The identification of the soddy-meadow soils is facilitated by the association with alluvial river plains which show clearly in aerial photographs. The gley and soddy gley-containing alluvial soils are associated mainly with areas of grainy alluvial plains or dried cut-off lakes. They are characterized by a high degree of moisture and development of powerful vegetation. In aerial photographs they are presented by a dark grey tone and at the areas of cut-off lakes they are characterized by curved shape of the pattern.

Soddy-meadow neogley soils are associated with areas of lamellated alluvial plains and are represented in aerial photographs by a light grey tone with dark spots characteristic of moistened microdepressions. Meadow-chernozem and chernozen-meadow soils containing considerable amounts of humus (8-10% in the first ones and 10-15% in the second ones) are identified by a dark tone of their image and by their locations in the relief. The former ones are associated with flat watershed areas slightly cut by a ravine-gully network; the latter are associated with lower parts of watershed slopes. At identical moisture, the image of chernozem-meadow soils in aerial photographs is represented in more intensive dark coloration in comparison with the dark background of meadow-chernozem soils. The variegated soil cover of the chernozem zone is illustrated in Figure 13.

Figure 13. Fragment of a panchromatic aerial photograph at a scale of 1:10,000 of a complex soil cover of the chernozem zone:
1 -- ordinary chernozem (virgin soil);
1a -- ordinary chernozem (plowed land);
2 -- ordinary thin chernozem;
3 -- soloth.

Alkaline chernozems and the solonetz are recognized among the chernozems in aerial photographs by their lighter images in comparison with nonalkaline soils (Figure 14). Eroded soils are widespread in the forest-steppe zone. They stand out clearly in aerial photographs because of their specific streaked, feathery or fan-shaped pattern.

It is more difficult to interpret soils covered by cultivated vegetation. The accuracy of identification will be lower than for plowed or virgin areas. The background on the image will depend on the crop, density of sowing and the development phase of the plants. Young and sparse shoots shield the soil surface very slightly and do not complicate the identification. Identification of soils by the images of cultivated vegetation is not yet well developed. Therefore, other indications are used mainly for interpreting soils under cultivated vegetation: the relief, form of the image, etc. The same should be said with respect to the identification of soils under forest vegetation. Identification methods for this purpose also have not yet been developed.

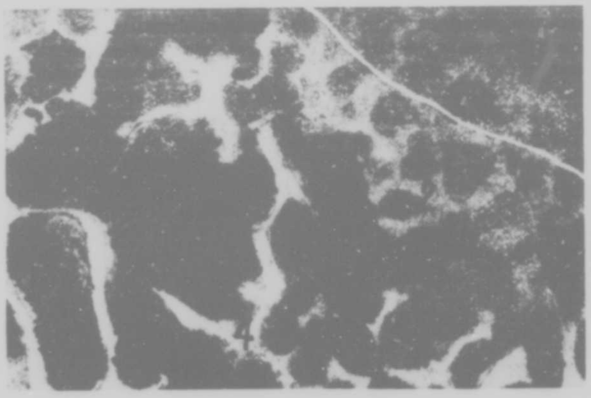

Figure 14. Fragment of a panchromatic aerial photograph at a scale of 1:10,000 of meadow-chernozem soils in combination with alkaline chernozem, solonetzs and soloths:
1 -- meadow-chernozem soils in microdepressions;
2 -- alkaline chernozems and solonchakous chernozems associated with microdepressions;
3 -- soloths under birch-aspen lumber sites;
4 -- meadow-solonetzs.

For farming purposes, it is expedient to carry out soil studies in the forest-steppe at a scale of 1:25,000 or 1:10,000, depending on the variety of the soil cover and the specialization of the farm. Aerial photographic material should be of the same scale or close to it.

