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Principles of Hydrographic Interpretation of Aerial Photographs

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PRINCIPLES OF HYDROGRAPHIC INTERPRETATION OF AERIAL PHOTOGRAPHS

Osnovy gidrograficheskogo deshifrirovaniya aerofotosnimkov

D. M. Kudritskiy etal.

Leningrad, 1956, Pages 3-202

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FOREWORD

The modern period in hydrology is characterized by a considerable increase in the use of new techniques and new methods of research. These are primarily associated with an increase in the requirements confronting hydrology due to the rapidly expanding national economy.

Among the new methods great importance has recently been attached to the use of aerial methods (in particular, aerial photography) in hydrological investigations.

The State Hydrological Institute has performed a number of investigations toward clarifying the possibilities for wide use of aerial survey materials for descriptive hydrographic works, for determining the descent of snow cover, and for clarifying certain special problems (for example, obtaining by periodic photographs the characteristics of sea swells, evaluating the intensity of erosion of the banks of large reservoirs, plotting the previous positions of a riverbed, etc.).

As result of these studies the Main Administration of Hydrometeorological Service decided to make wide use of existing aerial photographic materials in hydrographic operations.

Familiarization with the principles of aerial photography in the wide circles of hydrologists should expand the area of its application in hydrological investigations.

This book is intended as a practical aid for engineer hydrologists using aerial photographs in hydrological operations. In addition, special aerial photographs of water objects may be made or aerial phtographs already in existence may be used, which photographs may have been made for purposes other than hydrological.

In the first place (that is, when the hydrologist is confronted with the problem of organizing aerial photographic operations) it is necessary that he be clearly aware of the possibilities presented by aerial photography in order to put it to proper and full use and also to be able to turn freely to the materials of aerial photography in order to derive from them hydrological conclusions.

In the second case (the use of existing aerial photographic materials), the hydrologist must devote special attention to obtaining hydrological data from aerial photographs and may not enter into the problems of execution of photographic operations in flight. These circumstances oblige us to devote a separate part to the principles of aerial photography, which comprises the first part of the book.

This part is not intended to present sufficient information to permit the hydrologist to perform independently all the aerial photographic operations, since he will not be confronted with such problems. At the same time this part cannot be limited to an exposition of the most general facts, since in this case it would not be possible to achieve a thorough and technically literate organization of aerial photographic operations.

The use of aerial photographs for the purpose of synthesizing the features of hydrological objects calls for quantitative as well as qualitative data. For this purpose it is necessary to know the principles of photogrammetry and stereophotogrammetry, even if the work is performed on the simplest stereoscopic instruments. In a number of cases in using aerial photographs for special hydrological problems it may be necessary to use complex stereoscopic instruments. This must be performed by stereophotogrammetric specialists in special laboratories.

Finally, this part presents general information concerning problems discussed in the second and third parts of the book, which parts are devoted to problems of special hydrological interpretation. In this way repetition is avoided. Thus, this part contains general information concerning the basic features of the interpretation of photographs and methods of measurement from aerial photographs.

The second part of the book is devoted principally to a description of the procedures and methods for using aerial photographs to obtain the data required for the characteristics of rivers and lakes.

Procedural elaborations of problems of application of aerial photographs in hydrological investigations as performed at GGI /State Hydrological

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Institute7 in recent years indicate that one of the chief obstacles to the hydrological application of aerial photographs and its utmost development in the unsatisfactory state of procedure in hydrological interpretation.

Present procedure in hydrographic interpretation is characterized as follows:

1. In most cases the identifying features of hydrological objects described in the literature are given marginally as limited and incidental material; they do not take into consideration the variety of natural conditions determining the nature of the obscuration of one or another element and, consequently, of the peculiarities of its image on which the accuracy of its reading and measurement depend.

2. For an entire series of elements of hydrological objects (even of such elements as the width of a river) no evaluative methods have been developed and certain methods of interpretation and measurement, especially those based on indirect evidence are performed without sufficient consideration of the hydrological regularities and relationships which might substantially facilitate and increase the preciseness of the determination of the dimensions under investigation.

3. The optimum scales and conditions of photography, which are the principal criteria in evaluating the possibility of obtaining the most valuable information from aerial photographs, in the works of different authors are only a qualitative evaluation based on extremely general and theoretical judgements and not on objective data concerning the accuracy of the interpretation and measurements. Hence the recommendations on these problems encountered in the literature reduce merely to the requirement of increasing the scale of aerial photographs and improving their photographic quality. The features of the image of one or another element and the change in character of this element according to the nature of the natural obscuration have not been sufficiently investigated.

With such a state prevailing in the methods of hydrographic interpretation it is difficult to judge to what extent the already existing materials of aerial photography may be used for hydrological purposes. For the same reason it is difficult to make a clear formulation of the requirements confronting aerial photography performed for special hydrological purposes.

The preparation of a practical textbook on hydrographic interpretation is a complex and, to a considerable degree, a research task the solution of which requires aerial and terrestial survey work of an experimental nature, the presentation of an entire series of theoretical and laboratory investigations both on problems of measurement interpretation and in the field of hydrology, and as well as the extensive introduction of existing aerial photographic materials with their terrestial foundation. It is apparent that such a task requires special facilities and a period of time on the order of several years.

Considering the urgent need for a practical handbook on hydrographic interpretation of aerial photographs, it may be prepared only on the basis of a minimum program utilizing existing developments in interpretation procedures and the presentation of special treatments of the principal related problems of hydrographic interpretation of bulk materials of aerial photography.

All this material has been subjected to a critical processing and checking by repeated interpretation performed by different persons experienced in field studies. Particular attention has been devoted to the characteristics which must be obtained in hydrographic works performed within the system of the GUGMS /Main Administration of Hydrometerorological Service/. Among the subjects receiving special treatment are the investigation of the effect of a secondary medium on the accuracy of the interpretation of depths as performed by A. A. Pugin and A. M. Solodovnikova, the further development of the method of indirect calculation of river depths as performed by I. I. Yakunin, a study of the accuracy of determining the overhang of river banks over the surface of water as performed by S. I. Pin'kovskiy. The book includes only the basic conclusions concerning the practical application of these developments.

The third part of the book is devoted to interpretation of aerial photographs of swamps.

Matters pertaining to the hydrographic interpretation of swamps were discussed in a separate section for a number of reasons. The use of aerial photographs of swamps has already found wide and varied application. The interpretation of aerial photographs of swamps is performed not only for topographical purposes but also for limited, special purposes (for example, for the survey of peat deposits, revealing swamps of agricultural importance, etc.).

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For each of these purposes the procedure for interpreting these photographs has its special and extensive literature.

The typological interpretation of swamps as developed by Soviet swamp specialists in recent years has been formulated by K. Ye. Ivanov and Ye. A. Romanov. They have developed a procedure for interpretation of the surface and subsurface filtration waters of streams in swamps which permits greater expansion of the field of application of aerial photographs in hydrographic investigations and descriptions of swamps.

Interpretation of swamps is discussed in a separate division due to considerations of the greater convenience for the use of the information on interpretation of swamps by swamp interpretation specialists.

In all cases of study of aerial photographs stereoscopic examination is recommended. In addition there is a detailed exposition of the procedure for visual or semi-instrumental study of aerial photographs used as an emergency measure in the absence of the proper equipment under field conditions or in using aerial photographs which are not suitable for stereoscopic examination (photomaps, photographic diagrams, photographs with inadequate overlap).

The book employs aerial photographs as illustrations. In using them the principal material consisted of photographs from GGI, aerogeodetic enterprises, the Lenaviaotryad Trust for forest aviation, etc.

Ground photography of swamps and the surface hydrographic system in swamps was performed by Ye. A. Romanov in systematic hydrographic studies of swamps by the use of aerial photographic materials.

In the body of the text references are made to the appended illustrations. In some cases, in order not to increase the size of the book, the same photograph serves for illustration of different elements. The aerial photographs in the appendix are provided with descriptions containing an explanation of the interpretation of the element illustrated by the given photograph.

The proposed book may be used for hydrographic interpretation of photographs both of aerial photographs of limited area (usually small-scale) and of special large-scale photographs made under various natural conditions. It did not seem possible to discuss in this book all the details of the features of various terrains under the conditions of difficulty of assembly and analysis of materials within a short period of time. For example, it

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was not possible to give illustrations for the interpretation of the phenomena of permafrost, certain desert characteristics, features of local constructions of hydrotechnical installations, etc. However, by using the basic instructions for the procedure of interpretation given in the present book, a hydrologist well acquainted with local conditions, without any particular difficulty may add to the handbook new specimen photographs and additional features of interpretation.

The first part of the book, "Basic Information On Aerial Photography and Procedures For Interpretation of Aerial Photographs," was prepared by D. M. Kudritskiy, Candidate in Technical Sciences.

The second part, "Hydrographic Interpretation of Aerial Photographs of Rivers and Lakes," was prepared by I. V. Popov, Candidate in Geographical Sciences.

The third part, "Hydrographic Interpretation of Swamps from Aerial Photographs," was prepared by Ye. A. Romanov, Junior Scientific Associate.

Preparation of additional remarks on identifying features and test interpretation was performed chiefly by V. S. Gershberg, Junior Scientific Associate, and on Chapter 8, "Interpretation of Hydrotechnical Installations," by S. I. Pin'kovskiy, Junior Scientific Associate.

PART ONE

BASIC INFORMATION ON AERIAL PHOTOGRAPHY AND METHODS OF INTERPRETATION OF AERIAL PHOTOGRAPHS

CHAPTER 1

AERIAL PHOTOGRAPHY

Section 1 - General Information

Aerial photography is the process of photographing the earth's surface from an aircraft or other flying device for the purpose of obtaining qualitative and quantitative characteristics of this surface from aerial photographs.

Aerial photography as a method of investigation of the earth's surface is used in the most varied fields of science and engineering: in topography, geology, the lumber industry, in transport surveys, for the purpose of ground constructions, in hydraulic investigations, etc. The aerial photography finds widest application in topography; here it has become the principal method for compiling topographic charts not only on small scales but also large scales.

The materials of aerial photography may be used:

(a) for obtaining the qualitative characteristics of the photographed surface as a whole and of individual objects located on it;

(b) for purposes of measurement; that is, in obtaining quantitative characteristics of the photographed locality and of individual objects and expressing them in the form of planes, profiles, and numerical values.

Section 2. Geometrical Foundations of Aerial Photography and General Concepts for The Solution of Photogrammetric Problems

In the photographic process the light rays reflected by different points of the object are collected by the lens of the camera and create an image on the light-sensitive layer of the plate or film. The optical qualities of lenses in modern aerial cameras permit obtaining sufficiently detailed central projections of the terrain. The latter possesses metric properties; that is, it permits measurement and by various transformations may be converted into a vertical (orthogonal) projection of the photographed locality (Figure 1).

Reproduction of the shape and dimensions of the object from its images on negative or positive prints for the purpose of obtaining a sketch or a steric image of the object or of the model is a subsequent task to be solved by photogrammetry.

The image of the horizontal portion of a flat terrain obtained with the optical axis of the aerial camera in the vertical position is represented as a contour sketch of this locality suitable for measurements.

The scale of this plane is expressed by the relation

$$\frac{1}{m} = \frac{ab}{AB} = \frac{ac}{AC} = \frac{bc}{BC} = \frac{f_k}{H},$$

where m is the denominator of the numerical scale of the photograph, f_k is the focal length of the camera, H is the height at which the photograph is made, ab, ac, bc, are line segments on the photograph, and AB, AC, BC are their corresponding distances on the photographed terrain.

Photographic images of the relief of a terrain are distorted; the greater the distortions, the greater the relative deviation of points in the terrain (Figure 2). Hence the scale of the image does not remain constant even if the photograph is obtained with the optical axis of the camera in the vertical position; it varies from point to point, remaining identical only for points of the same elevation, that is, for points located on the same contour.

Distortion of the scale occurs even more sharply in photographs obtained with a tilted position of the optical axis of the camera (see Section 4).

Thus, there exist two causes for the difference of an aerial photograph (as a central projection) from a plane (an orthogonal projection): (a) the relief of the terrain, and (b) the non-horizontality of the photograph itself. In order to eliminate these defects and to use the metrical properties of photographs for the purpose of obtaining the quantitative characteristics of a locality and to express them in the form of a plane in contour lines and profiles, photogrammetry has at its disposal procedures and apparatus worked out in great detail.

In order to eliminate the lack of horizontality of the photograph, the bunches of light rays causing the image on the light-sensitive layer of the plate are reproduced by means of an appropriate projector. By placing the screen of the projector in the proper position, it is possible to convert (transform) the image on the negative and thereby to eliminate the effect of tilt of the optical axis of the camera and to obtain it on the desired scale. However, in such transformation the reproduced image retains the inherent errors of relief.

Elimination of the errors due to relief is achieved either by transforming the photograph in parts corresponding to different elevations, or by reproducing a three-dimensional model of the locality.

In the latter case it is necessary to have two overlapping photographs of this locality obtained from different points in space -- the ends of a certain base. In aerial photography this base is a section of the path traveled by the aircraft during the interval of time between two exposures.

In order to obtain a distortion - free model it is necessary: (1) by using appropriate projectors, to restore the bunches of light rays causing the image on the li-ht-sensitive layer; and (2) to orient the restored rays in space.

For solution of the first problem it is necessary to know the values determining the position of the center of the projection relative to the photograph; or the elements of interior orientation of the photographs; for solution of the second problem it is necessary to know the position of each photograph at the moment it was exposed, or the elements of exterior orientation.

The elements of interior orientation include the focal length, f_k, and the position of the principal point, O, of the photograph -- the base of the perpendicular from the center of the projection to the plane of the photograph. The position of the principal point is determined by the coordinates x_o and y_o within the coordinate system of the photograph (Figure 3a).

The elements of exterior orientation (Figure 3b) include: X_o, Y_o, and Z_o -- coordinates of the center of the projection; c_o -- the directional angle of the optical axis; -- the angle of deflection of the optical axis from the vertical; and x -- the angle of rotation of the photograph about the optical axis.

In photogrammetric processing of aerial photographs the angular elements of exterior orientation are the longitudinal and transverse angles of tilt as well as the angle of rotation of the photograph about the optical axis.

Thus, each photograph has six elements of exterior orientation. In order to obtain a spatial model of the terrain from two overlapping photographs it is necessary and sufficient that within the zone of overlap of these photographs at six previously chosen identical points the light beams formed within them, known as the congruent rays, intersect.

The process of placing photographs in that position at which they were made and at which only may there be achieved intersection of congruent rays is known as relative orientation of photographs.

The model obtained by relative orientation of the photographs may be reduced to a given scale and oriented in space. For this purpose it is necessary that on the models there be identified not less than three points having geodetic coordinater (X,Y, and H) not lying in a straight line. By changing the scale of the model (varying the distance between projectors and their height), by rotating and tilting the model, the control points may be brought to the previously given position in the plane and at the proper height. Thereby the entire model becomes in effect an image of the photographed surface.

The process of reducing the model to the assigned scale and adjusting it relative to the horizontal plane is known as exterior or absolute orientation of the model. Thereby the reproduced model is placed in the correct position in space to obtain the quantitative (numerical) characteristics of the photographed surface and to compile a topographic map.

To obtain a general idea of the photographed portion of the earth's surface and a description of its properties we may limit ourselves to the process of relative orientation of the photographs, without obtaining a precise likeness of the model and tolerating unavoidable distortions.

The above described scheme of optical reproduction of the model of a photographed surface is one of the methods of photogrammetric processing of the materials of aerial photography. There are other methods of processing described in the special literature. The final results in all cases of photogrammetric processing of aerial photographs is the ordinary topographic map or the numerical characteristics of the elements of the landscape.

Section 3. Photographic Equipment

The initial material of aerial photography is the aerial negative.

In order to obtain negatives intended for purposes of measurement, use

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is made of the so-called topographic aerial cameras (AFA).

Any cameras, including non-professional cameras, without any changes whatsoever in their construction, may be used to record the qualitative state of an object of investigation and to fix the processes occurring in it.

The equipment used for aerial photography may be divided into three groups;

(1) automatic cameras, fastened by one or another method to the aircraft and remotely controlled;

(2) semi-automatic hand cameras;

(3) non-professional cameras.

Automatic cameras, designed to obtain both individual and series photographs, are complex, fully automatic optical-mechanical assemblies. They may be actuated by current from a storage battery or from the aircraft's own power system; in most cases the latter method is used.

A modern camera (Figure 4) consists of the following basic parts; (a) the camera proper with a lens, a shutter, and a regulating mechanism; (b) magazines, with mechanisms for winding, metering, and flattening the film; (c) the control device; (d) the electric motors; (e) the camera mounts.

The camera proper is a rectangular metal housing in the upper part of which, within the focal plane, there is fastened a frame with four notched fiducial marks fixing the position of the principal point (center) on the photograph. In the lower part of the camera there is mounted tightly (sometimes on a removable cone) a lens with a shutter.

According to the angle of the image and the focal distance, the lenses as well as the aerial cameras are divided into three groups:

(1) narrow-angle, long-focus -- with an image angle of $2\beta \leq 45$ degrees at a focal length f_k = 200-1200 mm;

(2) normal -- with an image angle of $2\beta \leq 45$-75 degrees at a focal length f_k = 150-200 mm;

(3) wide-angle, short-focus, having an image angle of $2\beta =$ 75-147 degrees at a focal length of f_k = 150-55 mm.

Designating d as the diagonal of the photograph, aerial cameras may also be divided into long-focus (if f_k is greater than d), normal (if f_k equals d) and short-focus (if f_k is smaller than d).

In the lenses of modern aerial cameras the relative aperture (ratio of the diameter of the input aperture to the focal length of the objective) is 1:4.5-1:6.3.

The lens of the AFA possesses a high resolving power (the number of lines freely distinguished on a portion of the focal plane with a length of 1 mm). In modern lenses it reaches 40 lines in the center of the field with a drop toward the edges of the image. A particularly noticeable drop in the resolving power toward the edges of the image (down to 7-8 lines) is observed in wide-angle lenses. The lenses of aerial cameras are focussed at infinity and are rigidly fastened in this position.

In the complex optical system which is used in an aerial survey lens two centers are distinguished, the front and rear nodal points. The distance from the rear nodal point to the plane of the photograph may be equal to the principal focal length of the lens. This distance, known as the focal length of the camera, as well as the position of the principal point on the photograph, being the elements of interior orientation of the photograph, must remain constant.

Many aerial cameras are provided with different recording devices, the indications of which are photographed on each aerial photograph (Figure 5).

The presence of all this data substantially facilitates consideration of the conditions in which each photograph is obtained.

Cameras designed for photogrammetric purposes are provided with between-the-lens shutters permitting shutter speeds of 1/50-1/300 sec. In cameras designed to obtain photographs of an illustrative nature, other types of shutters are also used, for example, focal-plane shutters which permit higher shutter speeds.

Release of the shutter, achieved with the aid of the regulating mechanism of the camera, occurs within time intervals fixed at the control instrument; the latter is adjusted according to the flight speed and the required overlap of photographs.

The complex mechanism of the magazine provides for winding, metering, and flattening of the film placed within it. The most frequently used aerial cameras are those with photo sizes of 18 x 18, 24 x 24, and 30 x 30 cm. This film is prepared in the form of rolls 30 to 60 m in length and placed on special spools, this being calculated to produce 150-200 photographs. The standardized dimensions of the magazines permit replacing them in flight.

Thorough flattening of the film at the moment of exposure is a necessary

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condition in using aerial photographs for measuring purposes.

Flattening of the film is achieved by means of a pressure plate in the magazine, which at the moment of exposure presses the film against the platen. In addition, air is forced into the camera (in some AFA's air is evacuated from the magazine) and the film is pressed against the platen, thereby flattening the film over the entire field of the photograph. Special attachments are provided to control flattening of the film in the AFA camera.

The operation of all mechanisms of the AFA is insured by two electric motors mounted in one housing. The first motor drives the camera mechanism and the second drives the air tube which forces air into the camera.

The command device or panel for control of the entire assembly serves to connect and disconnect the assembly, to adjust the interval between exposures, to signal for the winding of the film, and for counting the number of exposures. The control device is usually placed in the pilot's cabin.

The camera is installed on a special mount provided with shock absorbers to absorb the vibrations which would otherwise affect the sharpness of image; it also serves for leveling of the camera according to a spirit-level located on the top of the magazine. The camera mount is provided with an attachment for rotation of the camera in order to correct for drift of the aircraft with the wind.

During flight an aerial photographer sits behind the camera and is in contact with the pilot by means of an intercommunication system.

Figure 6 shows the AFA-33/20 aerial camera produced in three models in the Soviet Union (focal lengths 20, 50, and 74 cm). Technical data for the AFA-33/20 are as follows.

Lens, "Orion" 1-A; focal length approximately 200 mm; angular field 92 degrees; relative aperture 1:6.3 with a fixed diaphram; a central, between-the-lens shutter; shutter speed 1/50, 1/100, and 1/200 sec; light filters -- yellow, orange, and red.

The film is perforated. The photograph size is 30 x 30 cm; film width is 32 cm, length up to 60 m; number of photographs 190-195 with intervals of 10-15 mm; flattening of the film is achieved by forcing air into the camera; on the photograph there are obtained images of the AFA number, focal length, frame counter, and circular level.

Operation of mechanisms. The assembly is fully automatic, fed a direct current of 6 amperes and a voltage of 24 volts; power consumed during operation, up to 200 watts; control of operation is remote from a control device.

Dimensions and weight of assembly with camera mount. Width 62 cm, length 81 cm, height 57 cm. Flight weight from 58 to 72.5 kg; weight of entire assembly in packing (in three boxes) approximately 200 kg.

Camera operation . . . is not affected by temperature variations within the range from 20 to -20 degrees. Upon connection of the electric heater, operation of all the mechanisms is insured even to lower temperatures, to -50, -60 degrees.

Table 1 gives the data for certain Soviet and foreign automatic cameras in practical use in Soviet aerial photographic operations.

The effort to embrace a wider area in the photograph (that is, to increase the "productivity" of the camera) has found its solution in the creation of short-focus lenses.

Short-focus, wide-angle, aerial lenses insure vertical aerial photographs with wide coverage. These lenses have been made by Soviet photogrammetrists. The latest achievement in this field is the R-2b lens (by V. S. Rodin et al.), having a focal length of 55 mm with an angular field of $2\beta = 136$ degrees.

In 1936 V. I. Semenov developed a completely new type of aerial survey, achieved by the so-called slot /shchelevoy/ camera and from which this method of photographic survey obtained the designation of slot survey.

The principle of surveying with a slot camera consists in the continuous photographing of a strip of terrain on a moving film which is projected by the lens through a narrow slot in the focal plane of the camera perpendicular to the line of flight (Figure 7). Thus, there is obtained on the film a continuous image of the strip of terrain over which the aircraft has flown, and hence in contact printing from this film there may be obtained a direct photograph of the entire flight.

There are relatively few models of hand-held, semi-automatic aerial cameras. They are not widely used and serve chiefly to obtain single perspective photographs at the choice of the observer. The photograph is taken by hand over the side of open aircraft or through special hatches or ports on closed aircraft.

The hand-held AFA-27-T aerial camera (Figure 8) weighs 12 kg. Its characteristics are: an "Industar" lens with a focal length of 40 cm, a

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relative aperture of 4.5 and image dimensions of 13 x 18 cm.

Of considerable interest is the design of the NMK-7 X 9 camera (Figure 9) in which a considerable decrease in weight and dimensions of the camera is achieved due to a decrease in the focal length (12.5 cm). The definition of the photographs and the possibility of a substantial increase in shutter speed during photography is insured by aperture-ratio optics (a relative aperture of 1:2). The small size of the photographs (7 x 9), permitting their use for purposes of illustration, may be increased on a special enlarger by 2.5 times (that is, up to dimensions of 18 x 24 cm).

Modern hand-held aerial cameras are loaded with roll film permitting 35 to 50 photographs. Winding of the film, and cocking and releasing of the shutter are achieved by hand in the same manner as in the FED camera and its models. In the rest of its design this camera does not differ from designs of large automatic aerial cameras (of course, those which are considerably simplified).

The magazines of hand-held aerial cameras are tightly fixed to the camera. For flattening of the film at the moment of exposure it is pressed against a glass plate located in the focal plane of the camera. The lens is focussed at infinity and is firmly fixed in this position.

Various cameras of non-professional quality may be used to record visual observations. The most convenient of these are cameras of the FED type.

Section 4. Types of Aerial Photography

According to the position of the optical axis of the camera at the moment of exposure, horizontal, vertical, and oblique (perspective) photographs are obtained.

A horizontal photograph is one which corresponds to the perpendicular position of the optical axis of the aerial camera. At the present state of the techniques of aerial flight and photographic equipment, it is not possible to obtain strictly horizontal photographs.

A vertical photograph is one obtained at a position close to the vertical position of the optical axis (Figure 10-A) on the condition that accidental deviations of the photograph from the perpendicular do not exceed 3 degrees. In the process of photogrammetric processing (transformation) vertical photographs may be converted to horizontal photographs.

Oblique (perspective) photographs are obtained with a fixed tilted position of the optical axis of the aerial camera (Figure 10-B).

In accordance with this, from the position of the optical axis of the aerial camera in flight there are determined also the principal varieties of aerial surveys: vertical, oblique, and vertical-oblique surveys.

Any of the existing single-lens aerial cameras, given an appropriately constructed camera mount and attendance in flight, may serve for the various types of surveys.

As was previously mentioned, any of the automatic aerial cameras may be used both for single and series photographs. In accordance with this, we distinguish single-photo, route, and mosaic aerial surveys.

The single-photo aerial survey is based upon individual photographs made according to a predesignated plan or at the choice of the aerial photographer while in flight. Most often it is performed with hand-held semi-automatic cameras.

(In order to obtain a clear photograph during hand-held operation it is necessary to avoid vibration of the camera and to avoid the undesirable effects of the backwash of the airstream on the camera. A large role is also played by the ability of the aerial photographer to make use of the conditions of the field of vision, which in certain types of aircraft is extremely limited.

(In the absence of a special camera mount vibration must be absorbed or changed by bracing of the arms, hence during photography the camera must not be in contact with vibrating portions of the aircraft.)

Route aerial survey is a sequential photography of a narrow strip of terrain (for instance, of river valleys) performed with an automatic camera on a straight-line, interrupted, or curved route (Figures 11 and 12).

Continuity of the route in the survey is insured by a previously assigned linear overlap of consecutive photographs calculated according to the formula

$$P\% = 100\left(0.6 + \frac{h}{H_T}\right) \geq 60\%,$$

where h is the greatest difference in elevation within the limits of the photographed portion, and H_t is the height of photography above the mean level of the photographed locality.

In practice the obtained overlap of the consecutive aerial photographs is determined from the formula

$$p\% = \frac{P_y}{L_y} 100,$$

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where L_y is the dimension of the photograph in the direction of flight in centimeters, P_y is the overlapped portion of the photograph in that same direction in centimeters.

The route survey is widely used in the most varied forms of investigations of natural resources. It may be used also for cartographic purposes, but under the condition that the route of observation is in a straight line. In connection with difficulties arising in the photogrammetric processing of curved routes, and also due to the substantial reduction in the accuracy in the results in topographo-geodetic work, interrupted routes are used only as the exception, for example, in surveying a seacoast; curved routes are not acceptable.

The route survey is usually carried out as a vertical survey, but under given conditions may also be vertical-oblique and oblique for the purpose of increasing effectiveness of the survey aircraft.

Mosaic aerial surveys are used in photographing large areas. They are carried out in the form of straight, overlapping routes (Figure 13) oriented in a longitudinal direction.

The lateral overlapping photorraphs of adjacent routes is calculated according to the formula

$$\delta\% = 100\left(0.3 + \frac{h}{H_T}\right) \geq 30\%.$$

In order to determine the actual overlap use is made of the formula

$$\delta\% = \frac{P_x}{L_x} 100,$$

where L_x is the size of the photograph across the direction of flight in centimeters and P_x is the part of the photograph overlapping in this same direction in centimeters.

A mosaic aerial photo survey performed for the purpose of obtaining a topographic chart is executed within the limits of a trapezium of the future chart. This survey is usually executed as a mosaic survey, but as with the route survey it may be a vertical-oblique or oblique; under our conditions the latter forms do not find wide application.

According to the scale we distinguish: large-scale surveys (1:10,000 and larger), surveys of medium-scale (1:10,000-1:30,000), small-scale surveys (1:30,000-1:80,000).

In topographic-geodetic operations using aerial photography for the purpose of compiling maps we distinguish survey scales and representative scales.

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The latter is the scale of the map for compilation of which the aerial survey was performed. Between survey and representative scales there exists a relation considering the conditions of the survey, the character of the region of operations, and the required accuracy of the image of relief; the latter is insured by an appropriately selected procedure of survey and processing and also by the proper number of geodetic control marks (Table 2).

The formula for the scale (Section 2) as a function of the height of photography H and the focal length f_k may be considered correct only for vertical photographs. For oblique photographs the scale formula considers also the angle of tilt of the optical axis from the perpendicular and is considerably complicated (Section 7), hence the possibility of classification according to scale for perspective (oblique) photographs is eliminated.

According to the method of sequential photogrammetric processing, and partly also accroding to the method of using the materials of aerial survey, we distinguish the following types: contour, combined-contour, and stereophotogrammetric (elevation-stereoscopic) surveys.

The contour survey is used to obtain site (contour) plans of a locality by replacing it with an ordinary vertical photograph along a certain route over a definite area. The tasks of contour aerial survey are sometimes limited to obtaining photographic plans (fotoskhema) (simple or detailed). The latter may with some success replace not only the visual but also the instrumental survey of a locality as performed in the preliminary surveys for hydrographic investigations.

The combined contour survey is a combination of two methods of obtaining a topographic map: the photogrammetric and the topographogeodetic. The contour portion of the map (the "fotoplan") is obtained by office methods from aerial photographs and the relief is obtained directly at the locality by one of the methods of plane geodetic survey. In addition, as the vertical base for survey of the relief use may be made of "fotoplans" or even of individual photographs, the use of which eliminates the necessity for a vertical tie-in of most points; the latter is replaced by simple control of points by comparing the photographic record with the terrain.

The combined contour aerial photo survey finds wide use in descriptive navigational hydrographic operations in which even non-transformed photographs (contact prints) aressuccessfully used for tying in measuring operations to the local orienting points giving rise to the image on the photographs.

The stereophotogrammetric (elevation-stereoscopic) aerial photo survey (Figure 14) or, in its modern and fullest definition, the aerial survey, has as its task the reproduction and measurement of an optical model of the photographed surface from aerial photographs for the purposes of obtaining a topographic map of this surface or its quantitative characteristics (without depiction of the obtained results in the form of graphic records).

Contemporary aerial photogrammetry has at its disposal apparatus and methods of processing of materials which permit limiting ground geodetic operations to a minimum, being satisfied by the smallest number of geodetic control marks necessary to produce a model on the given scale and to orient it in space.

Due to the fact that the task of the topographic aerial photographic survey is to obtain equally precise characteristics for all elements of the landscape, the materials of these photographs may be used as a basis for the most varied (including hydrographic) investigations under the condition that the scale of the survey, the quality of the photographic image, as well as the time of the survey (in some cases the latter circumstance may play a decisive role) correspond to the purposes of the investigations being conducted. The materials of topographic aerial surveys, as mass materials (by which a considerable part of the territory of the Soviet Union has been mapped and which insure a reliable geodetic foundation) are used in the most varied investigations of natural resources both as a topographic base and as a means of obtaining information concerning the objects under study and the surrounding environment.

Having agreed to consider the topographic aerial survey as a universal survey, every other aerial survey (hydrographic, forestry, geological, etc) may be considered as a specialized survey suited for the solution of special problems confronting the given investigation. This consists first of all in the choice of conditions of the survey, which conditions insure obtaining the fullest information concerning the objects or elements of the landscape of interest to one or another investigator (in certain cases this possibility is insured at the cost of a deterioration in the quality of the photographic image of the remaining object).

A second peculiarity of the specialized aerial surveys is the individual approach to their organization and to the problem of the accuracy of results. It is also chosen on the basis of the problems confronting the given investigation. In distinction from the universal aerial survey (which as a method of compilation of topographic maps meet the requirements for geodetic accuracy as established for maps of a given scale) in the production of specialized aerial surveys there are a number of extremely varied approaches to determining the accuracy of measurement. Very often the accuracy of measurements from aerial photographs and from a model is considered in connection with the accuracy of the investigations underway and the results expected from them; hence the generally adopted concept of geodetic accuracy as a function of the scale of the map is replaced with the idea of "operational accuracy," arising from the problems confronting one or another investigation. Between these concepts it is not possible to find a strict correspondence. In certain cases the requirements for operational accuracy may be higher than for the accuracy of the geodetic. Thus, for example, photographs intended for special riverbed studies (in particular, for determining the depths of streams) must meet higher requirements than photographs intended for ordinary cartographic operations.

In the application of aerial surveys in hydrographic investigations it is necessary to distinguish:

Photographic observations -- periodic or systematic aerial survey of the object of investigation for the purposes of explaining and calculating the changes occurring in it, for example, the aerial survey of ice formations, floods, melting snow, icebergs, riverbed formations, etc.

Photographic investigations -- the aerial survey of one and the same object on different scales and under different conditions with the use of various portions of the spectrum for the purpose of clarifying the optimum conditions for obtaining a clear image of the object of investigation on aerial photographs, establishing its basic properties, disclosing the natural and artificial identifying characteristics, etc.

Photographic observations and investigations are used chiefly in detailed hydrographic investigations and are used as one of the means for obtaining the regime characteristics of water objects and studying the seasonal changes in them.

In the initial hydrographic investigations for obtaining the necessary information concerning a water object or a group of them there are performed various specialized aerial surveys. Execution of the latter is undertaken in the case where for any reason it does not appear possible to use the materials of existing topographic aerial surveys.

Section 5. Information on The Technological Process of The Photographic Aerial Survey

In the complex process of the photographic aerial survey used for measuring purposes we distinguish four distinct but closely interrelated processes performed in a given sequence: aerial survey, photographic, photogrammetric, and geodetic. In addition, the interpretation of aerial photographs is considered as an independent operation in aerial photographic surveys. The latter is treated (see Chapter IV) as a definite scientific investigative process having as its task the explanation by means of photographs of one or another object or element of a landacape and obtaining detailed characteristics of them.

The processes comprising the aerial survey acquire specific features and importance within the overall volume of operations according to the tasks confronting the survey. For example, geodetic operations may be minimized or completely omitted where the aerial survey is undertaken for the purpose of obtaining illustrative material or as a method of recording the changing properties of one or another object. This circumstance imposes definite limitations on the photogrammetric process; the ensuing photogrammetric construction, completely lacking a geodetic base, will permit obtaining only approximate quantitative characteristics. At the same time, with such specialization in the aerial photographic survey there is a considerable increase in the role of the photographic process, since for solution of the task confronting one or another investigator, the aerial survey calls for an especially clear, easily photographic image of the object under study, and this in turn gives certain specific properties to the process of the aerial survey (the type and scale of the photographic survey, the type of aerial camera, and the aircraft, the conditions and time of survey, etc).

All the peculiarities of the technological process of the aerial photographic survey find their reflection in the technical plan of the survey, which plan is drawn up for each individual case.

1. The Aerial Survey Process

The task of the aerial survey process (the principal process of the aerial photographic survey) is photographing the earth's surface according to definite rules, observation of which guarantees the possibility of using the materials of the aerial photographic survey with the thoroughness required by the purpose of the survey.

The principal requirements confronting the results of aerial survey operations are as follows:

(a) obtaining a clear photographic image of sharp contrast with the proper transmission of color shading of the elements of the landscape;

(b) observing the given route and scale of the survey in complete, uninterrupted coverage of the area under survey;

(c) observing the assigned position of the optical axis of the aerial camera.

There are no aircraft especially designed for aerial photography. Ordinary transport aircraft of the most varied characteristics are used for aerial photographic surveys. Some of these differences (for example, speed) cause a whole series of difficulties not only in obtaining the initial materials (the negatives) but also in processing them.

The execution of aerial photographic survey operations is possible only under specific meteorological and atmospheric-optical conditions which go under the general term of aerial survey weather. These conditions are: clear, cloudless sky and the absence of haze (atmospheric haze, dust, smoke, city haze, etc). A choice of these conditions usually presents considerable difficulties due to the fact that the number of clear days in the year is usually extremely small; in spring and summer, when aerial survey operations are carried out, the number of survey days within the various latitudes ranges from 30 to 60.

Under certain conditions aerial photography may be performed even in the presence of clouds (including solid clouds) but with the stipulation that neither the cloud nor its shadow shall fall within the field of view of the lens, otherwise the resulting photographs will be useless.

(a). Characteristics of Aerial Photography

Aerial photography has a whole series of special characteristics; the principal of these is as follows:

(1) the survey is made with an aerial camera the optical axis of which is continually displaced relative to the ground with considerable velocity.

(2) Between the lens of the aerial camera and the survey object there is a considerable depth of atmosphere, which is a turbid medium and extremely heterogeneous in its composition, which composition varies with time.

The first of these characteristics necessitates adjustment for rapid exposures of the light-sensitive layer, and the second of these characteristics calls for prolonged exposures. In order to satisfy both requirements and to obtain thereby photographs which are suitable for future use it is necessary to have at one's disposal the greatest possible selection of aerial survey facilities and photographic materials. The possibilities in this respect are somewhat limited, hence the deciding factor in the success of aerial photography is the proper selection and use of the conditions of photography as well as allowance for them in processing the materials.

Due to the high-speed forward movement of the aerial camera in flight, and especially also because the problem of stabilization of the optical axis of the camera during the survey has still not been solved, during exposure all points constituting the image of local objects on the light-sensitive layer are displaced by a certain value S known as the image shift (Figure 15). This value, depending on the flight altitude H, the focal length of the camera f_k, the flight speed W, and exposure E, is determined from the formula. $S = \frac{f_k}{H} WE$.

With reference to the accuracy of the photogrammetric measurements, image shifts exceeding 0.04 mm are considered excessive for aerial photographs intended for measuring purposes. In photographs used for illustration or to obtain the qualitative characteristics of the objects under investigation permissible image shifts may be considerably greater; however, if this shift exceeds 0.10 mm, then it becomes visible even to the naked eye and the image itself lacks sharpness and is blurred. Such photographs are considered useless.

Assigning the values $S = 0.04$ mm, $f_k = 100$ mm, $H = 3{,}000$ m, and $E = 1/50$ sec, we know that the flight speed of the aircraft used for the aerial photographic survey must not exceed 60 m/sec or 216 km/hr.

Such a requirement for the aircraft, established on the basis of a survey scale of 1:30,000, may be considered optimal.

The use of aircraft at high speeds is not eliminated; however, in this case, especially in surveys at low altitudes, there is necessary a considerable decrease in the duration of the exposure, which is limited:

(1) by the design characteristics of the shutters of photogrammetric aerial cameras, which permit a reduction in shutter speed only to 1/300 sec;

(2) the light sensitivity of the photographic materials;

(3) the conditions of aerial photography, which must be adjusted for increased durations of exposure in comparison with the calculated durations on the basis of the above formula.

(b) Conditions of Aerial Photography

The duration of exposure necessary to obtain the clearest and most informative details of the photographic image on the light-sensitive layer of the film depends upon an entire series of factors; chief among these are:

(1) the illumination of the survey object; (2) the reflectivity of the survey object; (3) the optical qualities of the aerial camera; (4) the light-sensitivity of the emulsion layer of the film.

The illumination of the earth's surface depends on the elevation of the sun above the horizon; it continually changes and often in the most random manner. On their way to the earth's surface the rays of the sun, in passing through the turbid atmosphere, undergo attenuation; this attenuation increases as the elevation of the sun decreases. In addition, these rays undergo scattering. The greatest scattering occurs with rays comprising the short-wave portion of the spectrum: the violet, blue, and indigo portions, forming the so-called haze.

Depending upon the presence of vapor, haze, dust, and other foreign matter, the transparency of the air may vary considerable over the course of a relatively short period of time, and the value and character of illumination intensity will vary accordingly.

Light rays falling upon the surface of the earth are to a considerable degree are absorbed by it. The average reflection of light by the objects of aerial photography during the summer amounts on the average to 20 percent, wherein moist surfaces reflect less than half the amount of light reflected by dry surfaces (Table 3). This also explains the difference in tone of their images on aerial photographs.

Reflection of light from open water varies from 2 to 70 percent, depending on the angle of incidence of the sun's rays and on the state of the surface of the water.

Before entering the lens of the aerial camera, the light rays reflected by the object of photography again pass through a certain layer of the atmosphere the height of which depends on the altitude of flight and is subjected thereby to a partial absorption and scattering which chiefly affects the rays in the short-wave portion of the spectrum.

In the passage of a light beam through the lens of the aerial camera there also occurs absorption and scattering of light rays amounting to 30 percent of the total incident rays at the objective; this figure varies for the different lenses. Along with the "useful" rays of the long-wave portion of the spectrum constituting the photographic image, there also falls on the light-sensitive layer in considerable quantity rays of the short-wave portion of the spectrum, scattered within the depth of the atmosphere forming the air haze.

These rays, acting uniformly on the light-sensitive layer, cause general fogging of the entire image, making it illegible.

The most effective method for eliminating or reducing the harmful effects of atmospheric haze is the use of colored light filters placed over the lens of the camera, and, in addition, the use of special types of film. The light filters used in aerial photography absorb the rays of the short-wave portion of the spectrum reflected and scattered by the atmosphere and, by thus decreasing the effect of atmospheric haze, increase the contrast of the photographic image.

By selecting a combination of film type and light filter and by using the appropriate photo-lab processing of the exposed film, it is possible to achieve a considerable increase in the contrast of the negatives.

In the system of measures for combating the effect of atmospheric haze a very important role is also played by the choice of time for aerial photography. It has been established that the most favorable time for a survey is in the morning hours, the periods after summer rains, and the periods of the stable winter anticycline.

Due to the fact that with the sun at elevations less than 20 degrees aerial photographs with extreme image contracts are obtained, and long deep shadows of local objects render interpretation difficult, it is recommended that the aerial photographic survey be begun not earlier than two hours after sunrise and concluded not later than three hours before sunset. It must also be pointed out that with the sun at elevations greater than 20 degrees there occurs a constancy of the spectral component of solar radiation over the entire visiable portion of the spectrum.

This circumstance is of great importance in conducting in conducting an aerial photographic survey, permitting the use of one and the same combination of film with a light filter in the course of the entire survey day. This, however, is possible only in the event that the choice of one or another combination of film with light filter, aside from considerations of combatting the effect of atmospheric haze, is not intended to solve a another special problem -- obtaining the greatest image contrast of one or another previosly chosen element of the terrain on the basis of a preliminary calculation of its spectral characteristic. Such possibility also exists; in the practice of aerial photography it is known as "spectrozonal survey" and is intended to reveal artificial or natural "color concealment" of the objects of photography (see above, Photographic Investigations).

The non-uniform effect of coloration of local objects on the light-sensitive layer of the film is expressed in the differing density of the negative upon development. Conversion of the color shades into different tones (from white to black on a monochromatic photograph) depends on the selectivity of the light-sensitive layer (its spectral sensitivity).

By the introduction of special coloring agents known as sensitizers into the photographic emulsions the emulsions acquire special sensitivity to certain rays of the spectrum, which appear especially strong with the use of an appropriate light filter, and in addition, with a specially chosen proportion of chemical ingredients and regime of processing.

With a great variety in the color of local objects it is difficult to select such a combination of film and filter as will, without excluding local objects and elements of the terrain, insure the necessary image contrast of the negative. Large or small exaggeration of the tone of images on a monochromatic photograph is unavoidable. This peculiarity of monochromatic photography also lies at the basis of the spectrozonal method of photography.

In essence it consists in the fact that to reveal one or another object or element of the terrain its photographic image is built up at the same in different portions of the spectrum; in other words, the object under study is photographed by several cameras at the same time on different types of film with the use of appropriate filters.

By comparing the photograph obtained in this manner it is possible to disclose the details which are variously recorded on the different types of film and thereby to insure the fullest study of one or another object ((Figure 16). In spectrozonal investigations both the visable invisible portion of the spectrum are used with success.

In performing aerial photographic surveys over large areas use is made of generalized spectral characteristics of the terrain and, according to their content, various combinations of film and filters are used.

(c) Film, Filters, and Their Use

The film used in aerial photographic surveys have a colluloid base and is produced in roll form for use on standard spools.

The light-sensitive layer consists of a layer of gelatin (0.01-0.02 mm thick) containing a suspension of uniformly distributed silver bromide crystals which are sensitive to light and with a small admixture of silver iodide.

The photographic qualities of the light-sensitive layer are characterized by the following indexes: (1) total and effective (with filter) sensitivity; (2) spectral sensitivity; (3) contrast; (4) latitude; (5) fog; (6) and;resolving power.

As has already been mentioned, the specific features of aerial photography make it necessary to strive for reduced shutter speeds, the use of which even under favorable atmospheric-optical conditions is possible only on the condition that the film possesses a high overall light-sensitivity. A film which is to be used under unfavorable conditions of illumination and in conducting a survey from low altitudes (when especially short exposures are required) must have the highest sensitivity.

The use of fulters is accompanied by a decrease in shutter speed by a factor of 1.5 to 4 according to the characteristics of the filter and the light-sensitive layer used. The inadequate effective sensitivity of aerial film when used with a light filter makes it impossible to obtain a photographic image under unfavorable conditions of photograph.

The spectral sensitivity of the film must correspond to the conditions of the survey and is chosen on the basis of the spectral characteristic of the object of the photographic survey. In photographing vegetative cover the predominate color is yellow-green; in photographing open terrain green, orange, and red predominate; and in photographing water surfaces indigo and blue predominate. On the basis of the "mean" landscape it must be required that film used for aerial photographic purposes be sensitive to the yellow-green and orange portions of the spectrum.

The contrast of the film (the "gamma") is expressed by the clearness with which the aerial negative shows the most insignificant difference of intensity of illumination of individual portions of the image of the survey object. In aerial photography use is made of high-contrast film ("gamma" not less than 1.5) characterized by a considerable increase in the density of the negative with a small increase in exposure.

Determination of the exposure (the product of the duration of action of light or the shutter speed and the brightness of individual portions of the terrain) depends upon an entire series of factors.

In order to determine the exposure necessary to obtain the normal photographic image it is necessary to know: (1) the brightness of the object of survey at a given moment; (2) the atmospheric-optical conditions; (3) the coloration of the earth's cover; (4) the optical characteristic of the aerial camera; (5) the characteristic of the camera shutter; (6) the effective sensitivity of the film.

Due to the fact that not all of the abovementioned factors may be calculated with sufficient accuracy (despite the existence of a whole series of tables and special devices for determining exposure) in the solution of this problem, especially in surveying irregular terrain, there are often obtained and may be considered unavoidable underexposures and overexposures within the limits of one and the same((even though not very long) flight route. Simply stated, within the limits of one and the same photograph different portions of the image may be considered as obtained under different exposures, depending on the brightness of these portions.

If the light-sensitive layer has sufficient latitude (that is, the ability to correctly reproduce the ratio of brightnesses of the survey object) then, without any special loss, for the quality of the photograph we may permit certain departures from the correct shutter speed both in the direction of underexposure and of overexposure. This condition must be met by all light-sensitive layers used in aerial photography; their latitudes must not be less than 1:8.

The tendency for aerial photographic film to fog appears over the course of a certain period of time which is relatively uniform for each type of emulsion. This period of time is known as the warranty period, in the course of which the film manintains its quality. For most types of film the warranty period under normal conditions of storage is 4-6 months. The tendency toward fogging is noted chiefly in the layers with the highest sensitivity.

The fog density, which may be observed by examining a specimen of unexposed processed film in the light, must not exceed the given standard.

The light-sensitive layers used for aerial photography must also have a high resolving power which permits distinguishing on the negatives the smallest details of the survey objects; this is especially important in those cases where the aerial photographic survey is used for measurement purposes.

The resolving power of the light-sensitive layers must not be less than 40 lines per mm, insuring that the requirements not only for visual but also for instrumental interpretation of the aerial photographs will be met.

The convenience of using one or another combination of a certain type of film with light filter depends on the conditions of aerial photography. Consideration is here given to the following factors:

(a) conditions of illumination (intensity and spectral component of light);

(b) presence of haze, its origin and intensity;

(c) distance from the object to the photograph;

(d) characteristic peculiarities of the object to be photographed (its coloration and reflectivity).

At the present time the motion picture industry produces the following types of film.

Orthochromatic film -- sensitive to violet, blue, and indigo, as well as to yellow-green rays of the spectrum. It may be used with excellent illumination, in the presence of fairly noticeable haze or in its complete absence, to obtain vertical photographs, with yellow or dark yellow light filter (Figure 17).

Isopanchromatic film -- sensitive to all rays from violet to the red portion of the spectrum. In addition to increased sensitivity to rays of the violet portion of the spectrum (which increase is ordinary for all light-sensitive layers), the film has increased sensitivity to the rays of the yellow portion. It is used with good illumination and weak haze, with yellow and bright orange filters (see Figure 17).

Panchromatic film -- sensitive to all rays of the visible portion of the spectrum and posseses increased sensitivity to the orange-red rays; it is used in the presence of poor illumination and solid clouds. Some types of this film, having a generally high sensitivity, permit photographing after the sun has set. The high sensitivity of panchromatic film to red rays of the spectrum permits photography in the presence of considerable haze when used with orange and red light filters (see Figure 17).

Infrachromatic film -- sensitive to all portions of the visible spectrum and, in addition, to the invisible, infra-red rays next in length to the visible red rays; it is not sensitive to green rays. This film is used under poor conditions of visibility, with orange or red (the so-called corrective filters) filters, which, having a high radius of curvature, displace the focal plane of the lens in infra-red photographs the focal plane is somewhat farther away from the lens than in photographs in the visible portion of the spectrum (see Figure 17).

The characteristic of filters used for aerial photography are given in Table 4.

The filter factor, usually marked on the rim of the filter, indicates the number of times by which the shutter speed must be increased as compared with exposure without the use of the filter.

Aerial photography is always performed with the use of a filter, except in those cases where its use will be known to cause underexposed negatives

In interpreting aerial photographs it is necessary to know what rays were used to obtain the photographic image. This considerably facilitates interpretation, hence the records of photographic flights contain detailed information concerning the conditions of photography and data concerning the combination of film and light filter used in performing the photography.

Along with the flight records, the exposed film is turned over to the photograph laboratory for processing (developing, fixing, washing and drying) which is performed with special devices, manual or automatic, depending on the volume of aerial photographic surveys operations.

2. The Photographic Process

It is the task of the photographic process to chemically record the light rays which, entering the lens of the aerial camera in its movement over the earth's surface, create within its focal plane a series of images of this terrain. The results of this recording are expressed in the form of negatives, contact prints, and various reproductions.

Both in the negative process and in the positive process of photography the task of converting the "latent" image into a visible (developed) image and fixing it in a state which is not sensitive to light (fixing) is solved by means of special solutions compounded after a detailed prescription and used under precisely controlled conditions.

By changing the ratio of reagents in solutions and the concentration of the latter it is possible to accelerate or retard the process of development, to obtain images with greater contrasts and better detail, to equalize the shortcomings caused by improperly determined exposure, itc under the conditions of a properly chosen cycle of development.

The use of one or another developing solution and the choice of a developing cycle for the film precedes the preliminary tests (development of samples) based on consideration of the conditions of photography, the characteristics of the film, as well as the purposes and types of further use of the materials of the aerial photographic survey.

The average developing time for a fully-metered /polnometrazhniy/ film (30 by 6,000 cm) is 15-20 minutes with a developer temperature of 18-20 degrees.

After washing the developed film (which is necessary in order to remove the residue of the developing solution) it is necessary to fix the film in an appropriate solution, in which the silver bromide not subject to the action of light is converted into a compound soluble in water and with subsequent washing is removed, while the layer itself acquires great stability.

The final washing and drying of the film completes the process for obtaining the source materials of the aerial survey -- the aerial negatives. The total time required for the negative process (without drying of the film) amounts to approximately two hours.

The aerial negatives must meet the following requirements:

(a) a clear image of the photographed object with detailed representation of the smallest features in semitones;

(b) adequate and approximately identical image density over the entire film;

(c) the absence of defects in the form of breaks, scratches, fogging, spots, blurs, and other defects which in obtaining the image on contact prints may complicate use of the photographs or lead to errors in interpretation.

Despite the existence of thoroughly elaborated procedure for the laboratory processing of film, it is extremely difficult to obtain aerial negatives which meet the above mentioned requirements. This is all the more true under field conditions. Hence, only highly skilled specialists should be employed in dealing with these problems.

A properly chosen method of laboratory processing of film permits a certain correction of the errors which were permitted during exposure. In particular, it is relatively easy to achieve correction of overexposed films and in any case, it is considerably easier to achieve correction of overexposed films than of underexposed films.

Considerable underexposure (such as is often encountered and proves unavoidable under unfavorable conditions of illumination, when using aerial film of low sensitivity) is generally not correctable.

Films considered suitable for processing are recorded in special aerial photographic survey production logs. They contain a detailed description of the conditions under which the initial materials of the aerial photographic survey were obtained -- such information as is necessary for their subsequent processing. All the negatives are numbered so that individual prints of them may be related to a film series or to the survey object. The inscriptions are made in India ink on the emulsion side in mirror type.

By the way of example we present one of the types of code which is used on aerial negatives:

47 14/148,

where 47 is the year of the survey, 14 is the film number, and 148 is the photograph series number.

Films prepared in this manner, with a group of contact prints for each of them, are the final product ofthe processing in the photographic laboratory. For further processing these materials are forwarded to the aerial photogrammetric laboratory.

It must be mentioned that in subsequent use of the materials of an aerial photographic survey for purposes of illustration or mesurement (in which wide use is made of the reversability of the photographic process) various photographic operations are performed: contact printing, transformation of photographs, the prepartation of various types of reproductions, etc. These operations are performed under the conditions associated with office operations specially equipped photo laboratories.

3. The Photogrammetric Process

The photogrammetric process embraces an entire complex of office operations which are performed in a special laboratory and are associated with the reproduction and measurement of an optical model of the photographed surface from aerial photographs. The ultimate purpose of these operations

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is a topographic map or the obtaining of a certain number of numerical characteristics (plane and elevational) for the individual objects and elements of the terrain.

In the variety of methods of photogrammetric processing of materials of aerial photograhic survey there are clearly distinguished two basic methods.

The universal method, in which the materials of the aerial photographic survey are processed on one instrument (as a rule, a very complex instrument) which by optical-mechanical means solves the problem of converting the aerial photographs to topographic plans of the terrain.

The differentiated method, in which the same problem is solved by means of a whole series of relatively ~~complexes~~ intruments and procedures performed in definite sequence according to the previously developed technological process.

(It has recently been planned to combine both methods of photogrammetric processing into a single method which uses the instruments and procedures of both the differentiated and the universal methods of photogrammetric processing of materials.)

The use of one or the other method of office photogrammetric processing of the aerial survey material is preceded by a careful check of theqquality of these materials as obtained under field conditions and being an unavoidable part of the aerial survey process.

As concerns the quality of the photographic image, the primary photographic processing provides for a check on execution of the aerial survey asigmment with respect to observing the assigned flight path and the scale of the survey, the assigned overlap of photographs, and also a check on the assigned position of the optical axis of the aerial camera.

For appraising the quality of the operations performed the results of the aerial photographic survey are gathered in the form of an overlap assembly (Figure 18) of all the overlapping contact prints. The overlap assembly is made by means of clips and tacks on the drafting table or a sheet of plywood. This assembly serves as visual proof of the overlap of the survey of

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the entire assigned area.

Materials of the aerial photographic survey intended for measurement purposes are subjected to detailed analyses with a view to establishing the absence of photogrammetric discontinuities and extreme differences in scale of the aerial photographs, which might otherwise complicate and even make impossible subsequent processing of the aerial photographs.

Phtogrammetric discontinuities appear in the case where the longitudinall and transverse overlap of photographs has proved smaller than permissible or in certain negatives where, for one or another reason, the photographic image is unsatisfactory, and also in the case of considerable deviations from a straight flight path.

Difference in scale of adjacent aerial photographs is due to the fact that during photography the assigned (vertical) position of the optical axis of the camera was not maintained, and in addition the assigned height of photography was not maintained. The difference in scale of photographs must not exceed 7 percent over the flight path and 8 percent between paths.

Aerial negatives not meeting these requirements are rejected and are not subject to office processing.

After correcting all defects of photography the final o erlap assembly is marked with the boundaries of the trapezia of the future map and notes are made on the nomenclature of the trapezia and the principal orienting features (large rivers and populated points).

A reproduction of the overlap assembly (obtained by photographing it with a reduction to delivery [sdatochniy] scale or in any case, to a size suitable for use) is used as an assembly sheet for the selection of negatives and contact prints in further processing; it is also used in compiling and making a plan of the geodetic base of the materials of the aerial photograhic survey.

Among the photogrammetric operations which may be performed under field conditions there is also included a compilation of simple aerial mosaics [fotoskhema] (see Appendix, Photo 16-a) which are used as a photographic base in investigations of a preliminary survey nature.

The simple aerial mosaic [fotoskhema] is a photographic image of terrain compiled in the form of a mosaic of contour-joined contact prints, the overlapping portions of which are removed by one or another method (cutting or tearing -- Figure 19).

In compiling aerial mosaics use is made principally of the useful portions of the photographs (Section 7) -- the clearest and least distorted portions. In this way there is obtained an increase in the overall (usually not very high) accuracy of simple aerial mosaics. Over flat terrain a route mosaic consisting of 10-12 photographs may be used for linear measurements if the relative error is on the order of 1/150.

In order to obtain precise aerial mosaics the photographs are brought to a single scale by means of a projector. The aerial mosaics obtained from such photographs are more orderly and more convenient to use, however, their accuracy cannot be materially increased since distortion due to perspective and relief in the individual photographs cannot be eliminated.

In order to eliminate distortions appearing in individual aerial photographs and to bring them to a single scale it is necessary to transform them, locating 4-5 control points on each photograph. Determination of the control points on the photographs is performed by photogrammetric means (phototriangulation) on the basis of a certain number of ground geodetic points used as origins.

In various survey practices, as the initial plotting for subsequent plots, points may be adopted which are defined on topographic maps and identified on the aerial photographs.

Having obtained aerial mosaics which are simple or slightly refined, the photogrammetric operations are completed in those cases where the investigators using the aerial photographic survey are satisfied with low accuracy of the cartographic base and use it chiefly to obtain qualitative characteristics of the landscape and to calculate their changes.

In an aerial photographic survey it is the purpose of photogrammetric process to obtain a topographic map of the given terrain. All the constructions for this map are performed by photogrammetric methods and the aerial survey and geodetic materials are used as initial data.

4. The Geodetic Process

It is the task of the geodetic process to create over a terrain the grid of control points, to determine their positions in the plane and elevational relations and to relate the aerial photographs to them, which is done directly on the terrain by identification of local objects (comparison of the photograph with the locality) and appropriate measurements. The personnel and volume of geodetic operations necessary to insure the given accuracy of the final result (a map, profile, individual measurements) depends on the type and scale of the aerial photographic survey and also on the adopted method of photogrammetric processing of the materials.

At the present time in the practice of aerial geodetic enterprises there have been established definite norms for performing topographic surveys by geodetic control points on the basis of the scale of the survey and also of the physical-geographical conditions under which it is performed (Table 5).

Continuous tying-in [privyazka] of aerial photographs by the geodetic method at the present time is practised in those cases where it is necessary to use a contour-combine [konturno-kombinirovannaya] aerial photographic survey, in particular in mapping lowland areas and, in addition, in compiling large-scale charts when photogrammetric methods of drawing relief from initial data do not provide the required accuracy of its image.

Geodetic operations may precede aerial survey operations or may be performed after them. In the first case, especially when the area of the survey lacks clearly expressed orienting points insuring location of geodetic marks on the photographs, these marks are made by one or another method (marking off crosses, trenching, pouring lime, etc). In the second case, the points of the control grid are joined to local objects clearly expressed on the photograph or with contours of the terrain by analytic or graphical means (theodolite, plane table).

The choice and tying-in of contour points to the existing geodetic grid is performed directly from aerial photographs on the basis of a previously compiled (from the overlap assembly) plan of the geodetic control grid.

For preliminary planning of operations for tying-in of photographs it is assumed that the number of tied-in contour points (control marks [opoznaky]) on each trapezium must be:

(a) in obtaining reconnaissance strips [fotoplany] on a scale of 1:50,000 from a flight on a scale of 1:25,000 -- from 6 to 10 contour points;

(b) in obtaining reconnaissance strips on a scale of 1:25,000 from a flight on a scale of 1:17,000 -- from 5 to 8 contour points.

In the practice of complex surveys, when the same photographs are used for different purposes (including for tying-in measuring operations replacing mapping) geodetic operations in the tying-in of contour points are usually performed with consideration of the requirements of special investigations.

In certain cases the tying-in of photographs is conveniently done after river measurements (in order to insure the plane and elevational tying-in of local objects and artificial constructions used as orienting points in performing the measurements and other special investigations). In other cases the tying-in of photographs is conveniently performed at the same time special investigations which include the geodetic survey.

The specific features of the aerial photographic survey which is to be used for different special investigations find their reflection also in the geodetic process. For example, in hydrological investigations the surface of the object of investigation (a river or a lake) may be considered as the initial elevation base or as an essential addition to the grid of elevation control points necessary for reproduction of the model. This possibility must quite often be used in surveys of rivers performed along curved or broken routes when, in the presence of previously known unfavorable survey conditions, there arises the need for a considerable increase in the number of control points in order to insure the given accuracy of measurements. At the same, especially in investigations of extremely wide rivers, there arises the need for a considerable increase in geodetic ground operations, because the use of photogrammetric methods of joining a grid of control points in such cases often proves impossible.

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(due to the fact that on the image of the water surface, in the absence of islands it is difficult to select control points for phototriangulation).

The volume and staff of geodetic operations, based on the materials of the aerial photographic survey, to a considerable degree depend on the features of the object of the investigations and on the tasks confronting them.

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CHAPTER II

PRINCIPLES OF PHOTOGRAMMETRY

Section 6. Terminology

The geometric foundations of photogrammetry proceed from the theory of perspective, the elements of which in their application to the aerial photographic survey have a special terminology. This terminology is most conveniently examined by way of example from an aerial photograph obtained with considerable tilt of the optical axis of the camera.

Figure 20 shows the relations between the elements of an oblique (perspective) photograph and the horizontal terrain.

The center of the projection S is the center of the lens (more exactly, the front nodal point of the lens of the aerial camera).

The picture plane P is the plane of the negative on which (by photograhic means) the coordinate marks are fixed, which marks are located in the middle on each of its sides.

The principal ray OS is the principal axis of the lens of the aerial camera, perpendicular to the plane of the negative.

The principal point of the picture, or the principal point of the photograph, O is the intersection of the principal optical axis with the plane of the negatives; on the photograph it is defined by the intersection of the straight lines joining opposite coordinate marks.

The base plane or object plane T is the mean level surface of the earth or the surface of plane E.

The principal vertical plane W is the vertical passing through the principal optical axis.

The principal vertical VV is the intersection of the plane of the principal vertical with the plane of the negative.

The horizon line $h_i h_i$ is the intersection of the plane of the negative with the horizontal plane passing through the center of the projection.

The principal horizontal hh is the intersection of the plane of the negative with the horizontal plane passing through the principal point of the photograph.

The horizontal is the intersection of the plane of the negative with the horizontal plane passing through an arbitrary point on the negative.

The perspective axis is the intersection of the picture plane with the object plane.

The survey height H is the distance from the center of the projection to the object plane measured along a perpendicular line.

The principal distance OS = f_k is the focal length of the camera measured along the principal optical axis from the rear nodal point of the lens to the focal plane (the plane of the negative).

The nadir point n is the point of intersection of the plane of the negative with a perpendicular line passing through the center of the projection S.

The principal point of convergence Io is the point of intersection of the principal vertical VV with the line of the horizon.

The point of zero distortions c is the point of intersection of the bisectrix of the angle α of the principal vertical.

The angle of tilt α is the angle lying between the main optical axis and the perpendicular.

The angle of swing x is the angle at the principal point of the photograph created by the principal vertical with the direction Y of the photograph.

The azimuth (the directional angle) is the angle comprised by the projection of the principal vertical and the direction of the meridian.

From Figure 20 we may make the following direct determinations of the positions of the principal points of a perspective (including the vertical) photograph:

the principal point of convergence

$$oI_o = f_k \cot \alpha ,$$

the nadir point

$$on = f_k \tan \alpha ,$$

the point of zero distortion

$$oc = f_k \tan \frac{\alpha}{2} .$$

The distance from the point of zero distortion c to the principal point

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of convergence

$$cI_o = SI_o = \frac{f_k}{\sin}$$

The distance from the perspective axis TT to the principal point of convergence is

$$I_oV = \frac{H}{\sin}$$

The statements of projective geometry used for analysis of the aerial photograph and in its use for measuring purposes are formulated in the following manner.

1. For a series of parallel straight lines lying in the object plane and parallel lines in the direction of photography, the point of convergence I_o lies at the intersection of the line of the horizon h_ih_i with the principal vertical EV (Figure 21) and is known as the principal point of convergence.

2. For a series of parallel straight lines not parallel to the direction of the line of photography, the point of convergence I_i lies on a line of the horizon h_ih_i, being the geometric location of the point of convergence of parallel straight lines lying in the object plane (Figure 22.)

3. For a series of parallel straight lines perpendicular to the object plane, the point of convergence is the nadir point n (Figure 23.)

Section 7. Aerial Photograph Scale, Image Distortion on Aerial Photographs, Their Useful Area

The relation between the elements of the image on the photograph and the corresponding elements on the terrain is expressed, as was stated in Section 2, in the form of a scale. The latter is a value which is constant for the entire picture plane (a horizontal photograph of flat terrain) and is determined from the formula.

$$\frac{1}{m} = \frac{f_k}{Hm}$$

For oblique photographs, as well as vertical ($\neq$ 0), the image scale is variable.

The scale of the aerial photograph along any contour line is

$$\frac{1}{m} = \frac{f_k}{H}(\cos - \frac{y}{f_k} \sin).$$

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The scale along the contour line passing through the nadir point is

$$\frac{1}{m} = \frac{f_k}{H} \quad \frac{1}{\cos}$$

The scale along the contour line passing through the principal point of the photograph is

$$\frac{1}{m} = \frac{f_k}{H} \cos$$

The scale along the line of the true horizon $h_i h_i$ passing through the principal point of convergence I_o is

$$\frac{1}{m} = \frac{f_k}{H} (\cos - \frac{f_k \cos \quad \sin}{f_k \sin}) = (0)$$

whence it follows that at the line of the true horizon any segment becomes a point.

The scale along the line of zero distortions is

$$\frac{1}{m} = \frac{f_k}{H}$$

The last formula points out an unusual property of the contour line passing through the point of zero distortions on an oblique photograph: on it, and only on it, the image scale is the same as on a horizontal photograph. This scale on an oblique photograph is known as the principal scale and the contour line passing through the point of zero distortions is known as the line of principal scale or the line of zero distortion.

The scale for a segment located on the principal vertical is variable and differs for each point taken on this segment.

Below we present a brief characterization of the distortions usually observed on an aerial photograph.

(a) Distortions of angles on an oblique photograph. There are two causes for distortions of angles on oblique photographs: (1) tilt of the optical axis of the camera and (2) the relief of the terrain.

Only those angles formed by lines originating at points of zero distortion (Figure 24) remain undistorted; for them

$$\tan \phi = \tan \phi_o$$

Angles at the nadir point of an oblique photograph are always less than their corresponding angles on the terrain (Figure 25); for them

$$\tan \phi = \tan \phi_o \quad \cos$$

Angles at the principal point of an oblique photograph are larger than their corresponding angles on the terrain (Figure 26); for them

$$\tan \phi = \frac{\tan \phi_o}{\cos}$$

Maximum distortions of angles formed by the principal vertical and a given line are with $\phi = \pm 45$ degrees and ± 135 degrees.

Distortion of angles at the principal axis of a vertical photograph of level terrain does not exceed 2-3 minutes.

Under the conditions of a clearly expressed relief the distortion of angles is determined by the abruptness of this relief.

(b) Displacement of points on the aerial photograph caused by tilt of the optical axis of the camera. Under the influence of the tilt of the optical axis of the aerial camera relative to the perpendicular all segments of the photograph change their length and direction, and points are displaced relative to the position which they are likely to occupy on a horizontal photograph with = 0 degrees.

Displacement of points caused by tilt of the optical axis is directed either toward the point of zero distortion or away from it.

For practical calculations the value of displacement of the points may be taken as

$$= \frac{r^2 am}{f}$$

where r is the distance between the observed point and the point of zero distortion, a = 0.03 for vertical photographs, m is the denominator of the numerical scale of the photograph, and f_k is the focal length of the camera.

(c) Distortion of image on the aerial photograph due to the effect of relief. On the photograph of a hilly terrain the images of points having certain deviations above the average level surface are displaced: either in the direction of the nadir point n (lowering) or away from it (raising). Segments aa_o and bb_o (Figure 27) expresses the displacement of the images of points A and B on an aerial photograph.

From the sketch it is seen that

$$h = \frac{rh}{f_k} \text{ and } S = a_o a = \frac{rh}{H}$$

The error in the image of a point as caused by the influence of the relief of the terrain is directly proportional to the deviation of this point from the mean level surface, the distance of the point from the principal point of the photograph, and is inversely proportional to the height of photography.

Distortion due to relief is a feature distinguishing the orthogonal projection (in which terrain plans are compiled) from the central projection (in which aerial photographs are made). It is not possible to avoid errors due to relief; they may only be decreased by increasing the focal length and the height of photography, as follows from the formula.

Additional angular distortion which results due to displacement of points on the aerial photograph due to the influence of relief is apparent if, over the extent of one km of terrain the difference in elevation of individual points exceeds ± 30 m. If the vertex of the angles to be measured is the point of zero distortions, then, as was mentioned above, these angles will be undistorted. This important property of the point of zero distortions lies at the basis of phototriangulation (see below).

On vertical aerial photographs the point of zero distortion in practice is taken to coincide with the principal point of the photograph.

(d) Scale difference of adjacent aerial photographs as caused by a change in the flight altitude. Flight altitude in aerial photography along a given route is maintained with an accuracy of ± 15 m, and between flight routes ± 30 m. Variations in the height of photography are reflected in a difference in position of identical points on adjacent photographs and is expressed as a lack of coincidence of contours for one and the same images.

Letting r represent the distance between the principal point of a photograph and an observed point, the error due to difference in scale at the juncture of two overlapping aerial photographs may be calculated from the formula

$$\Delta_{dH} = \frac{rdH}{H}$$

Linear displacement of the points of an image, caused by change in the height of photography, is directed toward the principal point of the camera.

The Useful Area of An Aerial Photograph

Analysis of the above formulae leads to the conclusion that distortion of the photographic image is greatest in the peripheral portions. Assuming that in general these distortions do not exceed a certain previously assigned value, on the photograph, it is possible to mark off the so-called useful area within the limits of which measurement may be performed.

The radius of this area may be determined from any formula taking into account the combined influence of the above-mentioned errors, for example, according to the Klimov formula

In this formula h_m is the maximum deviation over the average plane, $1/m$ is the average scale of the photograph, Δ is the assigned accuracy of measurement in mm.

In practice, the useful area is not taken to be circular but a rectangle, the sides of which are lines extending through the center of the actual overlap of adjacent photographs.

Section 8. The Transformation of Aerial Photographs

Direct calculation of distortions and obtaining precise qualitative characteristics of the different elements of a landscape from vertical aerial photographs (contact prints) are somewhat complex and, what is more, an extremely difficult and labor-consuming task. Hence it is convenient to convert the aerial photograph as a whole (or in parts) to a horizontal photograph in order that on it, as on a plan, any measurements may be performed. Such conversion is known as transformation of aerial photographs. It usually entails reducing all aerial photographs of a given flight route to one, preassigned scale convenient for use. This work is performed on special instruments known as transforming printers (Figure 28 and 29) in which there is reproduced and then fixed on an appropriately placed screen the tie-in of projecting rays (Figure 30).

In order to place the screen in the required position it is necessary to have not less than four control points on the photograph. These points by one or another method must be applied to the screen and through each of them there must pass the corresponding projecting rays from the light beams, reproduced by means of the projector of the transforming printer. After this, there is fastened to the screen a sheet of printing paper and on it is printed the converted image of the locality, free of distortions which might arise due to perspective.

Here it is especially necessary to emphasize that in transforming aerial photographs distortion due to relief and a change in flight altitude are not eliminated. They may only be reduced to a certain minimum. Thus, in transforming photographs of hilly terrain and in large-scale aerial photographic survey transformation must be performed for elevated areas and thereby it will be possible to observe the scale of the photographic image over the entire area of the photograph.

Determination of control points necessary for transformation is performed either by geodetic or photogrammetric means. The first method is used only in compiling plans on a very large scale in the form of a continuous tie-in of aerial photographs to a specially developed geodetic grid. In all other cases, the number of control points necessary for transformation of the photographs is determined photogrammetrically, by a method of phototriangulation based on a sparse grid of geodetically determined and identified points (control marks) on the aerial photographs. A phototriangulation series for a certain flight path is constructed graphically by means of intersections and resections relative to the initial directions, which are the directions between the principal or central points of adjacent photographs. In this way constancy of the orienting points of photographs within the limits of the flight path is achieved. The principal method of development of phototriangulation is the construction of a single-route, rhombic series, which is evolved both from the negatives and from contact prints (Figure 31).

Marking by means of a templet the principal or central points on the negatives or prints, they are subsequently used to plot at these points angles which are practically equal (see above) according to the angles of the terrain, and whence the images of central points on adjacent photographs are located and marked off. Thus, the initial directions are obtained and from them the photographic base of the survey scale. Thereby, by means of the intersections, as in the plane-table survey, it is possible to determine the position: (1) of the tie points (P), (2) the transformation points (T), and (3) the grid control points (B) (Figure 33). The tie points are chosen in pairs in the zone of triple overlap; the transformation points, according to which the

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transformation of photographs is subsequently performed, are brought approximately to the points of intersection of lines passing through the center of longitudinal and transverse overlapping (that is, 4 per each photograph). After marking the points with pin pricks (or at the same time) the so-called "radial" tracings are prepared. Placing the aerial photograph on a sheet of tracing paper, all the marked points are repricked on it and then encircled in pencil and lines drawn in their directions (radials) from the principal (central) points.

By placing a pair of adjacent tracing sheets together along the initial directions, it is possible to obtain on any scale a grid of points determining the relative base. Placing a third sheet next to the pair, it is moved along the initial direction 2-3 so that the radials at tie-points P_2 and P_2' pass through the intersection of the same radials on the preceding photographs. In this manner there is determined (tied-in) the position of the third photograph, and together with it a new pair of tie points, etc.

As a rule, phototriangulation is performed on an arbitrary scale and hence the plotted series must be copied on a strip of tracing paper of appropriate size and reduced to the required scale. This work is performed by optical-mechanical means on a special device known as a photo reducer. This is a large and accurate projector in which the sheet of tracing paper with the applied phototriangulation grid is placed and illuminated. On the screen of the reducer there is a plane table with the control points marked on it. Upon achieving satisfactory coincidence of the projected control points with the control points on the plane table, a hard, sharp pencil is used to mark the position of the central and transforming points. With this the process of concentration of the vertical control grid by means of triangulation is concluded. In transforming the photographs, as was stated above, relief is taken into account, hence the transformed points must obtain the corresponding displacement on the plane table base.

After transformation, photographs are obtained which are practically free of distortion. From these it is possible to assemble either uncontrolled mosaics (fotoplan) or controlled mosaics (fotoskhema). For this purpose it is necessary to remove the overlapping portions of photographs marked by reduced image quality. This work, just as in compiling the mosaic of the useful area on a plane-table base, is exceedingly painstaking. Each photograph on the plane table is placed according to control marks which are cut into the photograph by means of a special punch and, in addition, are made to coincide with the adjacent photographs by contour. In this position each photograph is glued to the base. Then on the resulting mosaic the frames of a map or plan of the appropriate scale are struck off and the rest of the rough delineation is performed.

The resulting uncontrolled mosaic (fotoplan) is referred to as "clear." In this form it is of greatest value for the investigator of natural resources, since in expressing the results of the interpretation by topographic or other symbols the image of the terrain is shaded and cohesive. The interpreted "fotoplan" is an ordinary topographic map on which the photographic image is removed by one or another means.

Section 9. Use of Aerial Photographs As A Topographic Base.

The possibility of using aerial photographs as a topographic base is fully insured by the method in which they are obtained (a strict central projection) and by the subsequent procedure of processing (conversion of the central projection into an orthogonal projection). Transformed by one or another method within the limits of their useful area, the aerial photographs are plans of the photographed terrain; with them it is possible to perform any measurements as are performed from ordinary plans.

The radius of useful area on the transformed photograph is calculated from the formula

$$r = \frac{\delta H}{h},$$

where the value δ is chosen on the basis of the assigned accuracy of measurements.

(a) Determining the Scale of the Aerial Photograph

The scale of the transformed aerial photograph may be ascertained from the record data. If such data are lacking, then it is necessary to compare the photograph with the map, or better, with the terrain.

In order to determine the scale of an aerial photograph from a map it is necessary to locate two identical points on the photograph and the map (Figure 33) and to measure the distances between them. The numerical scale of the photograph, determined as the ratio of the distance between the two points on the photograph to the distance between them are the same points on the terrain, is expressed by the formula

$$\frac{1}{M_c} = \frac{l_c}{L_k M_k},$$

where l_c is the distance between the points on the photograph (in mm), L_k is the distance between the points on the map (in mm), m_k is the denominator of the numerical scale of the map.

The distances are measured with a beam compass with an accuracy of tenths of a millimeter.

Example. The distance between two bridges on a river l_c = 151.0 mm, on the map with a scale of 1:100,000 the same distance is equal to 15.1 mm. The scale of the photograph is

$$\frac{1}{M_c} = \frac{151}{15.1 \times 100{,}000} = \frac{1}{10{,}000}.$$

In the absence of a large-scale map or in the event of difficulties associated with establishing identical points on the photograph and the map, this same problem may be solved by comparing the dimensions of any object with its actual dimensions. In this case use is made of the formula

$$\frac{1}{M} = \frac{l_c}{L},$$

where l_c is the size of the image on the photograph (in mm), L is the actual size of the object on the terrain (in mm).

This formula is also used for determining the scale of a photograph in direct comparison with the terrain. In this case it is necessary to note that in order to determine the scale of the photograph it is necessary to choose such objects as have a clear image and linear dimensions of not less than 2-3 mm.

Example. It is known that the distance between telegraph poles on the terrain is 54 m. On the photograph this distance proved to be 18 mm.

The scale of the aerial photograph is

$$\frac{1}{M} = \frac{18}{54{,}000} = \frac{1}{3{,}000}.$$

The above formulas and rules are used also for determining the scale of non-transformed (plane) aerial photographs. However, in the given case, due to unavoidable distortions, such determinations are approximate in nature and contain not only errors in the identification of points and the measurement of the chosen segment, but also errors due to tilt of the optical axis of the camera, etc., of which more will be said later.

Determination of the scale on non-transformed aerial photographs is performed within the limits of their useful area with not less than two pairs of points, with mutually perpendicular directions, and from all the scale determination there is derived the mean arithmetical value.

The calculations are made by use of the previously mentioned formula (Section 3) for the mean or navigation scale

$$\frac{1}{M} = \frac{f_k}{H},$$

the data for which are derived from calculation according to the aerial photographic survey.

(b) Orientation Of Aerial Photographs.

Orientation of aerial photographs throughout the points of the compass may be performed by the following methods: (1) from a map; (2) from local objects; and (3) from shadows.

1. Orientation of aerial photographs according to a map. Establishing two identical points on the map and on the photographs, we join them by straight lines (Figure 33). Then we determine the value of the directional angle of the line ab on the map and we plot it on the photograph by means of intersections or a protractor. The drawn direction on the photograph is the direction of the axis of plane rectangular coordinates, from which it is possible to obtain the direction both of the true and the megnetic meridian passing through point A on the terrain and on the photograph.

2. Orienting the aerial photograph according to local objects does not differ essentially from the orientation of ordinary maps. Comparing the photograph with the locality and using a compass, the aerial photograph may be oriented relative to the point of the compass an in an ordinary topographic map.

3. Orienting the aerial photograph according to shadows. This method of orientation is a specific method for aerial photographs. It may be used in most cases where photography is performed in clear weather and if the time of photography is known (hours and minutes). Images of shadows on aerial photographs obtained at noon (1300 hours, mean local time) are directed to the north; on photographs made before noon the images of shadows are directed to the northwest; and after noon, to the northeast. Knowing the angular velocity of rotation of the earth ($360^{\circ}:24 = 15$ degrees per hour) and the time of photography, from the shadows of local objects on aerial photographs it is possible to determine the direction of the true meridian. This is done in the following manner. On the photograph there is drawn the direction of the shadow (Figure 34) and then, by means of a protractor, the angle is laid off (its value depending

on the time of photography). If the survey was performed before noon, then the time of photography is subtracted from 13; if the survey was performed after noon, then 13 is subtracted from the time of photography. The resulting value is multiplied by the angular velocity of rotation of the earth (15 degrees per hour) and in this manner the required angle is obtained. This angle is laid off along the shadow in the appropriate direction: from the right side of the shadow if the photography was performed before noon, and from the left side if it was performed after noon.

The same problem, without additional calculations, is solved by means of the Ban'kovskiy device (Figure 35) -- a celluloid disc graduated in hours of photography (every 15 minutes) and the directions of the cardinal points of the compass.

This disc is placed with the center at the edge of a shadow on the aerial photograph in such a way that the latter passes through the time markings for photography. After this the north-south direction is drawn on the aerial photograph along this line. In order to avoid errors of 180° it must be ascertained that in placing the disc on the photograph the indicating arrows on the time scale coincide with the direction of the shadow.

Section 10. Procedural Instructions For Using Single Aerial Photographs

The camera records the image of the terrain in that form in which it would be seen by one eye. Hence, in attempting to obtain the most correct presentation of the image printed on a single aerial photograph, it must be examined monocularly (that is, with one eye). In this case and on the condition that between the eye of the observer and the photograph the proper distance is preserved, it is possible to obtain a most correct presentation of the photographed terrain, including also to some degree its relief.

In order to maintain the correct perspective the photograph must be viewed with one eye at a distance approximately equal to the focal length of the aerial camera, with the aid of a magnifying glass. Then even a single aerial photograph gives a certain impression of relief and depth, whereby the shadows and other oblique features intensify the impression of relief, facilitating study of the aerial photograph.

The distance of greatest visibility for the normal human eye is approximately 25 cm, hence photographs obtained with a normal lens (f_k = 200-250 mm) may and must be examined at this distance. It is to be noticed that photographs obtained with long-focus cameras do not lose relief in binocular examination.

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In examining with both eyes a single photograph obtained with a normal camera a relief image is not obtained, for in this case there is absent the necessary distinction of images of one and the same object which, being received by each of the eyes, permits a sense of vision to recreate a relief image of the observed object. It will be further observed that simultaneous examination by both eyes of two photographs of one and the same object, obtained from a certain base, will permit reproduction of a stereoscopic model of this object. This method of examination of overlapping photographs, based on the natural properties of optical equipment, is referred to as stereoscopic, just as our vision is stereoscopic. Thus, having a single photograph, it is necessary to examine it with one eye, whether the right or the left eye, since in this respect even a stereoscopic camera possesses no selectivity.

In studying aerial photographs it must be kept in mind that on any topographic map, along with the scale symbols accurately duplicating the outline of local objects in the plain view, wide use is also made of non-scale (in the literal sense of the word) symbols. On an aerial photograph, in distinction from a topographic map, all images of local objects are to scale. Depending upon the conditions of photography, one or another object on the aerial photograph may not obtain an image or will be hard to distinguish from its surroundings. This is especially true of objects having small dimensions in the plan view as well as of objects which are camouflaged by one or another method, blending with the overall background of the locality.

In examining aerial photographs with the aid of ordinary magnifying glasses or measuring lenses, or in overall magnification of the image it is possible to improve the legibility of the photograph somewhat and to distinguish on it relatively small details. However, it is necessary to keep in mind that in overall enlargement of photographs by more than two and a half times there may occur a noticeable shift of image, this being an unavoidable consequence of movement of the aerial camera at the moment of exposure (Section 5, Paragraph 1-a). Further magnification of the photograph will serve only for a general survey of the photographed object and to obtain its qualitative characteristics.

In establishing a certain limit or useful magnification of an aerial photograph (K_{max}) it is possible to determine the maximum scale of the survey, permitting measurement of objects with a known linear extension.

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For a vertical aerial photograph the formula for the maximum scale is derived in the following form:

$$\frac{1}{M} = \frac{f_k}{H} = \frac{n}{N}\frac{1}{K_{max}}.$$

It follows from the formula that if the survey is performed on a scale of 1:25,000, linear segment n (having an actual length of N = 10m) on an aerial photograph examined through a magnifying glass with a magnification of 2.5 times, will have a length of one millimeter (that is, for such objects a scale of 1:25,000 may be considered as the limit). The described method establishing the limit of a scale is not exhaustive, since it only considers the metric properties of the photograph. The problem of determining the optimum and maximum scales for aerial photographs used for hydrographic purposes is examined in greater detail later (Section 23).

In order to obtain a complete idea of the entire object under investigation and to establish its relations with its surroundings, individual aerial photographs are joined into a photodiagram (fotoskhema) in the form of an overlay assembly (mosaic) glued to any rigid base (pasteboard). The dimensions of the individual photodiagram must not exceed 60 by 90 cm (that is, the ordinary drawing sheet), otherwise the photodiagram's usefulness as a summary tool will be limited.

It must be pointed out that irregular tones of the individual prints, caused by errors in the positive photographic process, somewhat complicates interpretation of the photographed image and the photodiagram has an untidy appearance.

Hence, in those cases when it is intended to compile a photodiagram or photoplan (fotoplan), it is possible and permissible to exaggerate somewhat the tone of the photographic image in preparing contact and transformed prints; however, in those cases where the use of single aerial photographs is intended, it is much preferred to use so-called "normal" prints; they are made according to previously selected standards for each object.

For an investigator using an aerial photographic survey as a method of study, aerial photographs prior to photogrammetric processing are of considerably greater interest than contact prints, since in transforming the aerial photographs and reproductions the legibility of the aerial photographs is considerably decreased and they usually lose the freshness of the original.

Hence not only in field investigations but also in hydrographic laboratory investigations it is recommended that contact prints be used, the more so since most information which is needed for the characteristics of a water object may avoid the distortions present in vertical photographs.

The legibility of contact prints depends to a considerable degree on the type of photographic paper and its sensitometric characteristics. These papers are specially selected for the positive process with a consideration of the quality of the negatives. Vastly greater legibility is obtained with prints made on glossy or mirror-gloss paper, hence it is also used for contact printing. Matt paper and semi-matt paper are used for making prints intended for work in the field or for those operations in which it is necessary to make pencilled notations on the photographs.

Photographic paper having low resolving power in comparison with the aerial negative (10 lines per mm) conceals individual small details and sometimes, especially in the hands of inexperienced photographic laboratory workers, may not express all the detail and light shadings fixed on the aerial negative. Hence, in individual cases, for detailed study of an object it is necessary to use the aerial negative.

Section 11. Devices Used In Monocular Study of Aerial Photographs.

The study of aerial photographs begins with a general examination of the photograph in which the basic outlines of the photographed terrain and its elements are represented. In this examination the use of devices of any sort is not required. For more detailed study of aerial photographs accompanied by a description of the object under investigation, and for examination and measurement of fine details of a photograph it is necessary to use special devices.

For a general familiarization with the results of the aerial photographic survey before contact printing, for a detailed study of individual aerial photographs, and also, in extreme cases, when the conditions of operation do not permit waiting for contact prints, for examination of the film a special device is used -- a light table (Figure 36) -- provided with attachments for movement of the film in roll form on a spool. This device is designed to operate both with natural and artificial illumination.

For study of details and also for examination of small-scale aerial photographs optical devices are used: both simple magnifying glasses and measuring lens, and panoramic mirrors; and for especially precise measurements, more complex devices.

The magnifying glass (the simplest of optical devices used for the study of photographs) consists of one or several lenses placed in a special mount.

For monocular study of aerial photographs so-called "panoramic" glasses are especially useful (Figure 37). They have a large field of view (diameter 10-15 cm) with low magnification and are fastened on a special support. Some of the relief of images may be viewed with these devices.

For examination of fine detail and small-scale aerial photographs a set of glasses (Figure 38) is used at a magnification of 4-6 times.

Some glasses are fastened in a special mount having an external threading which permits displacement of the glass within a special support and may be held in a given position when adjusted for sharpness. Such glasses are usually convenient for use with aerial photographs.

For measurement of fine details measuring microscopes (magnifications of 8-10) are used. These are analytical magnifiers with a scale marked off in divisions of 0.1 mm within the field of view.

Included under the heading of magnifying devices is the panoramic mirror (Figure 39), having a fixed radius of curvature. The aerial photograph which is to be examined is fastened on a movable support within this device and is located within the focal plane of a mirror. The panoramic mirror, giving a magnified image of the photograph, imparts to it a certain impression of relief; the latter may be intensified if the photograph is tilted slightly during examination.

For a comparison of tones in a single photograph or in different photographs, which has often been of extreme importance in detecting local objects and deriving their characteristics, it is necessary to measure the density of the negative.

Microphotometers are used for measurement of the density of aerial negatives, permitting derivation of density characteristics either at individual points or, by means of recording instruments, in the form of curves on script records. Integration of the data of these measurements and explanation of the causes for a change in density at one or another part of the image is the task of instrumental interpretation (Part II), in which a change in density is considered as an objective indicator of a change in properties of the object under investigation. In particular, this indicator is used for determining the depth of a river (Figure 40).

CHAPTER III

REPRODUCTION AND MEASUREMENT OF AN OPTICAL MODEL OF A TERRAIN FROM OVERLAPPING AERIAL PHOTOGRAPHS

(STEREOPHOTOGRAMMETRY)

Section 12. General Information

The theory and practice of reproduction and subsequent measurement of a spacial model of a photographed surface is based on a singular property of our visual apparatus -- stereoscopic vision due to which the visual apparatus has additional facilities for perceiving and evaluating spacial forms of local objects and their location within the limits of its field of view.

The essence of stereoscopic vision consists in the following.

Images M and M_1 of one and the same point M of a terrain which is intersected from different ends of an optical base b are perceived differently by each eye. The perception of space is obtained from the difference in muscular efforts in the combination of visual impressions. This difference is due to asymmetry of images on the retina of the eyes or physiological parallax.

Possessing a sharpness of vision of

$$\Delta\gamma = \gamma - \gamma_1$$

(the difference in the parallactic angles), the visual apparatus perceives the separation of any point M_1 relative to a point of fixation M on the condition that there exists a physiological parallax, that is, the difference of arc (Figure 41)

$$\eta = m_1 m - m_1' m'.$$

(Figure 41 gives the conventional geometric expression of parallax without considering rotation of the eye. In fact, perception of a single point in space is obtained if individual images of it arise in corresponding points of the retina linked by nerve paths.)

If point M_1 is located further from the observer than point M, then

$$\eta < 0$$

If point M_1 is located closer to the observer than point M, then

$$\eta > 0$$

If point M_1 coincides with point M, then the physiological parallax

$$\eta = 0$$

Between the optical base b, separation L, and the parallactic angle γ there exists the following dependence:

$$\tan\frac{\gamma}{2} = \frac{b}{2L}$$

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The value of the optical base (the distance between the centers of the pupils) is an average 65 mm; it varies from 58 to 72 mm. The parallactic angles corresponding to these values at a distance of optimum vision (250 mm) amounts correspondingly to 13 and 16 degrees. In observation of extremely remote objects the parallactic angle is especially small; hence

$$\gamma = \frac{b}{L},$$

whence

$$L = \frac{b}{\gamma}$$

Differentiating the above formula for γ and converting to finite differences, we determine that with a small change in the parallactic angle $\nu = \gamma - \gamma_1$ at which the visual apparatus is still able to perceive a displacement in depth of point M_1 relative to M, the value of displacement is

$$\Delta L = L^2 \frac{\nu}{b};$$

that is, that the minimum difference in the separation which is perceived in stereoscopic vision is proportional to the square of the distance to the observed point.

It has been established experimentally that the sharpness of vision is approximately 30 minutes. If the parallactic angle γ is assumed equal to the sharpness of vision ν'', then we may determine the maximum separation or radius of unaided stereoscopic vision, which will be equal to

$$R_0 = \frac{b}{\nu} = \frac{0.065}{30''} \rho'' \approx 450 \text{ m}$$

This explains why the terrain below an observer flying at high altitude appears to be flat.

Special instruments are used to increase the radius of stereoscopic vision L. In these instruments the introduction of a mirror or a prism increases the base, and due to the introduction of lenses there is an increase in the sharpness of stereoscopic vision. Such instruments are known as stereoscopic instruments.

Section 13. Stereoscopic Examination of Aerial Photographs

The property of stereoscopic vision is used for reproduction of a special image of a photographed object from its photographs. The following conditions are necessary for such observation.

1. The photographs of the object must be obtained from two different points in space; such photographs constitute a stereoscopic pair or stereopair.

2. The difference in scale of the photographs must not exceed 16 percent.

3. The photographs must be located at the distance of optimum vision for the given observer (an average of approximately 250 mm).

4. Both photographs are viewed simultaneously, wherein each eye must observe one of the two images of the object.

5. The distance between identical points on the photographs comprising the stereopair must be equal to the optical base of the observer.

6. Lines joining identical points must be located parallel to the optical base.

7. The optical axes of the eyes must be parallel, that is, they must be directed to infinity. (It is just this departure from the natural conditions of operation of the visual apparatus which constitutes the difficulty in unaided examination of a stereopair).

With the fulfillment of these conditions, instead of two plane images of an object the observer sees one relief image. Special test patterns (Figure 42) are used in training personnel for stereoscopic vision. They are also used for the selection of personnel to operate stereoscopic devices. Looking at the sketch, such a position must be achieved as will cause the observer to see an imaginary image of a third circle with the objects sketched within it. This image is located between the sketched circles. In the third, imaginary, image the sketched figures must seem to be located at different heights (give the impression of depth).

The stereoscopic effect is more easily obtained if the optical rays are, as it were, isolated by a hand applied to the nose or by a plate. This idea has found its formulation in the form of special instruments known as stereoscopes.

There are simple stereoscopes, mirror stereoscopes, and lens-mirror stereoscopes. Stereoscopes provided with attachments for measuring special models are known as topographic stereoscopes.

The simple stereoscope is an H-shaped stand 25 cm high. On the upper shelf of the stand there are two cut-outs for the eyes and a notch for the nose, and on the lower shelf are placed the photographs to be examined. Such stereoscopes are suitable for examining small (6 by 6 cm) photographs.

For the purpose of calculating the natural convergence of the optical axes and the accomodation of the eyes, as well as for magnifying the images, simple stereoscopes employ special lenses. In addition, the holder for the photographs (the lower shelf) may be displaced. All non-professional stereoscopes (Figure 43) are constructed in this manner.

A simple, easily used stereoscope similar to that shown in Figure 44 may be constructed with the use of two identical magnifying glasses.

For examination of large photographs mirror stereoscopes or lens-mirror stereoscopes are used. Among these is the widely used LZ collapsible lens-mirror stereoscope (Figure 45), consisting of two pairs of mirrors and two lenses mounted in a common frame. Instead of lenses in such stereoscopes there is sometimes used a removable prismatic binocular which permits stereoscopic examination of photographs without magnification.

The distance d, measured in the stereoscope along the central ray from the eye of the observer to the photograph, is known as the principal distance of the stereoscope. In the lens-mirror stereoscope this distance is measured from the center of the lens to the photograph along the ray. The power of the stereoscope is

$$V = \frac{25}{d},$$

where d is expressed in centimeters.

Calculated according to this formula, the power of the LZ stereoscope is 1.4.

It must be pointed out that magnification of the base in stereoscopic instruments has no effect on the relief and plastic of a stereo model. It only permits examination of large photographs; herein also lies the advantage of mirror stereoscopes over simple stereoscopes.

Section 14. Working With A Stereoscope

For stereoscopic study it is necessary:

(1) to select the photographs forming the pair so that the overlapping portions will face one another;

(2) to establish from each photograph the principal points and to draw the initial directions -- lines joining the principal points of the photographs comprising the stereopair (Figure 46).

One of the photographs (the left) is fastened to the base of the stereoscope (in the case of the LZ stereoscope, to a special plate around the table), and the other is moved until doubling of contours is eliminated and a clear stereo effect is obtained without strain. It should be pointed out that most stereoscopes do not have a device for focusing the lenses, hence an observer wearing glasses must not remove them in working with such stereoscopes as, for example, the LZ stereoscope. Observers suffering from astigmatism must not wear glasses intended for reading when working with a stereoscope.

The lighting must be sufficiently strong and uniform in working with a stereoscope. As for the light source, the photographs must be placed in such a manner that the images of shadows on them fall in the natural direction.

The stereo effect has a different appearance depending upon placement of the photographs in the stereoscopic instrument. If the photographs are observed as per the above instructions, then a direct stereo effect is obtained (Figure 47) in which the treetops, housetops, etc. are raised slightly above the surface of the earth and there is a distinct impression of relief over the entire model. If the photographs are interchanged without turning them around, there is obtained the reverse (pseudoscopic) stereo effect. In this case the relief of the model is also perceived, but elevations appear to be depressed and depressions (for example, river valleys) become convex. Especially curious are the images of rivers and lakes: to the observer they appear to be overrunning their banks. In some cases the pseudo-effect is of practical use, permitting better expression of a river valley on a stereo model.

In rotating both photographs through 90 degrees there results a "datum-level" stereo effect in which all the photographed points appear to be lying in one plane. In photographs of mountainous regions it becomes more difficult to obtain the "datum-level" stereo effect, for, though the points also appear to be lying in one plane, deep shadows are still manifest and the relief of the image remains.

Section 15. Basic Properties of the Stereo Model

A natural requirement for a stereo model is the topological requirement or the observation of precise geometric similarity of the stereo model to an actual model. This requirement may be expressed in the following form:

$$C = \frac{1:m_h}{1:m_1} = 1$$

where $1:m_h$ is the vertical (depth) scale, $1:m_1 = f_k/H$ is the horizontal scale.

Actually (after N. G. Koll') there occurs a depth distortion of the stereo model, the magnitude of which is determined from the following relation:

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$$C = \frac{D}{f_k}$$

or

$$C = \frac{f}{f_k}$$

where D is the distance of optimum vision if the stereoscope is used without a lens, f is the focal length of the lens of the stereoscope, f_k is the focal length of the aerial camera.

Hence the stereoscopic model obtained from aerial photographs by means of the simplest instrument is topological. Distortion of the model is expressed as a lack of correspondence between the vertical and horizontal scales.

The coefficient C is known as the coefficient of relative elasticity of the model. If C is greater than 1, then the visible forms of the relief will be stretched in comparison with their actual forms (that is, the relief becomes exaggerated and the entire model is deformed). If the deformation of the model is uniform, this property of the model is viewed not as a shortcoming but as an advantage, permitting detection of all the details of the microrelief.

Establishing the depth scale of the stereo model, it is possible to evaluate the relative height of local objects by multiplying the visually estimated height (in millimeters) by the depth scale of the stereo model -- the product CK (page 61, original text).

The height of the object to be measured (an individual tree, a bridge, an individual peak, the bank of a stream, etc.) is compared with the millimeter scale, which is mentally placed alongside the given object.

The experience of forestry specialists, who make wide use of visual approximations of the height of stands of timber, has shown that the mean square error of such a determination does not exceed 2-3 meters.

Deformation of a stereo model becomes especially noticeable and difficult to deal with in calculations when the stereo model is reproduced from an ordinary vertical photograph, with all the attendant distortions, on instruments in which these distortions have not been taken into consideration. For example, the mutual longitudinal tilt of the photographs comprising a stereo pair causes depression of the stereo model; mutual transverse tilt of the photographs results in a twisted appearance of the model; there are also noted both longitudinal and transverse tilts of the model observed in stereoscopic study of photographs.

In addition to the distortions caused by orientational elements of the photographs, it must be kept in mind that considerable distortions arise in the model due to the stereoscope itself and the method of its use. For example, considerable distortion which is difficult to calculate may be noticed in a model when the mirror in a lens-mirror stereoscope has been poorly ground. There may also be observed a distortion (generally quite considerable) in the lenses of a stereoscope which sometimes may compensate for the effect of distortion in the lens of the aerial camera, but more often only intensifies this effect. Hence, in compiling a map it is recommended that the sketch of the relief under a stereoscope be performed without lenses.

For convenience in work with a stereoscope the aerial photographs are fixed in place and for best examination of individual parts of the stereo model the stereoscope is displaced. In the case of slight disturbance of parallelism of the initial directions and the optical base (see Section 16) the stereo effect is preserved but perception is accompanied by strain and observation becomes extremely fatiguing. With considerable disturbance of this basic rule of stereo examination of photographs the stereo effect is disturbed and contour images undergo doubling.

It should be kept in mind that doubling of contours may also appear due to a defect of the stereoscope. Before beginning work it is necessary to check the perpendicularity of the plane of the mirrors of the stereoscope relative to the plane passing through the optical base of the observer and forming a right angle with the plane of the photographs. Compliance with this requirement is checked in the following manner. In place of the photographs it is necessary to place a sheet of white paper with a straight line on it along the base. If, in stereoscopic examination this line is doubled, then one of the mirrors must be removed from the holder and a strip of tin foil or aluminum foil placed beneath it. This check is repeated until doubling of the line is eliminated.

In displacing the stereoscope the peaks of mountains appear to be tilted in the direction in which the instrument is displaced, hence the slope of declivities in the direction of displacement of the stereoscope is increased, while the heights of observed points remain constant. Hence it follows that in order to obtain a correct representation of the photographed terrain it is necessary to use a stereoscope with a large field of vision and it is not permissible to move the photographs any great distance off center.

From the above remarks concerning the properties of a stereo model plotted from vertical aerial photographs it follows that:

(1) a stereo model reproduced by stereoscopic examination of a pair of overlapping vertical aerial photographs is deformed;

(2) in order to use vertical photographs for measuring purposes it is necessary to use special instruments and to adopt measures permitting calculation of the elements of orientation of the photographs;

(3) in those cases where the conditions of operation may permit obtaining approximate characteristics of the elements of a locality, obtaining their values by means the simplest instruments, it is necessary that the values to be measured considerably exceed the deformation of the model under observation.

Section 16. Stereo Model Measurements

Placing overlapping horizontal aerial photographs so that their coordinate axes coincide, we notice that the images of identical points appear to be displaced. Segment (a') a" (Figure 48) shows complete parallactic displacement of point a of the terrain or its complete parallax. The latter, as a vector, may be laid off on two components: along the Y axis (the longitudinal parallax p) and along the X axis (transverse parallax q).

The impression of space and relief of the model arises due to the presence of longitudinal parallaxes, to which our vision is more sensitive than to transverse parallax.

Longitudinal parallax of observation point A of the terrain (Figure 48) is equal to the algebraic difference of the ordinates of images a' and a" of this point on the left and right photographs

$$p = y_2 - y_1.$$

Points having identical longitudinal parallaxes lie at one elevation. The large parallax corresponds to the higher point; hence it follows that the sign of the difference of parallaxes determines the sign of deviation of the points on the terrain.

Thus, in order to evaluate the deviation of the different points of the model, their longitudinal parallaxes may be determined by the use of a compass and a ruler.

The accuracy of such a determination is not very great (on the order of 0.2 mm), while the minimum detectable stereoscopic parallax is expressed in hundredths of a millimeter. Hence, for the measurement of parallax special instruments and various attachments are used which insure measurement of the longitudinal parallaxes or their differences with sufficient accuracy.

Photogrammetric methods of determining the elevation from aerial photographs provide the simpler and more accurate solution of the problem when the aerial photographs are obtained with a strictly vertical position of the optical axis of the aerial camera and, moreover, with a horizontal base for the aerial photography.

In Figure 49, let O_1 and O_2 represent the positions of the centers of the lens of the camera, from which the horizontal photographs comprising the stereopair are obtained. Let B be the base of photography, the distance between the centers of the projection. Assuming that the optical axis of the aerial camera, in being displaced from point O_1 to O_2, occupies a position parallel to its previous position, and producing the images a' and a" of point A obtained on the photograph in one vertical plane, on the basis of the similarity of triangles AO_1O_2 and O_2 a" (a"), we may

write
$$\frac{H_A}{f_k} = \frac{B}{y_2 - y_1} = \frac{B}{p}$$

and
$$H_A = \frac{B f_k}{p}.$$

In the derived formula
$$B = \frac{b}{f_k} H,$$
where $b = \frac{b_1 + b_2}{2}$, whence it follows that
$$H_A = \frac{b}{p} H,$$
where H is the average height of the flight over the given plane.

By determining the relative elevation of point A we may calculate its height above a given mean plane
$$\Delta H = H_0 - H_A,$$
where H_0 is the height of photography relative to the mean plane or a certain datum point with a known elevation.

In view of the fact that in obtaining vertical aerial photographs the conditions presented in the conclusion of the given formula are not observed, the parallaxes of points to be measured from vertical photographs will be

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distorted or conditional parallaxes. However, in the case where the points to be observed are located relatively close to one another or, what is the same, when the difference in their heights is relatively small, distortion of parallaxes may be assumed to be equal for both points and it may be assumed that the difference in the conditional parallaxes g is equal to the difference of the actual parallaxes p. Hence the above-formula may be used for determining the difference in elevations of points of the model.

$$\Delta H = H_2 - H_1 = \frac{bH}{p_2} - \frac{bH}{p_1} = \frac{bH}{p_1 p_2} \Delta p$$

Noting that

$$p = \frac{fB}{H}, \quad B = b,$$

that is, that the horizontal longitudinal parallax of the point relative to which the mean flight elevation is determined is the base expressed in the scale of the survey, we may assume that $p_1 p_2 = b^2$ and derive a working formula for determining the deviation in height of points from the differences in their longitudinal parallaxes.

$$\Delta H = \frac{H}{b} \Delta p = K \Delta p,$$

where ΔH and H are expressed in meters, and b and Δp are expressed in millimeters.

The parallactic coefficient K is assumed to be constant for the given stereopair and is considered as a depth scale of the stereo model, indicating the number of meters of deviation in height corresponding to one millimeter of difference in longitudinal parallax.

The given formula is used to determine relatively small deviations in height.

In order to determine considerable deviations with a small height of photography, use is made of the complete formula

$$\Delta H = \frac{H}{b + \Delta p} \Delta p$$

in which the values entering into the coefficient

$$K = \frac{H}{b + \Delta p}$$

are the same as in the previous formula.

To determine the order of the values entering into the above formula we are given the values: H= 2500 m, b= 72 mm, and ΔH= 10m. In this case Δp=0.29 mm, that is, 10m deviation in height corresponds to 0.3 mm of difference in longitudinal parallax.

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Hence it follows that in order to determine the difference in elevation of two points with an accuracy of one millimeter, the difference in their longitudinal parallaxes must be measured with an accuracy up to 0.03 mm.

In order to determine the values of deviation in height for which the simplified formula may be used instead of the complete formula, there exists a relation

$$h = \pm \sqrt{Hdh}.$$

Allowing a limit error of dh 0.5 m in determining the deviation in height, we know that with H = 3200 m the simplified formula may be used for determining differences in height not exceeding 40 m.

From analysis of the formulas it follows that the greatest effects on error in determining the deviation in height is had by errors in determining longitudinal parallaxes Δ p, and that errors in determining H and b have less effect.

The greatest changes in longitudinal parallaxes are caused by: tilting of the aerial photographs at the base of photography and unsatisfactory flattening of the film at the moment of exposure (that is, all those factors which cause deformation of the model). Along with changes in the longitudinal parallax which cause distortion of the model it is necessary to consider also errors arising in measuring parallax, specifically the error in the instrument by means of which the model is reproduced and deficiencies in the methods of reproduction as well as measurement of the model, as well as, finally, errors introduced by the observer.

It is noted that with an increase in the parallactic coefficient K the accuracy of determining the deviation in height is reduced and this is obvious because the value of this coefficient characterizes the angle of spacial intersection of local objects with a given base and height of photography. The smallest value for K is obtained for photographs made with short-focus, wide-angle aerial lenses which have now found wide application at aerial geodetic enterprises.

In order to insure the required accuracy of measurement the appropriate camera and method of processing must be chosen, and a reliable geodetic base for the stereo model must be adopted.

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In those cases when the abovementioned conditions are ignored, determination of deviations in height of points and the subsequently calculated indexes for the latter must be considered as approximate, meeting the conditions of simplified preliminary survey investigations.

One method by which a precise height characteristic for a stereo model may be obtained employs transformed aerial photographs.

In order to insure the required accuracy in drawing relief directly on vertical photographs by means of a stereoscope various methods are used for condensing the elevational control grid. In practice the widest use has been made of the methods of the straight line and the undistorted model as developed by G. V. Romanovskiy. These methods are described in detail in the special literature and are accompanied by appropriate instructions.

As experience has shown, in drawing relief with the simplest instruments it is necessary to have a considerable number (up to 15) of elevation points on the stereopair at distances of 3-4 cm from one another. They are obtained by photogrammetric means as a result of compression of a grid of points on the geodetic base with maximum spacing.

In using aerial photographs for hydrographic purposes as a control and in the absence of a geodetic base, the elevational base may be the image of the surface of the water object under investigation (rivers, a lake, or other bodies of water).