Aerial survey materials are exceptionally important in studying the soils of the dry steppe, where the soil cover is characterized by a great complexity and variety. Mapping it by ordinary methods (without employing aerial photographs) is most difficult and does not yield the necessary accuracy. The reason for this is that here we have an extensively developed microrelief which is not reflected even in large-scale topographic maps, while 1:25,000 scale aerial photographs show micro relief elements down to 2.5 m in diameter. Increasing the scale to 1:10,000 results in considerably more details in the image of the microrelief and its complex vegetative and soil covers. Further increase in the aerial survey scale is not expedient because many unnecessary details will make the interpretation more difficult. Moreover, increasing the scale is accompanied by an increase in the number of aerial photographs, which complicates their analysis, because each picture covers a smaller area and it is more difficult to determine the position of the contour in the environment, etc.

Thus, for the dry steppe zone it is most expedient to use a scale of 1:25,000 in soil studies and mapping. The same scale, or one close to it, should be used for aerial pictures. It is also necessary to consider the time of the survey. It must be different for different subzones. In the northern regions with prevailing uniform areas of dark-chestnut and chestnut soils, the most contrasting image is obtained in spring and summer aerial photographs when the fields are not covered by cultivated vegetation. A complex virgin steppe is reflected better in summer photographs when the contrasts and the boundaries between the elementary landscapes and their soils are expressed most sharply for the soil cover as a whole. Depending on its complexity, a corresponding pattern is reflected in aerial photographs. The zonal dark chestnut and chestnut soils are represented by uniform tones in the aerial pictures: grey and light grey for unplowed areas and dark grey for plowed fields. The tones of these subtypes are almost identical in aerial pictures. Therefore, they are distinguished by other criteria. For example, in Northern Kazakhstan, the dark-chestnut soils are readily isolated by the presence of light spots, or "marmot hills," formed by the rodents. These spots are clearly visible in aerial pictures as white dots. In the mountainous and bald mountain regions, they are reflected in a characteristic pattern (Figure 15).

Figure 15. Fragment of a panchromatic aerial picture of 1:10,000 scale showing the soils of Kazakhstan's small mound area:
1 -- rubble-containing poorly developed soils and outcrop of massive solid rock;
2 -- dark chestnut soils of depressions between mounds;
3 -- meadow-chestnut soils of microdepressions.

Among the chestnut soils, areas with complex soil covers are encountered more often, and solonetzs and solonchaks are most prevalent. Therefore, the consideration of special characteristics of natural and cultivated landscapes (in the subzone of chestnut soils where land is not plowed as much) makes it possible to separate dark chestnut soils from chestnut soils. Homogeneous areas of light chestnut soils are reflected in aerial photographs by light grey tones. But unlike the chestnut soils, the light chestnut soils are surrounded by complex soils which are reflected in a pattern of fine spots. The solonetzs and alkaline soils which are widespread in the zone of dry steppes in the form of small spots, are identified in aerial photographs among zonal soils by their light tone and the fine spots of their pattern.

Meadow-chestnut soils are represented in aerial photographs by a uniform dark grey background. Within a complex steppe, they can be well identified by their image type and association with definite elements of the relief. More or less identical contours of these soils are encountered in terrain depressions. The shape of the depressions vary; their rounded and oval area varies from several tens of square meters to 3-5 hectares and more. Shallow troughs are formed along the slopes by deluvial streams. Their width varies from 2 to 3 m at a height of from 50 to 100 m and more in the lower parts of the slopes. The length of a trough depends on the angles of slope, its exposure, etc., and varies from 100-300 m to several hundred meters.

Aerial photographs make it possible to isolate by laboratory methods depressions and troughs with meadow-chestnut soils.

Solonchaks are reflected variously in aerial photographs depending on their nature. Dry and puffed solonchaks with bare surfaces and efflorescences of salts are represented by a bright white tome. Solonchaks covered by halophyte vegetation are represented by a grey tone. Solonchaks are often reflected in aerial photographs in spotted patterns with sharply changing tones -- from white to black, which corresponds to the soils changing from puffed to wet solonchaks and the vegetation associations changing from sparse thistle to wormwood-gramineous plants.

Solonchaks in salada depressions stand out sharply in aerial photographs. They are readily identified by the light color and the characteristic shape of their image. In the center of a salada, where a layer of water several centimeters thick may be present, or where the solonchak vegetation appears, aerial photographs have a darker tone -- light grey or grey.