Within the limits of a separate stereo model (a pair of overlapping photographs) the water surface of a portion of the river, especially in a lowland, may be considered a horizontal surface. Measuring the parallaxes of points projected to a section of water at different parts of the stereo model, the character and extent of distortions of the model may be ascertained to some degree, since in order to determine the deviations use is made of the approximate formula without considering the elements of orientation of the photographs.

The visible tilt of the model may be somewhat corrected in the following manner. After orientation of the photographs from the initial directions it is necessary to measure the parallaxes of a series of points located approximately at the base line. If there is noticed a longitudinal tilt in one or another direction (that is, a visible difference in the elevation as distinguished from the differences in markings for the projected points),

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then one of the photographs (usually the right-hand photograph) must be tilted somewhat in one or another direction. If there is noticed a transverse tilt of the model, then it is necessary to rotate both photographs within their planes around the principal points in such a manner that the stereo effect remains undisturbed.

Neither of these methods guarantees complete elimination of distortions in the stereo model and only gives approximate corrections.

In order to correct for the elevation of points located in the immediate vicinity of the water object, especially in the case where the latter has a meandering outline and occupies a considerable portion of the stereo model, the following simple method may be recommended. Locating a certain number of control points reliably identified on the stereo model and determining their deviations in height by photogrammetric methods, it is necessary to write opposite each of the points the value representing the departure between the geodetic and photogrammetric markings (that is, the value of the correction which must be made in the marking obtained by photogrammetric means from the distorted model). Thence, by producing isolines of equal correction, any point projected on the model may be corrected.

The described method gives excellent results and is of importance in achieving efficiency in the case where the stereo model is provided with a sufficient number of control points uniformly distributed over the entire model, for interpolation for the straight line (the case of flexure of the model) is permissible only for points lying on a straight line perpendicular to the base of the survey. As for points located on arbitrarily oriented straight lines relative to the base, in the given case interpolation must be performed according to a more complex rule (a parabola). Hence, it follows that to obtain corrections by the method of interpolation from a straight line the distance between points must not be greater than 1.5-2.0 cm.

In order to obtain reliable results it is necessary to employ the method of the undistorted model, calculating the corrections for elevations by analytical means or obtaining them from the grid-sheet drafts proposed by G. V. Romanovskiy.

Section 17. Instruments and Methods for Reproduction of the Stereo Model

Conversion of an ordinary stereoscope into a measuring instrument is achieved by inserting within the path of the rays of the observation system two movable measuring marks m_1 and m_2 (Figure 50). Their displacement over the model is measured by means of attachments in the form of micrometric parallactic screws or scales.

The measuring marks may be affixed by various means. They may be placed directly over the photographs to be examined, the marks themselves being engraved on glass plates in the form of points, crosses, or short lines. They may be fiber or metallic filaments held stretched in special holders and superimposed on the photographs. Finally, marks in the form of points or crosses engraved on glass plates may be inserted within the observation system on the stereo instrument. In some instruments use is made of illuminated marks.

During the stereoscopic examination, instead of two actual flat marks m_1 and m_2 the observer sees one imaginary tridimensional mark and obtains a picture of its remoteness relative to a certain point A (Figure 51) and any other points of the model reproduced in this stereo instrument.

The change in the distance between marks m_1 and m_2 is perceived by the observer as a depth displacement of the mark. If the distance between the actual marks m_1 and m_2 is less than the distance between the corresponding points a_1 and a_2, then the plastic image of the imaginary model appears to be suspended above the stereo model (Figure 51). Simultaneous displacement of both the actual marks by the same distance is perceived as a displacement of the imaginary mark in a plane parallel to the plane of the photographs. If the distance between the actual marks is greater than the distance between the corresponding points, then the imaginary mark appears to be depressed within the model. An indication of this is the doubling of the image of the mark (or a break in the filament).

With the possibility of separate and joint displacement of the actual marks, the observer may align the imaginary mark with any point on the stereo model by bringing the mark into juxtaposition with it. At the moment juxtaposition of the imaginary mark with the model the images of the actual points m_1 and m_2 appear to be joined with the corresponding points a_1 and a_2 on the photographs (Figure 51). The readings are then made from the appropriate scales on the instrument.

For measurement of the coordinates as well as of the longitudinal and transverse parallaxes of the points the photographs are placed in the instrument so that their coordinate axes are parallel to the corresponding guides of the instrument from which a combined displacement of the actual marks is achieved.

In some measuring stereo devices, instead of displacement of the actual marks displacement of the photographs relative to the observation system is often practiced. Thus, movement of the marks in the direction perpendicular to the optical base may be replaced by combined displacement of the photographs in the same direction and displacement of one mark relative to another by a corresponding relative displacement of the photographs. Thus, the distance between the actual marks within the stereo instrument may remain constant.

The principal instrument for stereoscopic study of photographs -- the stereocomparator (Figure 52) -- in which the method of an imaginary measuring mark is used is constructed in just this manner. This instrument, designed for the measurement of coordinates and parallaxes of points, is a prototype and a distinct part of most modern stereoscopic measuring devices.

The stereocomparator is one of the most precise and at the same time one of the simplest stereoscopic instruments in operation. In the latest of Soviet aerial photographic stereocomparators (Figure 53), designed for processing of photographs with dimensions of 30 by 30 cm, measurement of coordinates as well as of longitudinal and transverse parallaxes of points is provided with an accuracy ±0.001 mm.

In the TSD-3 topographic stereoscope of F. V. Drobyshev (Figure 54) the marks are thin nickeline or textile filaments drawn tight over special frames which are placed over the photographs under examination. For measurement of the parallaxes at any point of the model the filaments may be displaced jointly and independently. Displacement of one of the filaments by means of the parallax screw may be recorded within the limits of 45-90 mm; the accuracy of the reading from the cylinder of the parallax screw is ± 0.01 mm.

For refinement and control of the measurements repeated alignment of the spatial screw at each observed point is employed. Under favorable conditions the accuracy of filament alignment is 0.02-0.03 mm.

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The accuracy of alignment of the filament on a point depends on the experience of the observer, on the character of the observed point, and on the quality of the photographic image. With considerable depth of the filament it is somewhat difficult to detect, for example, the tops of deciduous trees. It is easier to detect the top of a mountain than the bottom of a gully. It is difficult to lay the filament in the glades between trees, etc. In some cases it is more convenient to interchange the photographs and perform the measurement of a model in the presence of the pseudoscopic effect.

In working with transformed photographs and having designated control points it is possible to calculate the value of a division of the parallactic screw for a given section of relief and to use the spatial sighting screw for determining points of the model with a given elevation and then, by selecting such points with sufficient frequency, to draw contour lines. In practice this is done in the following manner: the parallax of a certain control point is assigned the value

$$\Delta p = \frac{\Delta h}{K}$$

where Δh is the difference in the markings for the control point and the contour line which is to be drawn.

Keeping in mind that with changes of H equal to Δp, as was shown above, there will not be correspondingly equal Δh, for each contour line it is necessary to perform individual calculations and not simply to total Δp, remembering during this procedure that the greatest parallax corresponds to the greatest elevation.

In processing vertical photographs this method of drawing contour lines may be used to derive the approximate characteristics of a terrain with respect to elevation, replacing the drawing of contour lines by eye in all types of sketches, schematic charts, etc.

The stereopantometer of F. V. Drobyshev (Figure 55) is designed for the measurement of longitudinal and transverse parallaxes and the coordinates of points (on the right-hand photograph). It may be used also as a sketching device for compiling maps from aerial photographs. Being light and small, the stereopantometer may be used not only under laboratory conditions but also under field conditions.

Measurement of parallax is performed with the use of dots applied to glass plates which are fastened close to the photographs; the latter are moved toward the marks conjointly (movement of the left relative to the right photograph). Displacement of the photographs is read from scales X and Y with an accuracy up to 0.1 mm. For measurement of parallax there is a micrometer unit in the form of two parallactic screws permitting measurements with an accuracy of ± 0.02 mm.

A pencil and pinpoint are used for fixing points of the model by the method of phototriangulation for transfer to the plotting board and tracing of the contours on the scale of the right-hand photograph or on another scale by the use of a special pantographic unit insuring a consistent change of scale in transferring from point to point, which is necessary in working with nontransformed photographs. Experience has shown that approximately 2.5 hours are required for processing on the stereopantometer a single stereopair having an average number of contours.

Preliminary surveys for the compilation of schematic charts find wide use for the field stereopantometer, consisting of a stereoscope which may be moved in parallel directions and is joined with a parallax bar with a drawing attachment. The instrument is mounted on a special table which also serves as the top of the case.

The stereoscope is mounted on parallel guide bars and may be moved to any portion of the stereo model without disturbing the initial orientation of the photographs once they have been oriented and fixed on the table; in this position the measuring marks of the parallax bar are constantly located within the field of view and its pencil may be used for sketching contours and tracing the horizontal lines.

The parallax bar (Figure 56) serves for the measurement of longitudinal parallax. It has the following construction. Glass plates with dots engraved upon them are fastened to a rod. Both dots may be displaced along the rod. The operating distance between dots is established by displacement of the left dot and fastened with a set screw. The right dot is displaced by means of a parallactic screw and the value of its displacement is determined first from the scale and then from the cylinder with an accuracy of ± 0.02 mm.

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With the aid of the parallax bar it is possible to mark the contours directly on the photographs by noting points of identical elevation or to draw them on the plotting board located beneath the stereoscope between the photographs. For this purpose and also for the transfer of contour lines use is made of a pencil attached to the parallax bar. Hence the parallax bar is sometimes referred to as a drafting stereometer.

For measurement of rectangular coordinates of points on the left-hand photograph the stereopantometer has two scales graduated in millimeters. The scales are mounted in such a manner that the beveled edge of the one serves as the reading line for the other. The coordinates are measured by eye with an accuracy of tenths of a millimeter.

For determination of height differences of individual points located close to one another (the height of a bank above water, the height of individual trees, etc.) the simple and sufficiently accurate D-6 measuring stereoscope (Figure 57) is used.

This instrument successfully combines a simple lens stereoscope with the above described parallax bar. The D-6 stereoscope is a binocular with lenses replaceable by plane parallel plates on which sighting lines are etched. In order to adjust the stereoscope for the optical base the left ocular is displaced relative to the right ocular and in the chosen position is fastened by means of a pressure screw. In aligning the spatial sighting line with points on the model the lower part of the right ocular is displaced relative to its upper part along the base by means of the parallax screw. A change in the distance between the sighting lines is perceived as a drop or a rise of the line relative to the observed point of the model and is read from the millimeter scale and the cylinder of the parallactic screw; the scale division of the latter is 0.02 mm.

In recent years the parallactic plates of F. V. Drobyshev (Figure 58) have found wide use as a measurement device for the lens-mirror stereoscope. They are constructed on the principle of sine or proportional scales and are used for measuring the differences in longitudinal parallax.

The assembly consists of two plates P_1 and P_2 made of organic glass (white plexiglass), a board D with clamps Z for the photographs, and a guide rule L_1.

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The sighting marks in this instrument are movable and are made in the form of parallel marks applied to the plates. The inner edges of the plates are beveled and have the same angle as the direction of the sighting marks ($\delta = 5^\circ 44' 20''$, $\sin\delta = 0.1$). On the beveled edges of the plates we find: on the left plate, a millimeter scale; and on the right plate, the index.

During measurements the plates are placed directly over the photographs so that they are oriented under the stereoscope and are fastened to the board; in addition the beveled edges of the plates are firmly pressed against one another and the sighting marks are located perpendicular to the direction of the base of photography -- the ordinate axis.

Moving the plates together along the guide rule or individually (the right plate along the beveled edge of the left) the observer sees beneath the stereoscope one spatial sighting mark suspended above the model, which mark may be made to merge with the stereo model at any point, just as in operation with the topographic stereoscope.

Alignment of the sighting marks and the numbering of the millimeter scale on the plates is performed so that the reading from the scale is made when the spatial sighting mark merges on the model with a certain point A equal to the distance between corresponding points a_1 and a_2 on the photographs or the longitudinal parallax of point A in its conventional expression.

In order to determine the difference in the longitudinal parallax of two or more points each of them must be aligned with the spatial sighting mark and the reading must be made from the scale. The difference in readings gives the required difference of Δp in millimeters.

On the left-hand plate there are five sighting marks 10 mm apart and numbered 0, 10, 20, 30, and 40. In measuring the parallax the operating mark is that mark which during binocular observation merges with the mark of the right-hand plate into one spatial sighting mark. If in the process it is necessary to change the operating mark (for example, if from the zero mark it is necessary to transfer to the mark numbered 10) then the reading from the scale is increased by 10 mm. If the entire model may be processed from one and the same mark, then it is not necessary to make any such change in the reading.

On the right-hand plate, in addition to the base index located in the middle of the inner edge, there are two auxiliary indexes located at the edges and inscribed + 10 and -10. These indexes are used when the base index goes beyond the limits of the scale; the reading then varies accordingly

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by +10 or -10 mm (Figure 59).

The error in measurement of Δp due to the use of sine rules is ten times less than the error in reading from the base scale; consequently, assuming the latter to be equal to ±0.2 mm, with the aid of parallactic rules Δp may be measured with an accuracy of ±0.02 mm. In practice such accuracy is not maintained, for in order to align the sighting mark having the same depth it is necessary to make the adjustment by hand.

The measurements are considered satisfactory when the difference between two readings upon alignment of the sighting mark with one and the same point does not exceed ±0.06 mm; in this case we take the arithmetical mean of the readings.

The data of the measurements and the calculations performed from them are entered into an appropriate record (Table 6).

All the above described instruments and attachments for measurement of the differences in longitudinal parallax are satisfactorily performed only in the case of the processing of horizontal photographs obtained on a horizontal base of aerial photography. In processing vertical aerial photographs determination of the differences in longitudinal parallax are accompanied by errors which in turn lead to errors in determining the deviations. These errors increase in proportion to the departure of the conditions under which the photographs were obtained from those conditions for which the formulas are derived for the relation between the difference of longitudinal parallax of points and the difference of their elevations. Calculation of these errors and correction of the resulting differences in longitudinal parallax are performed by analytical, graphic, or optico-mechanical means.

For more precise work directly on nontransformed photographs with dimensions of 18 by 18 cm F. V. Drobyshev has proposed the use of a stereometer consisting of a stereocomparator with the addition of corrective attachments compensating for the effect of elements of exterior orientation.

The Drobyshev stereometer is produced in two variants: a precision stereometer (which, with zero adjustments of the corrective attachments, is converted into a stereocomparator) and a simpler device which is a topographic stereometer.

Determination of the height of points on the precision stereometer corresponds in accuracy to the requirements for compilation of a map on a scale of 1:25,000, and on the topographic stereometer on a map with a scale of 1:50,000.

The contours obtained by means of stereometers pass through the images of points through which they must pass in nature, hence such drawings made directly on contact prints may find widest use in survey practice, providing material for the planning of various installations even before obtaining a precise topographic map of the entire region. For the compilation of maps the resulting contours must be transformed, and this problem is solved by means of various types of drafting pantographs or ordinary transforming printers with the simultaneous reduction of the scale of the photograph at which the contours were drawn to the scale of the compiled map.

The above instruments are the basic instruments used for obtaining the elevational characteristics of a photographed terrain from its stereo model. Each of them is designed for the solution of a relatively limited problem in the complex process of compiling a map by the differentiated method. Most of these instruments, being simple in operation and portable, may find wide application under expedition conditions in the most varied investigations of natural resources.

In the instruments of the universal method of compilation of a topographic chart all the processes of photogrammetric handling of photographs, beginning with the reproduction of the optical model and ending with the topographic map, are automatically operated and combined in one, usually extremely complex, and hence somewhat bulky, instrument.

The instruments of the universal type are produced in three variants: (a) instruments of optical projection; (b) instruments of optico-mechanical projection; and (c) instruments of mechanical projection. Practice in the Soviet Union finds widest use for the first two variants, one of them being the aerial projector multiplex and the other the stereoplanigraph. Description of these complex instruments is given in special courses.

Procedure for Plotting the Transverse Profile across a River Valley

From the points of a stereo model chosen along a straight line it is possible to construct both longitudinal and transverse profiles for water objects. For the plotting of a transverse profile across a river valley it is necessary to give its direction on one of the photographs comprising

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the stereo pair (the left), to locate the points of flexure on the stereo model, and to keep them well in mind on the given direction of the profile. After this it is possible to proceed to measuring the longitudinal parallax and to determining deviations from the above formulas (Table 6). Particular care must be exercised in measuring points corresponding to the shoreline and the ridgeline of the valley.

TABLE 6

SPECIMEN OF JOURNAL FOR MEASUREMENTS OF TRANSVERSE PROFILE

The transverse profile is compiled from the obtained data by the usual method.

As was mentioned above, in plotting the profile, especially for large rivers, it may happen that the parallax of a point taken at the water level of the left bank differs from the parallax of a point taken at the water level of the right bank by a more or less considerable value, which indicates the presence of general transverse tilt of the model. If rotation of the photographs in their plane (as was discussed above) does not give the desired results, then it is necessary to restore the orientation of the photographs from the initial directions and to perform the measurements, processing them in the following manner. One of the points (Figure 60) must be assumed at zero and a general rotation of the profile must be achieved relative to it, taking into consideration the correction for each point of the profile proportional to the distance of the latter from the point taken as zero. This calculation may be performed by graphic methods as shown in Figure 60.

The calculated corrections with the appropriate sign are inserted in the measured differences of parallax, after which the deviations are calculated (Table 7).

Experience has shown that if the model does not have substantial distortions and the line of the profile with the direction of the base of the survey forms an angle approaching a straight line (Figure 60), then a transverse profile plotted across the river valley from aerial photographs is in excellent agreement with the geodetic profile even when the stereo model lacks definite geodetic control points and is processed with the simplest instruments. Errors not exceeding in most cases one meter are obtained at points removed from the base and, in addition, in those cases where, due to an indistinct image or at extremely small geological folds in the terrain, the observer is not sure of his observations.

The results are considered sufficiently accurate and replace instrumental measurements in those cases where the stereo pair provides such a number of control points as will permit reliable control of photogrammetric determinations and corrections from them according to the method of the undistorted model. In this case the profile plotted from photographs is quite indistinguishable from and is even more accurate than a profile which may be plotted from a large-scale topographic map.

TABLE 7

SPECIMEN OF A JOURNAL FOR CALCULATIONS

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In those cases where it is possible to use instruments designed for precise reproduction of the bunches of projecting radials and to obtain topological stereo models, the plotting of such profiles becomes possible in any direction and, moreover, is performed by automatic means. The widest use of stereoscopic profiles is found in the preliminary study of water objects for the selection of those points and portions of water objects at which it is necessary to lay off instrumental profiles directly on the terrain or to perform specific investigations with the aid of photometric and other devices.

In any case, the profiles plotted from aerial photographs are considerably more accurate than profiles plotted on the basis of visual or semi-instrumental surveys. Their use for the explanation and description of a type of river valley, lacustrine basin, etc., must find wide application in hydrographic investigations.

CHAPTER IV

INTERPRETATION OF AERIAL PHOTOGRAPHS

Section 18. General

The completeness and reliability of information obtained from an aerial photograph depends:

(a) on the accuracy of the calculation of the conditions under which the photograph was obtained;

(b) on the ability of the investigator to develop an original code to which the image of the investigated object may be subjected (its interpretation) and to interpret the resulting information.

The task of interpretation thus reduces to a representation of the object under investigation on photographs, establishing its qualitative and quantitative characteristics, and explaining the relation of this object to its environment.

By analogy with a general geographic map, on an aerial photograph we may observe: a base, being a contour map of the terrain on the scale of the photograph, and the superimposed information in a volume determined by the tasks of the given investigation. In this connection interpretation is divided into general and special hydrographic interpretation.

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It is the task of general or topographic interpretation to explain and evaluate the principal elements of a landscape comprising the topographic base of special investigations.

The volume and tasks of special interpretation may vary over a wide range.

The methods of general interpretation of aerial photographs have been developed in adequate detail and presented in instructions and handbooks for the compilation of topographic maps by the aerial photographic method as well as in all works devoted to problems of application of the aerial photographic survey within various branches of investigation of natural resources. In these works considerable attention is usually devoted to the interpretation of water objects as the principal elements of the landscape.

Problems of special interpretation have not been so well developed and the detail in their development is in direct proportion to the volume of those tasks which the aerial photographic survey procedure has been able to solve in one or another branch of investigation of the natural resources.

The photographic interpretation of forest areas has been more thoroughly developed. Forestry specialists were among the first to use the aerial photographic survey in their investigations and have accumulated a wealth of experience in the interpretation of aerial photographs. This experience is widely used in contiguous regions, including hydrographic interpretation.

According to the site of its execution the interpretation of aerial photographs may be divided into field interpretation and office interpretation.

In performing field interpretation (in which the recognition of local objects and elements of the landscape on the photograph is performed directly in the field) the interpreter achieves a complete ground investigation of the object, relieving him of the mapping and limitations which are created under the conditions of a ground survey. This advantage, arising in the use of the aerial photograph as a topographic base, may be even greater if so-called standard sections are previously chosen from the materials of aerial photography and then subjected to detailed investigation and the conclusions obtained from them are applied to considerable areas. In this case the field interpretation of photographs may to a considerable degree be replaced by office interpretation.

The method of standard interpretation, which has found wide application in aerial-geodetic enterprises, may also prove extremely convenient in hydrographic investigations, especially in those cases where continuous investigations of one or another object (for example, of a large swamp area) are replaced by selective investigations and the identity of the remaining portions is established only from the general externals of their appearance.

Office interpretation of aerial photographs is performed when absolutely reliable identifying features are available (see Section 19).

Notwithstanding the fact that an extremely large number of elements of a landscape on aerial photographs is recognized without any difficulty and may easily be identified with standards, the results of office interpretation of a number of elements of water objects and terrain, even in the presence of standards, may be considered reliable only on the condition that they are obtained by specialists having adequate experience. Hence it is necessary to conduct a trial field interpretation, especially in view of the present state of the procedure of hydrographic interpretation of aerial photographs.

Thus, the distinction between field and office interpretation is extremely conditional.

Interpretation must be considered as a distinct process of photographic investigation in which both field and office operations are performed and supplement and control one another. According to the tasks confronting the investigator, one or another form of operation acquires greater or lesser importance. Thus, in detailed investigations great importance is attached to field interpretation, and in reconnaisance investigations great importance is attached to office interpretation; however, as will be seen, this assumption cannot be considered invariable.

Finally, interpretation may be: visual, semi-instrumental, and instrumental.

Each investigation of the materials of an aerial photographic survey begins with a general examination of individual photographs or a series of photographs joined in a photomosaic /fotoplan/ or a photodiagram /fotoskhema/. In some cases (for example, for objects of considerable size and clearly shown on the photographs) such examination for visual interpretation may be adequate and sometimes even exhaustive.

Semi-instrumental interpretation is performed visually with the aid of the simplest instruments (ranging from a magnifying glass to a stereoscope). It is the principal method of operation in studying aerial photographs and is used both under field and under office conditions. Semi-instrumental interpretation is performed from contact prints, individually or mounted in a photodiagram, and from a photomosaic.

Instrumental interpretation reduces to the measurement of an object and the compilation of graphic and tabular quantitative characteristics achieved under office conditions with the aid of sometimes somewhat complex photogrammetric and other precise measuring instruments. Instrumental interpretation is performed chiefly from aerial negatives. The above classification of interpretation of aerial photographs is not without qualification. More accurately, we distinguish two types: the visual and the conceptual (in the broad sense of the word) instrumental interpretation.

The term "instrumental interpretation" is sometimes used for designating the more objective methods of interpretation in which the personal participation of the observer is reduced to a minimum. Among such methods are photometric investigations of aerial negatives, performed for the purpose of establishing certain relations (for example, between the optical plane of the negative and the depth of a stream of water, etc.). Such interpretation is instrumental in the real sense of the word, and hence there is justification for distinguishing an intermediate type consisting of semi-instrumental interpretation.)

Section 19. Identifying Features

The factors determining the character of a photographic image are often not constant and under given conditions one and the same terrain on a photograph (see Figure 16) may have completely different images. However, for all objects there exist sufficiently stable "features" which directly or indirectly indicate the presence of a given object on a photograph and the natural conditions of the object as well as its relation to the environment. Such features are known as identifying features.

Interpretation of aerial photographs is based on direct, indirect, and complex features.

Direct identifying features permit the detection and examination of local objects seen on the photograph.

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The direct identifying features are the shape and size of the image on the photograph, the tone((which gives the image its clarity), and finally the image of shadows of local objects on the photograph.

The shape of the image is one of the principal identifying features from which we first establish the presence of the object to be studied on the photograph and then its basic properties. For example, from the shape of the image we establish the presence of a canal and its distinction from a stream; on the basis of this same feature we distinguish a highway from an ordinary dirt road, etc.

Notwithstanding the fact that in being subject to the laws of perspective the shape of the image depends on the conditions of the survey and hence the same objects may have different images on vertical and oblique photographs, in interpreting them the shape of the image is a sufficiently stable identifying feature. By representing the object as a series of lines and planes and knowing the position of this object relative to the center of projection, which is the center of the lens of the aerial camera, we may predict the image of a given object on a vertical or oblique photograph.

It must be pointed out that, despite the sharp distortion of geometrical outlines of local objects on oblique photographs, interpretation is easier with oblique photographs than with vertical photographs. This explains the greater adaptability of our eyes to the image of a terrain on oblique photographs.

The outlines of flat objects lying in the plane of the base are transmitted completely and without distortion on vertical photographs. The shapes of objects having elevation are transmitted only in part, since the photograph obtains an image of only the visible portion of the object (for example, in the case of a house, its roof); in addition, these shapes are distorted, since the aerial photographic survey is a central and not an orthogonal projection. Hence an individual tree at the center of a vertical photograph is expressed in the form of a projection of its top over its greatest diameter, and at the edges of the photograph this projection is displaced from the base in the direction of the nadir point; it is correspondingly lengthened and, along with the projection of the top of the tree the side surface of the tree also becomes visible.

In the interpretation of single photographs the actual shapes of objects must be reconstructed from the parts forming the image on the photograph, in which process a large part is played by the shadows of the local objects falling on open ground or a water surface. For example, shadows permit us to recognize the construction of a bridge, to distinguish an industrial installation from an ordinary residence, to establish the presence of lines of communication on the photograph. Shadows substantially facilitate interpretation of forest areas, etc. Hence the shape of the image of local objects on photographs, as an identifying feature, must be studied along with the shape of the image of its shadow.

In order to obtain the most accurate representation of the spatial shapes of local objects from their images, stereoscopic study of the aerial photographs is performed.

The dimensions of the image are just as important as its shape in permitting identification of the object under study from the mass of similar objects shown on the photograph on the condition that the scale of the image permits distinguishing the given object, evaluating its dimensions as though viewed visually, and comparing these dimensions with those of other objects.

In the interpretation of local objects of small size it is first of all necessary to determine whether or not, on the given scale of survey and with the given resulting power of the lens and the given photographic emulsion, it is possible to obtain images of these objects on a contact print.

In making this determination it is necessary to consider not only the dimensions of one or another object but also its other properties (for example, the color, the reflectivity of its surface, etc). It is known, for example, that on large-scale photographs the ties and rails of railroad tracks are quite distinct, despite the fact that in a given case the objects have very small width. This is partly due to the high reflectivity of the polished surface of metal, especially apparent with adequate illumination, over the extent of an object with a series of very small ties which nevertheless cause a definite outline of the images. Due to the shadows on a monotone surface of snow as well as on a meadow, the footpaths, individual furrows, shrubs, etc. are clearly distinguishable; on a water surface the same applies to waves and other objects.

The resulting power of the retina of the normal human eye permits detection of objects having dimensions of approximately 0.08 millimeters at the distance of optimum field and the comparison of linear values if the difference between them is 0.1 millimeters. It is noted that the minimum length which is distinguishable on an aerial photograph is assumed to be 0.08 millimeters for elongated objects and the minimum area for circular objects is a point with a diameter of 0.10-0.15 millimeters.

If 0.2 mm is assumed to be the minimum dimension of the image (that is, to assume the accuracy employed in graphic measurements), then the error in determining the dimensions of such objects may reach ±0.1 mm or 50 per cent, and in the absolute expression it will depend on the scale of the survey. Thus, the graphic accuracy of measurement on a scale of 1: 5,000 is ± 1M and on a scale of 1:50,000 it is equal to ± 10 M.

In order to increase the accuracy in measuring dimensions and to examine especially small objects use is made of magnifying devices and, particularly, special measuring glasses. However, the use of the latter is possible only within relatively small limits under the conditions of exceptionally clear images. Experience has shown that the magnification of images obtained on aerial photographs cannot be greater than 2.5 times due to the low resolving power of the photographic emulsions.

In determining the height of objects of an aerial photograph in those cases when the conditions of work do not require high accuracy, visual approximations are made with the use of an ordinary stereoscope. In more precise operations use is made of measuring stereoscopes and other instruments used in the stereoscopic processing of photographs for the compilation of topographic maps.

The accuracy of the determination of height characteristics depends on the instrument and the method by which they were obtained; in other words, on the accuracy of reproduction of the model and the method of its measurement.

The tone of the image or the degree of blackening of the photographic emulsion on the aerial photographs depends on a large number of factors. Chief among these are: the angular elevation of the sun's rays, the nature of the surface of the photographed object, the color of the object, the state of the atmosphere, the characteristics of the negative and positive materials.

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etc. Most of these factors are extremely variable from point to point and in time, hence the tone of the image cannot be considered a stable and reliable feature. In interpretation image tone is used within the limits of a relatively small series of photographs and under the conditions of a monotone terrain — within the limits only of a single photograph and in conjunction with other features. However, the use of the tone as a feature for judgment of the general character of a terrain or local objects is sufficiently reliable. For example, from the overall tone of an aerial photograph we may judge the character of the relief of the terrain monotone grays in a photograph indicate the level surface of a terrain, and alternating dark and light portions may indicate the presence of sharply expressed relief.

An invariable condition for the use of image tone as an identifying feature is the presence of information concerning the state of the object itself at the moment of photography and the conditions under which the photography was performed. This is necessary because one and the same locality, photographed at different times and under different conditions, has images which differ in tone. It is especially necessary to keep this in mind in hydrographic interpretation where it is quite often necessary to use the tone of the image as an identifying feature.

As an independent identifying feature the tone of the image is used in aerial photographic investigations performed after the method of spectrozonal survey (Section 5). Selecting the appropriate combinations of film and filters, from the tone of the resulting images we may establish not only the presence on the photograph of one or another object having natural or artificial concealment and thereby causing the latter to blend with the surroundings, but also to determine certain specific peculiarities of this object. An imperative condition for such determinations is the possibility of comparing two or several images of the object plotted in different portions of the spectrum and obtained simultaneously within a short period of time (Figure 16).

Shadows are a principal feature from which the spatial forms of local objects may be identified on a single photograph. Shadow is used chiefly in establishing the shape of local object and plays a large role in interpreting relief, vegetation, and artificial structures. Shadow must be studied according to dimension, shape, tone, and direction. Only under these conditions may it be fully utilized as an identifying feature.

In all local objects imaged on the aerial photograph distinction is made between shadows proper and incident shadows.

The shadow proper, covering that part of the surface of the object which is not illuminated by the sun, has somewhat brighter tone than the incident shadow of the object on the earth's surface or the surface of a body of water (Figure 61).

The presence of shadow at local objects in most cases somewhat facilitates their interpretation, especially under the conditions of flat terrain in studying miccrorelief. In the latter case the shadow is a principal identifying feature, for example, in detecting small features which are difficult to examine even under a stereoscope.

In some cases the shadows become an inhibiting factor in interpretation rather than an identifying feature. Their application to the aerial photographic survey has a special terminology. Quite often a shoreline is concealed in a deep shadow casttby high treos or banks; underbrush and small details of relief are also often concealed by tree shadows; in rugged terrain the images of bank slopes may be invisible due to shadows; wide ravines and fjords may be concealed in the shadows cast by high peaks. Hence, in interpreting aerial photographs particular attention must be paid to the shadowed portions and in the selection of contact prints photographs with extreme contrast; poorly developed semi-tones must be rejected.

On the basis of the proportion between the height of an object and the length of its shadow the latter may be used in determining the height of the object. Such determination is not marked by a high degree of accuracy and is used chiefly to obtain the qualitative characteristics of relief (since it is known that the length of the shadow depends upon the angle of the slope) but sometimes also for determining the height of individual objects.

This is done in the following manner.

According to the length of the shadow of the local object as measured on the aerial photograph (for example, of a tree) its height may be determined from the formula $h=T\tan\varphi$,

where h is the desired height, T is the length of the shadow, and φ is the angle of incidence of the sun's rays with the horizon (see Figure 61).

On a vertical aerial photograph $T=tm$, where t is the length of the shadow and m is the denominator of the numerical scale of the photograph; whence $h=tm\tan\varphi$

The angle φ in this case must be determined by somewhat complex calculations. The results obtained by use of the above formula cannot be considered highly accurate, for the length of the shadow depends not only on the elevation of the sun but also on the characteristics of the surface on which the shadow falls. If the shadow falls on a sloping surface, then its length will be distorted (Figure 62).

By using appropriate tables or graphs of relative heights of shadows and knowing the latitude of the locality, we may determine the height of local objects from the formula

$$h = \frac{T}{n} = \frac{tm}{n},$$

where T, t, and m are the same values as given in the above formulas, but n is the relative length of the shadow chosen from tables or graphs for the known latitude of the locality, the date, and the time of photography.

Example. On a photograph with a scale of 1:15,000 made on 10 June at 9 o'clock in the morning the length of the shadow of a tree is 2 mm. The latitude of the locality is 58 degrees and its surface is flat. The relative length of the shadow under such condition is 0.95 (Figure 63).

Substituting these values in the formula, we obtain the following height of the tree:

$$h = \frac{2 \text{ X } 15{,}000}{0.95} \approx 31 \text{ M.}$$

More simply but with the same reservations concerning the slope of the surface, the height of locat objects is determined by comparing the length of their shadows with the length of the shadow of an object whose height is already known.

In this case we use the formula

$$\frac{h_1}{h_2} = \frac{t_1}{t_2},$$

where h_1 and h_2 are respectively the known and undetermined height of local objects, t_1 and t_2 are the corresponding lengths of shadows on the aerial photographs.

As a particular example of determining the height from a single aerial photograph we may refer to the method used by geologists. It consists in the following. Proceeding from an observed uniformity of slope of ridges, mountainsides, etc, and knowing for the area under study the mean angle of equilibrium (25-30 degrees), the heights of individual slopes may be determined from the formula

$$h = \; M\tan$$

where is the width of the anterior slope of the ridge, is the angle of equilibrium of the slope, and m is the denominator of the numerical scale of the photograph.

Indirect identifying features permit the use of directly detached features associated with the given object in determining the presence of other associated objects or phenomena. Consequently they flow from the natural circumstances of a given object and its relations with the environment.

For example, if a dirt road proceeds from both banks of a river, then it may be assumed that at the given locality there must be some means of crossing even though there is no ferry or other means of transportation visible. If this section of the river is shallow, then it may be concluded that there is a ford here.

The assumption of the existence of a ford or other means of crossing at one or another part of a river is checked also by other means (for example, by consulting existing data on river depths, the location of sandbars, etc.) whereby we check for the possible existence of one or another type of crossing at the given section of the river under investigation. Such a check provides the required verification of the previous conclusion.

Proceeding further along this line of reasoning, a straight road not interrupted in its approach to the river may be considered as an indication that the banks of the river slope gradually, that the river flow is slow, that the river bed consists of compacted materials. The continuity of a road may be indirectly judged from the frequency of the use of fords. The width of a road or tracks, if the latter are shown on the photograph, may be an indication (as in the case of a ford) of the use of the road by horses or automobile transport, etc.

Thus, logical conclusions based on indirect signs lead to establishing a series of relationships whereby we may express what are often complex regularities associated with the various elements of the terrain. As an example we may cite the relations between the tree types, the lithological composition, and the relief as developed in forestry interpretation.

Complex identifying features permit determining the general characteristics of the terrain or the association of similar objects from a definite combination of individual direct and sometimes also indirect features.

Complex features include:

(a) The number or recurrence of objects on the photograph. Thus, if the photograph shows a large number of randomly dispersed boulders each of which is reliably identified, then it may definitely be concluded that there are signs of glacial activity in the area. This evidence may also serve for a general evaluation of the character and intensity of ice flow on the river.

(b) The relative location of objects characterizes the interdependence and time relations existing between the elements of the terrain as well as between elements of artificial structures. This feature is easily used in distinguishing a fruit orchard from a park, and the latter from a forest. In the given case the external appearance of the image (its shape) plays a principal role. From the shape of the image and the relative location of objects we may establish the existence of reclamation ditches in a locality and determine their purpose -- for irrigation or for drainage. The observed regularity in location of dwellings characterizes the type of settlement, etc.

(c) The signs of human activity or economic utilization of objects. Despite the numerous types of economic uses for water objects, each of these types has definite and stable features. For example, the presence of a dam with a sluice or without a sluice affirms or rules out the use of the river as a passageway for vessels, even in the absence of visible vessels on the photograph. Peat bogs have a definite image on an aerial photograph. From their appearance we may establish not only the state of utilization of the peat but also the method of extraction, etc.

(d) The over-all character of the image. Certain elements of the landscape, being of greater or less area (for example, forest masses, arable land, swamp, etc) have a well-defined structural pattern. Such structure, perceived as a whole, may be considered as a direct sign for the interpretation of certain elements of the landscape. This feature is usually associated with the tone of the image.

This discussion has been limited to the principal complex identifying features. Their number may be considerably increased by consideration of the indirect stable features by means of which we identify one or another object.

In recommending the aerial photographic survey as a method of investigation of natural resources, A. Ye. Fersman pointed out that "little by little the problems of interpretation and expansion of the analysis of aerial photographs turn to the special branch of geographic science, reflecting in a completely new manner those interrelationships which exist between the individual elements of the earth's surface." Hence, it is natural that the interpretation of aerial photographs performed for hydrological purposes, as in all geographic investigations, is inconceivable without preliminary familiarization with the object under investigation according to existing materials. Preliminary information concerning a water object under investigation permits grouping of the indirect features for a given purpose and also permits generalizations on the basis of an analysis of the interrelationships existing between individual elements of the landscape.

The possibility of greater or smaller use of both direct and indirect identifying features depends on the type and scale of the aerial photographic survey, the type of camera equipment, the conditions of photography, selection of a portion of the spectrum, the methods of processing the materials, and a whole series of conditions determining the possibility of using the aerial photographs which meet the purposes of the investigation in progress. The effectiveness of these features depends to a considerable degree on the experience and knowledge of the investigater.

Section 20. Methods of Interpretation

If the object to be interpreted has a clear image on the photograph and the identifying features are known, then interpretation of this object presents no particular difficulties; it is simply interpreted from the photograph.

The absence or insufficiently clear appearance of even one of the direct identifying features adds considerably to the difficulty of interpreting aerial photographs. In this case it is necessary to search the photographs for evidences of such relations between the elements of the landscape as exist between then in nature. It often happens that certain of the components of such a relationship may be lacking or have distorted images on the photograph. This is most often the case with the tone of the image, for it is one of the least stable identifying features. In such cases the interpreter, having at his disposal a group of features which are, as a rule, peculiar to a whole series of different objects (for example, similarity in shape, dimensions, or in the tone of the image), draws up a series of assumptions concerning

That which is shown on the given photograph. Eliminating the least likely of these assumptions and adopting various additional features, he proceeds by the method of sequential approximations to the most likely representation of the photographed terrain and makes his conclusion as to the presence of the object under investigation on the photograph as well as its properties. Obviously the data obtained in such a manner are not extremely reliable.

In studying the individual elements of any object (generally an object for which control points have been established) interpretation proceeds from the general to the particular. For example, on a meandering lowland river we may with good reason assume the presence of channel (deeper) and sandbank (shallower) sections and, selecting the tone of the image of the water on the photograph as the identifying feature, we may, by following Farga's instructions, search for the actual location of these sections, and we may attempt to make out the outline of the channel, etc. In this case, also, we do not eliminate the necessity to make conclusions with the aid of successive approximations. However, in the given case the conclusions are more reliable, since the object itself and its outline are more reliably established.

In the interpretation of extremely large objects it is often necessary to proceed from the particular to the general. Establishing on the photograph any element or group of elements of the object under study and knowing their interrelations as well as their association with other elements (the regularity in location, timing, etc), the overall picture is gradually reconstructed and we reveal not only the object itself on the photograph but also its relationship with the surrounding environment.

In the interpretation of aerial photographs it is quite often necessary to resort to the method of proceeding from the particular to the general, since on the photographs all objects having a certain height are only partially shown: on vertical photographs we obtain an image only of the upper part of the objects and on oblique photographs, part of the image's side surface. For this reason, in the interpretation of aerial photographs it is necessary to use a stereoscope, thereby avoiding guesswork in reproducing the whole object from a part.

Under no circumstances does interpretation become a complex investigation of all the details of the image obtained on the photograph. Secondary details on the aerial photograph are established with less thoroughness and may be grouped under macro features. For example, according to the thoroughness and accuracy of interpretation we distinguish the interpretation of terrain adjacent to a river valley, the valley itself, and, finally, the riverbed.

The volume and composition of work performed in interpretation depends upon the tasks confronting the investigations. For example, in preliminary hydrographic surveys of rivers these problems are determined by the schedule for the river survey.

One of the major shortcomings in interpretation (especially in office interpretation) is its subjectivity. This shortcoming can only be eliminated by appropriate organization of the process of interpretation, correct formulation of conclusions, and above all, standardization of these conclusions. Particular attention must be devoted to standardizing and checking the conclusions of the interpreter.

Section 21. The Basic Materials of Interpretation

For the most valuable and thorough use of the materials of an aerial photographic survey the interpreter must have at his disposal a whole complex of materials. Among this complex are included:

(1) aerial film or a series of aerial negatives (for instrumental interpretation);

(2) a series of contact prints;

(3) reproduction of an overlap assembly;

(4) clean (uninterpreted) aerial mosaics [fotoplan] or photo diagrams [fotoskhema];

(5) a topographic map;

(6) a record of the work performed with a detailed description of the conditions under which the aerial photographic survey was performed, the method of processing the materials, their plane and elevational bases, the characteristics of the resulting materials, etc.

Such completeness of materials can be expected in only a relatively few cases, as provided by materials two to three years old (that is, after such materials of an aerial survey have already been used for their initial purpose). In addition, it must be kept in mind that such completeness is to be found only in materials gathered by aerial geodetic enterprises of the system of the Main Administration of Geodesy and Cartography (GUGK). The materials of other institutes (geological, forestry, agricultural, and other aerial photographic surveys) are usually relatively incomplete.

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In all cases of servicing production enterprises, it is necessary to concentrate on obtaining the intermediate materials: a series of contact prints, reproduction of the overlap assembly, and a record of the operations performed.

One shortcoming of the materials of a photographic survey performed by GUGK (especially in hydrographic investigations of small water objects) is the relatively small scale of the survey as well as the fact that in certain cases the configuration of the flight paths does not correspond to the configuration of the water objects, rendering difficult the study of the latter. One advantage of these aerial surveys lies in the fact that they usually cover a considerable area and are excellent from the geodetic point of view, which cannot be said of surveys performed by other institutions.

In carrying out their principal taks (the compilation of topographic maps of different scales) the aerial geodetic enterprises of GUGK strive to make the scale of the survey coincide with the scale of the map which is to be compiled; hence, the intermediate products of the aerial photographic survey operation, especially from flights in recent years, are distinguished by their small scale (1:30,000 - 1:60,000). This should be kept in mind in selecting materials obtained in recent years in aerial geodetic enterprises of the system of GUGK.

The materials of specialized aerial survey enterprises (geological, railroad, agricultural, forestry, etc) are distinguished by relatively great diversity. At these enterprises large-scale aerial surveys are often performed; however, in using the materials of these enterprises it is necessary to keep in mind the variety of these special purposes for which the aerial photographic operations were performed and to make the best of these unavoidable limitations. These limitations are most often associated with the area of the flight and its configurations. The flight may be performed over a predetermined route without embracing all of one or another water object. In addition, in conducting photography for special purposes use may be made of such a combination of film and filters as will result in an unsatisfactory image of the water object under investigation.

It is necessary to keep the above circumstances in mind in using the materials of mass aerial surveys as well as of specialized aerial surveys. It is clear that the greatest thoroughness and accuracy of information obtained from the materials of aerial survey is insured only when the latter is performed for the specific assignment of the hydrologist, with a consideration of all the specific features of the object under investigation.

Information concerning the presence of materials of an aerial photographic survey of one or another region of the Soviet Union is gathered in GUGK and its authorized agents throughout the Soviet Union. The nomenclature of topographic maps is used in controlling the materials of aerial surveys. The control unit is a map sheet on a scale of 1:100,000; the record materials for the aerial survey are usually formulated according to the individually performed operations -- aerial flights. Hence the study of the materials of an aerial survey must begin with a consideration of the work performed, deriving therefrom the data for selection of materials concerning one or another object or region.

For a thorough consideration of all the factors influencing the character of the photographic image in the aerial survey, the process of interpretation must employ the following data:

(1) information as to the time of the survey (date, hour, and minute);

(2) the characteristic of the aircraft and the aerial camera;

(3) the height of photography;

(4) a detailed description of the atmospheric-optical conditions and other conditions of survey;

(5) the characteristics of the film, filter, and materials used in the survey; and information concerning the treatment of these;

(6) the recorded information concerning the quality of the flight survey.

In order to insure the possibility of obtaining quantitative characteristics for the elements of a landscape it is necessary to have detailed information concerning the geodetic elements of the entire area covered by the survey in the form of a record of the coordinates, markings, and the system of the base.

In the records of aerial geodetic enterprises of the GUGK system as well as certain other aerial survey enterprises, in accordance with the current instructions for compilation of topographic maps, there are extremely thorough physical geographic descriptions of regions subjected to aerial photographic surveys. These descriptions are made according to an all-embracing program. Such descriptions are accompanied by numerous supplements and, in particular, by materials of standard interpretation performed directly in the field with the compulsory participation of qualified geographers.

From this portion of the record for the aerial survey the hydrologists may draw important information necessary for interpretation of aerial photographs and the compilation of a hydrographic description.

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PART TWO

HYDROGRAPHIC INTERPRETATION OF RIVERS AND LAKES FROM AERIAL PHOTOGRAPHS

CHAPTER V

GENERAL REMARKS ON THE HYDROGRAPHIC INTERPRETATION OF AERIAL PHOTOGRAPHS

Section 22. The Tasks of Hydrographic Interpretation

The first works in the field of application of aerial surveys to hydrologic investigations were begun in 1932 in the former Central Bureau of Water Cadastre of the State Hydrological Institute (GGI). A group of co-workers of GGI (D. I. Nikiforov, N. P. Predtechenskiy, S. L. Vendrov, L. O. Pallon, et al.) together with specialists of the Scientific Research Institute of Aerial Surveying (V. A. Fass, A. P. Yushchenko, et al.) studied the possibility of obtaining hydrological characteristics from aerial photographs and there were performed the first experiments in the application of the photometric method of determining depths.

The results of these works were published in a special collection [75].

It must be pointed out that as a result of these works there were obtained a series of important additional data for the use of aerial surveys in hydrological investigations which even at this late date have not been fully exploited.

In 1945 - 1947 GGI performed a number of special aerial survey operations. There was also developed a method of aerial visual observation of the state of the ice cover, floods, and snow cover, and a number of important works were performed on the stereoscopic - photographic survey of sea swells.

In this same period recommendations were made for the use of materials of aerial surveys in preliminary hydrographic surveys, resulting in the present "Instructions for Preliminary Hydrographic Surveys of Rivers" (published in 1949).

Since 1948 GGI has devoted special attention to problems of accuracy in interpretation, particularly in the effect of natural concealment on the accuracy of measurements of individual elements of rivers. As a result of these studies it has been possible to proceed to the problem of selecting

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optimum scales for surveys.

In 1950 work was begun on the preparation of the present textbook, since the recommendations of the abovementioned instructions did not provide for a procedure of hydrographic interpretation and there were no provisions made for practical instructions and illustrations in this regard. The first results of these preparations were published in 1952 [51].

As a result we may proceed to the following basic conclusions.

The use of aerial surveys permits:

(1) fixing the practically instantaneous state of a photographed surface over a large area;

(2) obtaining a detailed image of this surface with a large selectivity of material; in other words, to obtain the characteristics of the photographed surface from the wealth of detail or data which may be obtained from large-scale maps, and in a number of cases also in the execution of ground surveys;

(3) using the aerial photograph for measuring purposes in order to obtain plan views, profiles, and numerical characteristics of the photographed surface or of its individual elements for practically any point of the terrain with sufficient frequency of repetition as to insure a high quality of materials and the possibility of careful control. Such possibility is practically eliminated in field investigations.

The use of aerial surveys for hydrographic investigations permits:

(1) obtaining informative characteristics of photographed water objects and their watersheds and to reveal a number of their elements which are not obtainable in ground investigations;

(2) on the basis of a compilation of a series of aerial photographs, fixing the instantaneous states of water objects in different characteristic periods of their regimes, to obtain data concerning the direction and intensity of development of a series of hydrological processes (the course of snow cover, icing phenomena, floods, erosion of banks, etc.). Due to the possibility of embracing large areas within short periods of time, such materials are undoubtedly more advantageous than those obtained from ground observations;

(3) to investigate the relationships both between individual

hydrological factors and between these factors and other elements of the geographic environment with respect to their periodicity, distribution, character of occurrence, etc;

(4) to trace the history of development of a series of hydrological processes. For example, the microrelief of a bottomland (a displacement fan) which is clearly visible on aerial photographs is extremely difficult to obtain by ground methods but permits tracing the different forms in displacement of a riverbed and also permits reconstructing the history of its development [7].

Thus, the use of an aerial survey in hydrological investigations makes possible its wide application not only for compiling hydrographic descriptions of a cadastral type, but also for a study of the regularities in a series of hydrological processes.

Consequently, in its application to hydrology the aerial survey may be considered as a method of investigation.

Hence it also follows that thorough interpretation of aerial photographs for hydrological purposes is not possible without a knowledge of the typical properties and characteristicsfeatures of a given terrain. Interpretation must be regarded as a definite creative process in which we not only state the presence of one or another group of objects and phenomena in the terrain under investigation but also establish and explain the causative relations between them. Without this the thoroughness and effectiveness of the information obtained as a result of interpretation are considerably reduced.

The present state of the procedures for general (topographic) and special (hydrological, geological, forestry, etc) interpretation permits in the investigation of rivers and lakes the solution of the following specific tasks with one or another degree of accuracy on the basis of aerial photographs:

(1) Determining the presence of water objects (rivers, lakes, swamps).

(2) Establishing the character of their relative locations, the local features and boundaries of the watersheds.

(3) Obtaining information concerning a river valley (or a lake basin), especially concerning the following elements thereof:

(a) the type of valley and its outlines in a plan view;

(b) the slopes of the valley — their height, abruptness, shape, intersections, vegetation, and soils;

(c) terraces, — their number, height, slope of embankments, surface slopes, width, vegetation, the degree of dissection, soil;

(d) the character of the bottom of the valley (bottomland) — its width, position to relative to the river banks (in the plan and elevation views), the nature of the surface, the degree of discontinuity, the vegetation, soils, the extent of flooding;

(e) the presence of landslides, rock waste (avalanches), mounds of eroded soil, and points of exit of ground waters;

(f) roads and footpaths on hillsides and at the bottom of the valley (bottomland);

(g) the swampiness of slopes and the bottom of the valley.

(4) Obtaining information concerning the river bed (or lake basin), that is:

(a) its outlines in the plan view — the meandering of the riverbed and the branches thereof (the presence of islands, channels, split streams, inlets, etc);

(b) river bed formations (reaches, sandbanks, falls, rapids, waterfalls, narrows, shallows, sandbars, beaches);

(c) the width, depth, direction, and rate of flow / current/;

(d) obstructions of the riverbed and their expansion;

(e) the relief of the bottom of the river and its soils;

(f) the river banks — their height and slope;

(g) the turbidity of the water.

(5) Obtaining information concerning hydrotechnical constructions — their location, type and construction, condition, dimensions, load capacity , and the nature of the approaches.

(6) Obtaining for an appraisal of the runoff conditions from the watershed of a river (or of a lake) the following data:

(a) concerning the relief — its type, predominant forms, their individual types, from the hydrographic point of view; the nature of the relative location of the various forms of the relief and their dimensions;

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(b) concerning the soil of the watershed — the limits of distribution of the principal soil varieties (clayey, sandy, gravelly, conglomerate, stony, peaty);

(c) concerning the vegetative cover in the area of the watershed — its character according to principal groupings (forest, shrubs, brush, meadows, fields, pastures, swamp), the nature of displacement over the area, the nature of each group (the visible composition, predominant rock formations, age, density).

In addition to obtaining the above information, the following tasks may be solved by interpretation of aerial photographs:

(1) Compilation from the aerial photographs of a cartographic base for navigation or pilotage maps with the interpreted details of the locality applied to them.

(2) Compilation of diagrammatic maps /Kart-skhema/ of the spatial distribution of hydrologic phenomena; for example, maps of floods, the course of freezing along the length of a river, the accumulation and movement of thaw or rain waters, selenium-bearing flows, the distribution of snow cover in an area, etc.

(3) Establishing the relationships between the hydrological factors and other factors of the geographic environment on the basis of an analysis of their relative periodicities. Solution of this problem is achieved chiefly due to great detail of the images of various natural elements and the selectivity presented by aerial photographs.

(4) Determining the direction of the development of various hydrological phenomena. As an example of such investigations we may consider: the study from a series of sequential photographs of the changes in relief of the bottom of watersheds or reservoirs, the study of the process of erosion of banks under the action of waves or landslides, study of the regularities in the formation of snow cover or its movement in the period of spotty cover of a landscape etc.

The list of problems which may be solved in interpreting aerial photographs for hydrological purposes has not been exhausted. Many possibilities for the use of an aerial photographic survey will undoubtedly present themselves in the future, which will prove to be of a wider practical use in employing the materials of the aerial survey for hydrological investigations.

Section 23. Detail of Information Obtained from Aerial Photographs and Selection of Scales for Aerial Surveys for Hydrographic Interpretation

The possibility of obtaining from aerial photographs detailed quantitative and qualitative characteristics of rivers and lakes depends upon the scale of the aerial photograph chosen for these purposes and on the n natural features determining the character of concealment of various elements.

We may distinguish optimum and extreme scales for aerial surveys used for hydrological interpretation.

By optimum scale is meant the scale permitting obtaining from the aerial photographs accurate, detailed information in the shortest time.

The extreme scale is the smallest scale permitting obtaining information concerning hydrological elements of the water objects in the form of generalized qualitative characteristics.

Thus, the optimum scale permits performing qualitative interpretation and detailed measurements from aerial photographs, but the extreme scale serves only for purposes of selection and permits obtaining only a general quantitative characteristic for the various hydrological elements.