Soloths or solothized soils are readily identified by their vegetation and by their location within the relief. They develop in shallow depressions covered by woody-shrubbery vegetation which is reflected in aerial photographs as a characteristic fine-grain pattern. In plowed areas, soloths stand out sharply in aerial photographs along the zonal soils because of their whitish background.

Poorly developed skeletal soils which developed on the weathering products of the original rock and are covered by a sparse herbaceous vegetation or small shrubs are reflected in a light grey or a light tone in aerial photographs. The presence of these soils is also established by interpreting the relief.

Eroded soils here, just as in other zones, stand out clearly in aerial photographs and are identified by their specific shape and the tone of the image.

A special characteristic of the soil cover of the dry steppe zone is an extensive development of soil complexes and combinations resulting from the complexity of the relief, geological structure, etc. Various complexes and combinations have definite images in aerial photographs. Areas with complex soils are readily isolated from the areas with a uniform soil cover. In turn, by the pattern of the photographic image, shapes and dimensions of various spots corresponding to ceratin components of the complex, the location of the complex in the environment and other indications, it is possible to determine the type of complex.

Lithologenic soil complexes whose formation results from the differences in the lithologic composition of the rock emerging to the surface or covered by a small layer of loose deposits are characgerized by a streaky pattern of the image. The basic components of such complexes are underdeveloped skeletal soils.

There are two types of complexes: meadow and meadow-steppe. Meadow soil complexes are formed when ground water is high. Among meadow complexes, two-member ones consisting of puffed solonchaks and meadow soils are widespread. They are associated with firths whose microrelief is well-developed and where the positive forms of the microrelief are occupied by puffed solonchaks and the negative forms by meadow soils. In aerial photographs, these complexes are represented by a complex striated pattern, where a light tone represents puffed solonchaks and a grey tone indicates meadow soils. Two-member complexes are widespread along the edges of the firths. They consist of saline solonetz and meadow soils which are represented by a streaky and dotted pattern in which a light tone reflects the solonetz and a dark tone indicates the meadow soils.

Meadow-steppe complexes with depressed microrelief are reflected in aerial photographs as a spotty pattern. Combinations of the components in these complexes are of many different kinds. A complex may include zonal soils, solonetzs, solonchaks, soloths, solodized soils, meadow and meadow-chestnut soils. Complexes may consist of two, three or more members. Solonchaks and solonetz are represented in aerial photographs by a light tone and meadow-chestnut soils -- by grey or dark grey tones. The tonality and shape of the soloth patterns depend on the nature of the vegetation under whose effect they were formed.

By aerial photographs, it is possible to determine with a high degree of accuracy the percentage of soils which compose a soil complex.

It is possible to determine rather accurately the percentage of meadow-chestnut soils. For this purpose it is necessary to calculate the number of narrow depressions and determine their average size. The same method is used to define soloths and solodized soils.

Slightly eroded soils are isolated on gentle slopes covered with a network of small narrow depressions. Medium-eroded soils are characteristic of slopes of medium steepness covered with drainage troughs.

Heavily eroded soils stand out clearly in aerial photographs among other soils because of their light tone and an unusual streaky pattern. Therefore, their outlining and calculation of their areas do not present any difficulty.

The quantity of solonetzs in a complex is determined by the tone of the image. The more solonetzs there are in a complex the lighter the general tone of the photograph image. When the tone is light a large area in the picture is occupied by solonetzs. When the general background of the picture is darker a large area is occupied by other soils of the complex. Thus, it is possible to plot boundaries of soil divisions by aerial photographs and, in many instances, to determine the genetic properties of the soils of these divisions, i.e. to determine the types, subtypes and small taxonomic subdivisions.

Practical Work on the Second Section

For the second section, "General Principles of Soil Interpretation from Aerial Photographs," students perform the following assignments in their laboratory work.

Assignment 1. Interpret the hydrographic network and relief from aerial photographs.

In order to fulfill this assignment, it is necessary to have 2-3 stereopairs of aerial photographs, a topographic map of the locality represented in the aerial photographs, a mirror lens stereoscope, a stereoaltimeter, rulers, compas and graph paper.

Each student interprets 2-3 stereopairs of aerial photographs under a mirror lens stereoscope. Measurement of relative altitudes of the terraine is done by means of the stereoaltimeter or by the objects in the pictures whose height is known.

In the process of fulfilling the assignment, the student must obtain a clear picture of the hydrographic network and the geomorphologic composition of the terrain represented in the pictures which he is interpreting and in the topographic map, and to determine the elementary forms of the relief: watersheds, slopes, river and ravine valleys, gullies, hollows and the basis of erosion (elevation of watersheds over the river talwegs). They have to determine the heights of the negative and positive forms of the relief and to sketch the profile of the terrain and give its brief geomorphological description.

Students must describe the surface form of watersheds, slopes, river valleys, etc. (determine their approximate dimensions).

Let us assume that the following heights of points in the terrain above sea level were determined in an interpreted aerial photograph at a scale of 1:10,000:

Number of point.	1	2	3	4	5	6
Elevation above sea level, m.	254	238	210	198	210	240

The data indicate that changes in the heights of the points of the profile vary from 198 to 254 m above sea level, i.e., relative elevations of the points in the terrain vary from 16 to 56 m. Having accepted vertical scale of 1/1000, the students begin to work out the profile of the terrain.

The essence of plotting the profile consists in the following. On the aerial picture, a profile line is drawn which crosses the minimum and maximum marks of the terrain. Then it is transferred at the same scale to a sheet of paper (preferably graph paper) and distances between the points whose heights were determined are plotted on it. Then, perpendiculars are erected from points 1, 2, 3, 4, 5, 6 which are equal to the altitude markings and a broken or smooth line is drawn through the vertexes of the perpendiculars which represents the profile of the terrain along the line AB.

Assignment 2. Interpret the terrain by aerial photographs. For this assignment it is necessary to have 2-3 stereopairs of aerial photographs, a mirror lens, stereoscope and a notebook.

In this case, the students are given a task to give a complete interpretation of aerial photographs of natural and cultivated landscapes of a terrain in 2-3 aerial photographs, i.e. to recognize completely all images in the pictures.

It is advisable to start with the identifications objects which are shown most clearly in the aerial photographs: populated points, roads, hydrographic network, artificial water reservoirs, cultivated areas (plowed fields, gardens, swamps, forests), outcrop of rock, etc. Identification is done by contours, and contours are numbered. All contours of interpreted aerial photograph are transferred to tracing paper. Descriptionsof contours are entered in the notebook in approximately the following form:

No. of aerial photograph, scale:	No. of contour	Interpretation Criteria	Conventional Symbols	Content of Contour
439-440	1,2,3	Geometrically regular configuration of area.	Standard	Field after harvesting crops.
				River
1:10,000	4	Dark background of photo image, curvy shape.		

Assignment 3. Interpret vegetation from aerial photographs.

For this assignment, the student must have 2-3 stereopairs of aerial photographs, a mirror-lens stereoscope and a notebook.

The student has a problem of identifying the vegetative cover in 2-3 stereopairs of aerial photographs by means of a mirror lens stereoscope. It should be kept in mind that the laboratory method can yield only a preliminary, incomplete interpretation of the vegetation: to isolate the types of forests (coniferous,

No. of Aerial Picture, scale	No. of Contour	Type, group of Vegetation.	Ecological Conditions	Interpretation Criteria	Conventional Symbols
452-453 1:10,000	1,2,3	Fir forest with parterres of asp groves and clearings of cut forest.	Flat watershed area.	Form of image. Fir forest -- fine-grain pattern of dark color. Asp -- coarse-grain lt. color. Clearings -- uniform grey color.	Standard
452-453 1:10,000	4,5	High sphagnum bog.	Shallow depression in watershed area.	Wavy pattern, light curvy stripes alternating with dark stripes and spots (beds, wet areas). Fine dark grains reflecting individual trees.	
582-589 1:10,000	1,2,3	Vegetation complexes of dry steppe.	Flat steppe with meso- and micro-depressions	Variegated pattern. Light-grey tone -- dry steppe vegetation, dark spots -- meadow vegetation of depressions.	