The principal features of the optimum scale of aerial photograph consist in the following:

(1) The optimum scale of a survey is established according to the type and purpose of interpretation.

The use of an aerial photograph for measurement purposes, as a rule, requires larger scales and in interpreting for descriptive purposes. In this as in other cases the scale of the photograph will depend also on the accuracy required by the task which must be solved by the information to be obtained from the aerial photographs. Moreover, in a number of cases smaller scales will be preferred to large scales due to the fact that the small scales provide a great selectivity of terrain.

(2) The optimum scale survey depends on the size of the objects to be interpreted. The larger the object, the smaller the survey scale may be in order to obtain the majority of its characteristics.

(3) The optimum scale of a survey depends upon the features of the

interpretation of

interpretation of the given element. For example, different forms of natural concealment of hydrological elements (shorelines, bank overhangs, etc) by vegetation, shadows from local objects, snow, ice, etc, cause a lack of coincidence in graphic accuracy of measurements permitted by the given scale as compared with their operational accuracy. In these cases it is convenient to use larger scales, as this will provide greater graphic accuracy.

Consequently, the general assumption that the greatest accuracy of interpretation from aerial photographs is obtained from the largest survey scales proves incorrect in a number of cases.

The above conclusions lead to the necessity in a number of cases of using photographs of different scales for the interpretation of different elements.

Considering that the same detail of information concerning different hydrological elements is not always required, it is often possible, depending on the assignment and the study program, to use an overall optimum survey scale. If this is difficult, then we must designate certain stages of the operation which are to be performed on the basis of the aerial survey, and the other stages to be achieved by conventional ground operations; that is, we resort to the combined method of obtaining the information.

General considerations of the optimum survey scales required for performing hydrographic operations reduced to the following.

A sufficiently detailed interpretation of large items of relief is possible in stereoscopic study of photographs on a scale of 1:25,000 - 1:40,000, depending upon the nature of the relief, its continuity, and its concealment. A survey scale of 1:25,000 is desirable for a level or undulating relief, a scale of 1:40,000 and smaller may be used for a hilly relief. The use of photographs on a scale of 1:10,000 somewhat complicates the general characteristic of a relief due to necessity of mounting large maps. For the interpretation of individual shapes of relief the most suitable photographs are on a scale of 1:10,000 - 1:15,000. Interpretation of the microrelief usually requires scales greater than 1:10,000.

The survey scale from which we may obtain the most complete information concerning a river valley depends upon the size of the valley. The general characteristics of the valley may be obtained from photographs on the same scale as was used in interpreting the relief.

In order to obtain the most detailed characteristics of the slopes of valleys of lowland rivers with a valley width of 1-2 kilometers, photographs with a scale of 1:10,000 - 1:15,000 are required. With a valley width greater than two kilometers sufficiently detailed data may be obtained with photographs with scales of 1:25, 000 - 1:30,000.

The sides of hills and deep cuts (well expressed) of valleys with the same upper width (1-2 kilometers) may be interpreted from materials of smaller scales -- 1:25,000 and even 1:40,000.

Quantitative interpretation of bottomlands is possible on photographs of the same scales as were employed in interpreting the slopes of valleys. Measurement interpretation of microrelief of bottomlands and the height of river banks calls for large scales -- preferably 1:5,000.

With the larger scales there is a sharp decrease in the selectivity of information concerning the bottomland and, while the accuracy of measurement of individual details of its surface structure is increased, the disclosure of general regularities in the relative location of individual elements of the microrelief will be somewhat more difficult. In these cases photographic reduction of the assembled charts is recommended.

For greatest accuracy in plotting the profile of a valley in accordance with the above observations it is necessary to use photographs on a scale of 1:5,000 - 1:10,000 in which it is possible to detect microrelief of the bottomland. However, if the lower part of the profile is obtained by geodetic means, then plotting of the remainder, where the slopes are well expressed, may be performed from photographs on a scale of 1:25,000 and 1:40,000.

In order to obtain the characteristic of a riverbed it is necessary to have information concerning its various elements with a varying degree of detail. Hence, selection of one optimum scale for all interpretation of the elements of a riverbed is difficult.

Information concerning the outlines of a riverbed in the plan view or concerning the presence of flowing lakes may be obtained from photographs of any scale. Choice of the survey scale at which it is possible to obtain detailed characteristics of riverbed dimensions, various riverbed formations, the condition of the riverbed (obstructions, etc.), the bottom of the bed, and the height of the banks is determined chiefly by the size of the river itself.

The principal characteristics of the riverbed (that is, the width, depth, and height of the banks) must be taken as the principal criterion for evaluating the suitability of photographs of a given scale for interpretation of the riverbed.

The accuracy of determination of the width of a river from an aerial photograph depends upon the accuracy in determining the shoreline. The latter is determined not only by the scale of the photograph and the quality of the photograph image, but also by the nature of the conjuncture of two surfaces (the surface of the water and the bank), the junction of which gives the shoreline.

Special experimental operations performed in dealing with problems of interpretation have shown that the accuracy in determining the shoreline within the scale limits of 1:2,000 to 1:15,000 is in practice determined by the natural conditions of its concealment. Absolute errors in determining the shoreline for the most favorable conditions (the combination of a dark water surface and a steep bank) average 1.4 meters, and for the least favorable (a riverbed overgrown with aquatic plants) averages up to 3.2 meters. Consequently, for each type of concealment of the shoreline there will be a corresponding optimum survey scale. It varies from 1:8,000 to 1:15,000 depending upon the type of concealment. Thus, in the case of an apparent predominance of any type of shoreline concealment on the section of the river under study, the scales of the aerial survey must be chosen on the basis of this type of concealment. For the selection of this scale the chart shown in Figure 64 may be used.

However, on lowland rivers there is usually observed an alternation of shorelines with different types of concealment, whereas on the opposite banks the latter do not coincide. Hence, it is convenient in these cases to consider the optimum scale to be 1:11,000 – 1:12,000: then the average accuracy of determining the shoreline is approximately 2.2 meters.

Measurement of the width of a river from aerial photographs is conveniently performed only in those cases where the error in determining the shoreline does not exceed the graphic accuracy of the measurements on the photograph of the given scale.

Thus, from aerial photographs with a scale of 1:2,000-1:15,000 it is convenient to conduct measurements of river shaving a width of bed from 20 meters and greater. In this case the error in determining the shoreline is less than 10% of the width of the river.

For scales smaller than 1:15,000 the error in determining the shoreline, depending upon the conditions of its concealment, is considerably overlapped by the graphic accuracy of measurement on the given scale and hence the possibility of identifying a river of given length will depend only on the graphic area of the scale. Hence, considering the maximum graphic accuracy of measurement to be 0.2 mm, on photographs with a scale of 1:25,000 with an accuracy up to 10%, we may measure rivers with widths from 50m and on photographs with a scale of 1:40,000 rivers with a width of 80 m and greater.

Interpretation of depth is based on two principal operations — determining the character of the relief of the bottom from an aerial photograph and measuring by one or another method the deviations of the characteristic points of its undulation.

Thus, determining the optimum scale in interpretation of depths requires an appraisal of the possibility of obtaining both distances and deviations of points from an aerial photograph.

On an average we may assume that for hydrographic purposes the smallest survey scale permitting qualitative determination of the shape of elements of a riverbed is 1:10,000.

The detail of elements of riverbed formations which may be examined on a photograph with a scale of 1:10,000, given conditions generally permitting examination of the underwater relief (see Section 35), depends on the size of the river. For rivers with a width of 20 to 100 m on this scale we may see only the relative location of water and sandbars. With river widths exceeding 80-100 m we may distinguish the microrelief of the surface of various riverbed formations (sand deposits at sandbars, etc.). This is well illustrated in photographs 23 and 33 (see appendix), showing the form of relief at the bottom of the same section of river on photographs of different scales.

On photographs with a scale of 1:25,000 under the same conditions it is possible to determine the location of stretches of water and sandbars only for rivers with a width of the order of 50-60 meters and greater, but it is not possible to examine the microrelief of the bottom of these rivers, while for rivers of considerable width (greater than 200-250 meters) we may accurately define the principal parts of sandbars (crests, troughs, etc).

Optimum survey scales for stereophotogrammetric determination of depths (given an image of the underwater relief), as determined from experience in measurements, are 1:3,000-1:5,000. In this case the typical accuracy in determining depths is approximately 10 cm. On photographs with a scale of 1:10,000 the accuracy in determining the deviations is approximately one meter. Survey scales smaller than 1:10,000 are suitable only for the most general appraisals of distribution and the sequence of depth values on large rivers.

The question of the optimum scale for stereoscopic determination of the height of banks can be solved by analogy with the requirements which are presented in determining the deviations of points on the terrain. This is explained by the fact that in the given case the concealment of the water surface, on which all the readings depend, has a marked effect on the accuracy of interpretation.

As investigations have shown, for determining the height of banks on the order of 2-5 m on lowland rivers with well-expressed bottomland the optimum survey scale is 1:3,000. For rivers with nonflooding bottomlands, in cases where the river banks are the slopes of the valley with a height on the order of 10-15 meters and more, for measurement of their deviations above the shoreline sufficiently accurate use may be made of photographs of all scales up to 1:20,000.

Thus, as follows from the above discussion, for measurement interpretation of the principal elements of a riverbed (width, depth, and height of banks) as a rule, it is necessary to use large scale photographs (larger than 1:10,000) with the exception of the width of the river, for determination of which it is permissible to use photographs with smaller scales.

Hence industrial surveys performed on scales of 1:25,000-1:40,000 and smaller are as a rule suitable only for qualitative interpretation of the beds of large rivers. However, even in this case the detail with which these data are obtained somewhat exceeds that which is possible in their determination from a map or a plan of any scale and even in preliminary ground survey.

Data for the optimum scales necessary for hydrological interpretation, obtained on the basis of the above considerations as well as from experience in interpretation, are given in Table 8. In this table, in addition to the optimum scales, we present the data for the smallest scales which will permit obtaining information concerning hydrological elements from aerial photographs.

Using the data of this table and considering the specific task of investigation, we may select the overall optimum survey scale which will to the greatest degree meet the requirements of the assigned problem. For example, for the purpose of compiling a description of rivers according to the program of the "Instructions" [66], the optimum survey scales are 1:10,000-1:15,000. By using aerial photographs of these scales we may compile a completely useful description of the watershed of the river under investigation, the terrain line next to the valley, the valley, and the riverbed with quantitative characteristics for all their elements with the exception of the data for the river depth, rate of flow, and the characteristic of the water regime. In order to obtain the missing information in this case it is necessary to conduct field investigations.

Adequate data may also be obtained by using photographs with a scale of 1:25,000-1:30,000 for lowland rivers and 1:40,000-1:50,000 for mountain rivers. However, in this case quantitative determination of a number of characteristics (height of the banks of the river, bottomlands, individual terraces) is not possible, as well as the measurement of the width of rivers less than 50 m, etc. In this case the volume of field determinations must be increased.

The impossibility of obtaining the number of hydrological characteristics from aerial photographs must not be taken as sufficient reason to

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neglect the materials of aerial surveys.

Even discontinuous information obtained from aerial photographs in a number of cases may contribute a great deal of information and be of considerable value, since they afford the possibility of obtaining detailed quantitative characteristics of the elements closely associated with this phenomenon. For example, by inserting into formulas for hydromorphological relationships data concerning the actual widths of a river as obtained from aerial photographs, it is possible to increase the accuracy of depth and flow calculations (Section 51, Paragraph 2). Detailed study of the relief of a watershed surface, the vegetation, the microrelief of bottomlands, the possibility of plotting transverse profiles of a valley for any direction — all these permit exceptionally valuable material for analysis of flow conditions, including inclined runoff, the nature of the descent and establishing the snow cover, the controllability of the riverbed, the floodability of the valley bottom, etc.

Finally, the possibility of replacing a number of laborious ground operations with information obtained from aerial photographs permits rationalzation of ground operations, contributing to their usefulness.

Thus, it is especially necessary to emphasize that the use of aerial survey materials in a number of hydrological and, in particular, hydrographic investigations does not replace ground operations, but substantially supplements and facilitates the latter. Only on the basis of a skillful combination of aerial survey operations or the use of already existing materials of aerial survey with the execution of ground investigations may a significant result be obtained.

Section 24. General Sequence of Operations in Interpreting Aerial Survey Materials for Hydrographic Purposes

In the interpretation of aerial photographs for hydrographic purposes it is necessary to distinguish: the interpretation of materials of mass-produced aerial photographs made for the compilation of topographic maps or other maps not intended for hydrological purposes, and the interpretation of special surveys performed for hydrological purposes.

In the first place the composition of information and the sequence of

operations are to a considerable

operations are to a considerable degree dictated by the scale of the aerial survey; in the second place interpretation is performed from charts made on a previously designated scale which more fully meets the requirements of the given investigation.

In the present section we examine chiefly the sequence of operations in interpreting the materials of mass production surveys performed for the compilation of a hydrographic description of rivers and lakes.

The use of the materials of an aerial survey for hydrographic investigations, as has already been mentioned, has as its purpose their use for obtaining: (1) qualitative characteristics necessary for compilation of a description of the terrain through which a river flows, its valley, and riverbed; (2) a series of quantitative characteristics of the cross section of the valley, the width of the riverbed; and (3) a topographic base for precise orientation of information gathered in the field, for their mapping, the compilation and refinement of a map of sections adjacent to the description, and also directly as illustrations.

The general sequence of hydrographic operations is as follows, (Detailed technical instructions for methods of working with photographs, preparing them for interpretation, and the execution of measurements are given in /75/.)

In this phase of operations, it is necessary to achieve general familiarization with the area of operations and individual objects of investigation from the literature, archival and cartographic materials, and to select the materials of aerial survey and general cartographic bases for the region under investigation.

The subsequent, basic and most important stage is the interpretation of aerial photographs and compilation from them of the preliminary description of objects underlying the study.

In addition to the compilation of the text of the description and the series of tabular and graphic illustrations required by the program of the "Instructions" /66/, or the assigned program of operations, at this time on the basis of information obtained from aerial photographs there must be compiled a concrete program or a plan-assignment for the execution of field interpretation and hydrological ground operations in the field. This permits refinement of the accuracy of information obtained in office interpretation. It permits subjecting the most characteristic portions of the object or the characteristic phenomena to ground investigations, and consequently, permits conducting operations more expeditiously and carefully. As a result it permits reducing the volume of ordinarily labor-consuming field operations, improving their quality.

The third stage of operations is the field check and refinement of accuracy of information obtained in office interpretation as well as the use of aerial photographs as a topographic base for mapping a number of hydrological characteristics obtained in the field.

The reasons for performing a field check may differ considerably. Its necessity may be determined by the use of only extremely small scales in interpretation, scales which are so small as not to permit performing the series of measuring operations with the required accuracy. It may be caused by local peculiarities of natural concealment of certain elements not reflected in known identifying features, the poor quality of the survey or processing, etc. In addition, field operations are performed in order to tie in the materials of the aerial surveys with the geodetic grid (see Section 9, the Geodetic Process).

In practice the field check consists in comparing the terrain with the materials obtained as a result of office interpretation in which the interpreter is not satisfield with these materials for one of the above-mentioned reasons, and also consists in supplementing the results of interpretation. Thus, the field check is selective in nature and is considerably facilitated by the fact that the basic schedule for this check is prescribed, as was mentioned previously, in the office interpretation.

The use of aerial photographs as a base for mapping data obtained in the field is one of the factors considerably increasing the quality of ground operations.

However carefully the field description of any water object is performed, the orientation of the resulting data for the terrain and the tying-in of this data to the local situation is always extremely sketchy, even if for these purposes use is made of a map of very large scale. However, an aerial photograph showing the local situation with exceptional detail permits such tying-in with great accuracy.

For example, in performing hydrographic investigations on an aerial photograph we may, even from the local situation, fix the location of measuring points of depths, directional lines for determining rate of flow and widths, the character of the river bottom, the height of banks, flood boundaries, etc. As a result it is possibile to achieve a graphic formulation of many hydrological chacteristics and, consequently, also to increase the accuracy of data with respect to their tie-ins to the locality and to considerably reduce all descriptive operations.

Aerial photographs may be used for somewhat accurate mapping of the snow-cover distribution during the period of irregular snow cover, icing phenomena, flooding, etc.

Finally, even without special annotations an aerial photograph may serve as an illustration for description of the most varied hydrological phenomena and in a number of cases may considerably simplify and otherwise extensive cases.

We will discuss the principal methods of office interpretation. They consist in the following.

(1) In all cases the stereoscopic examination of aerial photographs is desirable. The reproduction under stereoscopic instruments of a tri-dimensional model of a terrain always increases the possibility of interpretation. In such examination of photographs many objects are detected directly.

Stereopairs are required for stereoscopic examination of aerial photographs. Considering that in performing hydrological operations the user does not always have stereopairs at his disposal and in a number of cases he is limited to the study of a photodiagram /fotoskhema/ or mosaic /fotoplan/ it is necessary to resort to monocular study of aerial photographs.

The interpreter must be familiar with the identifying features, since not all local objects are directly expressed on the aerial photograph.

(3) In monocular examination of photographs it is recommended that at least a few stereopairs be available for the most typical sections of the water object and the locality in order that, by using them for careful and detailed interpretation, the interpreter may subsequently use them as a standard (see Section 12) for the characteristics of identical portions of objects, using only the external features for their recognition.

(4) The study of a water object from aerial photographs must begin with a general review of the territory in which it is located, from a mosaic /fotoplan/, a photodiagram /fotoskhema/, an overlap assembly, or a reproduction thereof. By this method the interpreter becomes familiar with the principal, typical features of the portion under study and its characteristic distinctions, and subsequently, in detailed interpretation, he may proceed with greater accuracy. In performing this operation the portions marked by uniformity of natural conditions must be distinguished.

In such work it is recommended that the beginning interpreter continually compare the photodiagram /fotoskhema/ with a topographic map. This permits him to establish on the aerial photograph the peculiarities of individual objects and the phenomena for the given terrain as well as to amplify or to refine those identifying features which he discerns. This is necessary also for purposes of independent control, for greater accuracy in work results. In addition, insofar as is possible, it is necessary to use a map of the largest scale for convenience in collation in order to approximate as closely as possible the scale of the aerial photograph. In addition to the fact that a topographic map must be used for general familiarization with the terrain (nature of its relief, the location of the hydrographic net, etc.), it serves for orientation of local objects on the aerial photographs, and from it permits establishing the identity of populated points, rivers, boundary lines, etc. In the case of the use of nontransformed contact prints, a stickup mosaic, a reproduction thereof, or a photodiagram /fotoskhema/, all vertical measurements are performed from a topographic chart, but from aerial photographs only the location of points shown on the map is refined. Only an assembled mosaic /fotoplan/ eliminated the need for using a map for measurements.

(5) The next stage of operations must be a detailed study of the object. It consists of two basic operations: a quantitative interpretation of the object and its individual elements and the execution of measurements. The latter is divided into operations for determining the vertical dimensions of water objects and into operations for determining the deviations of points on the terrain.

The determination of vertical dimensions of objects is practically the same in procedure and technique as in performing measurements from a topographic map. It must only be remembered that these measurements on nontransformed photographs must be performed only within the limits of the useful portion of a single photograph.

The measurement of deviations requires the use of special instruments (the simplest, such as the lens-mirror stereoscope with parallax plates, or complex, such as the stereoplanigraph and the multiplex). These operations must be performed as an individual part of the work.

(6) The sequence of interpretation of different hydrological and other elements of a terrain depends on the purposes of their investigation and may differ.

In the interpretation of rivers for the purpose of compiling hydrographic descriptions thereof the same sequence is recommended in the description of individual characteristics as is given in the "Instructions" /66/ for the execution of ground operations; that is, first describing the river valley and the bottomland, and then the riverbed. Actually, the methods of gathering information in interpretation, especially from a stereo model, differs but little from the direct description in performing ground operations.

(7) In the process of interpretation it is recommended that the object be examined in parts — the smallest parts distinguished by a uniformity of conditions.

In such examination it is almost always possible to trace changes not only in one but in several closely interrelated characteristics.

(8) In detailed interpretation of an object and its individual characteristics it is recommended (especially for beginning interpreters) that

the stereophotograph be covered with tracing paper and that the contour lines be marked on it. This is of assistance in subsequent measuring operations and does not require the execution of secondary determinations in compiling the description, since certain details may always be forgotten by the interpreter. In addition, the presence of such tracing paper with an image of the interpreted material is extremely convenient for control of operations or in solving disputed questions in the repetition of interpretation by another person. Finally, it may serve as an illustration for description and somewhat reduce the text.

Specific instructions on special features and the sequence of operations in interpretation of individual elements of water objects are given below.

Interpretation of river valleys and bottomlands. Since in information concerning a river valley it is necessary to distinguish general data (concerning the type of valley, its extent over the length of the river, terraces, general information on the location of the bottomland, etc) and more detailed data (on peculiarities of structure of slopes and terraces, microrelief bottomlands, etc), work with aerial photographs may conveniently be divided into several stages.

The first of these stages will consist in investigation of the peculiarities of distribution of various elements of the valley along the length of the river; the second stage will consist in the measurement of individual elements of the valley; and the third stage will consist in detailed examination of individual, characteristic portions. A preliminary separation of characteristic portions must be performed from topographic maps on the largest possible scales.

During interpretation it is necessary to note the location of cross-sectional profiles of the valley which may subsequently, as has been mentioned, be plotted by photogrammetric means (see Part 1, Chapter III).

Measurements must be performed as an independent operation, since they always require excellent training on the part of the person performing them.

Interpretation of riverbeds. As in the interpretation of river

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valleys, it is also necessary to obtain general data (meandering, branching, predominant types of riverbed formations, etc), to perform a series of measurements, and to give specific characteristics of the riverbed over short portions. Thus, work with aerial photographs is conveniently performed in the following sequence: (1) a study of the general regularities in spatial distribution of individual elements; (2) measurements — river widths, height of banks, depth (in portions where the bottom is visible); (3) description of individual, characteristic portions and stretches.

Measurement must be considered an independent operation and may not be performed as an incidental operation in qualitative description.

It is also useful to treat the interpretation of hydrotechnical structures as an independent operation. The work consists in determining the location, description of the type, structural features, and material of the installation, in an appraisal of the state of the installation and approaches to it, in the execution of stereoscopic measurements and measurement of vertical characteristics of the installation. These operations may be fully executed only in the stereoscopic study of the photographs.

The interpretation of a river catchment is always divided into a series of stages. This is first of all necessary in order to become familiar with the general character of the geomorphology and the geology of the region under study on the basis of the literature and cartographic materials in order to obtain an idea of the type of relief and its relation to the geological structure as well as to be able to explain the occurence of a relief of a given type and its individual forms.

Interpretation of the relief must begin with a comparison of mosaics, [fotoplan] (aerial photographs) with existing topographic maps of the region under study on the largest scale (1:100,000 and greater).

After selecting the photographs and detecting the more clearly expressed forms of relief, we may then proceed to detailed study of the type and elements of relief from the individual aerial photographs with the compilation of descriptions and execution of necessary measurements (the technique of this work is discussed in greater detail in Chapter III).

The experienced interpreter easily dispenses with maps and immediately determines the type of relief from the external appearance of a sketch of the photograph; the relief is next elaborated in detail.

It is sometimes convenient for the inexperienced interpreter to begin not with a determination of tye type of relief but with a study of its individual forms and then to make generalizations.

Interpretation of soils is performed after or simultaneously with interpretation of the mesorelief and vegetation, since the closest relationships exist between these three elements of the terrain (correlative dependences). A comparison of soils on the basis of the tone of the image may be performed within the limits of a single series of photographs, but with a poorly expressed difference of tones this comparison may be performed only from a single photograph. Interpretation of soils is achieved in the same order as in preliminary surveys. First it is necessary to locate on the photographs points of erosion (at washouts, ravines, pits, gullies, on the slopes of a valley, etc), and then to interpret these points in terms of soils. In the absence of such exposed surfaces determination of possible soil types is based upon the elements of terrain which enter into the correlative relations (relief and vegetation). The results of interpretation must immediately be mapped in order to avoid compilation of unwieldy intermediate descriptions.

In the interpretation of vegetations, as in the interpretation of other elements of the terrain, it is first necessary to have a knowledge of the principal regularities in distribution of vegetative formations (the basis of ecological concurrence among different forms of relief, soils, etc) as they apply to the conditions of the region under investigation. Interpretation is performed, as a rule, on the basis of the materials of an area survey.

The first stage of work is the delimitation of areas covered with forest and those areas not so covered. Since interpretation with photographs affords up-to-date and extremely valuable qualitative as well as quantitative evaluation of the forest cover of the terrain, it is desirable to perform measurements and the compilation of sketches of areas occupied by forests (in the predominance of uncovered areas) or open portions (in the predominance of forest areas) within the limits of the watersheds. Such measurements are convenient for small watershed areas, that is, in cases where small rivers are under investigation and the assembly of mosaics does not present special difficulties. With watersheds of considerable size, requiring an area survey and the performance of labor-consuming work in assembling photographs, this work must be considered as independent. Having established the character and extent of forest cover, we may proceed to a more detailed investigation of the forest portions and portions occupies by other growth.

Interpretation of roads must be performed both for the study of relief and for the characteristics of soils. By comparing aerial photographs with a topographic map it is possible to reveal the main roads, establish the identity of populated points, and then perform more detailed examination thereof, which is best done from contact prints.

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CHAPTER VI

INTERPRETATION OF RIVER VALLEYS

Section 25. General Information Concerning Identifying Features of River Valleys

River valleys are usually recognized in the examination of single photographs with the unaided eye, but they are especially easily detected in the stereoscopic examination of aerial photographs.

A detailed examination of a photograph under a stereoscope permits easy determination of the size and type of the valley itself as well as its principal elements -(slopes, terraces, bottomland, etc) that is those elements which are immediately visible on the photograph).

However, concerning a number of other characteristics of the valley not directly shown on the aerial photograph (for example, the degree of swampiness of slopes and the bottom of the valley, soils, etc) information may be obtained only on the basis of a knowledge of the identifying features. The latter is necessary also because the person performing the work is rarely limited to the use of a mosaic, /fotoplan/ a photodiagram, /fotoskhema/ or even a reproduction of an overlap assembly, (that is, monocular examination of the photographs).

River valleys and other structural formations associated with the activity of water are elements of relief subject to interpretation on the basis of identifying features which are sufficiently well developed in the general (topographic) or special (geomorphologic and geologic) interpretation.

Below we present a description of the principal identifying features of river valleys with a view to their use in obtaining hydrological characteristics.

The primary identifying feature for establishing the presence of a river valley is an image of a water surface (of a river). The riverbed is among the most clearly distinguished elements of terrain on an aerial photograph. In the absence of water or given a stream of small dimensions the identifying feature is the image of the relief of the terrain.

The relief of the terrain as examined with the unaided eye on an aerial photograph is perceived due to shadows caused by the different exposures of slopes, as a result of which the latter obtain different tones on the print. The dark tones usually correspond to the unilluminated portions of the surface and the light tones correspond to the illuminated portions. Due to the contrast between the illuminated and dark slopes the expressed relief formations are easily read and the flat outlines are less easily read.

Hence, even from the general appearance of a photograph we may easily distinguish the expressed valleys in mountainous and intersected terrain from flat, lowland terrain with weakly expressed sculptural forms of slopes (see Sections 26-28).

In order to determine the limits and, subsequently, the dimensions of unexpressed valleys as well as the microrelief at the bottom and slopes it is necessary to resort to indirect features.

One of these features is the tone of the image of the vegetative cover. Dark-toned vegetative cover is usually characteristic of the lower surface of the terrain and the light-toned cover is characteristic of the upper sections. However, this feature is unreliable and under the influence of local conditions they have other significance (Sections 26 and 27); hence, at the same time it is necessary to resort to other features, including: the location of the road network, portions of the agricultural layout, populated points (Section 28).

There is an entire series of interfering factors which make interpretation of valleys and microrelief difficult. Among these, in addition to defects arising in execution of the aerial survey process and the processing of photographic materials, we include the snow cover, forest growth, in some cases the developed sections, as well as shadows obscuring details. Among the interfering factors we may also consider the optical distortions of the model under the stereoscope (exaggerations of relief). This refers principally to visual appraisal of large elements of valleys. As for the smaller shapes, exaggeration here may be considered as a factor facilitating at least a qualitative interpretation.

Section 26. Interpretation of Valleys under Conditions of Mountainous Relief.

In a mountainous relief the increases in elevation regulatly alternate with decreases in elevation. Prominences, the relative elevations of which may reach hundreds of meters, form chains and ridges, often with sharp outlines of peaks and steep slopes separated by a network of deep valleys.

Under these conditions, in the description of a river valley considerable attention must be devoted to the characteristics of individual shapes of mountain relief accompanying the river. The declivities of mountains under these conditions are naturally a continuation of the valley slopes.

The principal identifying features of valleys under these conditions are the shadowing, the shape of the images, and the structural pattern.

Characteristic for the general appearance of the image of a mountain relief on an aerial photograph is the alternation of sharply contoured large areas of dark and light tones (Photograph 1, appendix). The more clearly expressed the relief, the clearer will be the boundary between these dark and light tones formed by the shadow of the mountain. The space covered by the shadow depends upon the angle of incidence of the sun's rays, wherein one boundary of the shadow corresponds to the peaks of the mountains (the upper edge of the shadow) and the second may proceed along the slopes or the bottom of the valley (the lower edge).

The boundaries of shadows usually have a complex configuration and often, due to the contrast between light and dark, appear as bright lines. An inexperienced interpreter may assume that the latter are the lines of roads or rivers (Photograph 1), but with careful study of the photograph, as is shown below, such errors should not occur.

By examining a photograph for the relative location of boundary lines of shadows we may clearly determine the location of ridges, individual peaks, and depressions, and we may distinguish valleys, basins, and their individual elements. We may thereby make out the watersheds. Due to the fact that the edges of shadows may also correspon, as has been shown, to the lines of mountain ridges and the axial lines of valleys, in monocular examination of a photograph it is important to determine the upper and lower boundaries of shadows, for without such distinction we may assume the peaks to be depressions and vice versa. Such identification is to a considerable degree facilitated by correct location of the photograph relative to the direction of the light source of the survey — it must be placed so that shadows from the objects fall toward the observer.

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The direction of the light source may be determined from the shadows of clearly expressed local objects. In this way it is easy to determine the position of the light source for inhabited localities or in the presence of easily identified objects (individual trees, shrubs, poles, etc) on the terrain and on the photograph. By establishing the direction of the light source it is easy to determine the upper and lower boundaries of shadows for individual shapes of relief and to locate the ridges of hills, slopes of valleys, hollows, and other elements of relief.

For uninhabited regions with a relief devoid of vegetations, in order to establish the upper and lower edges of shadows and, consequently, the lines of mountain ridges and the axes of valleys it is sometimes necessary to resort to indirect features. These features are as follows:

(1) with sharply expressed forms of relief (heavily dissected relief) the upper edge of the shadow usually has finer dissection than the lower (Photograph 1); with level outlines of relief, on the other hand, it is s sharper than the lower portion (Photograph 2);

(2) the lower boundary is always turned toward the axis of a water-collecting depression — a riverbed or a temporary stream of water clearly expressed on the photograph in the form of light lines (Photograph 1). As has been shown, the light lines of rivers may be mistaken by an inexperienced interpreter for the lines of ridges. However, in this case the bright line of the river image does not clearly correspond to the edge of the shadow — the shadow overlaps or on individual sections does not reach the right line of the river image;

(3) under mountainour conditions the roads, always clearly visible on the photograph, also usually found in the lower portion of the slopes, valleys, and in the depressions in the terrain;

(4) narrow trenches, ravines, pits, and gullies are visible on illuminated slopes with the wide portion turned toward the bottom of the valley or depression, and their branches are joined toward the mouth, creating a fanlike appearance in the upper reaches (Photograph 1);

(5) patches of strips of vegetation noticed on the slopes are denser in their lower portion than in the upper (Photograph 2);

(6) the deeper the valley, the more dense the tone of the shadow (Photograph 1).

Using such signs for determining the upper and lower edges of shadows from the relief formations and orienting the photograph relative to the light source by which it is examined in such a way that the images of shadows on the photographs are turned toward the observer, we may proceed to a detailed description of individual elements of the valley and the forms of relief accompanying them.

The principal sign of the upper elevation is convergence of the upper edges of a shadow to a point.

With pyramidal sharp peaks of the edge of light and shadow there sometimes occur dissected outlines and sharp transitions of tone. The sharper the peak of a mountain, the sharper the angle of separation between light and shadow (Photograph 1).

On photographs of smoothed forms of relief the boundary between light and shadow has curved outlines and is weakly expressed due to the gradual transition in tones (Photograph 2).

Section 27. Interpretation of Valleys with Hilly Relief

Hilly relief is characterized by frequent alternation of increases in the height of the terrain with decreases, wherein the increases have smoothed outlines. The relative heights of terrain do not exceed 200 meters. On the whole, valley formations play a subordinate role.

Depending upon the character of the landscape and the size of individual hills we distinguish the following types of hilly terrain.

(1) Small-hill relief. It is formed by an accumulation of low hills and ridges (relative height up to 15 meters), among which are dispersed valley-shaped depressions, most of which are closed. The hills are without sharp outlines and have predominantly convex slopes. In the plan view the hills are usually circular.

(2) Medium-hill relief. In general it conforms to the above description, but the relative heights of hills (relative to their bases) varies from 15 to 50 meters.

(3) Large-hill relief. The relative height of the hills is 50-200 meters and in some cases greater. Their slopes are often abrupt. The hills are grouped in distinct prominences, forming chains and ridges. The terrain in this case may be considered mountainous.

With any variance of hilly relief between hills, swamps and lakes may be encountered in hollows and depressions. If the lakes in depressions between hills are sufficiently frequent that they give the terrain a special appearance, then its relief may be considered to be small-, medium-, and large- hill lake relief.

Under hilly conditions of relief the slopes of river valleys often serve as the slopes of hills between which a river flows. It is often accompanied by ridges or chains of hills. Thus, interpretation of a river valley under conditions of hilly terrain, as in mountainous terrain, will consist to a considerable degree, in describing from aerial photographs the individual elements of relief of the terrain — hills, their slopes and peaks, the hollows between them, etc.

With unforested hilly relief the principal feature of the valley, as for mountainous relief, is the shadow; h . However, the contrast between lighted and darkened slopes of valleys which characterizes their photographs under hilly relief conditions is not sharply expressed and usually there are smooth transitions of tones. In this case interpretation of the valley is often complicated by the character of the non-turfed slopes, their forest cover, and the presence of farm lands.

Thus, the general appearance of hilly relief on the photograph is characterized by an alternation of relatively small dark and bright areas with smoothed outlines.

Non-turfed or evenly turfed peaks of hills have a brighter tone than the slopes and hollows. They usually have circular or oval outlines. Toward the peaks there is a convergence of lines of bright tone corresponding to the ridges of mountain ranges. The bottoms of valleys on the photograph correspond to the darkest areas.

On the very steep slopes of hills (large-hill relief) there may be outcroppings of soil which on the photograph have a brighter tone than the turfed surface of the peak. In this case the peak of the hill appears as a dark spot.

The sharply outlined contours under conditions of hilly relief appear as ravines, usually covered by a dark shadow. The deeper such gulley, the darker the shadow of the photograph.

On photographs of forest areas the hollows appear brighter than the peaks of hills, especially if these hollows are swampy. In this case the fine-grained structure of the pattern of the bottom of the hollow is characteristic. Interpretation of the hollow is also facilitated by an inspection of the hydrographic network, since rivers, lakes, streams, braided channels, etc. are always found in depressions of relief and are easily observed.

The complex features for densely populated localities under conditions of hilly relief are the location of roads and the layout of the populated points. The latter are distinguished by their irregular outlines (see Section 28).

Among the hindrances to interpretation are:

(1) The effect of forest growth, which somewhat softens and sometimes greatly conceals the effect produced by a shadow. The principal identifying features in this case are the general tone and structure of the pattern (for interpretation of forests, see Sections 29 and 45).

In forest terrain the peaks of hills are often darker than the slopes and the bottom of the valley. This is explained by the fact that with steep slopes the conditions of growth of trees at the top of the hill are more favorable than on the slopes, in connection with which the forest at the top is denser and on the photograph gives a darker tone (Photograph 3). The denseness of the growth pattern characterizing forested areas hence is different on the peaks, on the slopes of hills, and in depressions, since with a decrease in the height of tree tops the denseness of the pattern increases. As a rule, the top of a hill in this case shows sparser growth than the slopes or depressions (Photograph 3).

(2) The plowing of slopes or the presence thereon of other agricultural activities sometimes considerably complicates interpretation of slopes at the bottom of valleys, especially under conditions of small-hill and medium-hill relief when even the peaks of hills may be plowed. Farmlands create an extremely mottled mosaic of shapes of bright tone of normally straight outline over large areas and considerably weaken the effect created by shadow. In such conditions the principal feature permitting evaluation of unevenness of the surface of a terrain is the irregularity of the outlines formed by the boundaries of farmland. Usually plowing is executed along the direction of the contours, that is, perpendicular to the slopes. Thus, plowed or sown portions outline irregularities in relief. By tracing these outlines and comparing them with other objects on the terrain, chiefly with the images of riverbeds, we may detect hills, ridges, steep slopes, and depressions with considerable clarity (Photograph 4). Outlines which bend in the direction of rivers correspond to ridges, hills, or the superior portions of valley slopes; outlines which bend away from rivers

correspond to depressions and hollows leading into the valley.

Section 28. Interpretation of Valleys under Flatland Conditions

A flatland relief is characterized by an almost level surface with little variation in elevation and relatively little dissection. Individual increases and decreases in elevation usually have a smooth outline in the plan and profile views.

We distinguish low flatlands — lowlands (elevation less than 200 meters absolute) — and high flatlands — plateaus. In addition, we distinguish sloping, concave, and rolling flatlands (changing slope in one or another direction). The characteristic elements of the mesorelief of the flatland are river valleys, saucer-shaped hollows, craters, basins, flat troughs, ravines, gulleys, pits, crests, ridges, and individual hills. Often they are well expressed and their interpretation byusing the features discussed in Sections # 26 and 27, is easily achieved.

For unexpressed valleys as well as for bottomlands, interpretation under all conditions is performed chiefly by indirect features, the chief of which is the tone of the image caused by the color represented on the photograph of the surface. The color gives to the photograph a whole gamut of greyish tones evenly blending into one another (Photograph 5). Shadow plays a subordinate role as a feature and on the whole is used only in interpretation of small well-expressed relief formations (see the image of the riverbed in Photograph 5).

Various other indirect features are of particular importance: the nature of the vegetation, the soil, the location of portions of farmlands, the road network, populated points, peculiarities of microrelief.

The tone of the image of the surface of the bottom of an unforested valley is determined chiefly by the color of the vegetative cover, and in the absence of such cover is determined by the color of the exposed soil.

(1) Determining Surface Irregularities from Tones as Caused by the Color of Vegetation

Usually the darkest tone of a flatland surface corresponds to depressions in which more favorable conditions are created for the growth of vegetation and, consequently, its density and richness of coloring. Elevated portions are characterized by brighter tone — vegetation is rarer here and less

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clearly colored. Often for relief formations within the limits of valleys there is a regular alternation of light and dark spots (depressions and elevations), whereby they usually have a general orientation. This is especially well seen in interpretation of the microrelief of bottomland (Photograph 16) in which the "fan of displacement" (an alternation of ridges and depressions) is always quite visible, due chiefly to the different tone of the vegetation on the ridges (bright) and in hollows (dark). The dark spots are often encircled by a bright ring. Its appearance is explained by the fact that, due to the intensified drainage along the bluffs of depressions, vegetation is rarer than in the depressions themselves.

The general rule for the correspondence of dark image tones to vegetation in depressed localities does not apply in a number of cases, and the indicated feature cannot always be considered applicable for all cases. However, the case of the exception to this rule is determined relatively easily and may even serve as an independent indirect feature.

These exceptions occur in the following cases.

(a) The presence of swamps and silt accumulations. In river valleys the depressions are often occupied by swamps the vegetative cover of which always appears on the photographs as a brighter tone than the cover of dry stretches and in this case the correspondence of dark tones to the lowest portions of the valley does not apply. However, such swamps are easily identified on the photograph from the characteristic blurred grainy structure over the considerable area which they usually occupy and the very fact of the presence of a swamp in the valley attests to the presence of depressions in the surface (see Chapter XI). The bright tone of small depressions may be caused by their silt accumulations and subsequent drying. Such small depressions are easily observed steroscopically.

(b) Flowering of vegetation. The tone of the image of vegetation on the photograph also depends on its condition. With variance in the growth periods of different vegetations the brighter tone will identify those which are in the flowering state. Thus, bright tones in this case will not always correspond to the depressed portions. The identifying features by which the presence of flowering may be observed are the fine patchiness (ripples) of the pattern within the limits of the contour occupied by the flowering vegetation and the absence of general orientations in the location

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of patches (Photograph 6).

(c) Hay mowing. A bright tone in the image of a surface may be caused by hay mowing. However, the always easily noticed indications of mowing (stacks, mowed rows of grass) confirm the correspondence in the tones and elevations of relief (Photograph 17).

2. <u>Determining Surface Irregularities from the Tones Caused by Soil Images</u>

Exposed soil usually appears on a photograph as a brighter surface than turfed areas. Since the prominent forms of relief (on peaks or slopes) are usually subject to greatest exposure, this fact to a considerable degree facilitates determining surface irregularities.

Bright spots caused by natural exposure of soils usually have extremely irregular outlines and a characteristic striped structure caused by the residue of vegetation (Photograph 5). This permits reliable determination of the brightness of tone of exposed soils (for discussions in greater detail see Section 44).

3. <u>Interpretation of Irregularities in the Bottom of a Valley in the Presence of Arable Lands</u>

In all cases the images of flatlands are usually a gradual transition of tones from bright to dark, causing a uniformity in the pattern of a regular surface. However, the smoothness in transition of tones is sharply disturbed by the always clearly contoured portions of farmlands (Photograph 4).

Plowed lands and fields, as always, cause a considerable variety of tones, giving the photograph the appearance of a mosaic. This is explained by the fact that the tone of each of the individual portions will be determined by the presence thereon of the vegetation and its state. Depending on the time of the year and the periods of vegetation of the crops, even adjacent sections may differ considerably in tone. In the presence of mature grasses on large-scale photographs the shadow may be detected from the contour of the portion. The principal feature for determining surface irregularities in this case, as under the conditions of a hilly relief, is the character of the relative location of individual tilled lands. On a [illegible] / usually extended in a direction perpendicular to the slopes as though embracing them (Photograph 4).

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4. <u>Determining the Nature of a Surface from the Location of the Road Network</u>

With flat undissected slopes of valleys in inhabited regions there is usually observed a branching road network with predominantly straight roads. There are numerous paths in the vicinity of crossroads (Photograph 18). Improved roads usually pass within the limits of terrain which is subject to flooding and hence such portions of the valley bottom are often hard to distinguish.

5. <u>Determining the Character of a Surface from the Layout of Populated Points</u>

When the slopes of the valley are not heavily dissected the populated points located in it are usually distinguished by a regular layout of streets and uniform distribution of yards (Photograph 5). When the slopes of the valley are dissected the streets of populated points are characterized by considerable irregularity and the yards are scattered.

<u>Section 29. Interpretation of Valleys in the Presence of a Flatland Forrested Relief</u>

The forest growth of a terrain increases the difficulty of interpretation of river valleys (Photographs 3, 7, 8) by concealing the folds of relief even of rather large forms.

In this case the principal sign permitting evaluation of the relief is the structure of the outline. Level surfaces of a forested terrain within the limits of a forest sector with trees of the same age is distinguished by a uniform graininess of the structure of the figure on the photograph without sharp changes of tone (Photograph 7, 8). This is explained by the fact that the absence of depressions and elevations on the surface of the terrain creates approximately identical conditions for the propagation of vegetative growth. Consequently, the strip of forest appears on each individual age sector uniform and identically complete (methods of identifying tree types and their age are given in Section 45).

In local depressions or hollows moisture conditions may be excessive and swamps are formed. The trees in a swamp are usually stunted and the outline of such trees on the photograph has a fine-grained, somewhat blurred structure, often quite unusual, due to the presence of dense undergrowth (Photographs 31, 33).

The unique structure of the forest pattern, not associated with relief, is caused by the presence of overgrowth in areas where trees have been felled. It is characterized by an alternation of bright and dark spots (discussed in detail in Section 45).

Approximate evaluation of the valley types in a forested terrain may be obtained on the basis of a correlation series between types of vegetation and the type of relief. Such series have not yet been developed for all types of land. Table 9 presents the correlation series between the prevailing type of vegetation, lythology, and relief as developed for a flatland-taiga zone.

Section 30. Interpretation of Valleys on Winter Photographs

Aerial photographs made in winter differ considerably in their external appearance from summer photographs. The distinctive features of interpretation of winter photographs consists in the following.

(1) The snow cover on a photograph is distinguished by a clear, bright tone caused by the extremely high coefficient of reflection of light rays; for example, for freshly fallen snow the coefficient of reflection is 0.90. Together with this, the shadows, which are the principal identifying features of relief, are longer on a winter photograph than on a summer photograph (the sun is at a lower elevation). Hence, with an unbroken layer of light snow cover, even fine shapes of relief appear to be emphasized (Photograph II). In addition, the shadow is cast by large objects and relief formations on the bright surface appear clear and permit tracing the features of the structure of slopes and concave forms of relief, which on photographs made in the summer are covered with thick shadows. On winter photographs, for example, it is easy to detect steep slopes of river valleys and ravines (Photograph II).

(2) General appearance of a flatland terrain with thick snow cover is a uniform monotone characterized by the absence of smooth transitions due to the fact that the solid, thick snow cover levels out the irregulatities of relief and generally masks the terrain, covering meadows, cloud fields, etc.(Photograph 12). Even the gulleys of small rivers and streams may appear unbroken under snow cover.

(3) With an unbroken snow cover these objects which are not covered by snow (structures, railings, roads, forests) are quite distinguishable in virtue of their contrast (Photograph 12) and more easily detected than

on summer photographs.

(4) Solid snow cover eliminates the possibility of using a whole series of indirect features (for example, in evaluating the microrelief on the basis of the tone of vegetation, etc) or makes it difficult to use them (in determining the shape of relief from the structure of the outline of a deciduous forest, etc.) and thereby limits its use for interpretation of correlative series.

(5) An interrupted snow cover, on the other hand, may emphasize details of relief. As the snow begins to melt the first patches of exposed earth permit interpretation of the relief, since they first appear on prominences. As considerable areas begin to be freed of snow, the sharp contrast between the snow cover and the dark melted areas makes interpretation difficult, since in the absence of smooth transitions of tones it is almost impossible to distinguish the details of these dark spots which at this time embrace not only the depressions but also concave forms of relief (Photograph 13).

Snow which has collected or remains in trenches, pits, holes, furrows, ditches, etc. at the end of the snow thaw are sharply distinguished by the outlines on the photograph (Photograph 14).

(6) The snow cover introduces considerable distinctiveness in the structure of the pattern of forested sectors (Photographs 13, 46). Deciduous forests on winter photographs has a characteristic hatched appearance caused by the shadows of the trees without their leaves. In the stereoscopic examination of relief this feature in a sparse forest facilitates interpretation of the relief, permitting direct examination of the surface of a terrain. In visual examination the dense streaking of the pattern smooths the shadows from the relief (Photograph 13). Along with this, as has already been mentioned, the loss of the leaves considerably restricts the use of correlative series due to the fact that under these conditions it is more difficult to determine the species of trees and the differences in height of the forest canopy (see Section 45).

Coniferous forest is usually better seen on winter photographs than on summer photographs. The snow which often remains on the crowns of coniferous emphasizes their outlines. Thus, the features for interpretation of valleys in terrain covered with coniferous growth, as discussed in Section 29, are applicable.

The general conclusion concerning interpretation of valleys on winter photographs may be formulated as follows. The possibility of interpretation of winter photographs depends upon the character of the relief, the depths and degree of snow cover over the terrain. For the conditions of mountainous relief snow is an obstruction, concealing details ordinarily clearly seen on a photograph. Accumulating in valleys and depressions, the snow gives a distorted representation of the dimensions in the plain view and in elevation.

For hilly relief snow cover facilitates interpretation of large outlines but hinders the interpretation of microrelief.

Under the conditions of flatland relief a thick continuous snow cover considerably hinders interpretation. With a thin or interrupted snow cover, on the other hand, it may be possible to detect the details of microrelief.

Section 31. Interpretation of Bottomlands

For those parts of a valley bottom which are subject to flooding (bottomlands) it is usually necessary to obtain information concerning the character of its location relative to the riverbed, its dimensions (widths, elevation), the type of bottomland according to the character of vegetation (meadow, scrub forests, swamp), the extent and periodicity of flooding, etc.

All this information may be obtained with varying detail from aerial photographs, wherein, on the basis of a number of bottomland characteristics observed in examining aerial photographs, it is possible to detect those details which usually escape the notice of even a ground observer.

In the interpretation of bottomlands the same identifying features are employed as in the case of interpreting river valleys under flatland conditions (see Section 28). However, the interpretation of a bottomland is an independent type of operations due to its considerable extent and certain peculiarities of the identifying features.

It is first necessary to point out the general identifying features which permit locating the bottomland on a photograph, that is permit distinguishing the bottomland from the non-flooded portion of the valley bottom and mapping it.

According to the character of the concealment by vegetation we distinguish: open (meadow), scrub, and swampy bottomland.

In addition swamps may be distinguished as being dry or flooded.

The principal identifying features of open meadow bottomland are the tone and structure of the pattern. The tone of the surface of a meadow bottomland, determined by the color of the grass cover, is usually uniform (grey). Depending on the character of the surface, the overall flat tone of the image of a bottomland may be streaky or spotted.

An undissected bottomland with level surface has a uniform light-grey tone (Photographs 5, 15). As dissection of the bottomland increases its appearance becomes more variegated. The presence of local fallows and depressions in the surface results in the appearance of spots of a darker tone than the general tone of the bottomland image. There then becomes evident the characteristic alternation of bright and dark bands corresponding to increases in elevation (light) and the depressions between them (dark bands and spots). These bands often have a fan-like arrangement ("displacement fan") Photograph 6; interpretation of displacement fans is discussed in greater detail below.

If the photograph is made during the hay-mowing period, then the tone of the bottomland land image at hay-making points appears bright. However, these hay-making points are clearly detected from the presence of ordinarily sharply distinguished rows of mown hay and hayricks. The image of the latter resembles the head of a pin (Photograph 17).

Scrub growth on the bottomland is detected on the aerial photograph as spots, usually with a circular outline, having a spongy pattern (see Section 45). Individual spots of the spongy structure merge and form curtains which in their external appearance resemble the typographical symbol for scrub growth (Photograph 17).

In those cases where the bottom of the valley is covered with forest growth interpretation of the bottomland becomes difficult. The forest, lacking the relief and microrelief of the surface, does not permit full use of the above-mentioned identifying features of the bottomland (Photographs, 8, 25). The most used method for determining the presence of bottomland when the valley is forested is the stereoscopic examination of photographs. Under the stereoscope the crowns of the trees appear to be suspended in the air, it is often possible to see the surface of the earth beneath the forest growth, its microrelief, and it is possible to measure the height of banks. Whereupon, though knowing only the approximate heights of increases in water level, we may judge the probability of flooding and the width of the flood area (see below). In monocular examination of photographs for determining the character of relief at the bottom of a valley it is necessary to use indirect features, as indicated in Section 29 — to study the graininess of the forest image and its corresponding changes of relief and the variety of trees. However, this is possible only with sharp variation in the height of terraces in the valley.

The key to identification of bottomland swampiness is the presence on the image of its surface spots or streaks of a light-grey tone (brighter than the general tone of the bottomland). With the characteristic blurred graininess of the pattern (see Chapter XI).

The next stage of operations is that in which we obtain detailed characteristics of the bottomland.

It is first necessary to determine the boundaries of the bottomland in order to obtain data concerning its width.

Information concerning the width of the bottomland may be obtained directly from aerial photographs and by plotting (Section 17) a transverse profile of the bottom of the valley and applying thereupon high-water marks. In a number of cases it is necessary to combine both of these methods.

For clearly expressed and well developed valleys the boundaries of the bottomland may be approximately established as the line dividing areas with a uniform grey tone corresponding to the bottom of the valley and areas having on the aerial photograph the appearance of a variegated mosaic and corresponding to the slopes of the valley (see Section 32, Photograph 20-24).

With clearly expressed "displacement fans" the boundary of the bottomland may be taken to be the line outlininggportions with such fans.

In some cases the boundary of the bottomland may be traced from the vestiges of the high water levels. During floods, at approximately the same width (the width of the bottomland and steep slopes of the valley or the bottomland with a well-expressed lateral gradient) along their boundaries, as a result of undercutting, there is often formed a small shoulder (Photograph 15), the slope of which is often detected and traced as a bright band.

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Sometimes the edge of the flood is clearly traced in the form of a bright line caused by the water and the strip of residue of vegetation, debris, etc. deposited in the form of an irregular band. It must be kept in mind that with sharp variations in the height of the high water, this line often only roughly indicates a border of the valley, since it may not correspond to the line of maximum flood level.

In many cases the edge of the bottomland may be taken to be the edge of the plowed portions in the river valley. These portions are usually located beyond the zone of flooding. However, in populated points the bottomland may be under truck-garden cultivation. In this case the plowed portions are small and form a variegated mosaic (Photograph 13). In many cases determination of the edge of the bottomland facilitates study of the character of the distribution of railroad systems, levees, and other hydrotechnical installations. Main roads usually proceed beyond the limits of the valley bottom subject to flooding and where they enter the bottomland they pass along levees and embankments. In this case the edge of the levee on a slope or within the limits of the valley bottom will at least correspond to the edge of the normal flood area of the rivers. Levees are often used on a river to protect a part of the bottomland and thereby serve as indications of flood boundaries.

The width of flood areas may be estimated from the boundary determinations of a bottomland. In order to establish the frequency of flooding it is necessary to determind the high, average, and low levels. This is achieved with the greatest accuracy by stereoscopic measurement of the height of the banks of the riverbed and plotting and the basis of these measurements a transverse profile of the valley (Section 52). As has been shown, in this case the height of increases in the level obtained from the data of water measurement observations is compared with the heights of the banks. For determination of increases in level we may also proceed on the basis of span measurements of bridges and other hydrotechnical installations (see Section 40).

The high level position of the bottomland may be approximately determined from indirect features. With uniform image tones for the bottomland, indicating little dissection of its surface, we may assume that the bottomland is high and seldom flooded (Photograph 15). The presence of sharply expressed displacement fans with a developed network of streams, braided channels, and bottomland ponds provides the basis for assuming a low elevation of the the bottomland and frequent flooding (Photograph 16). This is also indicated by the presence of swampy surfaces in the bottomland.

A detailed study of the microrelief of the bottomland permits in isolated cases evaluating the periodicity of flooding and the elimination of flood waters — stereoscopic examination of the bottomland surface of the banks with determination of the height of banks and crests as well as of the relative depth of individual hollows in the bottomland permits determining the sequence of flooding of individual portions of the bottomland or of the sequence of their elimination of water during the recessions of spring floods.

In addition, a study of the microrelief permits certain conclusions concerning the hydrodynamicfeatures of the stream in a given portion, noting the probable distribution of velocities during flooding, and evaluating the intensity of riverbed processes.

The displacement fan is formed due to the displacement of the riverbed. The more intensive the meandering the greater the curvature of the bands. The degree of curvature and the frequency of bands comprising the image of the displacement fan may indicate the intensity of riverbed processes. A multiple pattern of displacement fans under stable soil conditions characterizes variability of action of the streamon the banks along the river. The microrelief of a bottomland under unstable soil conditions, with the soil poorly retained by vegetation, may permit evaluating the coincidence of direction of flow of the river and the flow of the river with the bottomland flooded during the spring flood. Finally, it is necessary to mention that the direction of the current (Section 39) may be determined from the arrangement of the displacement of the current (Section 39) may be determined from the arrangement of the displacement fan.

The above information confirms the fact that a study of the pattern of the displacement fan permits paleohydrographic analysis (that is, tracing the history of development of the riverbed by plotting its previous position from the bands of the fan). The displacement fans, repeating the outlines of the present riverbed are usually located below the fans of the upper pattern. This permits, at least qualitatively, distinguishing during investigation of even a mosaic or a single photograph, portions of the bottomland with different depths of flooding and different ground water levels relative to its surface (this problem is examined in greater detail in the article by I. V. Popov /74/).

Section 32. Complex Identifying Features of Different Types of Valleys

A combination of various identifying features, as mentioned in the previous sections, permits establishing the type of a valley directly from the external appearance of its image.

A complex identifying feature, permitting determination of the presence of a valley within the limits of an aerial photograph, tracing its ridges, slopes, and bottom, is the characteristic structure of the pattern of the slopes in the bottom of the valley, which is due to the fact that river valleys to a greater degree than other relief formations, are associated with the interaction of water and soils, as a result of which there are created extremely unusual sculptured surface forms in the form of erosion trenches, gulleys, and ravines on the slopes, displacement fans in the bottomland, etc. Due to this feature, on the photograph it is easy to distinguish the slopes of the valley from the surface of the adjacent terrain and from the bottom of the valley even on the basis of the general character of the image.

Thus, from both banks of the river it is usually possible to trace three bands of terrain with a different image pattern.

The first band from the riverbed corresponds to the image of the bottomland. Its general appearance is characterized by uniform image tone if the bottomland is level, and crescent-shaped radials of bright and dark bands in the case of the presence of crests and depressions between them (a displacement fan).

In the presence of steep slopes, the second band from the river, corresponding to the slopes of the valley, is characterized by the greatest variegation and mosaic structure. It is caused by the presence of outcroppings of rock, often with a characteristic striped pattern and by a network of erosion trenches, gullies, and ravines fanning out into the river valley. They are almost always clearly visible on photographs due to the contrast between their darkened and brightened slopes. The images of flat slopes are often characterized by large striped patterns. Parallel stripes in this case correspond to the different levels of terraces.

The third band from the river, with a distinctive structural pattern, is a feature of the surface of the terrain adjacent to the river. The structure of this band depends on the general relief of terrain removed from the direct influence of the currents of the river. This band is characterized by the larger forms of relief and consequently also by the smallest variation in pattern.

In the presence of fields and with flat slopes of the valley such contrast in the pattern of the slopes and the adjacent terrain does not usually occur and in this case, as has been mentioned, in order to locate the ridges of the valley without a stereoscope it is necessary to study the character of the arrangement of the fields relative to one another (see Section 27). With steep slopes location of the ridges of the valley facilitates the study of the formations characteristic for the valley slopes: ravines, gullies, outcroppings, etc. In this case it must be kept in mind that the ridge cannot extend along the upper parts of ravines and gullies; it usually lies in the vicinity of the expanded, water-discharge portions.

We present below a summary of the identifying features of different types of valleys.

(1) Crevasses (fissures), canyons, gorges. They are easily detected on photographs from their shadows. A hindrance to interpretation lies in the usually long shadows from the high and abrupt slopes, sometimes preventing examination of the bottom of the valley (Photograph 20).

(2) V-shaped (undeveloped) valleys (Photograph 20). Their features on an aerial photograph are:

(a) the variegated and sharply expressed mosaic of the pattern of the slopes as caused by an abundance of outcroppings and sculptured forms;

(b) the weak development of bottomlands, which are easily recognized from the characteristic pattern of their surface (see Section 31);

(c) the presence of lateral terraces and formations in the riverbed in the form of waterfalls and large rapids (Photograph 20).

(3) A trough-shaped valley (a glacial trough). It reveals on photographs a wide bottom with a narrow band (with clear borders) with the characteristic variegated mosaic pattern for slopes as well as the presence of a wide bottomland (Photographs 18 and 22).

(4) Trapezoidal valleys. They are similar to the bin-shaped valley.

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The particular identifying feature is the weakly expressed band with the mosaic structure characteristic of slopes. This band is broader than in the bin-shaped valley but somewhat narrower than in the V-shaped valley and in the glacial trough (photograph 23).

For reliable interpretation of this form of valley, stereoscopic examination of photographs is recommended.

(5) The unexpressed valley. In the absence of clearly expressed discontinuity of the transverse profile of the valley, the principal feature for identifying its type is the tone of the surface as caused by the vegetation. The latter, in accordance with the conditions of drainage (moisture), creates within the limits of the valley and its slopes definite zones which differ in tone and facilitates distinguishing the irregularities of relief.

(6) The dry valley. The identifying features of dry valleys differ but little from those of river valleys. The principal identifying features are the shadow, the tone (determined by the character of the surface cover of the slopes and the bottom of the dry valley), and the structure of the slope pattern.

(7) Ravines are always easily identified on photographs from the contrast of light and dark. A hindrance to interpretation is the presence of a long shadow, preventing examination of the details of slopes in the bottom of ravines. With incorrect placement of the photograph relative to the lights the ravines often appear as convex formations (an inverse effect) (Photograph 24).

For more reliable determination of the type of valley it is necessary to plot its transverse profile in characteristic directions. These profiles may also serve as illustrations supplementing the description of the rivers. In addition to the transverse profiles, the heights and steepness of slopes for a number of principal directions may be determined in order to provide the most basic quantitative appraisal of them. The methods of determining these characteristics of slopes and plotting the transverse profiles are described in Chapter IV.

Detailed characteristics of the relief of slopes in the bottom of the valley, there intersections and dissections, the presence of terraces, landslides, talus, and cave-ins, as well as alluvial fans and data concerning their dimensions are determined on the basis of identifying features as given in Sections 26-29. Swamp, vegetation, soils, and the road network of slopes and the valley bottom are also determined from features described in the appropriate sections.

CHAPTER VII

INTERPRETATION OF RIVERBEDS

Section 33. General Information Concerning Riverbed Interpretation

As was shown in Section 24, riverbed interpretation consists of three principal stages.

The first of these stages consist of determining the contours of the riverbed. This makes it possible to obtain information concerning the character of the riverbed in the plan view: its crookedness, branching, the presence of islands, flowing lakes, etc.

The second stage is that in which information is obtained concerning the various riverbed formations, their appearance and type, the distribution, the character of their relative location, their spacing and structure, the periodicity with respect to the vertical outlines of the riverbed, the type of banks, etc.

The third state consists in determining the quantitative characteristics of the riverbed and of its individual elements (that is, measurement interpretation).

A number of riverbed characteristics is read from aerial photographs on the basis of direct identifying features (the riverbed outline in the plan view, the presence of certain riverbed formations, the character of the banks, installations on the river, etc.) However, many riverbed characteristics are obtained from aerial photographs only on the basis of indirect features (information concerning bottom soils, depths, rates of flow, direction of flow, etc.).

Numerical characteristics of many elements read directly on the aerial photograph may be obtained also from an ordinary large-scale map. However, some of them as well as a number of characteristics obtained from indirect features, may be quantitatively expressed only on the basis of special photogrammetric and stereophotogrammetric methods of measurement.

In the ensuing sections we present the description of the principal identifying features of the most important characteristics of the riverbed. Information concerning stereophotogrammetric and photometric methods of measuring is given in an independent chapter in which we set forth the special features of application of these methods in order to obtain the riverbed characteristics. The principles for performing these operations are discussed in Chapter IV and in item /54/ in the bibliography.

Section 34. Determining the Contours of Rivers and Lakes

The general outlines of riverbeds are almost always easily detected due to the difference in illumination of banks even on photographs of the smallest scale.

Hence, with incorrect placement of the photograph relative to the light source a riverbed often appears as a convex, twisted embankment (Photograph 25), but is easily distinguished from other objects on the terrain by its characteristic crookedness.

Thus, an important identifying feature of a riverbed is the nature of its crookedness /meandering/. The crookedness of riverbeds is usually not repeated over different sections, whereas for artificial structures (roads, canals) it is customary to observe smoother or geometric curves. Hence, the curves formed by a river may not be confused with the outline of any other object seen on the photograph.

Indirect identifying features for a riverbed are suitability for the depressed portions of relief (waterfalls, valleys), the presence of structures peculiar to rivers, ridges, dams), etc.

If on the photograph there is seen an open water surface, then it may easily be recognized from the uniformity of the tone, the regular or often completely structureless outline of its image, or (with transparency of the water) from the characteristic smooth outline of images of the relief of the bottom.

A water surface concealed by aquatic vegetation is identified chiefly from the structure of the outline, but a frozen surface is identified from the uniformity of the surface and the clearly visible shadows of the banks (Photograph 11).

According to the tone of the water surface, the following distinctions are made, an open water surface (summer photographs) may have a different image tone on the photograph, depending on the conditions of the survey and processing of the negative (or positive), the color of the water, its transparency, depth, bottom soils, condition of the water surface, and cloudiness. However, distinctions in tone (namely, in the uniformity of density of tone or the gradualness of transition from dark to bright tones) are so characteristic that an image of open water surface is unmistakably identified.

A black tone for the surface of the water occurs on photographic prints in the following cases:

(1) with the sun at a high elevation at the moment of photography, as performed with the vertical position of the optical axis of the aerial camera (Photograph 24);

(2) with large depths of reservoir;

(3) with a dark color from the bottom of the reservoir;

(4) with concealment of the water surface by shadows falling from the banks, from vegetation on them (photographs 20 and 25) or from clouds. Shadows from clouds usually have irregular outlines (Photograph 4), and cover not only the surface of the water but also part of the shore.

In all these cases we assume the presence of considerable transparency of waterand a quiet state of the water surface.

Bright tones are obtained:

(1) In the presence of flashes on the surface of the water (agitation, with the sun at a low of elevation at the time of photography, tilting of the optical axis of the aerial camera), even it is transparent (Photograph 26). Flashes during agitation of the water surface due to movement of waves are arranged in rows broken at the leading edge (Photograph 27);

(2) In bright bottom soils with shallow water; in this case we observe a smooth transition of tones from dark to bright and can examine the relief of the bottom (Photograph 32);

(3) With considerable muddiness of the stream (mountain rivers, flatland rivers during flooding); the general character of the tone in this case is distinguished by uniformity (Photographs 28 and 29);

(4) With concealment of the water surface by aquatic vegetation; in this case the characteristic structure of the image is that of isolated circular spots or groups of grains depending on the scale of the survey (Photograph 17);

(5) The white tone of the image of exposed water, sometimes encountered on photographs, is usually a defect in the survey and indicates that at the moment of the photograph the rays of the sun reflected from the surfase of the water, entered the lens of the aerial camera. This is easily established by comparison of two adjacent photographs. If the white spot appears

only one one of them, then its occurrence can only be attributed to reflection of the sun's rays. The presence of a white spot on both photographs indicates other causes for its appearance. In a few cases the tone of the image of the water surface is caused by the reflection of clouds; this is indicated by the characteristic structure of the pattern, in the form of curling vapor (Photograph 4).

A water surface concealing a solid ice cover cannot, of course, be seen through on photographs. In this case the presence of a river or a lake is indicated only by the identifying features used for interpretation of relief, anmely the shadows of banks and the level character of the surface lying between them. If the ice cover is concealed byysnow, the tone of its image does not differ from that of snow cover on a terrain adjacent to a river. Exposed ice cover in an area of snow appears on a photograph in dark tones, whence on large-scale photographs there is usually seen an irregularity in the structure of the ice, patches of snow, often in the form of ridges, fissures, etc. (Photographs 11, 12).

In some terrains (wooded or steppe) a riverbed may appear to be continuously inclosed by the tops of trees or examined only in a stereoscope (Photograph 30). In steppe terrain a narrowbband of forest (with its characteristic sinuousness) is in itself an indication of the presence of a riverbed since vegetation in such areas is usually adapted to riverbeds and streams (Photograph 30).

In a heavily forested terrain a riverbed, even when fully surrounded by tree tops, may still be detected from the presence in the midst of the forest of the characteristic twisted band of dark tone accompanying the usual riverbed. This band is formed by the tops of trees growing close to the river which are the richest in coloring and largest. In addition, the presence of a river may be determined from the difference in elevation of the forest canopy in the vicinity of the riverbed and on the shoulders of the valley if the river valley is clearly expressed (see Section 29, Photograph 31).

Section 35. Interpretation of Riverbed Formations

Riverbed formations are detected on aerial photographs on the basis of both direct features (the image of the elements themselves on photographs) and from a number of indirect features. The possibility of obtaining this information depends on the natural peculiarities of the object under investigation and to a great degree on the conditions of photography and its processing.

We have discussed the causes for the different tone of images of water surface on a photograph. It is clear that the relief of the bottom and the different formations in a riverbed will be directly seen only in case the water is sufficiently transparent, the riverbed consists of bright soil, and the surface of the water does not reflect the sun's rays. The only exceptions are certain riparian formations in the form of alluvial fans, not fully covered by the water, sandbars, and shoals, waterfalls, and rapids. The latter are responsible for a considerable change in the character of the pattern of the water surface and may usually be quite easily interpreted according to this feature.

The indirect features permitting determining the presence of one or another formation in a riverbed are based on well-known, largely qualitative relationships between the outlines of a riverbed in the plan view and in the profile, the relations between them and the character of the relief of banks, bottom soils, the aquatic and riparian vegetation, and also on the suitability for the particular features of the riverbed under the local conditions — chiefly the roads intersecting them, footpaths, and various artificial structures.

Below we present descriptions of the direct and indirect features of various elements of a riverbed and of riverbed formations. It must be pointed out that the direct features may be used only in a transparent layer of water.

(1) Those points of a riverbed with the brightest bottom tones are sandbanks. Sandbanks are indicated by tone of irregular density, ranging from light to dark grey. The brightest points correspond to the lowest depth, the darkest points correspond to the greatest depth. On large-scale photographs it is often possible to examine and identify the parts of a sandbank — the ridge, the bottom, and even the regularities in the bottom surface caused by currents and agitation (Photographs 15, 32, 33).

According to the nature of the relative location of the ridges of the

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sandbank and the shoreline, we may easily determine its type (normal, and oblique sandbank-spit, et al.).

(2) Those portions with the densest dark tone of surface usually correspond to the water reaches (Photograph 32). In determining the location of reaches and sandbanks on the photograph it is necessary to check the relative location of these with respect to the bends of the riverbed (Farfa's rule).

(3) The darkest portions of the image of a water surface correspond to the water channel. In determining the location of a channel it is necessary that it be matched with the locations of the water reaches and sandbanks (Photograph 32).

(4) Flat, shallows, shoals, sandbars, and beaches are identified by direct features (that is, as in nature, directly, according to the character of the location of the corresponding bright tones in the riverbed). In those cases where these formations are covered, even if by a shallow layer of water, on the photographs there is always clearly seen their microrelief, resembling in external appearance the photograph of a rippled water surface (small sand ridges formed as the result of movement of water over their surface). Sometimes beneath the water there is seen a narrow white band formed by a shelf created by the river during a period in which the water level remains at a given height.

The exposed surface of these formations is almost always distinguished by the brighter tone and the usually structureless appearance of the outline. Only under the stereoscope is it possible in this case to see the irregularities of relief. The brightest tones are usually on sandy soil, the darkest tones are usually on clayey soil. In wide shoals and beaches sometimes against the generally bright tone, even in examining the photograph with the naked eye, there are apparent small, usually circular figures, patches. This is the grassy vegetation which grows on their surface during a prolonged period of low level during which this surface remains exposed for a considerable length of time. Sometimes on such formation there are visible small, dark narrow bands. They are formed by the shadows of small shelves arising during prolonged maintenance of a given level and its subsequent reduction.

(5) Rapids are usually easily recognized by the white bands of different dimensions extending over the surface of the water, wherein from these patches

there are usually two well-expressed, expanding white bands extending over the direction of the flow (Photograph 34). Both the patches and the bands are formed by foaming water as it flows at a great rate over local obstacles — rocks, boulders, etc. (discussed in greater detail in Section 53). Small underwater shelves will sometimes be evident by the shadow cast by the shelf even if it is located at a considerable depth.

(6) Waterfalls are also often clearly seen on a photograph. They appear either in the form of a white band running perpendicular to the riverbed and formed by the reflection of the falling water (Photograph 34), or in the form of a dark band formed by the shadow from the shelf of the waterfall (Photograph 20). Since the waterfalls occur chiefly on mountain rivers, the water surface of which usually has a light gray tone on the photograph, both the white and the black band corresponding to a waterfall is clearly seen. From the photographs we may easily determine not only the location of the waterfall, but also the upper and lower waters thereof, and by stereoscopic means we may examine large scale photographs to determine the drop of the waterfalls.

If a waterfall appears as a white band, then its upper portion is usually clearly delineated against the general tone of the surface of the water above the waterfall, while the lower portion forms a ring of white patches or isolated white bands of foaming water. If the waterfall appears as a dark band at right angles to the flow of the river (Photograph 20), then, as in the previous case, the upper edge of the shadow is usually clear and the lower edge is irregular and recedes downstream (Photograph 20).

Sometimes the image of a waterfall may resemble the image of a spillway dam. However, while the waterfall is differently oriented with respect to the riverbed and has an irregular outline at its crest, the dam is distinguished by its always strictly regular outline and its usually perpendicular orientation relative to the banks.

Section 36. Identifying Bottom Soils

Bottom soil is identified on the basis of identifying features described in Section 44. In the interpretation of soils the principal procedure is is based on evaluation of the tonality of the image of the bottom as adjusted

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for a series of indirect terrain features (according to the nature of the structure of the banks of the riverbed, sections at the mouth, the vegetation on the banks and in the bottomland, etc.). If the bottom of the riverbed cannot be examined, then it is necessary to employ one of the abovementioned indirect features on the basis of all the information which is obtained in interpreting the soils of a terrain adjacent to a river.

As a supplement to the above (direct and indirect) features for identification of soils we may introduce the following indirect features. With a sandy riverbed the tone of the image of the water surface, as has been mentioned, is distinguished by bright tones, the density of which depends chiefly on the depth. With clayey or muddy soils the relief of the bottom, even with extremely shallow water in the bank portions, is almost not detectable and the tone of the image of the water surface is usually gray. The gray tone of the water may also be due to other causes (for example, a high content of detritus in the water).

A rockly bottom on flatland rivers gives black tones for the images of the water surface even at shallow depths with considerable transparency. In those cases where we may assume that the water layer is of considerable depth, identification of a rockly bottom is extremely difficult; however on photographs of the largest scale it is possible to examine the shadow from large rocks under water. If the rocks extend beyond the surface of the water, then the general rockly character of the bottom is determined without difficulty.

Section 37. Determining the Presence of Vegetation in a Riverbed

Information concerning growth of vegetation in a riverbed is usually obtained from a photograph without particular difficulty.

The presence of vegetation in a riverbed is determined from the characteristic structure of the outline and the bright tone in comparison with the dark image of the water surface usually obtained in these cases (a muddy dark bottom).

The outline of the image of aquatic vegetation usually has a fine-grained structure, wherein there are clearly visible the various sizes of patches with circular outlines. The outer boundary of the bands of aquatic vegetation (directed toward the river) is usually not clear and has an extremely irregular

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outline (Photograph 17).

Underwater vegetation, as a rule, has the darker tone, vegetation above the water has the brighter tone. The presence of large patches in the latter case is clearly distinguished. From these features it is often possible to establish the edge of underwater vegetation as well as that above water. In those cases where the overgrowth of a reservoir occurs by the invasion of aquatic, swampy vegetation from the banks, among the bright grainy patches there are detected small irregular outlines of almost black patches corresponding to the areas without such vegetation. They sometimes form a rather complex mosaic resembling lace.

In order to check the resulting information concerning the overgrowth of the riverbed it is necessary to consider the general character of the riverbed and the banks so that we may establish the extent of the typical correspondence of the located points of vegetation on the photograph to the conditions of their growth. For example, aquatic vegetation growing above the water, among which we may include lillies and waterlillies, are usually widely found in mills, small lakes, and in the vicinity of swampy banks, etc.

Section 38. Interpretation of River Banks

In order to obtain characteristics for river banks it is necessary to determine their height, slope, soil, vegetation, and stability.

The most complete quantitative characteristics of banks may be obtained only by stereoscopic examination and measurement. This is usually from any direction on a river, whereby with a considerably greater accuracy than from any topographic map, on which the image of the banks is always quite sketchy.

For a discussion of the methods of stereophotogrammetric measurement of the height of banks see Section 52.

When it is not possible to conduct stereophotogrammetric measurement of the banks of a riverbed (small scales or extremely small rivers with mildly sloped banks), their characteristics may be obtained by using various indirect features, permitting evaluation of the character of the river banks. The most thorough qualitative determination of the height of banks may be obtained by evaluating the character of the bottomland. As was mentioned in Section 31, it is sometimes possible to evaluate the degree of flooding of a bottomland from an aerial photograph and, in studying the microrelief of this bottomland, to proceed to a qualitative evaluation of the banks.

By the use of an aerial photograph the height of the banks may also be approximately determined by comparing it with the height of known objects located on them (shrubs, trees, buildings, etc.). The steepness of the slopes of banks may be qualitatively determined by the presence of shadows, by the extent of their vegetative cover, by the nature of the outline of the surface of the slopes, by the soils composing the bank, by the width of the visible portion of the slope.

The identifying features of steep banks may be:

(a) the presence of a clearly expressed shoulder (the shadow of the banks);

(b) erosion of the bank, in the absence of shoals, and sandy stretches of considerable width;

(c) the presence of horizontal stratification on the image of the slope, with small intervals between individual layers;

(d) the presence of shrubs and trees located close to the shoreline;

(e) the predominance of dense soils in the riverbed and on the bottomland: the narrower the visible portion of the bank slope, the steeper the slope.

For steeply slanting slopes the characteristic features are an absence of shadows, the absence at the shoreline of scrub and tree vegetation, the predominance of friable or porous soils in the riverbed and the bottomland, swampiness of the banks, and indistinctly expressed shoreline (except the case where it is covered with a shadow from the bank).

The soils, vegetation, and, especially, the turf condition of the banks are ascertained from identifying features for the corresponding elements of the terrain (see Sections 44 and 45).

It must be pointed out that the banks consisting of sandstone have a brighter image, tone and the clayey soils have a gray tone, often with a striped pattern structure. Banks composed of rock formations are distinguished by the complex structure of the relief of the slopes due to the presence of fissures, crevasses, trenches, etc. The more the exposed slope is subject to moisture, the darker the tone of its image. Turfed slopes, on the other hand, are seen on the photograph as areas which increase in brightness in proportion to the moisture content.

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The stability of banks may be judged from the character of their soils, from the character of the shoreline, and portions of tributaries, gulleys, and ravines of intersecting banks in the vicinity of estuaries.

An important factor for evaluating the stability of the banks of a riverbed is the study of the character of the microrelief of the bottom (displacement fans). The less stable the soils of the bottomland of the riverbed, the more numerous the banks and the more complex their pattern (see Section 31).

In the presence of wooded growth, the stability of banks may also be judged from the condition and the character of the growth. For example, on undercut banks in a forested terrain it is often seen that trees have fallen into the river.

Section 39. Determining the Direction of Current

The direction of a river current is determined from aerial photographs on the basis of numerous indirect features. These are: the character of the relative positions of rivers and their tributaries; the shape of riverbed formations; the character of the arrangement of hydrotechnical structures and navigation facilities on rivers; the character of the image of the water surface. In addition, a conclusion as to the direction of a current of a river must, as a rule, proceed not from one of the abovementioned features but from a number of them.

(1) The character of the inflow of tributaries has particular significance in determining the direction of a current, especially for small rivers which appear on the aerial photograph as narrow bands. The direction of the current is determined from the angle at which the tributary enters the river. As a rule, the tributaries of a river enter at a sharp angle, the vertex of which points down stream.

(2) The shape of riverbed formations permits determining the directinn of the current from the following features.

The peaks of bends in the shoreline are, as a rule, directed downstream (Photograph 32).

Islands rotated in the middle of a riverbed usually have an elongated pear-shaped outline in which the pointed portion of the island is always turned downstream.
turned downstream. Often its extension is a sandy shoal, but in a number of cases such a sandbar is washed out and sedimentation occurs in the upper

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portion of the island. Thus, it is not feasible to base preliminary observations of the shape of an island on the presence of a sandbar alone. This same shape is apparent in the outlines of flats, that is, sandbanks located in the middle of a riverbed.

Sandbars with a pointed tip are also always located downstream (Photograph 16b). Dead end back-waters are directed against the current (Photograph 17).

With a transparent river bottom the bent ridges forming the usual micro-relief of shoal and sandbar surfaces have the convex side directed upstream.

The edges of shoals and sandbars are directed upstream on the convex side; their downstream edges are sharply outlined (subterraced), and their upstream sides are indistinct (Photographs 32, 33).

The arrangement of displacement fans also facilitates determining the direction of current. Usually the broad part of the fan extends into the stream (Photograph 16b).

(3) Location of ice-guards and other hydrotechnical structures is a reliable feature for determining the current.

The ice-guards (at abutments or in the form of individual groups of piles) at bridges are always clearly seen on photographs and are located on the upstream side (Photographs 27, 36).

Pontoon (floating) bridges bend downstream. There are also floating log-catchers and other floating devices.

Retaining dikes are located at a sharp angle to the current, that is, the ends of the dike head into the stream (Photograph 19).

Boats and barges moored at river landings point downstream.

The gates of river locks are pointed toward the current (Photograph 38b).

The clearly expressed outline of a dam faces upstream (Photograph 38b).

(4) The direction of the current is determined from the image of a water surface in the following manner.

White bands formed by the water as it foams in flowing around obstacles or in passing through narrows are extended downstream and are most clearly visible at the obstacles. In flowing around the obstacles the water forms two bands gradually diminishing downstream and often having the form of diverging parabolas. Thus, the peaks of such parabolas lie upstream.

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In the blending of two streams of different turbidity the image of the water surface below their fusion often has the form of two differently colored streams with the most sharply expressed differences in tone immediately below the fusion and with gradual matching of the tone of the water downstream (Photograph 29).

CHAPTER VIII

INTERPRETATION OF HYDROTECHNICAL STRUCTURES

Section 40. Principal Identifying Features of Bridges

Interpretation of hydrotechnical structures is of interest not only in itself but also in that it provides information of a hydrological nature. For example, stereoscopic measurement of the height of bridge spans gives indirect indications of the probable height of flood levels; the location of individual details, as was mentioned in Section 39, permits judging the direction of the current, etc.

The principal direct identifying features of bridges are the shape of the image of the outline of the shadow of the bridge. The road network is an indirect but wholly reliable feature.

The presence and location of a bridge is clearly established on photographs of all scales. The principal feature determining the location of a bridge is the roads leading to it and the narrow, often bright band (the deck of the bridge) joining them across the river, a ravine, or other obstacle. From its regular outline (in the form of a rectangle) in the plan view of a bridge is easily distinguished without a stereoscope (Photograph 27).

The deck of a bridge (on dirt roads or highways and sometimes on railroad bridges) is usually narrower than the roads leading to it (roads on the approaches to a bridge are often widened) and has an extremely sharp outline. Thus, the image of a bridge on an aerial photograph resembles the symbol by which bridges are represented on a topographic map (Photographs 27, 36).

The type and construction of bridges are easily determined from the shape of the shadow cast by the bridge and often permits observing even the details of construction (Photograph 36).

On large-scale photographs construction details of a bridge, especially with magnification and stereoscopic examination, may be determined directly: the visible parts of piers and abutments, crossbeams, girders, etc. (Photograph 36).

The material of the bridge may be determined from indirect features by taking into consideration its type and construction. These indirect features of the tone of the image, features of construction, dimensions of the bridge, etc. (Photograph 37).

Reinforced-concrete bridges are distinguished by great width, regular and distinct outlines, and a light-gray tone. Only when the deck of the bridge is covered with asphalt is its image dark. It must be pointed out that, other conditions being equal, the deck of the bridge is usually brighter in tone than the roadways leading to it.

Steel bridges are always easily identified from the dark tone of the image and the shadows from girders.

Wooden bridges as well as reinforced-concrete bridges usually have a light gray tone and it is difficult to distinguish the material of the bridge in this case.

On large-scale photographs, with careful stereoscopic examination and with adequate magnification, the concrete is sometimes distinguished from wood by its smoother and brighter surface.

The image of wooden structures always gives a somewhat rough and darker surface. Thus, the tone of the image in this case is not a reliable identifying feature and the principal identifying feature is the shape of the outline of the bridge. Usually the outlines of wooden bridges are irregular and the edges of crossbeams and other compliments of wooden structures are visible; hence, in a careful study of a photograph wooden bridges are easily distinguished from all others.

The upper dimensions of a bridge are easily determined by direct measurement. The height of the bridge above the surface of the water may be determined stereoscopically with an average accuracy of 0.1 to 1 meter depending on the scale of the photograph.

Section 41. Interpretation of Dams, Locks, and Hydrotechnical Installations

For all hydrotechnical installations on a river (dams, locks, bank reinforcements, riverbed retaining structures, special installations of irrigation systems -- lock regulators, aqueducts, etc.), in compiling a hydrographic description information is gathered concerning the location, materials, dimensions, and features of construction of the hydrotechnical installations. In addition, the following information for individual installations is assembled:

For dams -- the purpose (water retaining, raising the level of water), a hydroelectric power station, the possibility of travel over the top of the dam, and concerning a reservoir (the nature of the banks, the dimensions, the volume of the overflow prism);

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For locks -- the depth of the water at the lower gate and the traffic capacity (the time required for the passage of a single ship through the locks);

For bank reinforcements -- the approaches to the banks;

For special installations of irrigation systems -- the flow capacity (greatest discharge in m^3/sec).

An aerial photograph permits obtaining almost all the basic information required for a hydrographic description with the exception of data concerning details of concealed structures (for example, the type of valves) and information associated with the operation of structures.

A necessary condition for obtaining information of the greatest possible value concerning hydrotechnical installations is the interpreter's preliminary knowledge concerning the types and constructions of a given type of installation. With such information at hand, an interpreter, according to the relative location of individual installations, can without particular difficulty determine all the basic data concerning an installation as read directly on the photograph.

The sequence of operations: determine the location of the installation, establish its appearance and type, distinguish the details of construction and material, perform measurements; then, on the basis of this data and the indirect features, make a logical conclusion concerning the character and type of installation. In using large scale photographs it is desirable to outline the installation with a pencil.

As in the case with bridges, the principal identifying features of hydrotechnical installations are the outline of the image, the shadow, and the tone of the image. In addition, in order to answer a number of questions it is necessary to resort to indirect features, chiefly for determining the purposes of the installation. Thus, in interpreting hydrotechnical installations use may be made of the same procedure as was used in interpreting bridges.

The images of various hydrotechnical installations with explanatory texts for their interpretation are given in Photographs 37-40.

CHAPTER IX

INTERPRETATION FROM AERIAL PHOTOGRAPHS OF THE GENERAL CHARACTER OF THE SURFACE OF A WATERSHED, SOILS, VEGETATION, AND LOCAL ORIENTING FEATURES (ROAD SYSTEMS)

Section 42. General Introduction

The interpretation of relief, soils, vegetation, and the road systems is one of the most important orienting features within the limits of the entire watershed area of a river and cannot be considered as one of the hydrological problems; however, obtaining information concerning these elements with one or another degree of detail is necessary in comparing hydrographic descriptions.

Obtaining data concerning the nature of the relief, soils, and vegetation of a river watershed is necessary also in the solution of many special hydrological problems (for example, in determining the conditions of surface runoff, establishing the degree of forestation of the basin, studying the regularity of the descent of snow cover, etc.). This chapter presents the principal methods of interpreting the above terrain elements.

Section 43. Interpreting Relief and the Boundaries of a Basin

(1) Determining the General Character of the Relief of a Basin

For the hydrographic description it is necessary to obtain data principally concerning the large forms of relief.

All this information may be obtained from aerial photographs with a greater degree of thoroughness than from a topographic map and even from the materials of a field reconnaisance. An exception is the obtaining of height markings,which are determined approximately in the form of relative heights of single points (hills, individual peaks, etc.) above others (a river, a lowland, etc.). The task of interpreting meso- and micro-relief pertains to the study of river valleys and bottomlands.

The principal identifying features by which relief is interpreted on aerial photographs are discussed in the description of interpretation of river valleys (Sections 25-32).

As an additional instruction it must be pointed out that one of the most important indirect features in the interpretation of relief is the structure of the hydrographic net. On the basis of the study of its outline from figures it is often possible to determine the morphology of a surface. For example, considerable twisting of riverbeds is usually

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characteristic of a lowland terrain. The presence of water streams which are parallel to one another over considerable distances permits concluding the presence of a general slope of the surface in the same direction as that in which the water streams flow. The presence of a series of parallel water divides and the trunk system of the hydrographic net characterize a rolling lowland. Convergence of the hydrographic net to one center, usually toward a lake or a swamp, indicates a concave lowland surface.

For these same purposes a study of the location of populated points and road systems may be used (Section 28).

(2) Determining the Boundaries of a Watershed

In the presence of a well-developed hydrographic network determination of the boundaries of a watershed from aerial photographs is performed with greater accuracy than from large-scale maps. This is possible due to the fact that on aerial photographs it is possible to detect even the smallest streams (brooks) and sometimes the smallest ravines and trenches formed in the runoff of thaw and rain waters and to examine under a stereoscope irregularities of the surface not detected on maps.

Especially valuable information may be obtained by using aerial photographs for determining watersheds under the conditions of a flat, swampy relief. With an aerial photograph it is possible to achieve great accuracy in determining the lines of surface flow on mossy, convex swamps. In addition, it fixes the image of the lines of streams flowing over the surface of the swamp (flowing swamp) due to the fact that at such points the richest and densest vegetation grows.

The interpretation of flowing swamps and hydrographic network of swamps is discussed in greater detail in Chapter XII.

In lowland areas in the presence of open, unforested stretches the water divides are determined with less accuracy than in swampy areas. However, due to the close relationship between vegetation and moisture conditions, and, consequently, with the microrelief of the line of water divides, even in this case they may be fairly accurately defined (Photograph 41) by using the identifying features discussed in Sections 28 and 31.

Correlative relations between forest vegetation and relief as determined by the difference in moisture of soil on elevated and depressed portions also permit noting the line of water divides under the conditions of a lowland, forested relief (Section 45).

In arid steppe regions on aerial photographs made during the summer (that is, during the period when the vegetation withers and consequently has a uniform color) lines of water divides are more weakly expressed. Yet, even under these conditions the traces of temporary streams flowing during the snow thaws may be detected from the residue carried by them, forming the typical striped outline of bright tones, or from the dark bands of vegetation typical of depressions in the terrain (the more moist portions) which may be detected chiefly due to the great density of vegetation at these points.

Finally, under the conditions of exposed soils in semi-arid and arid areas the fine network of small streams formed during the rainy period is detected on the aerial photograph with sufficient clarity if the soils are not extremely loose and are not subject to intensive erosion (Photograph 42).

Thus, by means of qualitative interpretation the lines of water divides may be detected even in those cases where their stereophotogrammetric determination becomes difficult or impossible due to a lack of clearly expressed relief and the presence of only inconsiderable deviations.

Section 44. Soil Interpretation

Interpretation of soils from aerial photographs is only approximate; however, under certain conditions, with careful study of a photograph and extensive use of indirect features, data concerning the soils may be obtained with sufficient accuracy for preliminary hydrographic survey operations. In addition, the aerial photographic survey permits embracing large areas which cannot be overlooked in preliminary surveys.

In the interpretation of soils use is made of direct features (the tone and pattern of the image) as well as, for the most part, indirect features and correlative relationships.

(1) Tone of Image

The tone of the image is determined largely by the color of the soil; consequently, from this feature the soil may be determined only for soils which are devoid of vegetative cover.

Soil colorations are usually caused by a combination of colors: black (humus) soils, red (caused by compounds of ferric hydroxide), and white (caused by the presence of kaolin, silicon dioxide, or compounds of aluminum hydroxide). According to the proportion of these compounds the photographic image of exposed soils is in most cases of a bright tone and only the black soils and red soils show dark grey tones. Sand, silt, limestones, etc. give the brightest, almost white tone (Photograph 32). Gravelly soils and conglomerates give a white tone with a characteristic speckled pattern on large-scale photographs. Clayey soils give greyish tones (Photograph 24).

The density of the tone of soil images on a photograph depends not only on its composition but also on the moisture content. The more moist the soil, the darker its tone. Hence, in interpretation allowance must be made for the degree of moisture of the soil (according to the time of the photography the effect of depressed forms of relief on the color of the soil, the proximity to the swamps, rivers, and lakes, the possible outflows of ground waters, etc.). In addition, the density of the tone of soil images on aerial photographs depends on a number of other factors: the conditions of illumination, the quality of the photographic film, laboratory procedures, etc. Hence, the tone of the image is often an unstable and unreliable feature.

(2) The Image Pattern

The image of gravelly soils and conglomerates, as has been mentioned, has a characteristically speckled pattern.

The presence at an outcropping (escarpment, cliff) of horizontal bands of different tones indicates the presence of close-packed rock formations (Photograph 24).

A variegated pattern of nonturfed sections (a sequence of bright and dark spots) corresponds to surfaces with rocky deposits and exposed rocky soils (Photograph 1).

(3) Indirect Features

The principal indirect feature is the character of the forms of relief and vegetation.

From the character of the relief we may establish the following varieties of soils.

Dunes and barkhans are characteristic only for loose, sandy soils (Photographs 43, 44).

Vertical walls, deep narrow ravines and jagged ridges of washouts are formed in compact sandstones and loess.

Cliffs consisting of slopes with convex formations and smooth outlines are found in areas with clayey soils (Photograph 24).

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The presence of rubble at the foot of a cliff is an indication of rock formations.

Isolated craters and closed depressions, if they are not located in river bottomlands (karst terrain) indicates the presence of limestone and marls.

The large exposed piles of detritus often encountered at the mouths of tributaries (streams and gullies) are evidence of the scattering of non-cemented soil (sands, gravelly rubble, etc.).

The presence of steep banks without reinforcement at artificial structures (dikes, open cuts, canals, highways and railroads, etc.) is an indication of the stability of the soils.

If there is evidence of plowing right up to a steep bank, this also is an indication of the stability of the soils.

(4) Correlation Series

As a rule, soils are associated with particular types of vegetation, which may permit approximating the characteristics of the predominating soils. For example:

Pine groves indicate the presence of sandy soils;

Spruce and fir occur chiefly on clayey and loamy soils, the spruce usually being located on swampy lowland sectors;

Osier usually grows on sandy and wet loamy soils;

Meadow vegetation occupies the greater part of alluvial sands, sandy-loamy or loamy-peat soils. Additional features are discussed in Section 29, Table 9.

Section 45. Interpretation of Vegetation

For the purposes of hydrographic investigation there are usually necessary:

(1) A short characteristic of the vegetation according to its principal groupings: forest, shrub, meadow, steppe, swamp;

(2) The characteristic location of vegetation in the basin area under study;

(3) A short characteristic of each grouping, to wit:

for forests -- tree species, the predominating rock types, the height of trees, the diameter of trunks or the age (young, mature);

for shrubs -- the predominating rocks, the height and density (sparse, dense);

for meadows -- dry, swamped, with a variety of grasses, with grama grass, with reed grass, the presence and nature of location of shrubs;

for steppes -- with a variety of grasses, with feather grass, etc.;

for swamps -- mossy, grassy, forested; the composition of vegetation -- grassy, shrubbed, with scrub forest, wooded;

in clearings and burned off areas it is necessary to ascertain the characteristics of the new vegetation.

The use of the materials of an aerial photographic survey in order to obtain information concerning vegetation is widely used, for example, in the timber industry, where data concerning stands of timber is obtained from photographs in considerably greater detail than required in hydrographic investigations. Thus, for general hydrographic purposes it may be considered that the materials obtained from an aerial photographic survey are wholly adequate.

The principal features for interpreting vegetation of photographs are the structure of the pattern, the tone, and the shadow, and to a considerable degree the outline of the image (for cultivated forests, plantings, and farmlands).

The graininess of the pattern, always clearly expressed, is determined by the image of the tree tops and easily permits identifying sectors and areas covered with trees and shrubs; shadows from a forest or individual trees and shrubs make the areas even more evident (Photograph 30).

For grassy vegetation the principal feature is the tone, while the character of the pattern plays a minor role. For swamps and farmland both these features are of importance and a substantial role is played by the outline (configuration) of the image.

Thus, it is not difficult to distinguish forested and unforested areas.

According to the character of the pattern (graininess) the tone of the surface of the shadows determine the principal characteristics which permit evaluating the composition of rocks. These features are given in Table 10, which is usually used in forest interpretation and in predicting the interpretation of fully mature stands of trees.

Most of the features listed in Table 10 are detected with the unaided eye, but certain of them (items 4, 7, 8) are detected only by the stereoscopic examination of photographs. As a rule, vegetation and many other elements of terrain are more easily and more rapidly identified under a stereoscope than with the unaided eye.

The differences in growth, the density of a forest, the time of the year, and the scales of photography may introduce considerable complication in the process of forest interpretation; however, in most cases the features listed in the table are considered satisfactory due to the fact that these conditions may usually be taken into account.

(1) The differences in growth are observed from the height of the forest canopy, the edges of sections with a different height of canopy, and from the size of treetops.

The higher the canopy, the older the forest. In comparing the heights of the canopy in different sections of a forest it is necessary:

(a) to establish that the sections are compared with identical types of trees, since the height of the latter depends not only on the age but also on the type of tree;

(b) to ascertain whether or not the change in height of the forest is due to irregularities in terrain;

(c) to determine whether or not there is a depression in the forest.

The types of trees forming the forest canopy are identified from the table and from the description of the identifying features of the individual species (see below). There are auxiliary tables (Table 11) for use in determining reforestation site classification /bonitet/.

The effect of the relief of terrain on the height of the canopy is explained by the following features. If the borders of sectors with different heights are sharp, then this is explained solely by differences in growth. Smooth changes in height (a gradual transition in tones of the surface of the canopy) are caused by changes in the relief of the surface (Photograph 45). It must be kept in mind that spruce-fir and mixed forests are characterized by a considerable difference in canopy height.

(2) A depression in a forest is indicated by thinning of the forest and a smaller diameter of treetops and the characteristic pattern of the terrain surface shining between the trees -- bright tones and a fine, blurred graininess -- the identifying features for a swamp (Photograph 31).

(3) The image tone of deciduous trees depends considerably on the time of year (in the fall the tone of deciduous trees, as seen from item 1, Table 10, is considerably brighter than at other times of the year).

In the winter only the coniferous trees are easily identified. Snow, falling on the branches, emphasizes the outline of the tree top.

(4) On small-scale photographs interpretation of forests is somewhat complicated even in stereoscopic examination and, due to the marked fine graininess of the pattern, errors are possible even in distinguishing shrubs and trees.

Information concerning the general identifying features of various large forest stands is given below.

Spruce-fir forests. The structure of the pattern of a stand of spruce and fir, as of all forests, is grainy. The distinguishing features which permit identifying a forest as a spruce-fir stand are as follows.

1. The entire pattern of a spruce-fir forest has a uniform clearly grainy appearance (Photograph 31), whereas deciduous forest is characterized by grouping of grains (curtains) and soft outlines of the latter;

In examining individual (illuminated) treetops there is clearly seen a sharp difference in intensity of illumination of the projection of the treetop and the shaded intervals between them;

The shape of the grains is elongated. On a photograph made with the sun at a low elevation, when only isolated high trees are illuminated, the grains will appear as bright streaks;

The dark intervals between the grains are irregular in shape, but the predominating shapes are elongated in the direction of the shadow and resemble triangles;

The size of the grains differs, but as a rule, the image of a spruce-fir forest is distinguished by smaller grain dimensions in comparison with pine and deciduous trees.

2. The general tone of the image, as a rule, is darker than in all other species of trees.

3. In stereoscopic examination the treetops have the appearance of a cone with the base turned toward the surface of the earth.

4. An easily discerned difference in tree height is characteristic of spruce-fir forests.

Mixtures of deciduous species in a spruce-fir forest are clearly distinguished by bright spots against the overall dark background of the image.

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5. Unmixed spruce and fir forests have the same identifying features, except that the fir trees have more circular shadows.

In addition to these identifying features, it is also helpful to determine the species of trees from the individuals trees (see Table 10).

Pine forests (Photograph 7). Unmixed pine forests have circular grain outlines with a gradual transition from the illuminated to the shaded portions of the treetops. The dark triangles formed by the shadows of treetops and characteristic for the spruce forests are not found here. If the forest grows on dry soil, then the grains are sparsely disributed, while on swampy soils the forest gives a dense grainy pattern.

The overall tone of the image of pine forest is brighter than that of spruce forest; the low classes of fullness give a light grey tone, a fullness of 0.7 meters and above gives a grey tone, and with extreme fullness a dark grey tone, but all of these are brighter than in spruce forests.

In stereoscopic examination the treetop resembles a hemisphere suspended in air. The older the forest the more convex the treetops. In young pines the depth of the top is considerably greater -- the lower branches of the trees are closer to the ground and are oval-shaped in appearance, hence their overhang appears smaller.

The canopy of a pine forest often permits examination of the surface of the earth, while this is not the case in a spruce forest.

The shadows of the trees are not dense.

The surface of the canopy of a pine forest is characterized by an almost complete lack of difference in height, hence the greater the density of treetops, the more level the canopy of such a forest appears on the photograph.

Distinction of the boundaries of unmixed stands of pine surrounded by stands of trees with other species predominating is quite clear. Young pines (up to three years) are quite similar to young spruce and it is difficult to distinguish them.

It must be pointed out that in external appearance on the photograph a pine forest resembles birch, hence it is necessary to exercise extreme care in interpretation. Mixtures of deciduous species are well-defined from the grouping of treetops among the generally uniform grainy pattern. This also is an indication of sharp variations in height of the canopy. (Photograph 7).

Birch forests. Birch forests do not lend themselves to interpretation and reliable identifying features for them have not as yet been evolved. In addition, it must be kept in mind that only mature forests lend themselves to interpretation.

According to the character of the graininess of the pattern a birch forest, as has been mentioned, somewhat resembles a pine forest. The size and shape of the grains is approximately the same as in a pine forest. The few distinctions lie in the fact that edges of birch tops have a blurred indistinct outline and there is sometimes noticed a grouping in the location of the grains in which the groups consist of 3-4 isolated, blended treetops. A greater number of grains in the group indicates a stand of aspen. The tone of the canopy of a birch forest is brighter than that of spruce and fir and is very close in tone to that of a pine forest. The tops of birch trees are denser than pines and as a rule there is no light visible through the trees. This is a singular and reliable feature distinguishing a birch forest from a pine forest. The difference in height of trees is negligible.

Aspen forests (Photograph 8). Aspen usually grows on the felled and burned out areas of other stands of timber, on sandy loams, clayey, or loamy soils. They often cover plateaus and river terraces. Aspens are normally not encountered on moist soils or on fans.

The structure of the pattern of an aspen forest is distinguished by clearly outlined grains with a variety of sizes; the greater part of the dot is clearly illuminated. Groupings of a large number of grains (curtains) with blurred outlines of the groups are characteristic.

In the mature growth the sizes of grains (treetops) are approximately three times greater than the treetops of spruce and two times greater than of birch and pine.

General tone of the image of an aspen is brighter than that of other species of trees.

Aspen stands have a completely level canopy surface and difference in height is observed only between isolated curtains.

Visibility through the curtain is very poor. The aspen tree is a lover of light and its top tends to spread, forming holes (Photograph 8).

Oak stands (Photograph 33). The structure of the pattern of an oak forest differs from the forests of other species in the great diameter of the grains; their general appearnaco is that of quilted flakes or clumps with small grey spaces between them (the greater part of the treetop is illuminated).

The treetops overlap and the canopy of the forest is almost opaque; under the stereoscope the asymmetry of the treetops is clearly seen.

Image of coniferous and deciduous forests at different times of the year. In photographs taken during the winter coniferous forests have a sharply contrasting image on the generally bright background, being distinguished by a dense dark tone due to the clumps of snow clinging to the branches of trees. The graininess of the pattern is often more clearly evident than on summer photographs (Photograph 46).

The image of a deciduous forest on winter and spring photographs is distinguished by the extremely unique structure of the pattern in the form of streaks formed by the shadow of the bared treetops with a parallel arrangement of the shadows of their trunks (Photograph 13).

In the fall the deciduous forests have a generally bright tone of image (Photograph 47).

Photographs of coniferous trees made in the spring differ but little from those taken at other times of the year.

Burned areas, cleared areas, windfalls. These areas, seen in many forests, are clearly distinguished on photographs from the irregular, clearly visible outlines and bright tone of the image.

Usually on burned areas there are isolated trees, standing without particular order, and curtains of young trees standing out sharply against the generally bright background. Dense stands of dead trees usually appear on the photograph as white spots and give weak grey shadows. A dead tree at the center of a photograph appears as a point, at the edges of the photograph it appears as a streak.

Windfall sections are also distinguished by broken outlines within the limits of which there are usually clearly visible streaks (slanting in one direction from the tree trunks).

Cleared areas, as with burned areas, have a bright tone and are characterized by the regularity of outlines. Those trees which are left standing (seedlings) and the curtains of young forests are clearly seen.

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Sometimes there are visible the evidences of lumbering operations (unhauled logs, piles of timber) in the form of white streaks. Cleared areas with all the trees felled are distinguished by their regular outlines.

General identifying features of scrub forests. The principal identifying features of scrub forests, as for tall forests, are the structure of the pattern (graininess), the tone, and the outline.

Structure of the pattern of areas occupied by scrub growth is characterized by fine graininess, sometimes somewhat blurred, and the even tone of the image. In virtue of these two features, on large-scale photographs (larger than 1:10,000-15,000) it is relatively easy to distinguish scrub growth from mature and even young trees. For the latter, even over small areas, there is always the characteristic different tonality caused by mixture with the principal species of other trees. Scrub growths are always more uniform in composition and hence the tone of their images is distinguished by evenness.

The outline of areas occupied by scrub growth is almost always circular. A forest has less circular, often straight, outlines.

The types of scrub growths (species) are determined from a number of direct, complex, and indirect features.

Among the direct features are: the shape of the grains, the tone, the outline, and transparency of the individual crowns. The arrangement of scrub growths serves as complex and indirect identifying features.

Willow scrubs. The principal feature for identifying willow scrubs is their grouping within the arrangement of grains, creating a bearded pattern of the surface occupied by this type of scrub, since the willows are usually arranged in curtains (Photograph 32).

Bright tones also are characteristic of willows, the circular outlines of the crowns and the considerable transparency of which are clearly seen in stereoscopic examination.

The indirect features of willows are the location of the scrub growths on alluvial islands, high sandbars and shoals, on lowland bottoms and along river banks.

Alder scrubs are characterized by the finely grained structure of even bright tones, without noticeable curtaining (the bearded pattern (Photograph 33). The tone of the images is brighter than in areas occupied by willows,

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since the crowns of the alder are usually closely packed and their illuminated portions usually predominate over the shadowed portions. The transparency of the crowns is less than in willows. Sometimes, the alder scrubs are mixed with willows, when the difference in tone and structure of the pattern is clearly seen.

As regards location, alder scrubs are usually adapted to the slopes of valleys, high bottomlands, ravines leading into rivers, and slopes.

Mixed birch and alder scrub is identified by the variety in tone of grains (the alder is bright, the birch is dark) and as concerns location are usually adapted to burned areas and cleared areas.

Meadow grasses are characterized on the photographs by a structureless pattern, a smooth transition of tones, and circular outlines of the meadow sections (Photographs 5, 6, 19).

These features are well expressed, and a meadow is easily distinguished from other farmlands, which also have clearly expressed image features. In addition, one of the distinguishing features of meadows is their location, that is, their tendency to occur in definite types of mesorelief (bottomlands, terraces, etc.).

The tone of the image of an unmowed meadow depends chiefly on the moisture content of the soils, the type of vegetation, the time of the year, and ranges from almost white to a gray tone.

With an even distribution of moisture over the surface the tone of the image of a meadow is also distinguished by a uniform or weakly varying spottiness (mottling).

With clearly expressed irregularities of the surface there is always easily distinguished a difference in the tone of the image of the meadow. Depressed portions have a dark tone, elevated portions have a bright tone. A brightness of tone may also be caused by blooming of plant growth (see Section 28, Photograph 6).

Fields with maturing grasses are shown on a photographic print with even brighter tones than a meadow and have a characteristic image pattern in the form of a weakly striped, generally uniform tone (Photograph 4). Fields with mature grasses (yellow color) give even brighter, almost white, tones. The outlines of fields, as a rule, are regular. The boundaries are clearly visible in the form of thin white lines, and the old boundaries and plowed under trenches are still in evidence. Plowlands are distinguished by regular outlines but a darker tone than fields (Photograph 4). The striped pattern, caused by the presence of furrows, is preserved and is often more sharply expressed than in fields. Clearly visible is the difference in tone between adjacent sections, which is explained by the different plowing periods. The recently plowed, more moist sections appear darker, the dry sections appear bright.

Section 46. Interpretation of Roads

In the hydrographic interpretation of aerial photographs roads are necessary as local orienting features and they are important in the planning of field operations. They must also be interpreted in using hydrotechnical installations on roads for the calculation of runoff. The road network facilitates interpretation of the relief of a basin and evaluating the likelihood of flooding of bottomlands, etc.

Roads are shown on aerial photographs in the form of thin bands of differing tone; in the summer they are often quite bright, but owing to interferences the roads are sometimes dark (darker than the surface of the surrounding terrain), and in the winter, with the presence of snow cover, as a rule, they are dark.

The principal features for identification of road types are the form of the image (the clarity of outlines, the character and degree of crookedness), and the presence of installations.

The straighter the outline of the roadbed, the higher the clasp of road; the more crooked the roadbed and the smaller radius of curvature, the lower the class of road. The different degrees in crookedness are observed also in mountain terrains, but in such terrain everything, including roads, is distinguished by considerable curvature and is particularly subject to irregularities of relief.