No. of Aerial Photograph, Scale	No. of Contour	Soil	Identification Criteria	Location (Relief)	Conventional Symbols
582-583 1:10,000	1,2,3	Light Chestnut	Variegated light grey pattern characteristic of virgin vegetation of semideserts.	Flat steppe with clearly expressed meso- and microrelief.	Standard colored or shady.
"	4,5,6	Meadow-chestnut	Dark grey or grey monotone pattern characteristic of meadow vegetation	Depressions, 0.5-2.5 mm in diameter, 30-50 mm long, 10-20 mm wide.	"
20-21 1:10,000	1,2,3	Soddy, weakly and medium podzolized.	Light grey pattern with grey stripes. Plowed field.	Flat watershed.	"
"	4,5,6	Same	Granular light grey pattern. Mixed fir-birch-aspen forest.	Same	"
452-453 1:10,000		High peat bog.	Wavy pattern (swamp) surrounded by fine-grain grey pattern (coniferous forest).	Depression at watershed.	"
"	2,3,4	Strongly podzolic.	Dark grey fine-grain pattern typical for dense coniferous forest.	Slightly wavy watershed.	"

Assignment 4. Interpret the soils from aerial photographs.

For this assignment, it is necessary to have 3-4 stereopairs of aerial photographs from different soil zones, a mirror lens stereoscope, rulers, magnifying glasses for 6-8 diameter magnification, a notebook, a set of colored pencils and tracing paper.

The students have the task of interpreting 2-3 aerial photographs from different zones. On the basis of the sum of direct and indirect indications, they first isolate similar contours in the aerial photographs. Each contour is numbered and its content is interpreted. Results are recorded in the notebook and contours are transferred to tracing paper which is colored or shaded according to standard symbols.

Assignment 5. Plot a topographic profile of the terrain.

For this assignment, it is necessary to have aerial photographs in which the elevations of the terrain have been determined or topographic maps, scale rulers and a compass.

In order to plot a topographic profile, it is necessary:

1) to plot two points A and B on the aerial photograph or the topographic map between which the profile is to be plotted and to connect these points by a straight line;

2) to plot the heights on this line;

3) on the left hand side, to plot the vertical scale according to the horizontal marks. Usually the vertical scale is 5-10 times larger than the horizontal scale;

4) then, from all lines with the markings of heights to lower perpendiculars in accordance with the scale. Connect the lower points of the perpendiculars by a running line (as shown in Figure 16) which will show the relief of the terrain.

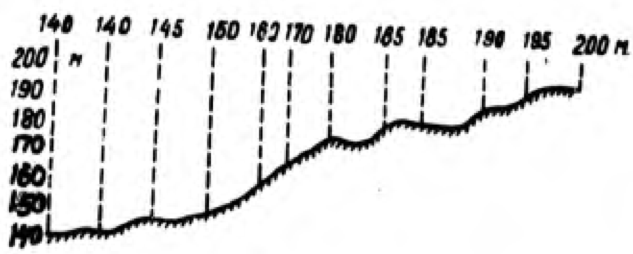

Figure 16. Topographic profile of a terrain. Horizontal scale 1:10,000, vertical scale -- 1:2,000.

The plotting of topographic profile and the subsequent transfer of the data on the soils, soil-forming rock and vegetation make it possible to study more comprehensively and establish clearly the interrelation between the relief and the nature of local soils.

(pp 58-63)

III. SOME SPECIAL CHARACTERISTICS OF THE METHODS AND ORGANIZATION OF SOIL INVESTIGATIONS WITH THE USE OF MATERIALS OF AERIAL PHOTOGRAPHIC SURVEY

Soil studies with the use of materials of aerial photographic survey, just as the work by ordinary methods, consist of three periods: preliminary, field and laboratory. The content of the work of individual periods changes somewhat.

The preliminary period. Before proceeding to the work location, the investigator or the student must study the natural-historical conditions of the region or the farm from published sources and manuscripts.