Darkening of the tone over individual sections with irregular configuration of dark spots indicates interruption of the surface of the road and the presence of hollows.

Highways with generally straight outlines have:

sharp outlines of roadbed (Photograph 40);

a radius of curvature maintained within a definite range and a width of about 6-7 meters;

They are usually intercepted at many points with sideroads and dirt roads, often entering them at a sharp angle;

Ordinary highways with drainage ditches and trenches are usually quite visible and are distinguished in tone from the roadbeds. For asphalt roads they appear brighter and for cobblestoned roads darker;

The presence of isolated piles of ballast along the road is characteristic;

In distinction from roads of low class, along highways there usually pass telegraph lines, which are detected from the shadows of poles located at regular intervals.

The type of road covering is determined in the following manner: asphalted and tarred highways are distinguished by the dark tone of the roadway in the summer and winter and only a heavily traveled highway during the dry period of the year is characterized by a certain brightness of tone due to the polished surface of the roadbed.

Gravel roads and cobbled pavements during the summer are distinguished by bright tones.

Improved dirt roads are distinguished from highways by greater crookedness. Their tone during the dry period of the summer is always bright. During the winter it is dark. Drainage ditches parallel all the roads and hence the width of the roadbed is rather constant.

Dirt (side) roads are distinguished by considerable crookedness, irregular width, the presence of widenings and branchings (sideroads, detours). Such widenings on the photographs often appear as junctions and are an indirect indication of a poor condition of the road (Photographs 27 and 34). Drainage ditches are lacking. The tone of the image of a sideroad depends on the composition of the ground and may vary over the length of a road, while on improved roads it is considerably more uniform and is preserved over a considerable extent. Only on a very heavily traveled dirt road is the tone brighter than on exposed soils in the adjacent terrain (with the exception of sands). After a rain the tone of the image of a road is darker than during a dry period.

Field roads are identified by their location. They pass along the edges of plowed lands and other farmlands. Beginning at a populated point or close to it, such a road often ends in a field and not at the populated point and does not proceed to other roads.

Footpaths. Even after the single transit of a human being over grass or the snow cover his traces are visible on aerial photographs, in the summer in the form of a fine white line, in the winter in the form of a gray line. The passage of automobiles or tractors leave traces visible on a large-scale (larger than 1:10,000) photograph in the form of two parallel bright lines (Photograph 17). The footpaths over a terrain often form a dense network.

Railroad lines are easily identified on aerial photographs of all scales. Their identifying features are:

regularity of outlines;

smooth and large radiuses of curvature;

constancy of the width of the roadbed over great distances (single-track approximately six meters, double-track ten meters);

the presence of railroad booths located at regular intervals;

station buildings and station structures. Large railroad junctions usually include a passenger station, a freight station, a car yard, a sorting station, a freight-loading station, a water tower, a locomotive depot and a turntable close to it, railroad shops, storages, warehouses, loading platforms, a populated locality, viaducts, etc.;

the presence of large cuts and high embankments;

snow-shield plantings;

the presence of rolling stock.

The tone of the image of the railroad bed is usually darker than roads without rails (Photographs 27 and 39).

On aerial photographs with scales larger than 1:7,000 the rails are clearly seen. They appear as thin, dark, parallel strands (on photographs with a scale of 1:7,000 the distance between rails for a wide-guage railroad is 0.22 millimeters, and on a scale of 1:5,000 the distance is 0.30 millimeters). On photographs of smaller scales the railroad line appears as a thin bright strand.

From aerial photographs we may determine the number of roads and the type of guage (wide-guage, narrow-guage). The type of guage for large scales (larger than 1:7,000) is determined directly by measuring the width of the track (for narrow-guage track it usually is 0.6-1 meter). For small scales the type of track is determined chiefly from indirect features: from the size of installations on the line, the overall width of the roadbed (for narrow-guage track, approximately 3 meters) and the sharpness of bends, down-grades, and up-grades. A wide-guage railroad is distinguished from a narrow-guage railroad by the smoother bends and the turns of elongated profile.

Section 47. Interpretation of Snow Cover

Aerial photographs may during the snow cover period permit evaluation of the extent of the cover in a basin with a high degree of accuracy. This is especially essential during the period of so-called mottled landscape, that is, the period of spotty snow cover. During this period evaluation of of the extent of snow cover over a terrain during ground snow measurements is especially difficult due to the extensive interruption of the snow cover by the exposed areas of ground at the beginning of this period or patches of snow at the end of a period.

On open spaces the exposed areas of ground are always clearly distinguished in the midst of the snow. The difference in the size of snow patches may vary considerably even within the limits of a small area (Photograph 13), which considerably complicates the calculation of the overall percentage of snow cover.

In a forested terrain with coniferous trees the snow cover beneath the canopy of the forest is perceived only by stereoscopic examination of photographs. With deciduous forests (Photograph 13) the snow cover on the forested portions is quite clearly seen. The surface of the snow in this case appears to be marked by a network of shadows from the bare trunks of the trees and hence the general pattern of the snow cover is characteristically streaked.

As is seen from Photographs 10 and 11, with a thin snow cover aerial photographs in individual cases may permit determining the thickness of this cover at least in qualitative degrees (high, average, and low). For example, an examination of Photograph 10 will permit determining the height of the snow cover as being small, on the order of 5-15 centimeters. This is indicated by the possibility of examining the smallest details of the micro-relief (for example, individual ridges in the fields, depressions, and gullies). The appearance of the snow cover on Photograph 12 indicates its great thickness.

Under mountain conditions determination of the thickness of a snow cover is possible on the basis of a comparison of the same profiles on a terrain plotted by stereophotogrammetric means from summer and winter photographs. The quantitative characteristics of the thickness of snow cover may be obtained in practice only in this case, if the thickness of the snow cover is at least several meters and the scale of the survey is large (1:3,000-1:5,000), since the accuracy of plotting of such a profile is inadequate. Thus, with a scale of 1:3,000 the error in determining the deviations ranges from +0.20 to 0.70 meters, and with a scale of 1:10,000 from +0.60 to 2.2 meters (Section 52).

Since an aerial photographic survey is performed under winter conditions only as the exception, it is not possible to depend on the use of prepared photographs. Hence, for a study of the snow cover in a basin it is necessary to perform special surveys. In this case it is necessary to consider that at the present state of the art of interpretation of snow cover from aerial photographs we may in practice evaluate only the extent of the terrain covered by it. Nor can we overlook the difficulty encountered in precise determination of the areas covered by snow during the period of mottled landscape (planimetric measurement, the method of the grid sheet or weighing for large areas). However, by means of systematic aerial photographic surveys accompanied by parallel ground observation we may, quite clearly, solve a whole series of problems associated with the study of snow cover. In particular, we have in mind the investigation on the basis of systematic aerial photographic surveys of the effect of the relief and the character of the surface on which the snow lies and the process of forming snow cover and its melting, a study of the cycle of accumulation of thaw waters which is especially important for steppe regions, checking the reliability of the data of ground measurements of snow with a view to determining the percentage of snow cover.

It follows from the above remarks that special aerial photographic surveys of snow cover must be performed for small basins or over given routes and these operations must not be considered as network operations but as exploratory operations.

The parallel execution of ground measurements of snow and aerial photographic operations will in the final result permit establishing definite correlative relations between the physical properties of snow and the peculiarities of the process of freeing a terrain of snow cover and, in all probability, to establish the relations between the physical properties and the microrelief of its surface.

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CHAPTER X

MEASUREMENTS OF ELEMENTS OF WATER OBJECTS FROM AERIAL PHOTOGRAPHS

Section 48. General Information

This division of the book discusses the basic principles and methods of performing measurements of the individual elements of water objects from aerial photographs. The methods of determining quantitative characteristics of water objects from aerial photographs may be divided into four basic groups.

(1) The direct measurement of images on a single print with the aid of the same simple instruments as are used in measurements on a topographic map. In this case the aerial photograph is used as an ordinary topographic map or plan.

(2) Methods based on the use of the stereo-effect. They require the presence of a stereo pair and special stereophotogrammetric instruments and are used in determining deviations of points on the terrain and for obtaining other quantitative characteristics associated with determinations of the height or volume of objects.

(3) The photometric method of measurements, used in measuring the depths of water objects. It is based on establishing the variations in the image density of a water surface with depth and the use of this property of the tone of the image as a standard.

(4) The use of indirect calculations on the basis of data definitely established from an aerial photograph by one of the abovementioned methods.

As general remarks on the applicability and potential use of the above methods for hydrological investigations we may make the following statements.

The measurement of linear dimensions from aerial photographs has a considerable advantage in the completeness of data as compared with a topographic map of any scale, since the latter, even at large scales, always is schematic and generalized in representing the image of the object.

The scale correspondence of the image of objects in nature fully compensates for such shortcomings of an untransformed photograph as distortion of the optical model (Chapter III).

The applicability of stereophotogrammetric methods of measurements is limited by a number of conditions. Thus, riverbed depth determinations are limited to those cases where the bottom of the river is transparent throughout the depth of the water and its relief is visible and the scale of the photograph does not exceed 1:5,000-1:10,000 (Section 23). The accuracy of determining deviations in the shoulders of the banks of a riverbed over the water surface depends not only on the quality and the scale of the photograph but also to a considerable degree on the nature of the concealment of the riverbed surface, for the latter facilitates or hinders the application of the sighting mark in measurement with the aid of parallactic rules or the measuring mark on other stereo measuring instruments (Section 17).

Concerning the photometric method of determining river depths it must be pointed out that, since the tone of the image of a water surface on aerial photographs depends on numerous variable and hence random factors, in practice the applicability of interpretation of depth by this method is extremely limited.

Indirect methods of obtaining the quantitative characteristics of a riverbed and a stream have the widest prospects for development. Their application localizes the shortcomings of an aerial survey (for example, distortion of the optical model, the impossibility of examining relief over many portions of the bottom, etc.).

However, the state of these methods at present is still such that we can only determine a relatively restricted group of characteristics (for example, only the averaged characteristics of sectors and data only for individual characteristic directions).

Section 49. The Use of Aerial Photographs for Measuring the Lengths of Rivers and the Area of Watersheds

The lengths of rivers and the areas of watersheds are determined from aerial photographs by the same methods and instruments as were used for these purposes on topographic maps. However, in this case the aerial photograph has considerable advantages over the topographic map. It permits disclosing many details and features of the measured object and thereby to avoid errors arising due to generalization of images, as is characteristic of the topographic map.

In measuring the lengths of rivers it is necessary to transform photographs. In order to distinguish the characteristic sectors it is most convenient to use a photomosaic /fotoplan/, a photodiagram /fotoskhema/, or at least an overlap assembly. The measurements themselves must be performed on a photomasaic. For more precise determination of the initial and terminal points of measurements or for study of complex sections it may be necessary to use individual stereopairs in order to obtain information of greatest detail.

Identification of outlets and tributaries (especially the tributaries of large rivers) is often extremely difficult not only on maps but also on the terrain. In this respect an aerial photograph has considerable advantages, increasing the detail of the image as compared with a topographic map and improving the selectivity as compared with ground surveys.

In order to measure the length of a river it is necessary to determine the channel line or the median line of the riverbed (depending on the posed problem), market, then to begin a measurement of the length.

In those cases where the bottom of the riverbed is clearly seen, determining the line of the channel, as has been mentioned, presents no particular problem. If the relief of the bottom is not visible, then in order to determine the line of the channel it is necessary to resort to indirect features (according to the overall meandering of the riverbed, determining it from the character of the banks, etc.) and to determine its position more precisely in comparison with the line of the channel as drawn on large scale navigation maps. With the possibility of measuring the width of a river along any line of direction, we may also make a precise trace of the median line of the river.

In order to avoid spoiling photographs in performing measurements with calipers (in accordance with the instructions for measuring the lengths of rivers) it is desirable to mark the line of the channel as noted on the aerial photographs on a tracing paper and to perform the measurements therefrom.

Photographs may also be used to obtain precise information concerning the meandering characteristics of the river. The aerial photograph permits careful division of the meanders and a reliable separation of the orographic meanders (of the valley), the hydrographic meanders (of the riverbed), and the meanders of the channel.

The latter is important for calculations of depths from hydromorphological relationships (see Section 51), for navigational characteristics of the river, etc.

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The use of aerial photographs for measurements of the areas of a watershed permits accurate definition of the line of a water divide in those cases where to perform such a determination on a topographic map would be difficult (in swampy terrain, in the presence of bifurcations, etc.). This is possible due to the fact that the aerial photograph permits tracing the structure of the microrelief, the lines of streams of water in the swamp (marsh) as indicated by dark bands, to determine the direction of water flows, etc.

In order to measure the area of basins it is necessary to have a mosaic at hand. However, in the absence of photomosaics /fotoplan/ or diagrams /skhema/, the compilation of an overlap assembly or the borders of the watershed will suffice. The measurements will then be performed from an ordinary large-scale map (1:50,000-1:100,000) with refinement of the boundary measurements of the basin from aerial photographs.

Determination of the boundaries of a basin, especially of those sections where they are not clearly expressed, requires, as a rule, the use of a stereoscope and, consequently, in addition to the photomosaic, it is necessary to have a series of contact prints at hand.

Section 50. Measuring the Width of a River from Aerial Photographs

Measurement of the width of a river may be performed only in those cases where the image of the riverbed on the photograph has a width of not less than 2-3 mm., for in these cases the graphic error of measurement averages +0.2 mm., which is not greater than 10 percent of the overall width of the river.

Thus, measurements with such accuracy are possible on photographs with scales greater than 1:15,000 for rivers with a width greater than 20-30 meters, with a scale of 1:25,000 for rivers with a width greater than 50 meters, and with a scale of 1:40,000 for rivers with a width greater than 80 meters.

Measurements of the width of the river may be formed in any line of direction, that is, as often as desired.

In addition to the general rules for selecting measurement directions (given in the "Instructions for Hydrographic Investigations of Rivers"), in choosing the characteristic directions it is first necessary to evaluate the distribution of the concealment of the shorelines over the length of the section under measurement in order that, in performing the measurements, every possible case of different concealment will be covered and thereby the most reliable values for the average width over the section will be obtained.

The accuracy of measurement of width under various conditions of concealment of the shorelines is given in Table 12. The data of this table was obtained by empirical means and must be considered approximate. Hence it is not possible to use this data in introducing corrections in measurements, since it has been established that in approximately 60 percent of the cases of error the values of the measurements are less than the actual width and in 40 percent of the cases they are greater. Thus, the errors have two signs and these are approximately equal in their distribution.

For more precise measurement of the width of a riverbed in determining the shoreline it is desirable to use stereoscopic instruments. In this case the results may be considerably improved over the data given in Table 12.

If the measurements are performed from nontransformed photographs, it is recommended that for each contact print the scale of the photograph be checked and measurements be made within the limits of the usefûl portion of the photograph (Section 7).

With a clearly expressed relief (deeply cut valleys), in order to calculate the width of a river it is desirable to determine the scale of a photograph for the plan of the surface of water (that is, to consider the difference in scale of the image of objects located at widely different elevations (see Section 7b).

All these refinements are performed in cases where it is necessary to have accurate data concerning river widths. In preliminary surveys the introduction of corrections is not obligatory.

The measurements themselves are performed in the following manner. The shoreline in a given direction is identified under the stereoscope and it is marked on both banks. Measurements of the distances between marks are best performed with the aid of a measuring lens with an accuracy up to 0.1 mm.

Instructions for defining the shoreline under various conditions of concealment are given below.

(1) A dark tone of the image of the water surface and the bank (joining of the water surface with an open, turfed bank). In this case the shoreline appears most clearly and further elucidation of the shoreline is not required.

(2) A dark tone of the image of the water surface but with an eroded bank. The legibility of the shoreline deteriorates somewhat and, though it was previously directly visible, it must now be carefully examined under a stereoscope.

(3) Bright tones of the image of the water surface and the bank (sandy shoals and surf strips). In this case, especially with a shoal of great width and shallow water, the shoreline is difficult to read and particular care must be exercised in determining it. This is explained by the fact that the thin layer of water on the shoal is hard to distinguish on the photograph, since the difference in tone of the covered and noncovered portion of the shoal is negligible.

The signs of the presence of a layer of water on portions of the shoal are as follows:

That part of the shoal which is not under water usually has a clear white tone, against the background of which it is almost impossible to distinguish the microrelief of the surface.

The presence of even a thin layer of water on the surface of a shoal usually permits examination of the microrelief at the bottom. This is explained by the fact that the characteristic formations of microrelief in the form of ridges caused by the wave movements and the movement of the water itself, are smoothed out in the drying of friable soils and under the action of the wind, and, in the second place, it is due to the specific optical characteristics which a dry surface and a wet surface possess in their images. The latter always appear on a photograph as dark, but refraction of the image due to the secondary median only emphasizes details of the microrelief.

Sometimes the shoreline on a shoal can be traced (in careful stereoscopic examination) from the presence of a small shelf along the shoreline; this shelf is formed during the stable condition of a shoreline.

This shelf is often detected from the shadow which it casts. In such cases, when the water rises and the shelf is flooded, it is usually seen in the form of a thin, wavy white line under the water and thus does not correspond to the shoreline.

The shoreline at shoal banks is usually extremely variable with time (small increases in the water level suffice to cause considerable displacements in the horizontal plane), hence error in determining the shoreline in shoal water is considerable.

In these cases it may be recommended that the width of the riverbed not be determined from the waterline, but between the shoulders of flood banks, the boundaries of which in ordinary flatland conditions may be traced from the boundaries of grassy vegetation which stand out on the photographs in contrast with the exposed surface. As a flood line we may often adopt a sufficiently distinctly distinguished boundary on a print of the microrelief of the bottom or the line of the abovementioned ledge (under water or above) formed during a stable condition of water level. For mountain rivers and rivers of the southern steppe regions the width of the riverbed within the limits of the shoulders of the banks often differs considerably from the width of the stream itself.

(4) The structural image of the water surface and the banks. The presence at the surface of the water of aquatic vegetation is a most unfavorable condition for determining the waterline. In this case determination of the waterline requires careful stereoscopic examination of the photograph, wherein it is necessary to investigate not only the given line of direction but also to trace the shoreline over the entire section of the river.

The shoreline is established as the boundary between the characteristic speckled surface of the aquatic vegetation (see Section 37) and the pattern of the bank.

(5) Concealment of the shoreline by shadows. In the case where the shoreline is masked by shadow it is also extremely difficult to interpret the shoreline. The clarity with which the shoreline is defined under such conditions depends upon the density and continuity of the shadow.

When the shadow is not very dense careful examination of the section covered by it often permits tracing the thin white line which outlines the banks and is formed by reflections at the surface of the water. A band of dark gleams usually appears close to the bank and without great error can be assumed to identify the position of the shoreline.

Where a dense, unbroken shadow occurs, the shoreline must be defined by stereoscopic examination of the photographs, since in this case it can only be determined by approximation from the shoulders of the banks. Consequently, the accuracy of its determination will depend chiefly on the steepness of the banks, which is determined only under a steroscope.

Where the banks are steep the shoreline will correspond almost exactly to the line of the shoulders of the banks. In this case the shoreline may be precisely determined by calculating the length of the shadow (see Section 19). If the shadow from the banks is not continuous (formed by trees or shrubs growing on the banks), then the shoreline may usually be traced at points not casting a shadow, while for shaded points the shoreline can be traced according to the points and outlines of the bank line obtained by this method.

Section 51. Determining Depths from Aerial Photographs

In order to determine the depth of open water objects from aerial photographs three methods are employed: stereophotogrammetric, photometric (by comparison with a standard), and the method of indirect calculations.

The photometric method, based on a comparison of the densities of a negative (a positive) and requiring special instruments due to the variety of natural concealment of riverbeds has limited application. Hence, we discuss below the two principal methods which may find application in hydrographic investigations.

(1) The stereoscopic measurement of depths is performed with the same instruments and methods as are used for determining deviations of points on a terrain (see Section 16), only in this case one of the points is always the shoreline, and the second is a point at the bottom. The second factor (the depth of water) introduces substantial distortions in determining the deviations and locating the actual position of a point, while the feasibility of the measurements themselves is limited, as has been mentioned many times, to those cases where the relief of the bottom is examined through a thickness of water where the scale of the photograph must be greater than 1:10,000. In practice this method is widely used for studying depths at maritime coastlines where, judging from recent works in this field, due to the high transparency of the water it is possible to examine the bottom to a depth of 20 meters and sometimes greater.

For measurement of river depths or the depths of lakes the stereoscopic method is used only on objects having a bright bottom free of growth and water of high transparency. In addition, it is usually necessary to produce special large-scale photographs in order to obtain the best conditions for viewing the bottom and to eliminate the effect of concealment of the water surface by bright flashes on waves, etc. In this case examination can be made to a depth of approximately 5 meters.

The simplest method of calculating the effect of the secondary medium (the water) consist in introducing correction factors (n) into the data of ordinary stereophotogrammetric determinations. The value of the n factor depends on the angular field of the aerial camera and on the position of the points to be defined relative to the center of the photograph. In measurements for obtaining approximate data the values of the factor may be assumed as follows:

For narrow-angle cameras	1.38
For cameras with normal angular fields	1.40
For wide-angle cameras	1.44

It is recommended that depth measurements with the simplest instruments (parallactic rules, the D-6 stereoscope, a stereopantometer) be performed on photographs obtained with slight tilting of the optical axis or on transformed photographs on a scale of 1:5,000.

Depth measurement with the aid of parallactic rules is performed in the same manner as in single-medium stereophotogrammetry [54]. The control points in this case are the shorelines of the right and left banks of the river, the heights of which are usually taken as zero.

The factor (n), considering the influence of the second medium, is inserted into the parallactic coefficient K by multiplying their values. The resulting general coefficient $K_1 = Kn$ must be multiplied by the difference in parallax Δp of each pair of the measured points (the bottom and the shoreline). Where it is necessary to have several selective points of depths on nontransformed photographs it is possible, with the aid of parallax plates or a D-6 stereoscope, to make one reading at the surface of the water and the other at a chosen point of the submarine relief. In addition, the points to be defined must be located in one vertical plane.

The accuracy of depth measurements, as in measurements in single-median photogrammetry depends on the scale of the photograph, on the value of K

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(the smaller k, the smallor the error), on the value of the scale divisions on the instrument, and on the accuracy and correctness of the reading, which in turn depend on the personal aptitude and experience of the observer.

(2) The application of hydromorphological relations. This method of determining depth consists in using hydromorphological relations (that is, the relationship between morphological characteristics of the riverbed and the slope, rate of flow, and discharge of water).

The combined application of hydromorphological relations and aerial photographs is of great advantage in obtaining the most reliable date for the following reasons.

In calculations on the basis of hydromorphological relations, the use of data which may be provided by aerial photographs permits:

(1) refinement of calculations due to the introduction of actual data which in practice may be obtained for any line of direction (this relates principally to the plan-view characteristics of the riverbed);

(2) the analysis (with great detail) of local conditions and a qualitative consideration of possible deviations of values of riverbed characteristics, caused by various local factors, which are not taken into account in hydromorphological relationships (the presence of hard soil discharge, contraction of the riverbed, alluvial fans, etc.).

As the basic relationship between the riverbed elements and the stream we may adopt the system of equations proposed by I. I. Yakunin [120].

Section 52. Measurement of Heights of Banks

The height of banks is determined from aerial photographs by stereogrammetric means (that is, by the same method as used in determining deviations of points on terrain or in determining the depths of water reservoirs and stream).

In addition, one of the points of measurement is always a watered surface, the image of which has a number of peculiarities on photographic prints, hence in the operation of interpretation there are certain specific features in comparison with the usual determination of deviations of points on the terrain. These circumstances also necessitate a special approach to evaluating the accuracy of these measurements.

The nature of the concealment of the image of a water surface, as has been mentioned, has a considerable effect on the accuracy of measurement of the height of banks.

We may consider it as established that the dark tones of an image of a water surface introduce considerably greater errors in measurement than the bright tones (when the bottom of the riverbed can be seen).

In measurements from a water surface, the sighting filament of parallactic plates or the elevation mark on other stereoscopic measuring instruments must not simply coincide with the surface of the water, where it will be difficult to select the given point, but with a point located at the shoreline within the limits of which it is easier to find the visible orienting point.

The accuracy of measurement of the height of banks is determined as follows.

The acceptable accuracy of readings in determining parallax is usually assumed to be within the limits of +0.02 to +0.08. If we plot a graph of the relationship between the values of the mean square errors in determining deviations, the values of the parallactic coefficients for definite degrees of overlap and acceptable accuracies of readings, then we may easily determine the accuracy of measurement (the mean square error) which we may expect to obtain at different scales with different accuracies of reading. This graph provides the following information.

With a scale of 1:3,000 and with an accuracy of reading practically equal to the accuracy of the instrument (+0.06), in determining the deviations there may be obtained an accuracy on the order of +0.20 m, and with an accuracy of reading of +0.08, approximately 0.70 m. Correspondingly, on a scale of 1:10,000, we obtain +0.60 and 2.2 m; on a scale of 1:25,000, we obtain 1.4 and 5.6 m.

Thus, the data for the height of banks (given the calculated value) may be obtained in practice only from photographs with scales larger than 1:10,000, while photographs of smaller scales (including 1:25,000-1:30,000) are usually required for mass area surveys and are suitable for obtaining only illustrative and qualitative characteristics of the height of banks in accordance with the instructions mentioned in Section 38. In addition, in interpreting the height of banks the "standard method" may be employed (that is, determining the character of distribution of height of banks from the length of the river on the basis of determining the relationship of the appearance of the image of the bank with the heights as precisely measured in individual directions).

Section 53. Determining the Rate of Flow

The rate of flow of streams may be determined from mass aerial photographs only on the basis of indirect features. Their characteristics are obtained chiefly in qualitative gradations and only in relatively rare cases is a more or less approximate quantitative evaluation possible.

The principal features by which rate of flow is determined from aerial photographs are as follows.

(1) The outline of the riverbed in the plan view. A meandering riverbed in a flatland terrain with easily eroded soils is an indication of low rates of flow at the low water level -- not more than 0.3 meter per second.

(2) The presence of aquatic vegetation in the riverbed also usually indicates low rates of flow with values close to those given in paragraph one.

(3) When the image of the streams surface is smooth the prevailing rates of flow are not greater than 1.5 meters per second.

(4) The presence of rapids and waterfalls (see Section 35) may indicate high rates of flow over a considerable extent of water.

(5) Interruption of the image of the surface of water, that is, the presence of a pattern in the form of white bands running along the direction of flow (eddies in the vicinity of obstacles in a riverbed -- abutments, bridges, ice guards, rocks, etc.) is usually observed with rates of flow greater than 1.5 m/sec. In this case there is possible a more precise quantitative determination of the local rate of flow, though even this calculation does not exceed the limits of experiment. It is based on the following conclusions. If the white bands formed by the agitated water in flowing around an obstacle have a parabolic form (parabolas joined at the point of location of the obstacle and spreading down stream) then, as experience has shown, the distance between the ends of the parabolas (at the point of their greatest divergence on the photograph) is proportional to the increase in level of the backed-up water at the obstacle. It has also been established by experiment that actual streams cause water backups of 0.2 to 1.0 meters in flowing around local objects. This corresponds to a range of flow of approximately 2 to 4 meters per second. Since a precise quantitative relationship between the distance from the ends of the parabola and the size of water back-up has still not been obtained, then

evaluation of this relationship is performed visually; for a widely diverging band we assume a flow of 4 m/sec; for small divergence, approximately 2/sec.

The formula relating the rate of flow to the size of the water back-up for the examined case is expressed as:

$$v^2 = 2g\Delta h.$$

(6) For well-expressed drops a difference of a marks may be determined stereophotogrammetrically and the slope (i) may be calculated; then the flow is determined from the formula

$$v = \sqrt{2gi}$$

where g is the acceleration of a freely falling body (9.81 m/sec^2).

(7) Calculation of flow may also be performed from hydromorphological relationships. In this case it is possible to obtain an approximate evaluation only for the average flow over the section and for the largest stretches of shoal water.

(8) Given two photographs of the same section made immediately after one another and with a precise knowledge of the time of the flight, the rate of flow may be established from floating objects which are not likely to be effected by the wind. It is clear that in these cases it is necessary to take special photographs. For rough measurement such objects may be floating ice cakes, etc., and for more accurate measurement special floats may be provided with smoke boxes for greater visibility.

It follows from the above remarks that it is not yet possible to obtain the values for the rate of flow from aerial photographs with sufficient precision to suffice for hydrometric purposes and for precise engineering calculations. But those flow characteristics which may be obtained from an aerial photograph do suffice for approximate measurements.

PART THREE

HYDROGRAPHIC INTERPRETATION OF SWAMPS FROM AERIAL PHOTOGRAPHS

CHAPTER XI

FUNDAMENTALS OF SWAMP INTERPRETATION

Section 54. General Information

In this part of the book we discuss the typological interpretation of aerial photographs of swamps and of the surface of the hydrographic network of swamps. By typological interpretation is meant not only the mapping of swamps from aerial photographic materials but also the distinction of internal features /contours/ in the swamps with a determination of types of swamp masses and the characteristics of individual microlandscapes.

The types of swamp masses discussed below are characterized by their particular surface forms and microrelief as determined by the vegetative cover and the upper layer of a peat bed, to which definite water properties also correspond. Hence, the typological interpretation of swamps is at the same time a hydrographic interpretation in connection with the fact that the typological interpretation of aerial photographs of swamps must be accompanied by adequately detailed interpretation of the surface of the hydrographic network of the swamps, which is always well expressed on aerial photographs.

The typological interpretation of aerial photographs of swamps became possible on the basis of modern landscape control of swamps as developed by Soviet scientists. It is assumed that persons using this book are adequately acquainted with the principles of this study. As concerns the present subject of discussion it is necessary the reader be acquainted the work by Ye. A. Galkina /18/ and the articles compiled by a group of authors /22/.

In distinction from all previously published worked on the interpretation of swamps, the present chapter dwells not only on the typological interpretation of swamps but also gives instructions concerning methods of obtainig data aerial photographs on hydrological features of swamps (extent of flooding, the hydrographic network, and courses of runoff from the swamp). This should find application both in hydrographic investigations of swamps and in obtaining information concerning swamps in preliminary surveys of rivers and in swamp reclamation work.

It must be pointed out that the hydrographic interpretation of aerial photographs of swamps is a relatively new practice and is almost the youngest branch in interpretation of aerial photographs of swamps.

General observations concerning the possibility of using aerial photographs for the study of swamps was first presented, insofar as we know, in 1932 in an article by I. Fedorov /111/.

The first results of the applications of aerial photographs of swamps in agriculture were reported in 1934 by N. P. Dyukarev /32/. The author presented his own observations of features for interpretation of lowland swamps in Kareliya and quite correctly stated that direct interpreting features are not fully adequate. He emphasized that the interpretation of aerial photographs of a swamp must be made with a consideration of analysis of the regularities in the landscape of a terrain. In 1935 N. P. Dyukarev /33/ began to publicize in the press the use of aerial photographs for surveying peat deposits.

In 1936 there appeared the collection of articles of the Central Administration of the Hydrometeorological Service on the use of aerial photographs in hydrological investigations. The article by L. O. Pallon /71/ shed light on a special problem in interpreting swamps from the data of aerial photographs. The author correctly noted that aerial photographs of swamps not only permit determining the type of swamp but also are an excellent indication of the extent of their flooding. Along with this he pointed to the need for using in addition to direct identifying features (tone, the pattern of the aerial photograph), indirect features for interpretation of swamps (the location of the swamp, etc.).

The interpretation of aerial photographs of swamps found futher development in the work of Ye. A. Galkina /16, 17/, who employed a new, genetic approach to the study of swamps and developed a classification of swamp terrians /18/.

The Leningrad Administration of the Hydrometerological Service devoted much attention to the hydrographic interpretation of aerial photographs of swamps.

It was at this organization, over a period of several years (1944-1949), that Ye. A. Romanov conducted systematic hydrographic investigations of swamps with the use of materials obtained from aerial photographs and ground checks of the indentifying features of swamps and of the surface of the hydrographic networks. This work was continued and extended into hydrological studies of swamps at a State Hydrological Institute.

At the present time the use of aerial photographs of swamps for various purposes has found wide application. Let is suffice to say that such materials have been interpreted for regions and oblasts in which the swamp area amounts to many thousands of square kilometers.

The definite advantages of aerial photographic materials contributed to the rapid development of interpretation of swamps.

In the first place, the interpretation of aerial photographic materials by plant methods permits obtaining not only a general representation of the swamp area but also establishing its type and a number of distinctive features even before the ground study of the swamp itself. This work is completely independent of the accessibility of a swamp and its cost is negligible.

In the second place, aerial photographic materials are objective and documentary. They permit comparisons between aerial photographs of different swamps as well as verious photographs of the same swamp.taken at different times. For example, a comparison may be made between the swamp itself in the natural state and after it has been drained or any other steps have been taken to alter it.

Inthe third place, it must be pointed out that aerial photographs are swamps are extremely graphic. In examing a pair of adjacent photographs in a steroscope, photographs are, in effect, a model of the swamp. Any aerial photograph is completely free of the schematization which is a feature of any map compiled by use of conventional symbols.

In the fourth place, aerial photographs of swamps are distinguished by exceptional preciseness, detail, completeness of situation, and the images of natural features of the surface of the swamp. They excellently reflect not only the character of the surface and the vegetative cover of the swamp but also the extent of flooding and the most minute internal hydrographic network, as well as the swamp's connection with external water-receiving bodies.

Aerial photographs of swamp clearly show the boundaries of the datum bed, dry islands, forested areas of the swamp, various marshes and bogs. It is sufficient to point out that in examining an aerial photograph of a swamp under a steroscope or even with a magnifying glass even the individual trees are visible (on large-scale photographs) and we may distinguish microlakes with a diameter of 10 meters. No ordinary ground survey of a swamp, no matter how detailed, provides such information.

Section 55. Fundamentals of Typological Interpretation of Aerial Photographs of Swamps

The interpretation of swamps from aerial photographs is based on investigation of the relationships between the geomorphological and hydrological factors, the vegetative cover, and other elements of the landscape of the terrain. In order to establish identifying features and methods of interpretation of aerial photographs of swamps, use is made at present of landscape control of swamps.

A swamp is considered to be a unique geographic landscape which is characterized by peat deposits, definite forms of surface relief, a special hydrological regime, and regularities in the distribution of vegetative cover.

It is well-known that large swamps are irregular and that there is considerable difference between their central and peripheral portions. Hence, in interpreting aerial photographs of swamps, it is first necessary to consider the degree of complexity of the swamp and to distinguish thereon the more or less distinctive portions. A swamp may be considered as a swamp system or an independent, isolated swamp mass. In turn, swamp masses are subdivided into swamp sectors (micro-landscapes).

A swamp system is formed as the result of a fusion of several swamp masses due to lateral extension as the result of swamping of adjacent dry sectors and the increase in the bog upwards in proportion to the growth in peat deposits. Usually the swamp system are separated into swamped masses by internal water receivers or by chains of mineral islands which are the remnants of non-peated accretions at the bottom of the swamp inlet.

In dividing swamps into landscape units it is necessary to consider the swamp masses which characterize and determine the type of swamp. By the term swamp mass is meant a swamp landscape with an accumulation of peat deposits in an isolated inlet of any form.

Swamp sectors (micro-landscapes) do not appear as wholly isolated portions of a swamp but, as a rule, they are located in a definite arrangement relative to one another at the surface of the swamp masses and are also characterized by the micro-relief, peculiar for each portion, a temporary vegetative cover, and the water properties of the upper layer of the peat deposit.

One of the principal criteria of typological interpretation of aerial photographs of swamp masses if the well-known regularity of distribution of vegetative cover associated with the course of development of the swamp. The general course of development of the swamp is determined from the location of the sectors on which there first begins to develop an oligotrophic vegetation fed chiefly from the atmosphere. Depending on where in this swamp the oligotrophic appears and develops--in the center, on the periphery, or in the center and on the periphery at the same time-- we distinguish three courses of development of swamp masses: the central-oligotrophic, the peripheral-oligotrophic, and mixed. Each course of development of swamps has not only its own regularity of distribution of vegetative cover but also surface forms of swamp masses, relative location of water receivers, and internal surfaces of the hydrographic network in the swamps.

Swamp masses of the central-oligotrophic course of development are encountered chiefly in terrains with a relatively undisturbed flatland relief and small surface slopes. Even while the central portion may be covered with oligotrophic vegetation, the peripheral portions may have eutrophic vegetative cover. These swamps often have a concave surface in which the central portion rises above the periphery by 5-8 meters. Swamp masses of the central-oligotrophic course of development are characteristic for the upper swamps of the forest zone.

The principal types of such masses are described futher along with their interpreting features.

Swamp masses of the peripheral-oligotrophic course of development are encountered chiefly in terrains with sharply intersected relief and frequent alternation of elevations and depressions. These swamps are usually elongated and have a concave surface and considerable longitudinal and transverse tilts of surface. Typical examples of swamp masses of the peripheral-oligotrophic course of development are the many swamps of the Kareliya and Pechorskiy krays.

Let it be pointed out that swamps on a whole are studied in connection with their location relative to other elements of the geographic landscape. In addition, each of the existing types of swamp masses may be examined as one of the stages of development of swamps. This results in conclusions of practical importance concerning the regularity of distribution in the vegetative cover and the formation of an internal hydrographic network of swamps, and in interpreting aerial photographs of swamps it permits distinguishing the so-called indirect identifying features. However, the necessary premise of typological interpretation of aerial photographs of swamps is a knowledge of the natural features of geographic region.

It is also necessary to point out that the specific features of images on aerial photographs of various swamps as well as of other objects are rarely caused by distinctive features of the aerial survey process and the scale of the photograph, which show a definite tendency to smooth out many details of the object and to present them in a somewhat unusual form.

Modern monochromatic aerial photographs of swamps permit in most cases, as a result of analysis of the character of the pattern and the tonal characteristics of the aerial photograph, establishing the boundaries, the vegetative cover, the extent of flooding, and relief of swamps. The above-mentioned features constitute the direct interpreting features of swamps on aerial photographs. The importance of these features in interpretation stems from the fact that each swamp, in any portion thereof has on the aerial photograph a definite pattern and tone.

In its external appearance in the general landscape of a terrain, a swamp is usually seen to be covered with vegetation or subject to considerable water inflex, as a consequence of which it is somewhat easily identified on aerial photographs, in distinction from dry portions with more extensive vegetative cover. On an aerial photograph the irregularities of shape in the plan view and the overall appearance of the borders of this same swamp can be distinguished.

However, precise delineation of the borders themselves is not always possible on an aerial photograph if the swamp is bounded by land parcels which have a similar coloration. Thus, it is difficult to distinguish the border of a grassy swamp which is located next to a swampy meadow or a forest swamp located in the midst of swampy forest masses. In these cases, due to the gradual transition, the borders of swamps are usually indistinct, and hence it is difficult to distinguish them on an aerial photograph.

As has been shown, the image patterns on aerial photographs of swamps are of various types. The image pattern of forest swamps and forested sections differs sharply in its gaininess from the smooth pattern of unmixed grass-moss swamps. Complex moss swamps with heavily dissected microrelief, with hillocks, ridges, and boggy soil have a streaked pattern. Variations in the tonality of the aerial photographs of swamps are due to two principal causes; the different reflexity of the vegetative cover according to its natural cover and structure, and the differing light absorption of the surface of swamp sections as associated with the extent of their flooding. For example, on aerial photographs of forests and afforested swamps the coniferous trees, especially the spruce, will be darker than the deciduous trees, and will give a darker tone in stands of trees (as well as a different pattern for the treetop). Other conditions being equal, the darker the flooded portions of the swamp, the darker they will appear on the aerial photographs. Hence, by careful analysis of the tone of an aerial photograph of a swamp we may evaluate the extent of the flooding of its individual sections.

However, it must be kept in mind that, due to the various combinations of reflectivity of vegetative cover and the differing light absorption of the swamped surface with inconstant moisture conditions, the same degree of intensity of tone of an aerial photograph does not always correspond to identical conditions in the swamp sections. The veriety of these sections may be revealed by ananysis of the pattern of the aerial photograph and from indirect identifying features.

The general tone of the aerial photographs depends also on the conditions of photography. For example, a forest swamp photographed with the sun at a high elevation will have a generally bright tone, and the same swamp when photographed with the sun at a low elevation will have a generally dark tone. This usually does not lead to misinterpretations, since in analyzing an aerial photograph the relative tone of the various portions of a swamp stands out in comparison with the other portions. Experience in interpreting aerial photographs of swamps shows that even the unaided human eye suffices to distinguish the relatively small differences in shading between these sections.

CHAPTER XII

METHOD OF INTERPRETATION OF SWAMPS AND THEIR HYDROGRAPHIC NETWORKS

Section 56. Principal Identifying Features of Swamps

It was stated above that the identifying features of aerial photographs of swamps and of the surface hydrographic networks in swampss may be divided into direct and indirect features.

Among the direct indentifying features are: the grainess and streaking of the pattern, the differing tonality of indiviidual portions of aerial photographs of swamps as well as the ponds, streams, and mineral islands in swamps. The presence of elements of the hydrographic network as well as of mineral islands condiderally facilitates interpretation.

The graininess of the pattern of an aerial photograph is an indication of the extant of forestation of the terrain. In addition, the image of trees in dry stretches is characterized by a considerably coarser and more diverse graininess of pattern than trees in the swamps, hence the forest swamps and afforested swampss are relatively easily distinguished on aerial photographs.

The characteristic streaked pattern of an aerial photograph is an indication al a well-developed microrelief of the swamp, and an alternation of ridges and boggy soil or ridges and ponds. Since the relative location of the elements of microrelief and of vegetative

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complexes in swamps differ, correspondingly there is a difference in the character of the striping of the pattern of aerial photographs.

The different tone of an aerial photograph reflects a difference in the extent of flooding of the individual sections of the swamp. All other conditions being equal, the darker the tone of a given section on an aerial photgraph, the greater the extent of flooding. There are often visible on aerial photographs wide bands having the appearance of brush strokes or streaks. These distinct bands on an aerial photograph are an indication of the flow and the direction of flow of water in the swamp.

Ponds and streams are excellent direct identifying features of swamps on aerial photographs. They are often numerous and vary in size from large to small. These ponds and streams are easily distinguished by the smooth, dark or black tone of the pattern and by their shape; circular (for ponds) and elongated, harrow and meandering (for streams).

Mineral islands stand out sharply on aerial photographs of swamps. These islands, as a rule, are forested and their pattern is distinguished by a course and clear graininess.

As indirect indentifying features of swamps use may be made of the definite regularities in the distribution of vegetative cover, the relative location of swamps and streams, and the location of types of swamp masses and the sections of micro-landscapes relative to the water receivers. For example, on lowland grassy swamps in various stages of development the water receivers are often located in the middle of the swamps. Moss swamps of confex shape have the water receivers at the margins. Where the water receivers are located in the central portion of large moss swamps this is an indication of a swamp system which was formed as a result of a combination of several swamp matters.

The signs of agricultural activity in a swamp are sufficiently definite interpreting features. Chief among these figures are peat-cutting activities, a drainage network, causeways, roads, paths, cuts, sections of clearing and mowing.

For convenience in reference a systematic description of identifying features of swamps is given in Tables 13-15. Table 13 gives a short description of the above mentioned direct identifying features pertaining to agriculture activity in swamps.

The principal indirect identifying features of aerial photographs are given in Table 14 for typological interpretation of swamps and in Table 15 for the surface hydrographic network in swamps. These tables also contain references to the corresponding aerial photographic examples given in the appendix and illistrating the images of individual types of swamps as well as the identifying features listed in the tables.

The typology of swamps, as given in table 14, was based on the following considerations.

As is known, there are many systems of classification of swamps based on various principles. However, due to the specific tasks confronting typological interpretation of swamps from aerial photographs, none of the existing swamp classifications may be used it its entirety for this purpose.

It is clear that purposes of interpretation the distinction of swamp types must not be very detailed. It is alsoclear that the basis distinguishing s wamp types for the above mentioned purpose must be those factors which can be quite clearly distinguished on aerial photographs. In this connection, the interpretation tables given inthe text divide swamps according to three classification features: forestation, distribution of vegetative cover, and surface structure.

As a result of the ananysis materials for interpretation and for the field check of interpretation of aerial photographs four principal groups of swamps are distinguished: (1) forest swamps; (2) grass swamps with a concave surface; (3) grass-moss swamps with a flat surface; (4) complex moss swamps with convex and concave surface structures. Each of these principles groupes is subdivided into subgroups.

Of the above groups, the most studied and clearly defined on aerial photographs are the complex moss swamps of the north and northwest regions of the Soviet Union. Among these swamps we distinguishe sharply convex, slanting conves, and planoconvex moss swamps, which in turn may be represented by several variants.

It must be emphasized that the apperance of swamps an aerial photographs and the possibility of interpreation depends upon the season and the conditions of photography. Only in certain cases will a winter photograph of a snow-covered swamp permit determining the type of swamp within general outlines. Aerial photographs of swamps made in early spring and late fall are of unequal value; the coloration of the vegetative cover of the swamp during these periods differs considerably from the color of the vegetative cover during the summer. In addition, in the spring and fall swamps have an abundance of water and are flooded in parts. Moreover, the aerial photographs appear somewhat differently according to the time of day at which the photograph is made—with the sun at a low or high elevation. Aerial photographs of swamps differ considerably when made with different light filters.

Interpretation of the boundaries of a swamp on an aerial photograph, as was mentioned above, will be more definite and reliable as a given border of a swamp is more clearly distinguished from an adjacent dry stretch of land. Gradual transitions in vegetation necessitate a ground check of the interpretation and probing of the peat deposit.

On the basis of experience in office interpretation of aerial photographs of many swamps and subsequent ground checks of the aerial photographs of swamps according to the degree of difficulty of an interpretation we may distinguish the following three groups.

1. Easily interpreted from direct features:

   (a) pond-bog complexes (Figure 65);

   (b) ridge-bog complexes (Figure 66);

   (c) afforested and forested portions of swamps (Figures 67 and 68);

   (d) nonswamp dry islands in swamps;

   (e) water objects (lakes, rivers, streams).

2. Interpreted with some difficulty, employing both direct and indirect features:

   (a) equisetacious and cane types of swamp;

   (b) moss-sedge vegegation groupings (Figure 69);

   (c) sphagnum and cotton-grass swamps.

3. Interpreted with difficulty, using direct and indirect features and hence requiring a ground checks:

   (a) the outer boundaries of swamp masses adjacent to swamped stretches of dry land;

(b) certain forest and grass swamps.

Table 14 gives the designation of swamp types, the identifying features of these swamps on aerial photographs, and brief ground characteristics thereof (vegetation, location of the terrain, sources of water).

Section 57. Identifying Features of the Hydrographic Network in Swamps

Some difficulty is encountered in distinguishing on aerial photographs the types of swamps already described in detail in their natural appearance. The elements of the hydrographic network in swamps, on the other hand, are well distinguished on aerial photographs, while they have not as yet been fully studied in nature. The literature contains descriptions of the principal elements of the hydrographic network of intra-bed waters (I. D. Bogdanovskaya-Giyenef 6) and surface waters (Ye. A. Romanova 84). Meanwhile, on the aerial photograph itself, in surveying the entire swamp the location, distribution, and types of elements of the hydrographic network in swamps are especially clearly defined. Keeping in mind the practical purposes of interpretation of aerial photographs of swamps, we performed a trial classification of the elements of the surface of the hydro-network; in this trial we employed not only literary data but also numerous materials of ground checks of the interpretation swamps from aerial photographs.

As the basis of division of the elements of the surface hydrographic network in swamps three classifications features were assumed; (1) the circulation of waters; (2) the origin and formation of corresponding elements; and (3) their suitability for given sections of the swamp landscapes. The scheme of this classification is given in Figure 70 and described in Table 15.

As is seen from this classification, according to the feature of c circulation of water the surface hydrographic network in swamps is divided into basins, streams, and bogs. The latter were distinguished because they are the most numerous and specific group in the surface hydrographic network appearing only in swamps in distinction from basins and streams, which are found also on dry stretches. In addition to this, it is often difficult to relate one or another form of bog to the water basins or streams, since the bogs are in essence intermediate elements.

According to their orign or formation the elements of the surface hydrographic network may be divided into two groups: those of primary and those of secondary orign. Those of primary origin are formed in mineral soil (prior to peat formation of the basin or day stretch), and have a mineral foundation; these of secondary origin developed according to the rate of development of this swamp, in the peat deposit itself.

The basins and streams in swamps may be both primary and secondary inorigin; the bogs are of secondary origin only. In addition, the basins and streams are encountered in swamps of all types, the bogs develop principally in swamps in the last stages of development (that is, on complex moss swamps).

In association of certain secondary elements of the hydrographic network with certain portions of swamps is determined in part by the previously adopted designations for them. For example, micro-ponds are divided into slope ponds (located in groups over the area of a smooth slope of the swamp) and contact ponds (usually located in a chain over the line of contact of the permeable and impervious layers of the peat deposit in the case of excape of the latter into a diurnal surface of the swamps. This is borne out by such bog designations as riparian bogs or bogs from mineral islands.

The ground characteristics and the indentifying features of elements of these surface hydrographic network in swamps are described in Table 15.

Section 58. Methods and Techniques of Interpreting Aerial Photographs of Swamps

The initial materials for interpretation of swamps in practice are the three types of positive production of the aerial photographic survey; contact prints, photodiagrams (foroskhema) of an overlap assembly, and photomosaics /mozaichiny fotoplan/.

A contact print is distinguished by the greatest definition and clearness and is always preferred in complex cases of interpretation of individual portions of swamps. The major shortcomings of contact prints are, in the first place, the discontinuity of individual photographs and the necessity of assembling them in order to obtain a photograph of the entire swamp and, in the second place, the difference in scale of the survey within the limits of even one contact print. For example, in the contact prints with dimensions of 20 by 25 centimeters distributed at the present time the scale of the survey may very within the limits of 1:24,000-1:26,000. Hence, in assembling the different contact prints there is usually obtained a certain lack of correspondence between the prints and a distortion in length and area.

On the other hand, photomosaics are precise images, since all the distortion of scale due to the perspective of the survey, variations in the flight altitude, dissection of the relief, etc, are automatically taken into consideration and corrected in the process of transformation of the contact print on a special device. However, the definitions and clarity of images is thereby somewhat decreased.

Thus, we may recommend the following additional materials for interpretation of aerial photographs of swamps. In case where the aerial photograph is easily interpreted, it is sufficient to use a precise mosaic (fotoplan). In those cases where the swamp is interpreted with difficulty, it is necessary to use at the same time both a mosaic and contact prints; the first in order to obtain precise contours and dimensions, and the second for a careful interpretation of the swamp sections. If it is not necessary to know the precise dimensions, then it will suffice to use only single contact prints.

The choice of a contact print is made from photodiagrams of an overlap assembly, knowing the coordinates of the swamp and the sheet of the map on a scale of 1:25, 000.

As a result of interpretation of photomosaics /aerofotoplan/ and contact prints the following materials may be compiled:

(1) a typological map of the swamp (71);

(2) a grid of lines for flow of surface and filtration waters with the location of the hydrographic network in the swamp (71a);

(3) a general description of the swamp.

The most important compiled on the basis of interpretation of aerial photographs of swamps in the typological map of the swamp.

The typological map of the swamp bears a detailed and precise situation of the boundaries of the datum bed/nulevaya zalezh'/, dry islands, and vegetative cover, as well as the internal hydrographic network--brooks, streams, lakes, bogs, boggy soils. In addition (even before going into the field) an impression is received concerning the complexity of the swamp and its characteristics relative to the typology of individual portions, the extent of forestation and flooding of different sections, which permits correct and accurate laying out of the routes of field investigations and reducing them to a minimum.

The typological map of a swamp is complied directly from materials of an aerial photographic survey by using the above mentioned identifying features in accordance with the typological characteristic of the swamp. The sequence of operations there in may be as follows.

A solid line is drawn around the external boundaries of the swamp (within the boundaries of the datum level of the bed) and the boundaries of the mineral inlands of the swamp. Vague boundaries are indicated by a think dotted line and are subject to ground check. Thin dotted lines seperate the inner conuours of the swamp sections which are characterized by different properties and are easily reflected on the photograph in the from of a definite graininess, streakiness, and tonality. At the same time, the complexity of an object and its genetic nature are revealed.

In practice it is convenient to outline the evident boundaries directly on aerial photographs by using a drawing pen and yellow ink (gouache). This color stands out very sharply against the general background of the photograph, and since gouache is soluble in water, it is easily removed from the photographic paper whenever necessary (with a wet rag or piece of cotton) without damaging the photograph. It is thereby possible to work with the initial material without fear of damaging it, and any errors which may occur are easily corrected.

After examining the swamp by sections, it is useful to once more ananyze the interpreted area in order to disclose an aliminate possible isolated obscurities at certain points in which interpretation is diffilcult, and then it is possible to proceed to preparation of the typological map of the swamp as a whole.

For this purpose tracing paper is placed over the photograph with the contours marked in yellow and a copy is made which isthen colored and marked according to the legend of the object and conventional symbols.

In the process of interpretation of aerial photographs of swamps it is necessary to use a magnifying glass with a power of 2.5 to 5 times; the most convenient magnification is obtained with a 4-power lens. It is desirable to have a lens with a large angular field (for example, with a diameter of 10-12 centimeters) which makes it easy to examine a large portion of the swamp. It is obvious that in all cases where it appears possible to use a steroscope and sterocopic pairs of aerial photographs are available (that is, adjoining contact prints with a considerable overlap) in the interpretation of aerial photographs of swamps it is convenient to use a steroscope. The resulting spatial image considerably facilitates accuracy in establishing the regularities in the swamp landscape.

Current developments will see the creation of photometric instruments with the application of quanitative features of interpretation and of color photographs which will undoubtedly increase the objecticity and reliability of interpretation of swamp photographs without particular complication of the technique of interpretation.

In addition to the basic typological map of a swamp there is compiled a net work of lines representing the runoff of the surface and filtration waters, locating the hydrographic network of the surface of the swamp. Such an independent hydrographic scheme is extremely graphic (Figure 71a and the tracing sheets for photographs 62 and 61) and constitutes a substantial addition to the typological map of a swamp.

The runoff lines are aseries of curves in the horizontal projection of the swamp which indicate the general direction of movement of ground waters in the flow layer of the swamp. For example, in case of a swamp located on a slope with uniform drop of surface and with runoff in one direction, the runoff lines will be parallel, straight lines leading in the same direction; in the case of a convex swamp with a right domal outline the runoff lines will have a radial pattern.

In swamps with atmospheric feed the unobstructed surface of ground waters usually follows the surface of the swamp. Hence, on a topographic plan of the swamp the runoff lines are interected by contours at right angles.

An orthogonal grid of runoff lines and contours of the swamp surface may be likened to the theoretial filtration of a hydromechanical network of the flow of ground waters.