Special attention should be given to the preparation of the topographic background materials. Such materials must include: contact prints, mosaic reproductions, topographic maps, a photomap or a land management map. The scale of the topographic background materials must be not less than the assigned scale of the survey or larger than it. It is desirable for the scale of the contact prints to correspond to the scale of the survey. However, since aerial photographs are very detailed, it is possible to use aerial photographs of smaller scales. For example, aerial photographs of 1:15,000-1:17,000 scale are used for preparing soil maps of a 1:10,000 scale. Scales of aerial photographs larger than 1:10,000 are undesirable because excessive details complicate the work and make it more expensive. When surveying at a scale of 1:25,000, it is better to use aerial photographs of the same scale. It should be kept in mind that although aerial photographs are the best topographic basis, however they are not connected with the terrain and do not have the markings of absolute heights. Therefore, for soil studies, the soil scientist must have a topographic map of a corresponding scale. If it is not available, it is possible to use a photomap. But in this case, it is necessary to have a topographic map of a smaller scale which gives an idea of a general structure of the territory and absolute markings of the basic elements of the relief. In the absence of topographic maps and photomaps, the soil scientist must use land management maps in his work with aerial photographs. In this case it is more difficult to connect aerial photographs with the land management map because it does not reflect many details of the terrain. Therefore, it is desirable that during the laboratory period the land management surveyor should correct the topographic map or the land management map by the materials of aerial photographic survey. It is particularly necessary with respect to the relief on the land management map and the microrelief on the topographic map.

The process of correcting maps and plans is very complicated and time-consuming, particularly if the topographic maps and the aerial photographs are of different scales. In this case, the corrections of the basic topographic materials are done with a projector, pantograph or by the method of graphic transformation.

It is the simplest to transfer soil contours from aerial pictures to a photomap. Therefore, soil scientists prefer to use photomaps.

The work with aerial photographs will be successful if the work is well organized and they are treated properly. Before going out to the field, aerial photographs should be prepared for the work. The contact prints must be arranged in accordance with the flight lines and kept in this order in the process of the entire working season. Then it is desirable to isolate the working areas in the aerial photographs within which the field work will be done. It is better to take every other photograph, and, for stereoscopic interpretation, to isolate the contours only in one picture of the stereopair leaving the second clean for the control.

Aerial photographs make it possible to compile preliminary landscape maps during the preparatory laboratory period. Examining the photographs in a stereoscope, the soil scientist isolates sections of the terrain surface which differ in their photographic image or in their position within the relief, i.e., identifies individual elementary landscapes. First he isolates the largest elements of the relief, watersheds, river valleys, etc., and then vegetative and soil contours within their limits. The accuracy of establishing the boundaries between the contours depends on the clearness of their image in the photograph.

Assuming that identical landscapes have identical soils, we make a kind of soil contour identification.

Upon completion of the preliminary interpretation, typical sections of the terrain are selected as clues for a more detailed study.

On the basis of published data and the results of laboratory identifications, the soil scientist compiles a list of soils which is refined and expanded during the field work period.

Preliminary identifications make it possible for the soil scientist to plan the routes of field trips and soil test pits for his soil surveys. Thus, it is possible to make sufficiently accurate determinations of the volume of the field work, the composition of the team of workers, the time necessary for conducting soil survey, etc.

Field work period. Field studies with the utilization of aerial photographs start with a reconnaissance survey of the territory. Its purpose is to reveal general regularities in the distribution of soils and to establish the interpretation criteria for their photographic images. Therefore, the routes of a reconnaissance survey must include all typical geomorphological elements of the territory under study.

Along the survey routes, soil test pits are made, which permits to establish the association of the soils with the elements of the relief, changes in the soil cover depending on the vegetation, the soil-forming rock, hydrological conditions, etc.

At the same time, the soil scientist makes a thorough study of the aerial photographs, i.e., establishes the nature of the photographic images of various soils and soil complexes. The most thorough study is made of the interpretation of typical sections of the territory which will become the key criteria for other territories. In this case, the soil scientist establishes interpretation criteria for further studies of the territory. In soil surveys with the use of aerial photographs, the soil scientist goes to the field with the contours of a preliminary landscape map prepared in advance. Therefore, his main task is to establish the content of these contours and determine the transition to the next contour more accurately. To perform this task, the necessary number of soil test pits are made. At the beginning of the field work, the number of pits can be rather large. Later, as the experience of working with aerial pictures grows, the number of pits will decrease because the soil scientist will be using interpolation methods. Therefore, the use of aerial photographs reduces the number of pits by 10 times and more if land management plans are employed as the topographic basis. However, the number of the pits must be such as to ensure accuracy and details in a soil map of a definite scale. Each isolated section of soil (contour) which differs in its nature and in its image in the aerial photograph must be substantiated by at least one soil pit. If the contour includes several types or varieties of soils, each of them must be substantiated by one test pit. Whenever the contours of an identical content and of approximately identical areas recur, it is possible to limit oneself to semisections or shallow digging.