Experience in the use of the materials of aerial photographs of swamps indicates that, with an aerial photograph, the runoff lines for oligotrophic convex may be accurately plotted without a typographic plan of the swamp. In this case the principal source for plotting the runoff lines is the aerial photograph of the swamp, on which there are visible with exceptional detail all the basins and streams, the various types of paths and, what is especially important, the sharply expressed ridge-bog micro-relief is clearly distinguished. The regular distribution of ridges and boggy soils follows the outline of the contours, which has been verified many times by direct comparison of the aerial photographs with terrestrial typographic plans of swamps.

Given an aerial photograph of a swamp, we may first of all establish the spatial distribution of the various elements of the hydrographic network throughout the swamp and their general character, and, subsequently, we may detect the stagnation or flow of waters, the extent of flooding of various sections, and the natural drainage of the swamp.

Furthermore, considering the location of the swamp's water receivers and the direction of runoff (clearly seen on an aerial photograph from the orientation of bogs), it is possible in many cases to trace the lines of the water divides within the swamp. Solution of this problem is considerably facilitated in the presence of a clearly expressed micro-relief, since, on the basis of hydrodynamic considerations, the paths of runoff of surface waters in a bog-ridge complex are directed perpendicular to the ridges and the forested sections.

On the basis of an aerial photograph of a swamp and its interpretation materials (the typological map of the swamp and the grid of runoff lines with the location of the hydrographic network) and using a large-scale map of the region (with a scale of 1:25, 000, 1:50,000), we may give a general description of the swamp. In it the following information will be given: general information concerning the swamp, the geomorphological location of the swamp, the complexity and condition of the surface, the characteristics of the types of individual sections, the presence and singularities of the existing hydrographic network in the swamp, the runoff paths of the surface waters, the presence of unusual water divides, the circulation of the water. A prognosis may be given concerning the peat deposit of the swamp by using the genetic scheme of development of the swamp landscapes and the typological characteristic of the swamp.

In conclusion it must again be emphasized that the typological interpretation of aerial photographs of swamps is a complex logical process requiring qualified specialists, definite skill, and appropriate experience, which it is true, are rather quickly obtained.

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APPENDIX

PHOTOGRAPHS AND EXPLANATIONS

EXPLANATIONS

This appendix contains aerial photographs illustrating the identifying features of elements or characteristics required for interpretation of rivers and swamps.

For the purpose of greater effectiveness and purpose in mastering methods of interpretation each photograph, as a rule, illustrates the identifying features of a single element or characteristic. In a few cases (in order to conserve space) a single photograph illustrates several identifying features. In order to conserve space the photograph shows only that portion which contains the identifying features of one or another element under discussion.

The photographs are accompanied by short explanations containing a description of the identifying features shown thereon. Each photograph has its corresponding citation in the main body of the text.

If a photograph illustrates several features, then the explanation for each of them is given in the order in which they are treated in the text.

The appendix contains both single photographs (intended for examination with the unaided eye) and stereo pairs. In the latter case, the photograph in the appendix has its number followed by the designation "right" or "left", which indicates the presence of a stereo pair and whether this is the right or the left photograph of the pair. The second photographs are found in a special pocket inside the back cover and has the same number. For the stereoscopic examination of photographs it is necessary to remove the corresponding photo in the pocket and to place it to the right or the left of the photograph given in the appendix. After this the photographs are examined under a stereoscope in order to obtain the stereo effect according to the instructions in Chapter IV.

In order to permit stereophotogrammetric measurements on photographs with trimmed coordinate markings, the number of the photograph is accompanied by the parallactic coefficient of the pair (K).

Photograph 1. Scale 1:40,000. River valleys under conditions of mountain relief. Judging from the presence of sharply defined bright portions with dark shadowed portions and considering the small scale of the photograph, it is apparent that the photograph is an image of a mountain terrain. The details of relief are clearly seen.

For unaided visual examination of the photograph it is first necessary to locate it properly relative to the light source. The sun at the moment of photography was located in the upper left-hand corner of the photograph. This is established from the lower edges of shadows located close to the rivers, the network of which is seen on the photograph. By orienting the photograph relative to the light source (that is, so that the shadows fall toward the observer) the following features may be observed with the unaided eye.

The photograph shows bare mountains with pyramidal peaks, having some slopes very abrupt and others less abrupt. Between them are located wide mountain valleys with rivers. The depression between mountains and on their slopes have the appearance of semi-circles in which the rivers and streams have their origin. The slopes of the valleys abound in erosion trenches. At individual points, on the slopes and along ravines, the snow cover has been preserved (bright spots).

The peak with the sharpest expressed relief (in the form of a trihedral pyramid)is located in the upper left portion of the photograph (1). The peak of the mountain is identified as the junction of intersecting bright lines corresponding to the individual ridges.

According to the density of the shadow in the valleys and depressions, we may make an approximate judgment of their relative depth. The more dense the shadow, the deeper the valley or depression. It must be kept in mind that snow at the bottom of the depression lightens the tone of a shadow.

The rivers shown on the photograph appear at first glance to be mountain ridges (2). However, they are easily distinguished by tracing the edges of the shadow along the river -- they usually do not strictly follow the lines of cleavage of the riverbed. If this were a ridge, then the edge of the shadow would strictly correspond to the line of the ridge.

In addition, when examining the erosion trenches it is easily seen that all of the upstream trenches present a pattern resembling a fan and those in the lower portion are connected into a general trough expanding toward the river.

Photograph 2. Scale 1:30,000. River valleys with smoothed mountain relief. The photograph shows converging river valleys bounded by mountains with smoothed outlines of ridges and individual peaks. This is caused by the gradual transition in density of shadow tones and hence the relief is more easily distinguished with the unaided eye than in the preceding photograph, permitting a more detailed examination of the various sculptural forms. The peak of the mountain (1) is examined without difficulty due to the convergence of ridges in its direction with clearly distinguished shadow contours. The lower edges of shadows (in the direction of the bottom of the valley) on the photograph have a darker tone than the upper edges. The peaks are almost exposed and are only lightly covered with a sparse scrub growth, which increases in density at the foot of the slopes.

The bottom of river valleys is adequately visible; the ravines intersecting mountain slopes in sections of which the shadow falls from the larger slopes are less visible. The heavily intersected channels and streams of the bottomland and the shelfs of terraces are clearly visible. They are overgrown with grassy vegetation (possessing a uniform, tone). Clearly visible on the surface of the terraces are the small ravines formed by waters flowing from the mountain slopes. The river bed is meandering and branched; the shoals and sandbars are distinguished by their bright tone, while the water surface is detected by a dark, almost black, tone.

Photograph 3, left. Scale 1:25,000. River valleys under hilly-relief conditions. Attention is called to the mosaic pattern. It is caused by the presence of plowed sections (patches of bright tone and regular outline) and small sections of forest and scrub which are easily identified from the dark tone and graininess of the structure of the pattern (1).

A river with a tributary, lakes, and a network of roads are clearly seen. The meandering nature of the roads facilitates interpretation of the relief.

The river valleys (2) are somewhat less apparent under these conditions than with mountain relief. This is explained by the fact that their dimensions are smaller and the contrast between the illuminated and darkened slopes of the valley is less sharp (compare Photographs 1 and 2).

Judging from the scale of the photograph the relief of the terrain must be considered a small-hill relief. The hills follow the river over its entire extent. The river valleys are narrow, with a weakly developed bottomland, frequently alternating on both banks of the river. While the peaks of individual hills and the depressions are rather clearly shown on the photograph, distinction of the ridges of the valley and details of the relief of its slope is for the most part difficult even with careful study of the photograph and requires stereoscopic examination (see Photograph 3, right).

Photograph 4. Scale 1:30,000. Concealment of relief by plowed fields. The photograph clearly shows the complex mosaic of plowed fields and other farm lands. In the general location of the distinct portions of plough lands the pattern is easily distinguished by the depressions and elevations. The plowed lands and fields appear as the elevated portion clearly seen in the center of the photograph (1). The plowed sections follow the contour lines. The presence of only small sections of plowed land is characteristic for the regions with extensive individual gardening or for foreign territories in which the land is worked by individual small landowners. For large territories occupied by plowlands (kolkhozes and sovkozes) the relief may be judged from the direction of the furrows, which are usually distinguishable on aerial photographs (see Photograph 15).

In the upper part of the photograph there is evidence of a cloud which came within the camera's field of view at the moment the picture was taken. In the lower left edge of the photograph there is seen the shadow cast by the cloud on the ground and masking this surface.

Photograph 5. Scale 1:10,000. A river valley in flatland terrain. The principal distinguishing feature of flatland terrain is its monotony and the smoothness in transition of gray tones and the straightness of contours of the terrain: plow lands, fields, roads, and populated points. The white patches are exposed soil. The shoulders, slopes, and bottom of the valley are indistinct and precise determination of their location (the boundaries) is possible only by stereoscopic examination of photographs. In monocular examination of a photograph the shoulders of the valley must be approximately determined chiefly from the depth of clearly distinguishable trenches intersecting the slopes of the valley. Shadows are of principal importance in identifying such relief formations. An additional sign of the presence of a shoulder is the location of populated points and plowlands, usually located beyond the zone of flooding. The bottomland is open with braided channels overgrown with brush (1). Its outline is rather clearly defined by the edge of the cultivated land and of the braided channels. Judging from the bright patches the soils are sandy loams. The meandering riverbed with islands, shallow water, and sand-banks is typical for flatland conditions.

Photograph 6. Scale 1:10,000. Concelament of the slopes of a valley and the bottomland by blooming grassy vegetation. On the photograph along the slopes of the valley, in the bottomland, and along the banks of the river there are distinguishable white patches or bright portions caused by various objects: plowlands, portions with rectilinear outlines in the upper left portion of the photograph -- (1), increases in the elevation of the terrain with sandy soils (outcroppings and deposits of sand along the banks of the river and on the slopes) -- (2), swamps and swampy sections (in the lower righthand portion of the photograph) -- (3), as well as blooming grassy vegetation (4). The portions covered with blooming lungwort (Figure 72) extends along the bottomland between the river and the forest in the central portion of the photograph. These sections are clearly distinguished from other bright portions (exposed soils, swamp, etc.) by the fine spotted structure of its pattern.

The image of the microrelief on portions covered with blooming vegetation is considerable smooth.

Photograph 7. Scale 1:10,000. (1) Concealment of the slopes of a river valley by a forest under flatland conditions. Clearly visible is the uniformity of structure and tone within the limits of the forest portions in which the trees are all of the same age, indicating identical conditions of feeding of plants; hence we conclude that the surface is a flatland (for comparison with a wooded, hilly relief see Photographs 3, 8, and 45). In concealing the shoulder of the valley, the mature forest also in this case conceals the bottomland, the lower and often flooded portion, as is indicated by the low banks (the absence of shadows) and the signs of swamping in the form of almost structureless patches of bright tone visible on its surface.

(2) Pine forests. The photograph shows a planted, cultivated pine forest with isolated sections of birch (1). The planting of the trees is ascertained from the isolated sections with clearly expressed regularity in the structure of the pattern and the geometric uniformity of the shape. The tone of the image of the canopy of the mature trees is gray, the young sections of forest are distinguished by their darker tone (2). The tops of mature trees are raised a little, the canopy is level, and the surface of the ground is clearly seen. The shadows from the trees are not dense. The graininess of the pattern is uniform with circular outlines for the grains. The transition from the illuminated to the shaded portions of the treetops is gradual.

Photograph 8, left. Scale 1:10,000. (1) Concealment of a valley and a bottomland by forest. The slopes of the valley in the bottomland are covered by forest. The sparse stands of trees and the braided channel facilitates distinguishing the bottom of the valley. The slopes may be examined only by stereoscopic means.

(2) Aspen scattered among spruce and fir. The forest composition: spruce, fir, aspen, birch, cedar. Spruce and fir trees predominate, but the aspen is distinguished by its contrast from the bright tone of the illuminated portion of the treetops and their size (1). The tops of aspen trees are slightly higher and appear as small caps above the canopy of the forest. Occasionally groups of aspen are encountered. The canopy of the forest is distinguished by little difference in tree height. The tree density is 0.7. The average tree height is 23 meters. The soil is loamy.

Photographs 9 and 10. Scale 1:18,000. Comparison of the images of terrain in summer and winter. We see the characteristic monotonous appearance of the terrain on the winter photograph (Photograph 10). Due to the long shadows and the thin snow cover on the winter photograph the irregularities of relief are emphasized; the individual objects are clearly seen. For example, the individual trees along roads, difficult to distinguish on a summer photograph, are clearly seen and the buildings and the populated point are also distinguishable. Comparison of the appearance of the terrain at different times of the year may be made from Photographs 46 and 47.

On the winter photograph we may evaluate the height of the snow cover. Judging from the fact that it does not completely conceal the small irregularities of relief (for example, the ridges in the fields) the height of the snow may be estimated at 5-15 centimeters.

Photograph 11. Scale 1:12,400. Legibility of microrelief with snow cover. The transparency of shadows in the presence of a snow cover permits examining the relief of shaded slopes. On the photograph even the details of the slopes of valleys may be examined and the character of the banks and the lines of cracks in the ice along the banks are clearly visible. Due to the transparency of the shadows and their great length (because of the low elevation of the sun) the tributary trough is clearly distinguished. The details of its slopes and the relief of the bottom (the thin snow cover) are clearly seen.

Judging from the fact that the snow cover does not prevent examining the microrelief, the height of the snow cover in comparison with the dimensions of the elements of microrelief may be estimated at 10-15 centimeters.

Photograph 12. Scale 1:5,000. Concealment of relief by thick snow cover. The appearance of the surface of the terrain covered by a thick snow cover is a monotone. It is extremely difficult to distinguish without a stereoscope the areas where the shoulders of the valley and the borders of its bottom are located. The microrelief is not apparent. It is entirely covered with snow, the height of which, judging from the presence of large snow drifts at the houses is considerable. At the same time the details of the terrain, the situation as regards the appearance of buildings and fences are seen with exceptional contrast. The paths and roads traversing the snow cover are seen; they are indicated by dark lines.

The river is free of snow; the dark surface of ice with the remnants of snow cover in the form of isolated elongated patches resembling ripples of the surface of the ice are clearly visible.

Photograph 13. Scale 1:5,000. Appearance of a terrain losing its snow cover. In the forest (the sections with a blurred streaky pattern) the snow cover is approximately 60 percent, and in the field (the dark patches) it is 10 percent. The dark patches correspond to the convex forms of relief (small-hill relief) in the process of losing its snow cover. It is easy to see the channels and trenches from which the snow has been removed. Their location on the slopes of elevated portions emphasizes the convex forms of relief. However, the density of the tone of the dark patches free of snow cover is caused by the considerable moisture content of the soil and the absence of grass cover, which does not permit examination of the microrelief. The terrain shown on the photograph has a considerable deciduous forest cover. This is easily established from the characteristic streaked pattern caused by the shadows of the trees without their leaves; they conceal the shadows from the convext forms of relief. However, on the forested portion one may still examine the surface of the snow cover and determine the extent of the terrain covered thereby.

Photograph 14. Scale 1:30,000. Snow patches at the end of the thawing period. The snow lies in ravines and trenches and clearly emphasizes their outlines. On the river the ice is flowing. Its dispersion over the surface of the water conceals the line of the stream.

Photograph 15. Scale 1:10,000. The image of a high bottomland not subject to annual flooding. The bottomland is distinguished by the generally uniform gray tone of the surface. The borders of the bottomland are easily determined from the shelf proceeding along the boundaries of the forest and in the lower half of the photograph from the boundary of the populated point and the farmlands. The split channel is clearly visible.

The elevation of the bottomland may be judged from the following features:

(1) the banks of the riverbed are clearly expressed and stand out on the photograph; by comparison of the height of local objects the banks may be seen to be high (compare, for example, the bank in the right hand portion of the photograph with the height of the stacks of hay and buildings);

(2) the uniform tone of the surface of the image of the bottomland indicates its slight dissection and, consequently, is an indication of the fact that the bottomland is not subject to annual flooding and the riverbed itself is subject to a very little displacement;

(3) fields with stacks of hay are located on the bottomland. This also indicates that the bottomland is at a high elevation and is not subject to flooding over its entire width each year.

Photograph 16a. Scale 1:10,000. The displacement fan of a riverbed. The photograph shows a section of a flat land river with numerous displacement fans. Attention is called to the differing orientation of the fans relative to the recent riverbed. The fans immediately adjacent to the river repeat the outlines of the recent riverbed and only occasionally do not correspond with it on the sections of the interrupted loop. The fans beyond the riverbed do not correspond either with the recent riverbed or with the possible direction of the water flow during the flood. This indicates that they are the result of a displacement of the riverbed within the bottomland in the period represented by the recent riverbed. It is also possible to detect on the photograph the displacements formed by the rivers and tributaries intersecting the bottomland. Such fans are characterized by smaller dimensions and greater density in the alternation of ridges and depressions between them.

Photograph 16b. Scale 1:5,000. Riverbed displacement fans in a river bend. The alternation of ridges and depressions forming the fans is clearly traced on the photograph. The conformity between the outlines of the fan and the riverbed is clearly seen.

Photograph 17, right. Scale 1:3,500. K = 21.0. A low bottomland with overgrown braided channels. The low bottomland is subject to annual flooding and is occupied by meadows. The microrelief is barely distinguishable. The mown rows of hay and the hay stacks (1) are clearly visible as are the tracks of trucks (2 thin parallel bright lines,)(2) the channels and braided channel lakes are seen on the photograph to be grown over with aqueous vegetation.

From the clearly expressed patchiness of the pattern and the bright tone of the surface of the braided channels and the creeks we may conclude that they are considerably covered with above-water vegetation.

Photograph 18. Scale 1:14,700. A narrow bottomland clearly visible against the background of a wide, plowed valley of box-shape form. The bottomland is located within the limits of a very flat bottom of a terraced box-shaped valley which is clearly visible under the stereoscope. The bottomland is detected from the unusual gray tone characteristic of a uniformly and well moistened surface.

The fields seen on the photograph also permit clear distinction between the steep slope of the flatland surface of the terrain adjacent to it. They are located perpendicular to the riverbed and proceed up to the foot of the slope but do not continue up the slope. This indicates the steepness of the slope. (1).

The bottom of the valley is high, not subject to flooding, which is indicated by the plowed portions, the road network, the individual structures and the populated point within the limits of the valley. The river

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cuts into the bottom of the valley and forms a narrow, double-ended bottomland which is identified on the photograph by the uniform gray tone (meadow) along both banks of the riverbed.

The photograph clearly shows the traces of "military erosion" in the form of trenches and numerous craters from mine and shell explosions.

The type of valley (box-shaped) is determined from the presence of clearly noticeable (even to the naked eye) extremely abrupt locations of steep slopes and a wide flat bottom. The shoulders of the valley are clearly expressed; the slopes are forested and the forest covers the structure of the pattern of the slopes, however, they are still easily traced in the form of meandering dark bands passing along the open flatland bottom of the valley and the open, also flatland, surface of the adjacent terrain.

In the stereoscopic examination of the photographs the height of the slopes is determined roughly to be 18-20 meters, the grade 40-45 degrees.

The network of roads is dense and proceeds in all directions with perpendicular intersections and clearly emphasizes the lowlands nature of the terrain.

Photograph 19. Scale 1:15,000. Part of a bottomland isolated from a river by levees, with traces of flooding. The space between the principal riverbed and the channel is occupied by a dried and partially plowed bottomland. From the river and the channel the bottomland is separated by levees. The drainage canals are seen. The part of the bottomland between the levees is covered with water, which is easily indicated by the amorphous, diffuse structure of the pattern, by the dark tone and white flashes on its surface (1). Flooding has occurred as a result of a break in part of the levy, the traces of which are seen along the levy in the form of white spots along the bank of the main river.

Photograph 20, right. Scale 1:15,000. K = 26.4. (1) a V-shaped valley. The valley is clearly visible on the photograph due to the presence of sharply expressed shadows. The height of the slopes of the valley shown on the photograph reaches 300-400 meters at some points, and the grade is 30-40 degrees.

On the right-hand slope (right-hand portion of the photograph) there are clearly seen the ravines and furrows which sometimes are traced right up to the riverbed.

On the left-hand slope (left-hand portion of the photograph) we see the characteristic pattern of the surface of a valley slope as caused by the horizontal stratification of exposed rocks (it is particularly clearly seen in the alternation of seams of hard crystal rock with more porous rock). The terrain is large-hilly, cultivated (small rectangles), and its pattern is sharply distinguished from the characteristic pattern of slopes caused by the exposures and the presence of sculptural forms. It must be pointed out that the shadows on the slopes of the valley are not very dense and sometimes permit examining the surface of the slope.

(2) A waterfall concealed by the shadow from a shelf from which the water falls. The waterfall located in the middle of the photograph is identified by means of the wide dark band passing across the river (1). In the given case the shadow covers the falling water and usually there is clearly seen a white band at right angles to the river concealing the waterfall. The lower water of the falls is covered by the shadow from the high, rocky bank. Hence we do not see the white bands of foam which are usually clearly distinguished in the lower water.

Photograph 21. Scale 1:30,000. A trough-shaped valley (glacial trough). Due to the absence of contrast of tones on its slopes, the shape of the valley and its boundaries may be determined chiefly from the character of the location of vegetation (scrub). The scrub growth is located in bands perpendicular to the axis of the water-collecting depression and alternating with bright bands representing small erosion channels.

The shoulder of the valley and the arms of the glacial trough are discernible in virtue of the thinning of vegetation along them.

The terrain adjacent to the river valley has a large hilly smoothed relief.

Photograph 22, right. Scale 1:15,000. K = 23.0. A valley of box-shape. The valley is located in the middle of a large-hilly terrain. It is clearly visible on the photograph due to the clearly expressed difference between the structure of the pattern of the adjacent terrain and the bottom of the valley and slopes with erosion channels and outcroppings.

The right-hand slope of the valley is well forested and turfed and relatively weakly intersected by small erosion channels. They begin in the upper part of the slope and terminate in the expanding area at its foot. The slope is irregularly shadowed (the steeper slopes have darker shading than the shallow slopes); the surface of the shallow slopes is clearly visible. The shoulder of the slope has smoothed outlines and is

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lightly turfed and hence is distinguished by a bright tone. The upper boundary of light and shadow (at the shoulder of the slope) is not sharp due to the smoothness of its outlines. Its lower boundary has a jagged outline, which is caused by the shadow of trees growing on the slope. The shadow often conceals sections of railroad lines. The network of ravines on the slopes clearly shows the direction of the slope.

The left-hand slope of the valley is lighted. Its shoulder is clearly expressed due to the abruptness and the exposure of the upper portion of the slope and the cultivation of the surface of the adjacent terrain. The abrupt, exposed portions alternate with flatter slopes with turf (a uniform grey tone of surface).

In stereoscopic examinations the steepness of the slopes proves to be 20-40 degrees, the height 170-180 meters. Along the foot of the slope there passes a railroad line with a tunnel approximately 300 meters long. The bottom of the valley is plowed. The presence of fields, a populated point, and isolated buildings indicates the high location of the valley bottom (not subject to flooding). The riverbed is deeply cut into the bottom of the valley.

Photograph 23. Scale 1:10,000. Trapezoidal valley. The type of valley is clearly determined from the clearly visible bottomland and the well expressed terrace just above the bottomland (1). The surface of the terrace is flat, plowed, and sharply distinguished from the pattern of the surface of the bottomland, on which displacement fans of the riverbed and the overgrown braided channel are seen.

Photograph 24. Scale 1:15,000. (1) The image of gullies on a valley slope. The photograph clearly shows the gullies intersecting the slope of the valley. They are easily recognized from the contour of the illuminated and darkened slopes and the variegated mosaic pattern of the latter. With incorrect placement of the photograph relative to the light source the gullies appear to be ridges.

(2) The image of clayey soils. The photograph shows a river valley with a broad, one-sided bottomland and a sharp slope almost completely exposed.

Despite the bright tone of the exposed portions of the bank slopes, from the characteristic striped pattern as well as from the location of structures close to the shoulders of the steep slopes and the steepness

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of the latter (25 degrees), their soils are identified as dense, clayey, or loamy soils. The predominance of bright tones indicate that we may most surely expect variations in the loamy soils. In the riverbed the sandy shoals are not exposed and the piles of detritus are small. All this is additional proof of the predominance of clayey soils. In addition, the smooth convex outlines of slopes of gullies also indicate the presence of clays.

The exposed plowlands located near buildings on the high bank have a dark tone, on the basis of which we may assume the predominance of chernozems.

(3) Image of a water surface with great depth and with the sun at a high elevation. The surface of the water is almost black, without semitones, which indicates great depth of water.

Photograph 25. Scale 1:10,000. Riverbed. The riverbed is traced in great detail as an element of relief, notwithstanding the fact that the terrain is almost unintemuptedly forested and the trees conceal the relief of the bottomland and the slopes of the valley.

The shadow indicates the shelf of the bank as well as the vegetation growing on it. The illuminated bank stands out in contrast to the sandy zaplesky, reflected by the white tone.

In addition to the main riverbed and tributaries on the photograph we see a considerable number of braided channels. Many of them are dry and have a sandy bottom. The light is coming from above. With incorrect placement of the photograph relative to the light source many braided channels and portions of the riverbed appear as convex relief formations in the form of embankments.

Attention is called to the lack of repetition in the meandering at the various sections.

Photograph 26. Scale 1:8,400. Image of a calm water surface with flashes. The flashes are clearly seen at the surface of the lake (left photo). Proof that the white tones are caused by flashes and are not a reflection of clouds or shoal waters is found in the fact that in the adjacent, overlapping territory the photograph (right-hand photograph) these are not seen; in addition, the structure of the pattern does not resemble the curling vapors which characterize the image of a cloud reflected in the water.

Photograph 27. Scale 1:10,000. Image of a water surface under agitation. Due to the flashes the image of even small waves is clearly emphasized (see the surface of the water at the issue of the tributary over which the railroad bridge passes). The white lines corresponding to the flashes are broken at the front and somewhat curved.

On the surface of the main river and its tributary below the bridge we clearly see the image of the agitation (ripples) which are especially apparent due to the flashes on the surface of the water. The absence of agitation above the railroad bridge and the bridge over the dirt road and at the leeward bank of the main river, as well as the character of the agitation on the main river and the tributary, permits determining the direction of wind (at a slight angle to the line of the left border of the photograph).

Photograph 28. Scale 1:9,000. Image of muddy and clear water. The photograph shows quite clearly the muddy mountain stream, having an almost white tone for the surface of the water entering the lake, and the lake having a high transparency and considerable depth; the latter is indicated by the dark, almost black tones of the image. The dispersion of the river waters entering the lake is clearly seen.

Photograph 29. Scale 1:9,000. Confluence of streams of different turbidity. The streams with high turbidity are shown by the bright tones. The river with clear water has a dark tone. The absence of considerable illumination of the tone of the surface of the water below the confluence indicates that the turbid water predominates.

Photograph 30. Scale 1:10,000. (1) Concealment of a riverbed by woody growth. In the central part of the photograph in the midst of the open terrain occupied by the plow lands and fields there flows a small meandering stream, the bed of which is fully concealed by the tops of trees growing on its banks. They form a wavy line, emphasizing the general outline of the riverbed. The considerable waviness of this line, not repeated in adjacent sections, indicates that these trees are not growing along a channel or ravine but along the banks of a riverbed.

(2). Open and forested sections. The forested sections are clearly distinguished due to the graininess of their pattern, which is caused by the image of the treetops. It is not difficult to distinguish the boundaries of the open and forested sections.

Photograph 31. Scale 1:10,000. (1) The image of a riverbed in a heavily forested terrain. The beds of small rivers in this case are almost invisible, but they are detected chiefly from the graininess of the pattern, which is coarser along the river and finer away from the river. The large grains form a wavy band along the river. The presence of large treetops is explained both by the sparseness of the trees close to the river and by the better drainage conditions. The trees along the riverbed become so sparse that in the space between them the surface of the water, shadowed by the trees, can be seen.

(2) Spruce-fir stands mixed with birch. The predominance of spruce and fir in the forest canopy is indicated by the sharply expressed, uniform, fine-grained structure of the pattern. On the photograph we clearly see the difference in intensity of the bright tone of the protruding treetops and the shaded spaces between them. Illuminated portions of the treetops are smaller than the shaded spaces. The predominance of shaded spaces gives the photograph a dark grey tone. Spruce and fir trees range in height from 18 to 20 meters. Birch trees abound among the spruce and fir. Illuminated portions of the birch tops are greater than in the spruce and fir. The shape of the birch top is distinguished by the elongated (oval) form with softer contours. In addition they often grow in groups, and in stereoscopic examination they appear above the canopy of the spruce-fir stand. Thus, the forest cover shown on the photograph is marked by a considerable variation in the height of trees due to the presence of different types of trees at different stages of growth. The average age of trees is 50-60 years, which is established from the height of the stand and the diameter of the treetops (see Table 11). The young trees consist of spruce and fir. The ground beneath the forest canopy is not visible.

The relief of the terrain is slightly rolling, the soil is loamy, which may be determined from the correlative series (Section 29).

Photograph 32, right. Scale 1:10,000. K = 19.2. Image of the relief of a large river bed (width approximately 500 meters) on large-scale photographs. Due to the bright (sandy) soils of the bottom and the transparent water, the relief and, in some places, the microrelief of the bottom are seen. A change in the tonality in this case corresponds to a change in depth. The almost white tone of the image corresponds to the surfaces of the following features on the photograph not covered by water: pobochnya, shoals, and flats changing into islands overgrown with willow. The dark tone corresponds to points with the greatest depth. By careful examination of the image of the bottom we may distinguish its microrelief in the form of small, regularly alternating sandy ridges.

Photograph 33. Scale 1:5,000. (1) Image of the relief of the bottom. The photograph clearly shows a sandbar and the microrelief of the bottom. We may even distinguish individual sandy ridges.

(2) The photograph also illustrates the image of alder shrubs (1) located on the surface of a high bottomland and along the river banks.

(3) Sparse oak grove. It is located on a high sandy bottomland. The tops of the oak trees are usually distinguished on the photograph from their form. They resemble gray balls of cotton, they are often asymmetrical, which is caused by the prevailing direction of wind (2). The diameters of the oak tops are two or three times greater than that of pine trees and the image is distinguished by its darker color. Between the treetops and the shadows there are almost no breaks. The shadow from the oak trees clearly gives the shape of the top in profile. In the oak stand we find dead trees, which are distinguished by the shadows of branches without leaves.

Photograph 34, left. Scale 1:5,000. Waterfalls and rapids. The photograph shows a V-shaped symmetrical valley with steep slopes in the upper portion and a river flowing along them, the riverbed being characterized by the presence of small waterfalls and the profusion of the forest canopy.

The direction of the sun's rays at the time of the photograph coincide with the direction of the axis of the valley, hence both of its slopes are almost identically illuminated.

Despite the widening of the valley its V-shape is not destroyed. The upper portions of the slopes of the valley are steep. Along the right bank the steep portion of the slope is wholly illuminated and is shown on the photograph as a bright band with a complex speckled pattern formed by trenches and watershouts. The lower portion of the slope is forested and only slightly broken up by ravines and gullies.

The band of the steep bank appears also on the left slope. It is partially shadowed, indicating that the slope is somewhat concave. In both cases the bright bands are distinguished by contrast and emphasize the difference in the structural pattern of the slopes on the surface of the terrain adjacent to the valley.

Within the limits of the photograph we find on the river (from left to right): rapids (1), identified from the white patches formed not only by the foaming water but also by the image of the large rocks protruding above the surface of the water; a waterfall (2) is clearly seen in the form of a white band, sharply contoured along the edge of the upper portion and less clearly seen in the lower portion. Downstream we find a section full of rapids, at the beginning of which there is a dam (3). It appears in the form of a white band with sharply contoured borders. Further downstream there is another such dam (4).

Photograph 35. Scale 1:10,000. Determining the location of sandbars from indirect features. The bottom of the river is hardly visible. The sandbar on this is easily identified from the ford passing along it.

Photograph 36. Scale 1:10,000. (1) Railroad bridges. Two railroad bridges are located in sequence but at a different height. The difference in height of location of the bridges is difficult to establish with the unaided eye. In stereoscopic examination of the photographs it is clearly seen. The upper bridge has four spans. The metal girders are parabolic, as is clearly seen from the shadows. The abutments and three piers are set in rubble masonry. The sloping of the piers on the upstream side serves as an iceguard. On the right-hand bank, upstream from the causeway, there is a jetty of earth preventing the railroad fill from being washed away during the ice flow and flooding.

The lower bridge some 35 meters away from the first bridge, is a combined overwater and overland bridge with eight spans. The two center spans consist of parabolic girders, the remaining spans are metal arch girders. The piers are of rubble masonry. The third pier from the left bank is located on a small island.

(2) A two-track railroad. The road is clearly identified by the presence of fills, cuts, and installations. It has separate parallel fills over which the tracks pass at a different elevation. The fills and cuts are identified on the photograph by means of shadows. The tone of the railroad is darker than that of dirt roads.

Photograph 37. Scale 1:10,000. The image of highway bridges. In the center of the photograph we clearly see two bridges side by side (1). One of them was destroyed, and a new wooden bridge was constructed next to it. The guard rail is distinguishable and the crossbeams on the supports can be seen. The central span permits passage of ships, which can be concluded from the presence of protective devices (pawls) for the passage of ships. The dimensions of the bridge: 25 meters long, 10 meters wide and the height of the lowest span structure above the water is approximately 5 meters. The girders of the demolished bridge are clearly visible, and we may judge the construction of the bridge from the image thereof.

The photograph also shows several other bridges, both in use and destroyed. For example, there is clearly visible a combined railroad and highway bridge (in the upper left-hand corner of the photograph). Its dimensions: height above water 8 meters, length 55 meters, width 30 meters.

Photograph 38a. Scale 1:10,000. A barrage dam with a single span watergate. The dam (in the right-hand portion of the photograph and in the bend of the river, (1) is easily identified on the photograph, first, from the reservoir created by it (compare the width of the river above and below the dam) and from the presence of white patches or bands in the lower water formed by the foaming water passing over the watergate. The linear dimensions and height of the dam are easily determined by direct measurement under the stereoscope. The bright tones of the image indicate that the dam is of reinforced concrete. It must be pointed out that the image of the dam is distinguished from the images of the bridges in this photograph by its great variety of tone.

Photograph 38b. Scale 1:10,000. A barrage dam with sectional watergate and sluice. Owing to the white bands of water the upper (dark) and lower (with bands) waters are clearly distinguished. We also see the rectangular abutments and their bright tones, which is characteristic of concrete. The service bridge passing along the top of the dam can be seen. Next to the dam is a single-chamber sluice with clearly distinguished double-wing gates turned at an angle to the stream and the controlling regulating installations in front of the entrance gates and below the lower gates, serving to insure safe passage of ships. They are distinguished by white, regular lines and appear as stockades on a pile foundation (pawls).

Photograph 39. Scale 1:10,000. A river port. River ports are easily recognized on aerial photographs from the location and the complex installations comprising them (canals, quays, storage buildings, approaches, etc.), which are usually quite visible.

The photograph shows a general view of the river port with landings, artificial backwaters for the docking of ships, storage buildings, and approaches.

Photograph 40. Scale 1:10,000. (1) A backwater for docking of ships. The backwaters are usually located within the confines of river ports which are near by. Backwater installations are often made from the arms of rivers, canals, and creeks; artificial backwaters are sometimes constructed. The backwaters are usually clearly interpreted from the presence of ships, storage structures, dwellings, landings, piers, dikes, etc. The photograph shows a backwater in a natural creek. There are many ships in the backwater and on the banks we see barges under construction, storage structures, and approaches.

A dredging pump (1) is in operation at the entrance to the backwater. On the river we clearly see the individual ships and rafts towed by them.

Below the backwater is located a pontoon bridge with a destroyed vascule.

The mooring installations are clearly identified from the photographs by the distinct contours in the presence of approaches. The photograph shows the mooring installations in the form of stockades on piers and floating landings (platforms).

(2) Highway. The photograph clearly shows a highway with distinct outlines and dirt with extremely indistinct outlines. Judging from the bright tones, the highway is made of crushed stone or cobblestones. The latter is indicated by the absence of pieces of crushed stone, which usually accompany a crushed stone highway.

(3) The image of an exposed (nonturfed) soil and of arable lands on a plain. Along the banks of a meandering, typical flatland river we see the bright white bands of sandy shoals; the exposed soil on the deteriorated portions of roads is clearly traced by the same bright tone as on the shoals.

Farmlands, clearly visible in the central part of the photograph, have a distinct tone. The dark tones correspond to fields with vegetation, and the bright tones correspond to ploughed lands (fallow). The bright patches of irregular outline among the cloud fields correspond to points with sparse vegetation and exposed soils. Their banded pattern (furrows formed by plowing) and the absence of regular outlines are clearly seen. The most illuminated portion appears as a band between the dirt road (highway) and the river along the slope of the terrace (the furrows run along the slope). In the bottomland we see small white patches of irregular outline. They are also caused by exposed soils on convex irregularities of the surface of the bottomland. This is clearly confirmed by their small dimensions and the irregular and heavily dissected contours.

Photograph 41. Scale 1:10,000. The image of a riverbed network of temporary streams under humid conditions. The photograph clearly shows the network of temporary streams which come into existence during the snow melting. It is visible despite the photograph was made during the summer. In this case the network is detected chiefly due to the vegetation, which is exceptionally well-developed in the riverbeds of this system. The confines of the basin area can be traced quite clearly. The terrain shown on this photograph is characteristic of well moistened regions.

Photograph 42. Scale 1:25,000. The image of a riverbed network of temporary streams under arid conditions. The traces of the stream network occurring during rainfalls is shown in the form of a network of thin lines of dark color. They are visible due to the contrast between the illuminated and darkened portions of the riverbed of this network. We may clearly trace the individual catchments on the photograph.

Photograph 43. Scale 1:15,000. Heaped drift sands. Clearly visible on the heaps, which immediately permit us to ascertain that the soils of the terrain are loose. The lower parts of the slopes of the heaps are partly overgrown with saliniferous shrubs. The orientation of the mounds is not strict, which indicates the absence of a definite prevailing wind direction.

The exposed drift sand shown on the photograph is of a light grey tone with fine waviness caused by the presence of sand ridges formed by the wind.

The white patches on the photograph are the beds of dry lakes covered by salt deposits.

Under the stereoscope we clearly see all the irregularities of the surface, caused by movement of the exposed sand under the action of the wind.

Photograph 44. Scale 1:15,000. Barkhans. The photograph shows the curved exposed sand ridges elongated in the direction of the prevailing winds. The depressions between them are partially overgrown with saliniferous shrubs. The exposed sands, as always, have a light grey tone.

Photograph 45. Scale 1:10,000. Difference in height of forest canopy caused by intersection of relief. Stereoscopic examination clearly reveals the hilly relief causing the difference in height of the forest canopy. The variety and graininess of the pattern is associated with the difference in trees species. The fine grained structure corresponds to spruce-fir growth. The individual large grains which can be distinguished on the photographs are the tops of high trees of the birch and aspen.

Photograph 46. Scale 1:7,500-1:8,000. Mixed forest in winter. Streakiness is characteristic of the sections occupied by deciduous trees. The sections with a clear predominance of coniferous trees have a dark tone and a distinct graininess of pattern. The snow cover is clearly seen beneath the deciduous growth.

Photograph 47. Scale 1:7,500-1:8,000. A mixed forest in autumn. The bright tones are characteristic of deciduous trees. The yellow leaves appear to be almost white on the photograph and stand out in contrast against the background of the dark coniferous trees.

Photograph 48. Scale 1:15,000. A forest swamp with a mixture of birch and pine. The pattern has a fine-grained structure which clearly distinguishes it from the pattern of the large-grained structure of the surrounding forested dry valley. The borders of the swamp in the lower part of the photograph are more distinct than in the upperpart where the swamp is bordered by a small forest, the pattern of which also has a fine-grained structure. The trees in the swamp are 4-6 meters high, the reforestation site classification is V. The density of treetops is 0.5-0.6.

Photograph 49. Scale 1:15,000. The grass swamp with varying degree of flooding. The smooth dark-grey background of the swamp stands out clearly on the photograph in the midst of the pattern of grainy structure of the surrounding forest over the dry valley. Attention is called to the differing tonality of the swamp photograph. All other conditions being equal, the darker the shading the greater the volume of water present in the swamp section, and vice versa (the bright patches on the photograph are moss sections, the darker patches are reed grass sections).

Photograph 50. Scale 1:25,000. Network of drainage ditches in a moss swamp. The canals are clearly visible on the photograph in the form of dark straight lines. The grainy structure of the pattern around them indicates that the shoulders of the canals are forested. On the left (from top to bottom) there runs the main canal. Entering it at a sharp angle are the parallel collecting ditches located at intervals of 250 meters.

Photograph 51. Scale 1:25,000. Peat mining in a moss swamp with a ridge-bog complex. In the upper part of the photograph we see dense, straight, parallel, dark lines -- the open cuts of peat mining filled with water (1). To the sides we see rectangular areas formed by the drainage ditches -- drying plots. On the brightest plots we notice dark spots -- piles of peat. In the lower portion of the photograph there is a concentric streaked pattern -- the ridge-bog complex (2). The dark bands are ridges with pine growth, the bright bands are bogs (cottongrass and sphagnum). The groups of black spots of circular and elongated shape are micro-pounds.

Photograph 52. Scale 1:25,000. Peat mining in a forested grass-moss swamp. In the center of the photograph the black straight lines (1) indicate the open strips from which the peat has been removed and are now filled with water; the bright lines between them are the intervals of unextracted peat. To the right and left of the open strips are the drying plots; the darkest portions (2) have the wet peat, the brightest portions with the black spots (3) represent the dry peat gathered in piles. At the bottom of the photograph the bright straight line (4) is a road passing through the swamp. The borders of the swamp at the edge of the dry valley are weakly expressed.

Photograph 53. Scale 1:25,000. A pine forest swamp with a grass-moss center. The swamp is forested with pine (1) 3-4 meters high, the density of treetops is 0.4-0.5. At the center of the swamp, in the area with the grass-moss cover (2), there are groups of dwarf pine with a height of 1.5-2.0 meters (weakly expressed by dark patches against the light grey background).

The borders of the swamp are well-expressed except for a small rectangular portion which has been cleared.

Photograph 54. Scale 1:25,000. Reed grass swamp in a river bottomland (with evidences of hay mowing). Against the grey background of the photograph of the swamp we clearly see the black meandering band of the river (1). In places the river-flow has been straightened by means of a canal. Along the banks of the river there is an overgrowth of willow scrub (2).

The difference in tonality of the photograph indicates the varying degree of water volume of the swamp. Clearly visible are the drainage ditches in the swamp (to the right of the river and below) and plowed sections (to the right and above), which are clearly distinguished by the generally bright background and straight boundaries. Throughout the swamp there are hay ricks which appear on the photograph in the form of white spots (3).

Photograph 55. Scale 1:10,000. A grass swamp with moss-grass margins. The dark, almost black, broad band passing through the center of the photograph is an abundantly watered horsetail-trefoil marsh (1). Through the sparse grass of the marsh we see the open water surface which gives this portion of the photograph an almost black color. The white patches against the dark background are moss and reed-grass saddles (2). The more elevated portions on the periphery of the swamp, which have a light grey tone on the photograph, are sphagnum and cotton grass sections (3).

Photograph 56. Scale 1:25,000. A sharply convex moss bog with a forested semicircle on the slope. A characteristic feature of a sharply convex moss bog is the forested sloped semicircle (2) (a sphagnum-scrub pine forest) which stands out sharply against the general gray background of the photograph of the swamp as a semicircle of dark color with a grainy structure of pattern. Toward the center of the forested semicircle we notice weakly expressed concentric bands -- a ridge-bog complex (1). In this case on the ridges of the sphagnum swamp is a sphagnum swamp forested with dwarf pine. In the boggy soils the soils with little moisture have a cottongrass sphagnum swamp and those with considerable moisture have a scheuchzeria sphagnum swamp. On the depressed slope of the swamp before the forested semicircle we clearly perceive the concentrations of ridge-pond marshes (5). Close to the periphery of the photograph there is a wide bright band -- a cottongrass sphagnum swamp (3). The grainy pattern on the photograph along the borders of the swamp is an indication of forestation.

Photograph 57. Scale 1:25,000. A moderately convex moss bog with a ridge-bog complex. Attention is called to the fact that the ridge-bog complex occupies the principal area of the swamp and is well-expressed on the photograph (the concentric striped pattern). The forested circle is lacking. Along the periphery of the swamp (the bright band) we find a cottongrass sphagnum swamp and areas with dwarf pine 1.5-2.0 meters high.

The thin black lines crossing the photograph are the edges of the contact prints from which the photograph was assembled.

Photograph 58. Scale 1:25,000. The central portion of a plano-convex moss bog with a ridge-lake complex. The depressed central portion of the swamp is occupied by the characteristic ridge-lake complex (1). Ponds of secondary formation (on the photograph the black irregularly shaped patches) alternate with unforested flat ridges (bright bands). On the slope of the swamp a ridge-moss bog complex (2) is growing, where the forested ridges appear as black bands with a grainy structure, while the boggy soil areas appear as bright bands. The large black circular patches distinguish the lakes of primary origin (3). From one of the lakes there flows a stream with forested banks (4).

Photograph 59. Scale 1:25,000. A swamp of concave shape with a ridge-bog complex (Karelian type of swamp). On the photograph it is clearly seen that the swamp is located within elongated lacustrine basins among the elevations ("sel'g"). The ridges and boggy areas of the ridge-bog complex are oriented perpendicular to the longitudinal slope of the swamp. The ridges are forested and against the generally bright background of the swamp appear as dark bands with a grainy structure.

Photograph 60. Scale 1:15,000. Grass-moss swamp with varying degree of water content in river valleys. Attention is called to the extremely unusual ribbonlike appearance of the swamp formed in the dissected valley of the river system in the midst of a vast forest mass. The riverbed in the lower portion of the valley is easily traced, in the upper portion it is swamped.

Photograph 61. Scale 1:15,000. A fan-shaped grass and moss swamp with concave surface and a ridge-bog marsh (the Pechorskiy type of swamp). The characteristic feature of the pattern in this case is that the dark gray strokes (the filtration streams) are directed from the periphery to the longitudinal axis of the swamp and merge, which indicate the convex shape of the surface in the presence of a generally longitudinal slope to the swamp. The dark bands with the striped pattern are the ridge-bog marsh. The ridges and boggy soils are at right angles to the longitudinal slope of the swamp.

The dotted lines on the overlay indicate the direction of the filtration stream in the swamp; the solid lines show the boundaries of the swamp and the mineral islands.

Photograph 62. Scale 1:25,000. Part of a moss swamp with a ridge-bog complex. The photograph shows a series of elements of the surface hydrographic network. Lakes of primary (1) and secondary (2) formation as well as the artificial drainage network (3, 4, 5), are easily distinguished by their arrangement. The dirt road (7), in distinction from the ditches, is identified on the photograph by the smooth turns and the white color of the line.

Overlay A gives the typological map of the swamp shown on the photograph and overlay B gives the network of flow lines of filtration waters.

Photograph 63. Scale 1:25,000. Micro-ponds of secondary formation in a swamp system with a ridge-bog complex. The microponds are clearly expressed on the photograph in the form of black circular patches of elongated shape which are located in various groupings. One of them is irregularly scattered over the flat slope of the convex mass -- slope microponds (1); the compact groups of the others are stretched out over a semicircle along the same horizontal line of the swamp -- contact microponds (2). The latter were formed upon the contact of two convex swamp masses.

Photograph 64. Scale 1:25,000. A river with an overgrown bed flowing through a grass-moss swamp. The river, with an almost fully overgrown bed, is distinguished on the photograph by the dark, meandering band against the smooth gray background of the reed grass and moss swamp. The dark gray band is interrupted in some places by black spots -- the water-retaining portions of the open (without overgrowth) riverbed.

Photograph 65. Scale 1:25,000. A river having its origin in marshes at the base of convex moss bogs of a swamp system. The photograph shows part of a complex swamp system consisting of a series of convex moss bogs with a ridge-bog complex. The dark band distinguishes the through marsh, which is located in the runoff basin which is located among the prominences of the swamp's system and serves as the origin of a river.

On the photograph, in addition to the through marsh (1) and the river (2), we see a ridge-pond marsh (3), contact microponds (4), a lake of primary origin (5), and a mineral island (6).

Photograph 66. Scale 1:15,000. A ridge-bog marsh and a lake overgrown with floating vegetation in a moss-forest swamp. The ridge-bog marsh (1) extends along the borders of the swamp on the right hand side of the photograph. The wide dark bands are heavily watered bogs with sparse grass-cover of sceuchzeria and "ocheretnika." They alternate with narrow bright bands, representing the unforested ridges. The orientation of the ridges in the upper and lower portion of the photograph differs, which indicates the presence of a filtration flow in different directions. The pattern of the ridge-bog marsh differs considerably from the fine-grained pattern of the forested portions of the swamp and the large-grained pattern of the forest in the dry valley surrounding the swamp.

The lake appears on the photograph of the swamp in the form of a black patch and in this case is bordered on all sides by a white hachured band representing the floating vegetation (2). On the left and right hand sides of the lake the floating mass is of considerable size and it is apparent that the mass on the right is older, since here the ridges begin to take shape. A small stream flows from the river, the bed of which is concealed on the photograph by the treetops (3).

Photograph 67. Scale 1:25,000. A ridge-bog marsh in a moss swamp with a ridge-bog complex. Against the general background of the moss swamp with a ridge-bog complex we distinguish darker, thick bands; this is the considerably more heavily watered portion of the swamp occupied by ridge-bog marsh (1). Within the limits of the ridge-bog marsh the boggy soils are extremely well developed and attain widths of 50-70 meters in distinction from the narrow boggy soils of the ridge-bog complex (2).

Photograph 68. Scale 1:15,000. Ridge-pond marsh (from which a river flows) in the midst of a moss swamp. In distinction from the previous

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ridge-bog marshes (Photographs 66, 67) the ridge-pond marsh has ponds with exposed water surface. Hence, the ponds have an almost black tone on the photograph and the ridge-pond marsh is positively identified.

Photograph 69. Scale 1:25,000. Marshes leading from a group of mineral islands in a slope swamp with ridge-bog and ridge-pond complexes. A distinctive feature of the swamp is the well expressed marshes beyond the mineral islands, which marshes appear as small, elongated, dark patches (1). These marshes run in the general direction of the slope of the surface and thereby indicate the direction of flow of filtration waters from the swamp. At the center of the swamp are the ridge-bog (2) and ridge-pond (3) complexes.

Photograph 70. Scale 1:25,000. Emergence marshes and slope microponds in a convex moss swamp. The emergence of water occurs from beneath the convexities of the moss swamp on the more condensed contours of the peat deposit and are clearly seen on the photograph (1). In the upper left hand corner of the photograph are scattered small black spots (2); these are slope microponds. The banks of the lake in the swamp are well forested (having a grainy pattern).

Photograph 71. Scale 1:25,000. Through marshes in a moss-grass swamp. These marshes are quite clearly seen on the photograph due to their elongated shape running in the direction of the runoff and the dark tone of the photograph. During the dry period portions of the through swamp are more moist than the surrounding portions of the swamp, and in the spring and autumn the water often flows here on the surface. The direction of runoff is shown on the overlay paper; the dotted line represents the filtration waters and the solid line the surface waters.

Photograph 72. Scale 1:25,000. A swamp system consisting of two moderately convex moss swamps with a ridge-bog complex. In examining the photograph we see that the swamp is in fact a system of swamps. The presence of two previously isolated swamp masses is seen from the unusual arrangement of mineral islands in the form of a sandbar, which clearly emphasizes the two distinct basins of the swamps. The ridge-bog complex is well developed and occupies almost the entire area of each swamp mass, which is characteristic for moderately convex moss swamps.

PHOTO CAPTIONS

Photograph 1. Scale 1:40,000. River valleys under conditions of mountain relief. 1, mountain top; 2, river valley.

Photograph 2. Scale 1:30,000. River valleys with smoothed mountain relief. 1, mountain top.

Photograph 3, left. Scale 1:25,000. River valleys under hilly relief conditions. 1, forested section; 2, river valleys.

Photograph 4. Scale 1:30,000. Concealment of relief by plowed fields. 1, hilltop.

Photograph 5. Scale 1:10,000. The river valley in flatland terrain. 1, braided channel almost dry and overgrown with vegetation.

Photograph 6. Scale 1:10,000. Concealment of the slopes of a valley and the bottomland by blooming grassy vegetation. 1, plowed land; 2, exposed sands among pine forest; 3, swamped portions; 4, blooming meadow in bottomland.

Photograph 7. Scale 1:10,000. Concealment of the slopes of a river valley by pine forest under flatland conditions. 1, birch forest; 2, young pine forest.

Photograph 8, left. Scale 1:10,000. Concealment of a valley and the bottomland by forests of spruce and fir mixed with aspen (1).

Photograph 9. Image of a terrain on an aerial photograph made during summer (compare with photograph 10).

Photograph 10. Image of terrain on an aerial photograph made during winter (compare with photograph 9).

Photograph 11. Scale 1:12,400. Legibility of microrelief with snow cover.

Photograph 12. Scale 1:5,000. Concealment of relief by thick snow cover.

Photograph 13. Scale 1:5,000. Appearance of a terrain losing its snow cover.

Photograph 14. Scale 1:30,000. Snow patches at the end of the thawing period.

Photograph 15. Scale 1:10,000. Image of a high bottomland not subject to annual flooding.

Photograph 16a. Scale 1:100,000 /sic/. The displacement fan of a river bed.

Photograph 16b. Scale 1:5,000. Riverbed displacement fans on a large-scale photograph.

Photograph 17. Scale 1:3,500. A low bottomland with overgrown braided channels. 1, hay ricks; 2, automobile tracks.

Photograph 18. Scale 1:14,700. A bottomland clearly seen against the background of a plowed valley bottom of box-shaped form. 1, ridge of valley.

Photograph 19. Scale 1:15,000. Part of a bottomland isolated from a river by levees, with traces of flooding (1).

Photograph 20, right. Scale 1:15,000. V-shaped valley. 1, waterfall.

Photograph 21. Scale 1:30,000. A trough shaped valley (glacial trough).

Photograph 22, left. Scale 1:15,000. A box-shaped valley.

Photograph 23. Scale 1:10,000. Trapezoidal valley. 1, terrace located above bottomland.

Photograph 24. Scale 1:15,000. Image of gulleys on a valley slope, clayey soils, and water surface.

Photograph 25. Scale 1:10,000. Riverbed.

Photograph 26. Scale 1:8,400. Image of a calm water surface with flashes (a) and without flashes (b).

Photograph 27. Scale 1:10,000. Image of a water surface under agitation.

Photograph 28. Scale 1:9,000. Image of muddy and clear water.

Photograph 29. Scale 1:9,000. Confluence of streams of different turbidity.

Photograph 30. Scale 1:15,000. Concealment of a riverbed by woody growth.

Photograph 31. Scale 1:10,000. Image of a riverbed in a heavily forested terrain (spruce-fir stand with mixture of birch).

Photograph 32, right. Scale 1:10,000. Image of the relief of a large riverbed on large-scale photographs.

Photograph 33, Scale 1:5,000. Image of the relief of the bottom of a small river. 1, alder scrub; 2, oak grove.

Photograph 34, left. Scale 1:5,000. Waterfalls and rapids. 1, rapids; 2, waterfall; 3, 4, dams.

Photograph 35. Scale 1:10,000. Determining the location of sandbars from indirect features.

Photograph 36. Scale 1:10,000. Railroad bridges.

Photograph 37. Scale 1:10,000. Highway bridges. 1, an old, destroyed bridge and a new bridge.

Photograph 38. Scale 1:10,000. (a) Barrage dam (1) with single span watergate; (b) barrage dam with sectional watergate and sluice.

Photograph 39. Scale 1:10,000. River port.

Photograph 40. Scale 1:10,000. Backwater for docking of ships. 1, dredging pump; 2, highway; 3, dirt road.

Photograph 41. Scale 1:10,000. Image of a riverbed network of temporary streams under humid conditions.

Photograph 42. Scale 1:25,000. Image of a riverbed network of temporary streams under arid conditions.

Photograph 43. Scale 1:15,000. Heaped drift sands.

Photograph 44. Scale 1:15,000. Barkhans.

Photograph 45. Scale 1:10,000. Difference in height of forest canopy caused by intersection of relief.

Photograph 46. Scale 1:7,500-1:8,000. Mixed forest in winter.

Photograph 47. Scale 1:7,500-1:8,000. The same forest section as shown on Photograph 46 but photographed during the autumn.

Photograph 48. Scale 1:15,000. Forest swamp with a mixture of birch and pine.

Photograph 49. Scale 1:15,000. Grass swamp with varying degrees of water volume.

Photograph 50. Scale 1:25,000. Network of drainage ditches in a moss swamp.

Photograph 51. Scale 1:25,000. Peat mining (1) in a moss swamp with ridge-bog complex (2).

Photograph 52. Scale 1:25,000. Peat mining in a forested grass-moss swamp. 1, open strips; 2, drying plots; 3, peat in piles; 4, road.

Photograph 53. Scale 1:25,000. A pine forest swamp (1) with grass-moss center (2).

Photograph 54. Scale 1:25,000. Reed grass swamp in a river bottomland (with evidences of hay mowing). 1, river with straightened bed; 2, willow scrub along riverbed; 3, hay ricks.

Photograph 55. Scale 1:10,000. Grass swamp with moss-grass margins. 1, horsetail-trefoil marsh; 2, reed-grass and moss saddles (white patches); 3, sphagnum and cottongrass sections.

Photograph 56. Scale 1:25,000. A sharply convex moss bog with forested semicircle on the slope. 1, ridge-bog complex; 2, forested slope semicircle (pine forest with sphagnum and scrub); 3, cottongrass and sphagnum swamp sections; 4, forested moss-grass border (sphagnum swamp with scrub and pine growth); 5, ridge-pond bogs.

Photograph 57. Scale 1:25,000. Moderately convex moss bog with a ridge-bog complex.

Photograph 58. Scale 1:25,000. Central portion of a planoconvex moss-bog with a ridge-lake complex. 1, ridge-lake complex; 2, ridge-bog complex; 3, lake (of primary origin); 4, river with overgrowth.

Photograph 59. Scale 1:25,000. Swamp of concave shape with a red-bog complex (Karelian type of swamp).

Photograph 60. Scale 1:15,000. Grass-moss swamp with varying degree of water content in river valleys.

Photograph 61. Scale 1:15,000. A fan-shaped grass and moss swamp with concave surface and a ridge-bog marsh (Pechorskiy type of swamp). /Overlay/ Dotted lines show the direction of the filtration stream in the swamp.

Photograph 62. Scale 1:25,000. Part of a moss swamp with a ridge-bog complex. 1, lake of primary origin; 2, lake of secondary origin; 3, network of plots of drainage ditches; 4, collection ditches; 5, main canal; 6, mineral island; 7, road. Overlay A, typological map of swamp shown on the photograph (for symbols see Figure 71). Overlay B, network of flow lines of filtration waters.

Photograph 63. Scale 1:25,000. Microponds of secondary formation in a swamp system with a ridge-bog complex. 1, slope microponds; 2, contact microponds.

Photograph 64. Scale 1:25,000. River with bed overgrown with vegetation, flowing through a grass-moss swamp.

Photograph 65. Scale 1:25,000. River originating in marshes at the base of convex moss bogs of a swamp system. 1, through marsh; 2, river; 3, ridge-pond marsh; 4, contact microponds; 5, lake of primary origin; 6, mineral island.

Photograph 66. Scale 1:15,000. Ridge-bog marsh (1) and lake overgrown with floating vegetation (2), in a forested moss swamp; river, bed of which is concealed by tree growth (3).

Photograph 67. Scale 1:25,000. Ridge-bog marsh (1) in a moss swamp with a ridge-bog complex (2).

Photograph 68. Scale 1:15,000. Ridge-pond marsh (from which a river flows) in the midst of a moss swamp.

Photograph 69. Scale 1:25,000. Marshes leading from a group of mineral islands (1) in a slope swamp with ridge-bog (2) and ridge-pond (3) complexes.

Photograph 70. Scale 1:25,000. Emergence marsh (1) and slope microponds (2) in a convex moss swamp.

Photograph 71. Scale 1:25,000. Through marshes in a moss-grass swamp, (overlay) system of flow lines of filtration (dotted lines) and surface (solid lines) waters.

Photograph 72. Scale 1:25,000. Swamp system consisting of two moderately convex moss swamps with a ridge-bog complex.

FIGURES

Figure 17.

Figure 18. Overlap assembly

Figure 19. Methods of cutting photographs in compiling a mosaic

Figure 20.

Figure 21.

Figure 22.

Figure 23.

Figure 24.

Figure 25.

Figure 26.

Figure 27.

Figure 28. Large transforming printer

Figure 29. Small transforming printer

Figure 30. Diagram of transformation. a, on the photograph; b, on the transforming printer

Figure 31. Diagram of route phototriangulation

Figure 32. Scheme of development of phototriangulation

Figure 33. Orientation of aerial photographs from a map. a, map; b, photograph

Figure 34. Orientation of aerial photogaphs from shadows

Figure 35. Ban'kovskiy device.

Figure 36. Light table

Figure 37. Panoramic lens

Figure 38. Set of magnifying glasses for interpretation

Figure 39. Panoramic mirror

Figure 40. Transverse profile of riverbed

Figure 41.

Figure 42. Stereoscopic test pattern

Figure 43. Diagram of simple stereoscope

Figure 44.

Figure 45. LZ lens-mirror stereoscope

Figure 46. Orientation of stereo pairs from the initial direction

Figure 47. (From the book by A. Dobrovol'skiy and S. Aleksandrov.) a, stereoscopy; b, pseudoscopy; c and d, plane image

Figure 48.

Figure 49.

Figure 50.

Figure 51.

Figure 52. Stereocomparator. a, general view; b, diagram of instrument

Figure 53. Stereocomparator. a, general view; b, diagram of binocular microscope of the stereocomparator

Figure 54. Topographic stereoscope TSD-3

Figure 55. Stereopantometer of F. V. Drobyshev. x a, sketch; b, general view

Figure 56. Parallax bar

Figure 57. D-6 stereoscope

Figure 58. Setting of parallactic plates

Figure 59. Reading from the scale of parallactic plates (g = 11.45 cm)

Figure 60.

Figure 61.

Figure 62.

Figure 63. Length of the shadow of an object expressed in ratio to its height for a latitude of 56 degrees.

Figure 64. Graph of optimum scales for aerial photographic surveys of water objects. 1, maximum errors in measuring distance from maps and plans; 2, probable errors in measuring distances from aerial photographs; 3, mean arithmetical errors in measuring distances from aerial photographs; 4, mean square errors in measuring distances from aerial photographs.

Figure 65. Pond-bog complexes

Figure 66. Ridge-bog complex (ridges of sphagnum-scrub growth forested with pine; moss-bog with sphagnum-cottongrass and sphagnum-scheuchzeria growth)

Figure 67. Reed grass and birch swamp (transitional type)

Figure 68. Scrub and pine swamp (upland type)

Figure 69. Reed grass swamp (lowland type)

Figure 70. Classification of elements of surface hydrographic networks in swamps (figure 70 on next page)

Figure 71. Typological map of a system of swamp masses compiled as the result of interpretation of aerial photographs. 1, reed grass and sphagnum swamps; 2, cotton grass and sphagnum swamps; 3, scrub and cotton-grass sphagnum swamp with sparse pine growth; 4, scrub and pine sphagnum swamp; 5, scrub and pine forest; 6, sphagnum swamp with cottongrass and birch with a mixture of pine; 7, ridge-bog complex (ridges forested with pine); 8, horsetail-trefoil-cottongrass (transitional) marshes; 9, scheuchzeria marshes (emergencies)

Figure 71a. Diagram of flow lines for surface filtration waters with a location of the hydrographic network in swamps. 10, flow lines of filtration waters; 11, flow lines in sections with periodic surface flows; 12, microponds; 13, rivers and streams; 14, mineral islands

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TABLE 1

Country	Camera	Purpose	Focal length, CM	Photo Size, CM	No. of photos	For vertical photograph width of path	area covered by photo
USSR	AFA-13 AFA-33 AFA-37	Vertical Photo-graphy	30 20 7	18x18	150	0.60 H	$0.36H^2$
Germany	RMK-S52	Vertical and Oblique	21				
	RMK-S11	Vertical	21				
	RV(20)30	Vertical	20				
	RMK-R10	Vertical	10				
USA	K-17B	Vertical	15.3				

Note. H is the flight altitude

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TABLE 3

REFLECTIVITY OF CERTAIN OBJECTS OF AERIAL PHOTOGRAPHY

(after Ye. L. Krinov [52])

Object	Reflected Light, %	Object	Reflected Light, %
Exposed chalky surface	90	Light soils	20-30
Yellow fields	20	Dark soils	10-15
Forest	15-20	Dry loam	15
Grass cover	20-30	Moist loam	7

TABLE 4

Designation				Emulsion speed		
GOMZ	IZOS	Filter color	Range	isopan	panchrome	infrachrome
I	ZhS-16	light yellow	472-480	1.5	1.5	1.5
II	ZhS-18	dark yellow	500-518	2.0	1.5	1.5
III	OS-12	light orange	542-560	3.0	2.0	2.0
IV	OS-14	dark orange	570-585	4.0	2.0	2.0

TABLE 5

NUMBER OF GEODETIC CONTROL POINTS ACCORDING TO SURVEY SCALE

Scale	Methods: Analytic	Methods: graphic
	Average of one point per area	
1:10,000	14 km^2	7 km^2
1:25,000	35 km^2	20 km^2
1:50,000	120 km^2	75 km^2

6

TABLE 2

SURVEY SCALES UNDER VARIOUS CONDITIONS

(after A. I. Shershen' [118])

		Geodetic base conditions		
		extremely limited	minimum adequate	complete
		Character of areas of operation		
Scale of Cartography	Required accuracy of relief, M	Northern, uninhabited	Barely accessible, concealed mountainous	Cultivated, densely populated
				1:10,000 and larger

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1:50,000		120 km^2	75 km^2

6

TABLE 6

SPECIMEN OF JOURNAL OF TRANSVERSE PROFILE MEASUREMENTS

Stereopair 84-85 H = 2000m, B= 1243m, $\frac{1}{m}$ = 1: 10,000

Point No, bank	Readings g_1	g_2	p= gav.	Δ p mm	$\Delta H = K \Delta p$, $K = \frac{H}{b} = 16.1$ m/mm	Distance between points, m
10 left	10.86	10.86	10.86	2.14	34.5	120
9 left						
8 left						
7 left						
6 left						
5 left						
4 left						
3 left						
2 left						
1 left					0 river	
1 right					0 river	
2 right						
3 right						
4 right						
5 right						
6 right						

TABLE 7

SPECIMEN OF JOURNAL FOR CALCULATIONS

Stereopair 61-62 H = 2000 m, B = 1200m, $\frac{1}{m}$ = 1:10,000

Point No, bank	g_1	g_2	p=gav.	Δ'p	$\delta\Delta$p	Δp	Δ H=KΔp K=$\frac{H}{b}$=16.7 m/mm	Distance between points, m
3 left	9.42	9.42	9.42	+0.70	+0.12	0.82	13.69	30
2 left	9.36	9.38	9.37	+0.65	+0.06	0.71	11.86	30
1 left	8.70	8.74	8.72	0.00	0.00	0.00	0.00	100 river
1 right								
2 right								
3 right								

TABLE 8

DATA FOR SMALLEST AND OPTIMUM SCALES OF AERIAL PHOTOGRAPHS FOR HYDROLOGICAL INTERPRETATION

Hydrological elements of interpretation and their composition [1]	Smallest scale [2]	Optimum scale [3]
I. River valleys (lacustrine basins)		
Type of valley, its outline in plan view	all scales	
Height, steepness, shape, dissection of slopes, vegetation and soils in form of characteristics #3/ generalized by sections:		
#2/ (a) for flatland conditions with valley width greater than 2 km	1:25,000-1:30,000	1:15,000
#3/ with width less than 2 km	1:15,000	1:10,000
#2/ (b) for mountainous conditions	1:40,000	1:25,000
same for isolated stretches or small sectors, with the addition of precise quantitative character- #3/ istics and profiles	1:10,000-1:15,000	1:15,000
Number of terraces, their heights, steepness of sections, surface slopes (longitudinal, transverse), width, extent of surface dissection, vegetation in the form of generalized data for characteristic sections	1:25,000-1:30,000	1:15,000
Same for individual directions or short sections with the introduction of precise qualitative characteristics and profiles	1:10,000-1:15,000	1:15,000
Width of bottomland, its position relative to the riverbed in the plan view, character of the surface, extent of dissection, vegetation:		
(a) under flatland conditions	1:25,000-1:30,000	1:10,000
(b) under mountainous conditions	1:40,000	1:25,000
Height of bottomland above level of water in riverbed in the form of qualitative characteristics (high, low, average)	1:25,000-1:40,000	1:15,000
Same in quantitative characteristics	1:10,000-1:15,000	1:3,000
High water lines	1:15,000	1:5,000
Presence of landslides, talus (scree), heaps of detritus	1:25,000-1:40,000	1:10,000-1:15,000
Presence of ground-water discharges in valley	1:15,000	1:5,000
Swampiness of slopes and valley bottom in qualitative degrees	1:40,000	1:25,000
Same with derivation of precise contours of swamps and of the different microrelief	1:10,000	1:5,000

TABLE 8 (continued)

[1]	[2]	[3]
II. Riverbeds (lacustrine basins)	all scales	
Extent of meandering and branching of riverbed in the form of generalized data for sections		
Information concerning the presence of riverbed formations (reaches, sandbanks, chutes, waterfalls, rapids, flats, shoals, sandbars, shallows, beaches)	1:25,000	1:10,000
Determination of vertical outlines of details of riverbed formations. Requires photographs with river bottom visible through water:		
(a) for rivers with widths from 20 to 80 m.	1:5,000	1:2,000
(b) for rivers with widths greater than 80 - 100 m.	1:10,000	1:5,000
(c) for rivers with widths of 200 - 300 m.	1:25,000	1:10,000
Measurement of river widths with accuracy within 10 percent with width of:		
20 m. and greater	1:15,000	1:12,000
50 m. and greater	1:25,000	1:12,000
80 m. and greater	1:40,000	1:12,000
Determination of river depths by stereophotogrammetric means (requires an image of bottom relief with an accuracy of:		
up to 10 cm	-	1:3,000 - 1:5,000
up to 1 m	-	1:5,000.
Qualitative determination of height and steepness of banks and their character (high, low, etc)	1:25,000	1:10,000
Measurement of height and steepness of banks from individual lines with the plotting of profiles for steep banks with heights of:		
up to 5 m	-	1:3,000
5-10 m	-	1:5,000
11 m and greater	-	1:20,000
Determination of bottom ground in the form of generalized characteristics for sections	1:25,000	1:5,000
Same for leading lines	1:15,000	1:5,000
Qualitative determination of turbidity of water	all scales	
Obstruction of riverbed and extent of vegetation in the form of characteristics for sections	1:25,000	1:5,000
Ice structures in rivers in the form of qualitative characteristics:		
rivers up to 20 m wide	larger than 1:10,000	
wider than 20 m	1:25,000	1:10,000
Determination of dimensions of elements of individual ice structures with river widths of:		
20 m and greater	1:15,000	1:10,000
50 m and greater	1:25,000	1:10,000
80 m and greater	1:40,000	1:10,000

TABLE 8 (continued)

[1]	[2]	[3]
III. Hydrotechnical installations		
Location of installations	all scales	
Type and construction of installations	1:15,000	1:5,000
Condition of installation	1:15,000	1:2,000
IV. Obtaining data for the characteristics of a watershed		
Type of relief, predominant forms, their individual a pearance, the relative location of various forms of relief:		
flatland relief	1:25,000	1:15,000
mountainous relief	1:40,000	1:25,000
Terrain elevations, precise quantitative planimetric characteristics of macrorelief and mesorelief	1:10,000	1:5,000
Same for microrelief	larger than 1:10,000	
Character of distribution within watershed of principal groupings of vegetation or farmlands (forest, burned areas, scrub growth; meadows, fields, plowlands, swamps)	all scales	
Species composition, predominant types	1:20,000	1:10,000
Age, density	1:15,000	1:5,000
Predominant soils of watershed:		
under flatland conditions	1:25,000	1:15,000
under mountainous conditions	1:40,000	1:10,000
Boundaries of soil types	larger than 1:10,000	
Planimetric determination of extent of snow cover during period of irregular cover	all scales	

TABLE 9

CORRELATION SERIES OF CERTAIN LANDSCAPE ELEMENTS OF THE FLATLAND - TAIGA ZONE

(After Gaveman (14))

Vegetation, predominant species	Lythology, predominant soils	
Spruce - fir forest with birch	Morainic loams	Smoothed forms with moderate slopes, developed on water divides. Due to the moraine cover and dense vegetation, erosion scouring is almost undetectable.
Aspen	Fluvio-glacial sandy loams with rubble	Isolated areas, terrace remnants on valley slopes, lying hypsometrically between morainic and alluvial deposits.
Pine	Alluvium	A stretch of piled ridges and isolated crests approximately 6-10 m above the level of sphagnum swamps, extending along the course of rivers; isolated sandy crests and entire stretches of them dispersed over the surface of sphagnum swamps.
Spruce - fir forest	Eluvial - deluvial deposits of the Kazanskiy formation. Loams, conglomerates.	Mounded lowland with height variations of 30-40 m; sculptured forms of relief predominate. Valley system well developed, especially in conglomerates.

TABLE 10

DETERMINING SPECIES OF UNMIXED, MATURE STANDS OF FOREST ON PHOTOGRAPHS WITH SCALES OF 1:15,000 AND 1:25,000

(After G. G. Samoylovich [39])

Designation of features	Scale of photograph	Identifying Features			
		Spruce and Fir	Pine	Birch	Aspen
(1)	(2)	(3)	(4)	(5)	(6)
1. General tone of image of tree stands	1:15,000	Dark grey and darkest of all species listed in table	Grey in the lower reforestation site classifications and, with an interrupted forest canopy, light grey. Always of brighter tone than the spruce-fir stands.	Grey; brighter than spruce-fir stands and somewhat darker than aspen.	Light grey, lightest of all species listed in table.
	1:25,000	same	same	same	same
2. Shape of tree-top	1:15,000	Conical, sometimes with truncated tip.	Simple spheroidal	Oval and spheroidal, simple. In over-mature growth (90 yrs old and over) spheroidal and complex with piled surface.	Simple spheroidal; 90 yrs. and over -- simple spheroidal with piled surface.
	1:25,000	Tapering, needle-shaped, often with truncated tip.	same	Simple spheroidal.	Simple spheroidal.
3. Difference in tone of illuminated and shaded portions of top.	1:15,000	In most cases sharp: illuminated portions of top light grey; shaded portions dark grey, often blending with dark grey interspaces.	Not sharp, gradual transition of illuminated portion into shaded portion; top clearly distinguished.	Not sharp, illuminated portion gradually blending into shaded portion or quite indistinguishable.	
	1:25,000	Illuniated and shaded portions of top distinguished with difficulty.	Difference in tone of illuminated portions of top less distinct.	Difference in tone of illuminated and shaded portions of top less distinct and difficult to distinguish.	

TABLE 10 (continued)

(1)	(2)	(3)	(4)	(5)	(6)
4. Difference in height of treetops of principal forest canopy.	1:15,000	Very large, with closed canopy difference in height is smoothed out. Canopy uneven.	Insignificant. Canopy quite even.	Inconsiderable. Canopy quite even. With broken canopy difference in height observed between groups of treetops.	Almost lacking. Canopy most even of all species.
	1:25,000	Same features, but less clearly expressed and distinguished with difficulty.	Same features, but less clearly expressed and distinguished with difficulty.	Same features, but less clearly expressed and distinguished with considerable difficulty.	
5. Character of distribution of treetops within a section (uniform, curtained, grouped.)	1:15,000	Uniform or irregular. No characteristic curtains or groups of treetops. Windfall glades and openings encountered.	Uniform. No characteristic curtains or groups observed, nor windfall glades and openings.	Mostly grouped (scrub). With dense canopy the groups are not always discernible.	Mostly scrub with dense growth and canopy quite even.
	1:25,000	same	same	same	same
6. Variations in the relative diameter of treetops of the principal stand canopy.	1:15,000	Varies over wide range -- up to 4 times and above, with increase in density the variation decreases.	Varies over small range.	Varies over small range in mature stands with dense canopy. In over-mature stands with broken canopy variation is considerable.	Varies over extremely small range.
	1:25,000	Varies over wide range up to 3-4 times.	same	same	same
7. Extent of treetop in depth.	1:15,000	Treetops long, extent noted to half the stereoscopic depth and below.	Treetops short, with medium and low density of canopy, treetops can be seen through to a small depth. Treetops appear to be suspended in air.	Treetops short, but somewhat longer than those of pine. Visibility in openings to a small depth.	Treetops short, visibility to small depth only in openings or with broken canopy.
	1:25,000	Same, but extent less clearly distinguished.	Same, but extent less clearly distinguished. Treetops appear to be suspended in the lower reforestation site classifications.	Same, but extent less clearly distinguished.	Same, but extent less clearly distinguished.

TABLE 10 (continued)

(1)	(2)	(3)	(4)	(5)	(6)
8. Visibility through canopy and visibility of tree stand in depth. Transparency of treetops.	1:15,000	Spruce stand appears as a dense shadow beneath canopy, creating the impression of a dark (shady) forest. Ground seen in rare cases. Treetops dense, non-transparent.	Canopy of principal stand in absence of secondary layer and high density permits passage of much direct sun-light, creating the impression of a bright forest. Well illuminated treetops are semitransparent.	Visibility through canopy insignificant due to poor isolation and nontransparency of treetops. Visibility through tree stand to depth only in openings and with broken canopy.	Visibility through canopy insignificant due to poor isolation and nontransparency of treetops. Visibility through tree stand to depth only in openings and with broken canopy.
	1:25,000	Same features but less clearly expressed and distinguished with difficulty.	Same features, but less clearly expressed and distinguished with difficulty.	Same features but less clearly expressed and distinguished with difficulty.	
9. Character of shadow of individual trees observed in breaks and in discontinous stands.	1:15,000	Dense shadow in the shape of a narrow, elongated triangle.	Shadow less dense, than that of spruce, resembling an elongated semicircle (protracted oval).	Shadow denser than that of pine, resembling an elongated semicircle or ellipsoid.	Shadow as dense as that of pine, resembling a slightly elongated semicircle.
	1:25,000	same	same	same	same

TABLE 11

FEATURES FOR DETERMINING AGE OF STANDS ON PHOTOGRAPHS WITH SCALES OF 1:15,000 AND 1:25,000

(After G. G. Samoylovich [39])

Age of stands		Features of Interpretation			Relative stereoscopic height of mixture
		Treetop sizes		Shape of treetop	
Seed propogations	Shoot propagations	absolute	relative		
(1)	(2)	(3)	(4)	(5)	(5)
		spruce-fir stands, scale 1:15,000			
II-III (30-50 years)	II-III (15-25 years)	small (approx. o.25 mm)	insignificant variations	indistinguishable, except age class III in which the shape of the treetop is conical.	Mixture of aspen and birch in age class III considerably taller than spruce. In age classes I and II (10-30 years) the mixture is generally indistinguishable.
IV-V (70-90 years)	IV-V (35-45 years)	medium (approx. o.6 mm)	variations up to 2-3 times	conical	mixture of aspen and birch considerably taller than spruce
VI and above (110 years and above)	VI and above (55 years and above)	large (approx. 1.0 mm)	variations up to 4 times	conical	mixture of aspen and birch of same or less height than spruce
				scale 1:25,000	
I-III (10-50 years)	I-III (5-25 years)	indistinguishable	indistinguishable	indistinguishable	indistinguishable
IV-V (70-90 years)	IV-V (35-45 years)	small (0.25 mm)	small variations	tapered	mixture of birch and aspen considerably taller than spruce
VI and above (110 years and above)	VI and above (55 years and above)	Medium (approx. 0.5 mm)	variations up to 2-3 times	tapered	mixture of birch and aspen of same or less height than spruce

TABLE 11 (continued)

(1)	(2)	(3)	(4)	(5)	(6)
			Pine stands, scale 1:15,000		
I-III (10-50 years)	I-III (5-25 years)	indistinguishable, except age class III which reaches 0.25 mm	indistinguishable in age classes I and II, uniform in age class III (sic).	indistinguishable	mixture indistinguishable
IV-V (70-90 years)	IV-V (35-45 years)	medium	variations relatively small, less in dense canopy	oval	--
VI and above (110 years and above)	VI and above (55 years and above)	large	variations relativel small	spheroidal	--
I-III (10-50 years)	I-III (5-25 years)	indistinguishable	indistinguishable	indistinguishable	--
IV-V (70-90 years)	IV-V (35-45 years)	small treetops predominate (approx. ¼mm)	variations insignificant	spheroidal in the shape of small grains	
VI and above (110 years and above)	VI and above (55 years and above)	medium treetops predominate (approx. ½ mm)	variations insignificant	spheroidal, in the shape of grains of medium diameter	--
			deciduous stands, scale 1:15,000		
I-III (10-50 years)	I-III (5-25 years)	treetop sizes indistinguishable up to age class III	indistinguishable up to age class III, uniform in age Class III	indistinguishable	--
III-V (50-90 years)	III-V (25-45 years)	small	small variations	conical, with sharp transition from illuminated portion of treetops to shaded portion	--
VI and above (110 years and above)	VI and above (55 years and above)	medium	small variations	parabolic, with gradual transition from illuminated protion to shaded portion	

TABLE 11 (continued)

(1)	(2)	(3)	(4)	(5)	(6)
birch and aspen stands, scale 1:15,000					
I-II (10-30 years	I-II (5-15 years)	indistinguishable	indistinguishable	indistinguishable	mixture indistinguishable
III-V (110 years and above)	III-V (25-45 years)	small treetops	variations insignificant	in shape of small grains and ovals	spruce mixture not as tall as birch and aspen
VI-VII (110 years and above)	VI-VIII (55-75 years)	medium treetops	variations considerable only with canopy of low density (up to 0.6)	simple spheroid	spruce mixture not as tall as birch and aspen
	IX and above (85 years and above)	large treetops	considerable variation	complex spheroid with piled surface	spruce mixture as tall as or taller than birch and aspen
linden stands, scale 1:15,000					
II-III (30-50 years)	II-III (15-25 years)	indistinguishable	indistinguishable	indistinguishable	--
IV-VI (70-110 years)	IV-VI (35-55 years)	small and medium	considerable variation	in shape of small hemispherical grains	--
VII and above (130 years and above)	VII and above (65 years and above)	large	large variations, on the order of 1:3 and greater	spheroidal	--

* Shoot propagations are forest growths arising on cleared sites. In this case the trees develop as shoots from stumps. In seed propagations the forest develops from seed dispersed by trees of the principal forest growth.

TABLE 12

CHARACTERISTIC OF ACCURACY OF VISUAL DETERMINATION OF SHORELINE

AS A FUNCTION OF THE CHARACTER OF ITS CONCEALMENT FOR SCALES OF 1:2,000 - 1:15,000

Types of concealment of shoreline		Absolute error of measurement ($\pm$ m) with subsequent guarantee of appearance of error(%)							
		10	25	50	75	90	95	97.5	99.9
Dark tones of image of surface of water and banks	large depths or muddy bottom and stable, moderately sloping banks	0.5	0.8	1.2	2.1	3.3	4.1	5.0	7.5
	large depth or muddy bottom and steep, exposed banks casting no shadows on water	0.6	0.9	0.4	2.9	5.0	7.4	8.5	9.8
Bright tones of image of water surface and banks (shoals, sandy surf strips)		0.5	0.9	1.6	3.0	[illegible]	4.6	5.0	6.0
Structural image of water surface and banks	Dense aqueous vegetation and open turfed banks	0.5	0.9	1.9	3.4	4.9	6.5	7.7	10.5
	Dense aqueous vegetation and banks covered with scrub growth	0.6	1.1	2.2	3.7	5.1	6.7	8.4	11.0

TABLE 13

GENERAL INTERPRETATION FEATURES OF SWAMPS

Interpretation features (1)	Significance of features (2)	Remarks (3)
	I. Direct Identifying Features	
Grainy pattern	Forestation: forest swamps and forested swamps. The denser and larger the graininess, the denser and taller the forest in the swamp (Photo 48).	Size and shape of graininess of pattern of various species of trees are distinguishable (Table 14).
Striped pattern (dark bands regularly alternating with light bands)	Ridge-bog and ridge-pond complexes (alternation of ridges and bogs or ridges and ponds) (Photo 51).	Various combinations of the striped pattern are distinguished.
Tonality	Varying degrees of flooding. Other conditions being equal, the darker the section the greater the flooding (Photo 49).	Horsetail marshes are darker than reed-grass marshes; reed-grass marshes are darker than cotton-grass marshes.
Isolated, sharply contoured sections with a large-grained pattern	Mineral islands in the swamp, overgrown with trees (Photo 62).	Clearly distinguished in the midst of swamps as a distinct shape.
Distinct swamp borders	Grass, grass-moss, and moss swamps bordered by forested and forest dry valleys (Photo 49).	The borders, as a rule, are irregular and closely outline the swamps.
Indistinct swamp borders	Grass and grass-moss swamps bordered by swamped meadow; moss swamps are bordered by plowlands and clearings; forest swamps are bordered by swamped forest (Photo 52).	A ground survey is required for precise delineation of swamp borders.
	II. Features Arising from Man's Economic Activity	
Level portions with distinctive pattern arranged in a definite system and bounded by dark straight lines	Swamps sections with peat-cutting activity; open pits, drying plots, etc., (Photos 51 and 52).	The various methods of extracting peat give the swamps distinctive patterns.

TABLE 13 (continued)

(1)	(2)	(3)
Dark or black straight lines (systems of lines)	Drainage ditches filled with water (Photo 50).	The well-drained portions along ditches are often overgrown with trees (having a grainy structure on the photograph).
Straight, bright narrow bands against a grainy background	Forest cuts (Photo 53)	Indistinguishable in sparsely forested swamps
Straight or gently twisting, bright, narrow bands	Causeways, roads, paths, trails in snow (Photos 52, 62).	Quite clearly distinguished on large-scale photographs. In stereoscopic examination the bands appeared to be depressed.
Bright areas with regular borders among dark sections with grainy pattern	Forest cuts -- locations of forest clearings in swamps.	Seen in forest swamps and in forested sections of moss swamps.
Bright spots on a dark background	Hay ricks in grass swamps (Photo 54).	Seen in sections along ponds and streams, sometimes on the edges of moss swamps.

TABLE 14

INTERPRETATION FEATURES AND BRIEF GROUND CHARACTERISTICS OF SWAMPS

Type of swamp (1)	Interpretation features of aerial photographs (2)	Brief ground characteristic of vegetation (3)	Geomorphological condition and sources of water-mineral supply (4)
I. Forest swamps	Photograph of dark-grey and light-grey tone with characteristic fine-grained pattern. Principal feature of the forest swamp is the fine graininess of of pattern compared with the pattern of surrounding forests in dry valleys. Swamps covered with deciduous growth appear somewhat brighter than coniferous swamps.	Swamps covered with solid, dense growth of coniferous or deciduous trees are in reforestation site class V and V-a, in well drained portions of swamps -- site classification IV.	Seen in the form of small, isolated swamps in water divides, in bottomlands of rivers, and in depressions near terraces, and border large masses of various types under various conditions of water-mineral feed.
1. Deciduous swamps	Tone of photograph light grey; pattern fine-grained. Projection of treetops bright, indistinct; intervals between treetops are dark and irregular in shape. In stereoscopic examination groups of trees of different height appear to stand out in relief (Photo 48).	Tree species include birch; in river bottomlands there are willows and black alder. Tree height is extremely varied.	Seen in depressions near terraces, in river bottomlands, often bordering grass swamps, under ground-feed conditions with strongly mineralized waters.
(a) Willow swamp	Tone of photograph grey; pattern not expressed (even under stereoscope). Interpreted from indirect features (Photo 54 (2)).	In tree-scrub cover willows 1.5-2 m tall predominate; profuse growth of reed grass. In northern regions of USSR considerable mixture of dwarf birch is encountered.	Seen almost exclusively in river bottomlands or along the borders of swamps in the presence of warmth from ground waters.
(b) Alder swamp	Graininess of pattern considerably finer than in deciduous forests in dry valleys.	In alder swamps the black alder is 10-14 m tall, sometimes mixed with birch, more rarely spruce. Grasses vary: on high hillocks near tree trunks there are various forest grasses; between hillocks there are reed grasses with a mixture of various large swamp grasses. Moss cover is suppressed or absent.	Seen in depressions near terraces or along the borders of large swamps in the presence of outflows of ground water or alluvial water feed.

TABLE 14 (continued)

(1)	(2)	(3)	(4)
(c) Birch swamp	Difficult to distinguish birch swamps from alder swamps on photographs, even on large-scale photograph with stereoscopic examination.	In birch swamps the tree cover consists of birches 8-10 m tall, sometimes with a mixture of pine and spruce. Grasses: reed grass, grama grass with small mixture of various other grasses. Moss cover is suppressed (in poor water-mineral supply sphagnum mosses develop).	Seen in the form of small swamps or bordering lowland marsh swamps. Rarely seen in river bottomlands and in these cases are flooded by periodic high waters. Water-mineral feed occurs in the transitional phase from ground feed to atmospheric feed.
2. Coniferous swamps	Tone of photograph dark grey; fine-grained pattern (Photo 53).	Coniferous species: spruce, pine, sometimes larch.	Water-mineral supply by ground or atmospheric feed.
(a) Spruce swamps	Tone of photograph dark grey (darkest of all tree species). Pattern fine-grained, heterogeneous, due to variation in height of tree stand. Light and shade composed of dark grey (treetops) and dark, almost black (shadows between treetops); difference between them sharply expressed. Considerable variation in size of treetops clearly discerned in stereoscopic examination.	Tree growth consists of spruce 8-10 m tall with small mixture (in secondary growth) of black alder and birch. Grass growth is usually hillocked reed grass. Between hillocks there is an abundance of various grasses: water arum, spiraea, marsh trefoil. Moss cover is poorly developed.	Seen in narrow bands along the borders of lowland, grassy swamps, on the slopes of terraces of river valleys, and rarely in isolated swamps, under conditions of inflow of abundant ground water and surface runoff.
(b) Pine swamp	Tone of photograph grey, darker than of birch swamp and brighter than spruce swamp. Pattern fine-grained, homogeneous. Transition from brighter tone of projections of treetops to darkened intervals gradual. Shape of projections of treetops oval, no variety in size as clearly seen in stereoscope.	Tree stand consists of pine 8-12 m tall; with nearby moving ground water there is a mixture of birch. Swamp scrub predominates in grass cover: cassandra, wild rosemary, whortleberry. Moss cover is well developed consisting of sphagnum moss with small mixture of hypnum moss (on prominences).	Seen in the form of small, isolated swamps in sandy soils. More often located in bands among large moss swamps, on well drained slopes, and near water receivers. Water feed consists of scanty ground and atmospheric waters.
II. Grass swamps	Tone of photograph dark grey, pattern smooth (no graininess). Heavily watered sections distinguished as darker (almost black) patches forming a mosaic pattern (Photos 49, 54, 55).	Surface of swamp covered with grassy vegetation of reed grasses or grama. Grasses with small mixture of various grasses. Moss cover lacking or poorly developed.	Typical of bottomlands, estuaries, and lacustrine depressions, given the warming influence of ground waters and periodic flooding in spring.

TABLE 14 (continued)

(1)	(2)	(3)	(4)
1. Horsetail swamp	Tone of photograph varies from dark grey to black with dark grey predominating. In connection with heavy watering of sections and irregular density of grass cover, a mosaic patchiness is noticed. The brighter patches (with dense grass or less watering) alternate with darker, almost black patches (with broken grass cover through which the surface of the water is seen (Photo 55 (1)).	Grass stand consists almost wholly of overgrowth of muddy horsetail, sometimes with sparse mixture of reed grass.	Seen in small areas as elongated narrow stripe along the periphery of swamps, somewhat warmed by concentrated (often ferruginous) waters or around lakes overgrown with vegetation and having flat banks.
2. Cane swamp	Appears on photograph as light grey, almost white bands near ponds or streams. In Western Siberia occupies vast areas and extends far from streams. In these cases, against the general background, there are usually distinguished diffuse black patches with indistinct outlines - sections with open water surface.	Grass stand is homogeneous consisting of solid overgrowth of cane up to 2 m tall, sometimes with a mixture of cattail and reed grass. In flats the cane reaches heights of 4-5 m.	Found in forest-steppe and steppe zones and chiefly suited to river valleys. Occupies large areas in the lower parts of large rivers: Dnieper, Kuban', Volga ("cane flats") and in Western Sibera, where they border upland swamps ("ryamy") and are known as "zaymisch." Cane swamps are fed by spring flood waters (in flats they are often flooded for prolonged periods).
3. Reed grass swamp	Tone of photograph dark grey, homogeneous (somewhat lighter than horsetail swamp and darker than cane swamp). When hay is mowed in the swamp against the general background of the photographs bright circular spots (hay ricks) are seen (Photo 54).	Grass cover consists of reed grass with small mixture of various grasses. Depending on conditions of moisture and mineral supply, the reed grass species differ. Moss cover is poorly developed.	Seen in river bottomlands, meadows, or narrow bands bordering upland or transitional swamps. They occupy rather large areas in the Poles'ye and in the lacustrine depressions of the Il'mensk and Chudsko-Pskov depressions. As a rule, these swamps have a steady ground feed and are subject to periodic river flooding or flooding by deluvial waters.

Note: Sometimes against the general background of photographs of grass swamps there is noticed a fine graininess, which indicates the presence of trees and scrub growth. The tree species are birch and black alder; in river bottomlands and valleys as well as in lacustrine depressions willow is most often encountered.

TABLE 14 (continued)

(1)	(2)	(3)	(4)
III. Grass-moss swamps	Tone of photograph grey, more or less homogeneous, somewhat lighter than preceding types (except cane swamp) (Photo 60).	Grass cover consists of reed grass or cotton grass, sometimes with large mixture of swamp scrubs. Moss cover is well developed, consisting of hypnum or sphagnum mosses.	Most often encountered along the borders of complex moss swamps: ground water and atmosphere feed.
1. Moss and reed grass swamp	Tone of photograph grey with white patches (lightly watered, moss covered, flat elevations). Among other types, this type of swamp can be distinguished only by indirect features (Photo 60).	Grass stand consists of reed grass (Carex lasiocarpa, Carex limosa, Carex rostrata). Moss cover solid, consisting of sphagnum mosses (sphagnum obtusum, sphagnum subsecundum, sphagnum angustifolium, sphagnum recurvum).	Encountered in well warmed borders of complex moss swamps and in river valleys.
2. Moss and cotton grass swamp	Tone of photograph light, almost white, in a complex with other types is sharply distinguished (Photos 56, 57).	Cotton grass (Eriophorum vaginatum) predominates in grass stand with small mixture of swamp scrub. Moss cover dense, consisting of sphagnum mosses (Sphagnum magellanicum, sphagnum angustifolium, in Kareliya -- Sphagnum papillosum).	In bands, suited for well drained borders of moss swamps, found under conditions of water feed with lightly mineralized ground waters. Isolated masses rarely formed.
3. Moss and scrub swamp	Against light-grey background the dark-grey latticed pattern is clearly outlined in stereoscopic examination. As a rule, these sections have a distinctly sparse graininess -- due to treetops.	In the grass stand, along with cotton grass, swamp scrub predominates (Cassandra, "podbel," wild rosemary). Moss cover is dense consisting of sphagnum mosses. Almost always encounter sparse stands of dwarf pine.	Same

Note: Often against the general background of a photograph of grass-moss swamp. There is observed a grainy pattern which indicates forestation of the swamp. Among tree species encountered in reed grass swamps in birch with small mixture of pine, in cotton grass swamps and scrub swamps only pine (in Siberia, larch) is encountered.

IV. Moss swamps with ridge-bog complex.	The principal feature of swamps of this type is the meandering streaked pattern. The stripes are concentric or parallel. Dark bands with grainy pattern (forested ridges) alternate with bright bands (bogs). In those cases where the bogs are heavily watered, they appear on the photographs as dark or black bands (depending on the extent of flooding), while the ridges are	In association with the dissected microrelief the vegetation is complex in character. On the elongated ridges (25-50 cm high) swamp scrub with a mixture of cotton grass predominates; the ridges are often forested with pine. Moss cover is dense consisting of sphagnum magellanicum). In the depressions between ridges: cotton grass grows in boggy soils and scheuchzeria in heavily	Moss swamps with ridge-bog complex have convex or concave surface. Depending on shape of surface, the water-mineral feed of these swamps is distinguished. They occupy vast areas in the northern and central parts of the Soviet Union and are the principal fla reserve of the USSR.

(1)	(2)	(3)	(4)
IV. Moss swamps with ridge-bog complex	much brighter. Heavily watered bogs are usually located near the periphery and are never forested, hence the dark bands of their images do not have a grainy pattern.	watered soils (with patches of "ocheretrik"). Moss cover loose consisting of sphagnum mosses (sphagnum balticum, sphagnum Dusenii, sphagnum cuspidatum, et al.).	
1. Swamps with convex surface	Characteristic feature of the photograph is the concentric striped pattern associated with the convex shape of the surface.	Elongated ridges covered with a dense cover of sphagnum moss (sphagnum fuscum, sphagnum magellanicum) with broken cover of swamp scrub ("podbel," Cassandra, wild rosemary) and cotton grass. In boggy soils the moss cover is loose and consists of sphagnum moss (sphagnum balticum, sphagnum Dusenil) with interrupted grass stand of scheuchzeria or cotton grass.	Swamps of this type are widespread in forest zone of European USSR and in Western Siberia, constituting the major part of the moss swamps and complex swamps. Encountered as isolated masses and as large swamp systems with area of several tens of thousands of hectares. Water-mineral feed consists of meager atmospheric supply; along borders of swamps the effect of ground waters is sometimes seen.
(a) Sharply convex moss swamps	Weakly expressed striped pattern (ridge-bog complex) in central part of photograph with grainy pattern (forested slope semicircle). Marginal portions of photograph light grey (cotton grass sections) or dark grey (reed grass sections) (Photo 56).	In central portion of mass, a weakly developed ridge-bog complex. On the ridges -- scrub and sphagnum swamp, with sparse growth of dwarf pines . In bogs -- cotton grass and sphagnum swamp. On the slope of the swamp mass there is a forested semicircle -- pine swamp with sphagnum mosses and scrub growth -- tree heights 10-12 m. Sections adjacent to dry valley are, as a rule, occupied by cotton grass or reed grass groupings (depending on the character of watering.) They are sometimes forested with pine or birch.	Encountered as isolated masses or as part of large swamp systems. Swamps of atmospheric feed, with less moisture in central portion and more heavily watered borders (due to delivial or ground waters).
(b) Moderately convex moss swamps	Clearly expressed concentric striped pattern occupies principal part of photograph of swamp and only along border is there a clearly defined light (rarely dark) grey band. Forested circle (or semicircle) with grainy pattern on photograph is, as a rule, absent (Photo 57).	Main areas of mass occupied by ridge-bog complex which is characterized by heavily dissected micro-relief. Elevations have the shape of narrow ridges between which lie boggy areas. Ridges are occupied chiefly by sphagnum and scrub groupings (sometimes with large mixture of cotton grass) and forested with pine, though they are sometimes treeless. Bogs occupied by sphagnum mosses (with loose sod) with sparse grass stand of scheuchzeria or, in less watered bogs, of cotton grass. (In Kareliya bogs are often encountered	Encountered in isolated swamp masses, but more often entering into the composition of complex, large swamp systems. Swamps of atmospheric feed. Ridges moderately moist, bogs heavily watered. In lower portions of slopes the water in bogs stands on the surface of the moss cover or forms micro-ponds with an open mirror of water.

TABLE 14 (continued)

(1)	(2)	(3)	(4)
(b) Moderately convex moss swamps		with exposed peat, in which bogs there are scattered trichoforum sods).	
(c) Plano-convex moss swamps	In central portion of photograph light patches or bands (sloping ridges) alternate with dark grey or black patches and bands of circular and elongated shape (bogs and ponds with open water surface). Between the patchy center and the light border there is a ring with a concentric striped pattern (ridge-bog complex) (Photo 58).	Central portion of the mass is occupied by a pond-bog complex (micro-ponds with open water surface alternate with flat ridges) which is bordered by a ridge-bog complex. Near the periphery are sphagnum and cotton grass or reed grass groupings, often forested.	Isolated masses are rarely encountered; as a rule, they enter into the composition of large swamp systems. The central portion of the mass, due to depression and poor runoff, is heavily watered by stagnant atmospheric water.
2. Swamps with concave surface, (Karel'skiy type)	Photographs of swamps of the Karel'skiy type appear in the form of grey, elongated (ribbon) or fan-shaped bands with a parallel striped pattern in the center. The striped pattern on the photograph is perpendicular to the logitudinal axes of the swamp (general slope of terrain) and distinguishes the concave surface of the swamp. The swamp borders are grey in tone, sometimes with a grainy pattern (Photos 59, 60, 61).	The central portion of the swamp is concave, with the result that it is more moist, and occupied by a ridge-bog complex which is perpendicular to the general slope of the swamp but not concentric as in the convex swamps. The ridges are flat and grass is predominately reed (Carex lasiocarpe) and molinia (Molinia caerulea); on the highest ridges scrubs and sphagnum fuscum grow, sometimes with patches of lichen. The bogs are heavily watered with weakly developed moss cover of hypnum moss and sparse grass stand of reed grass, marsh trefoil, and horsetail. Bogs completely devoid of vegetation are encountered and are bog-ponds or bogs with exposed peat. Along the periphery of the swamp there are sphagnum and scrub groupings, sometimes forested with pine.	Widespread in the Karelo-Finskaya SSR, especially in the southern regions of the Kola Peninsula and in the region of the Pechora River. These swamps are located in more or less elongated depressions with considerable longitudinal slope; they are heavily watered and in the spring flooded by mineralized waters.

Note: The presence of a grainy pattern in moss swamps indicates the forestation of sections. Forested sections are most often located along the periphery of the swamp and on ridges. Of the tree species, characteristic of most regions is the dwarf pine, for Western Siberia the cedar, for Eastern Siberia and the Far East the Daurskaya larch.

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TABLE 15

INTERPRETATION FEATURES AND BRIEF GROUND CHARACTERISTIC OF THE SURFACE HYDROGRAPHIC NETWORK IN SWAMPS

Water object (1)	Interpretation features on aerial photograph (2)	Brief ground characteristic (3)
I. Reservoirs 1. Lakes	Lakes appear on photograph in the form of black spots of circular or oval shape (rather large dimensions) and are clearly distinguished by tone in the bright background of swamps. Most often encountered singly.	Lakes have wide distribution in upland swamps and are somewhat less frequently encountered in swamps of other types. Large lakes, as a rule, are the remnants of primary reservoirs of glacial origin. They differ greatly in depth and size. Lakes are sometimes a genetic focus and occupy the highest points of swamps where the thickest peat layers are concentrated. Conversely, in a depressed position relative to the relief of the swamps, lakes often serve as water receivers for surface and ground waters.
(a) With open water surface	Black spots for the greater part circular or oval in shape with distinguished borders. Clearly distinguished against the grey background of swamps (Photos 62, 65).	
(b) Overgrown with floating vegetation	A grey band on a black photograph of lake with indistinct inner outline -- floating vegetation. In the case where floating vegetation extends over almost the entire lake, it appears on the photograph in the form of a dark grey spot with isolated black marks (Photo 66).	
2. Micro-ponds	Micro-ponds, just as lakes, appear on the photograph in the form of black, circular or elongated patches, but they are distinguished by their smaller size and are found most often in groups or in extended chains.	In distinction from lakes, they are, as a rule, of secondary origin, considerably smaller size, and most often occur in groups. They are found only in moss swamps with convex surface. They are formed by the emergence of ground waters on moderate slopes or at the borders of convex moss swamps. According to location and origin, micro-ponds may be divided into slope and contact micro-ponds.
(a) Slope micro-ponds	Groups of black spots of circular and oval shape with distinct borders. Located without noticeable regularity and system (Photo 63).	Characteristic for flat slopes of moderately convex and plano-convex moss swamps often entering into swamp systems. They are most often found in groups, rarely encountered singly.
(b) Contact micro-ponds	Groups of black spots of elongated shape located in a semicircle (along one contour) at the feet of slopes of convex moss swamps (Photo 63).	As a rule, they are formed as the result of emergence of ground waters along the line of contact of two convex moss swamps and in such cases are located in a semicircle in the lower portions of slopes. They are rarely encountered in isolated masses.

TABLE 15 (continued)

(1)	(2)	(3)
II. Streams 3. Rivers and creeks (a) With open channel (b) With overgrown channel	Rivers and creeks are distinguished on a photograph as dark grey or black meandering lines against the brighter background of the swamp. Dark grey or black meandering lines (Photos 54, 65). Dark broken line; black portions alternating with brighter portions (Photos 58, 64).	Rivers and creeks, in distinction from the rest of the surface hydrographic network in swamps, are characterized by the presence of a channel. They are encountered in swamps of all types and may be of primary or secondary origin. The first of these, as a rule, has a turfy bottom (occasionally, in the lower reaches, mineral) with a layer of sapropel and are joined with external water receivers. They are fed by marshes (of transitional character). Their sources often lie beyond the limits of the swamp. Rivers and creeks of secondary origin were formed in the latest stages of development of swamps in the combination of several swamp masses into a system. They originate in the swamps and empty into internal water receivers, but they sometimes disappear or change to slow-flowing marshes.
III. Marshes	Marshes appear on the photograph as dark stripes or strokes, often with a variegated mosaic or striped pattern in which portions of dark grey and black tones alternate with brigher patches. They are clearly distinguished against the general background of swamps and are easily interpreted (Photos 65, 71).	Marshes in swamps are a distinctive element of the internal hydrographic network of secondary origin and are heavily over-saturated portions of swamps (without open water surface) with light turf of sphagnum of hypnum moss interrupted by grass stands. They are found only in complex swamp systems with convex and concave surface. In distinction from streams, marshes do not have a distinct channel. According to the character of flow, marshes may be subdivided into standing, filtration, and flowing.
4. Standing marshes	Dark grey hachured strokes without clearly defined direction of runoff or sections of dark grey background with fine, light grey areas with a distinctive mosaic pattern.	Over-damp portions of swamp, typical of depressed local water divides or of bank sections of swamps without clearly expressed runoff. For the most part, they are lightly turfed and have a broken vegetative cover.
(a) Water-divide marshes	Dark grey, hachured strokes (often over a large area.	Chiefly atmospheric feed, typical of depressed local water divides of swamp systems without clearly expressed runoff. Loose turf with patchy grass stand.
(b) Riparian marshes	Ind distinction from water-divide marshes, these marshes do not appear as hachured strokes but as sections of dark grey tone with small isolated black and light grey areas as are formed in a mosaic.	Found on the borders of swamps and at the bottom of slopes of convex moss bogs. Grass stand is discontinuous and there is sometimes an open water surface.

TABLE 15 (continued)

(1)	(2)	(3)
5. Filtration marshes	Regularly alternating light and dark bands against the background of the characteristic pattern of the swamp with a ridge-bog complex. Dark bands several times wider than light.	Marshes of the filtration type, ridge-bog marshes, and ridge-pond marshes are widely found in swamps with convex and concave surface shapes. They are typical of slopes of moderately convex and plano-convex moss swamps of isolated masses and of complex bog systems; they appear as a regular alternation of ridges and bogs or ridges and ponds with concentric or parallel orientation.
(a) Ridge-bog marshes	Light meandering bands alternating with parallel, wide, dark grey bands. The first correspond to the ridges, the second to heavily watered bogs (Photos 61, 66, 67).	In these marshes the bogs do not have an open water surface. They have an extended loose cover of sphagnum moss with a sparse grass stand of scheuchzeria and "ocheretnik." They are encountered in the form of elongated bands among the ridge-bog complex and are divided into wider and deeper bogs.
(b) Ridge-pond marshes	Light, sometimes white bands of ridges alternating with black, wider pond bands with open water surface (Photos 65, 68).	In these marshes the ponds are of elongated shapes (10-100 m long and 5-10 m wide, with water depth of 1.5 - 3.0 m), encountered on flat slopes of terraced ledges of swamp systems, rarely, in isolated masses.
6. Flowing marshes	Strokes of dark grey and black tone, often streaked with brighter spots in the direction of the over-all direction or a particular direction of slope of the swamp.	Heavily over-saturated sections of swamps with constant or periodic discharge.
(a) Marshes near mineral islands	Dark grey bands beyond islands gradually narrowing in the direction of the periphery of the swamp (Photo 69).	Marsh sections located near mineral islands downhill from the swamp.
(b) Emergence marshes	Dark grey with black-streaked diverging bands formed, for the most part, at the periphery of the swamp and gradually disapperaring, or a network of multi-branched converging dark bands. One or another degree of sharpness of outline and complexity of shape of the marshes indicates greater or lesser assurance of water supply for the marshes (Photo 70).	Formed due to emergence of water on slopes and at the foot of slopes of moderately convex moss swamps and swamp systems.

TABLE 15 (continued)

(1)	(2)	(3)
(c) Transitional marshes	Sharply defined dark grey or black thick lines of runoff of considerable extent. They often end in a black, meandering, narrow line -- a river or creek (Photo 71).	Over-saturated strips of considerable extent along the hollows of a swamp system. Steady runoff is insured due to emergence of waters from adjacent convex masses and the sources of supply often located beyond the swamp system. Sometimes, as the result of peat formation, river and creek outlets are formed and are usually joined with external water receivers.