In order to determine the contents of a soil complex and establish the identification criteria, the soil scientist makes test pits in all components of a given contour, which makes it possible later to recognize similar complexes and their components in aerial photographs.

Aerial photographs are particularly important in the study of a complex soil cover. They make it possible not only to isolate complex soils from land areas with a uniform soil cover, but also to identify the contents of the complex, i.e., to determine its components. The boundaries of the contours of soil complexes are established by aerial photographs. When the boundary between the soil contours is not clearly visible in aerial pictures under a stereoscope, it is necessary to find it in the field by ordinary methods through surface digging. If the boundaries of the soil contours are clearly reflected in aerial photographs, it becomes unnecessary to perform surface digging for their determination. This considerably reduces the volume of field studies.

Thus, the interpretation and use of aerial pictures are a part of the field and laboratory work in soil studies. It does not eliminate the field studies of soils, but shortens the time and increases the accuracy of soil curvey. This is particularly true of establishing the boundaries of soil contours, which, as a rule, are clearly reflected in aerial photographs. Consequently, mapping -- the most labor-consuming and responsible work in soil survey -- is performed with a sufficient degree of accuracy and less efforts than with any other basis.

It is simple to transfer soil contours from aerial photographs to topographic maps or a photomap if the scale of the aerial photographs corresponds to the scale of topographic basis. If the scales of the aerial photographs and the topographic basis are different, the soil contours are transferred from the aerial photographs by means of additional auxiliary graphs. The graphs are plotted (with consideration for the scale) on aerial photographs and on the map (topographic basis). To plot the graphs, four prominent points are selected in the map and in the photograph. With their aid, the soil contours are transferred from the aerial picture to the topographical basis. This method of transferring contours from aerial photographs to a map is called graphic transformation. It makes it possible not only to transfer the image on the appropriate scale but also to remove the distortions caused by unevenness in the regions of weakly broken relief.

It is permissible to compile a field soil map on aerial photographs. In this case, not only soil contours are isolated in the aerial photographs, but also the numbers of test pits and geological boreholes are marked. During the laboratory period, the compiler's copy of the soil map of a required scale is compiled.

The laboratory period. The laboratory period concludes the entire program of the soil studies. The work of the laboratory period with the use of aerial photographic survey materials does not differ substantially from the work of this period in soil surveys on the ordinary topographic basis. During this period, the material collected during the field period is systematized and processed. On the basis of the analytic data, the field soil map is corrected: the names of soils, their mechanical composition, etc., are defined more accurately (boundaries of the soil contours are not changed, as a rule).

If the field soil map was compiled only on the aerial pictures, then its compiler's copy is prepared on an appropriate basis during the laboratory period. The original of the soil map is prepared on the basis of the compiler's copy.

A soil map compiled with the use of aerial photographs is characterized by a higher degree of accuracy and more details as compared to maps compiled on some other basis and, therefore, the computation of the areas of soils and land of the studied object becomes particularly important. There exist several methods of computing the areas. It is simple and rather accurate to compute the areas by means of a transparent sheet divided into squares. Planimeters are widely used for the same purpose; they make it possible to make more accurate and rapid computations.

Soil studies with the use of aerial photographs not only shorten the time of work, but also improve their quality which must be reflected in the report on soil description. The structure of the report can be the same as in ordinary investigations, but the content of the description (report) must be more thorough and concrete because aerial photographs reflect such details (for example, the complexity of soils) which are not reflected in studies on any other topographic basis.

Bibliography

1. Andronnikov, V. L. On Methods for Interpreting the Soil Cover of the Forest-Steppe by Aerial Photographic Materials: Pochvovedeniye (Soil Science), No. 5, 1957.

2. Vinogradov, V. V., Volkov, A. I., Miroshnichenko, V. P., Preobrazhenskiy, A. S. Application of Aeromethods in the Study of Landscapes. Vestnik (Herald), Acad. of Sciences USSR, No. 1, 1957.

3. Gaveman, A. V., Liverovskiy, Yu. A. Aerial Survey in Soil Mapping. Pochvovedeniye, No. 3, 1953.

4. Gospodinov, G. V. Interpretation of Aerial Photographs. Moscow State Univ. Press, 1961.

5. Liverovskiy, Yu. A. Methods of compiling Large-Scale Soil Maps with Application of Aerial Survey Materials. Acad. of Sciences, USSR, 1962.

6. Liverovskiy, Yu. A. (Editor), Simakova, M. S., Grigor'-yev, G. I., et al. Application of Aeromethods in Soil Science. Pochvovedeniye, No. 6, 1957.

7. Collection: Materials on the Use of Aeromethods in Studying the Soils and Vegetation of the Northern Kazakhstan. Acad. of Sciences Publishing House, USSR, 1957.

8. Miroshnichenko, V. P. Aerogeosurvey. Application of Aerial Survey to Geological Studies. Moscow-Leningrad, Geodeizdat, 1944.

9. Platonenko, M. A. On the Accuracy of Soil Mapping on the Materials of Aerial Survey. Pochvovedeniye, No. 1, 1950.

10. Platonenko, M. A. Soil Survey. A Guide to Field Soil Studies. Acad. of Sciences Press, USSR, 1959.

11. Semenova, N. N. Some Soil Complexes of the Northern Kazakhstan Revealed in Aerial Photographs. Pochvovedeniye, No. 8, 1958.

12. Semenova, N. N. Study of Soil Erosion on Aerial Photographs. Pochvovedeniye, No. 5, 1959.

13. Tolchel'nikov, Yu. S. On the Problem of Soils of Some Steppe Depressions of the Northern Kazakhstan. Pochvovedeniye, No. 5. 1957.

14. Tsiganenko, A. F. From the Experience of Using the Materials of Aerial Survey in Soil Mapping. Geographic Collection, No. 7, Acad. of Sciences Press, USSR, 1957.

15. Prasolov, L. I. On the Applications of Aerial Survey in Soil Cartography, Trudy (Works), GNIIiK, No. 12, 1931.

16. Fersman, A. Ye. Aviation's role in Modern Geography. Leningrad State University Press, Vol. 1, 1928.

Table of Contents

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
Foreign Science and Technology Center
US Army Materiel Command
Department of the Army

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE
MANUAL FOR USING AERIAL PHOTOGRAPHS IN SOIL MAPPING

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Translation

5. AUTHOR(S) (First name, middle initial, last name)
A. P. Mershin

6. REPORT DATE
8 May 70

7a. TOTAL NO. OF PAGES
48

7b. NO. OF REFS
N/A

8a. CONTRACT OR GRANT NO.

b. PROJECT NO.

c. 02RD500 2301

d. CRREL

9a. ORIGINATOR'S REPORT NUMBER(S)
FSTC-HT-23-732-68

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
ACSI Control Number J-6369

10. DISTRIBUTION STATEMENT
This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
US Army Foreign Science and Technology Center

13. ABSTRACT

This translation discusses the use of aerial photography in the mapping of soils. Much attention is given to the methods of interpreting soils by aerial photographs and to the study of interpreting soils by their distinctive characteristics in various zones and provinces. Several authors give their views on the interpretation of different soil characteristics such as those of alkali, saline, chestnut, meadow-chestnut, forest-steppe zones, forest and tundra zones, and swamps.

The authors also point out that the application of aeromethods in the practice of large-scale soil mapping in the Soviet Union and abroad indicates the use of materials from aerial survey increases considerably the accuracy of soil mapping, reduces the volume of the field work, cuts down its cost and increases the practical value of soil maps.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Aerial photography Soil mapping Aeromethods Agrochemistry Soil science						