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Mapping from aerial photographs and its relation to mining enterprises

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MAPPING FROM AERIAL PHOTOGRAPHS

AND

ITS RELATION TO MINING ENTERPRISES.

by

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A

THESIS

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C O N T E N T S.

LIST OF ILLUSTRATIONS.

INTRODUCTION.

It is not my purpose to discuss aerial cameras or the theory of aerial photographs in this thesis but to confine my efforts to the very practical business of making maps from aerial photographs and to point out where this system of mapping can be used to advantage in the mining industry.

Aerial photographs were used very extensively during the World War for plotting desired information on existing maps. Since the war however, great progress has been made in the use of aerial photographs as the basis for making maps.

Two destinctly different methods of utilizing aerial photographs for delineating parts of the earth's surface have been developed namely, the mosaic and the map. In the following pages I will only mention briefly the making of mosaics, but I will go into some detail regarding the making of aerial maps.

T.R.T.

MOSAICS.

SCOPE. Mosaics are made by joining a member of vertical photographs or parts of photographs which have been reduced to a common scale. The result is a continuous photographic representation of a part of the earth's surface and is generally mounted on composition board or cloth.

Such an arrangement of photographs affords an excellent means for studying the configuration of the ground and it will embody a wealth of detail which cannot be shown on a map made by ordinary surveying and drafting methods. The use of mosaics as maps is somewhat limited, due to distortion, but they are very valuable in the study of city planning and zoning, traffic, and park and landscape gardening.

CONTROL. In order that the images in a mosaic shall have the same relation to each other as their respective points on the ground, it is necessary that the mosaic be controlled. This is accomplished by building up the mosaic over a plotted network of control.

DISTORTION. Due to perspective, the images which fall some distance from the centers of the photographs will be somewhat displaced from their true positions.

This condition can be overcome to a large extent by using the central parts of photographs when constructing a mosaic. However, it is physically impossible to eliminate all the distortion in a mosaic, and to eliminate it to the same degree as is done in a map would make the cost economically prohibitive.

REPRODUCTION. Mosaics can only be reproduced by photography.

MAPS.

SCOPE. In my opinion, the use of aerial photography in connection with mapping has only reached the elementary stage and I believe that the possibilities for future development in this branch of engineering are practically unlimited. Rapid progress has been made since the War and as many engineers know, aerial surveys have been made commercially for several years.

The controlled map made from aerial photographs marks the greatest advancement in aerial surveys to date. There are several methods of making these maps but they are similar in that all are intersection methods and require overlapping photographs and a certain amount of ground control.

Topographic maps of this type have been used extensively by the War Department in connection with river improvement and hyro-electric power investigations. Aerial surveys have also been made for transmission line location, recconnaissance for railroad location and similar projects.

In Europe a great deal of attention has been paid to divising methods for producing contours direct from photographs. Positive results have been obtained but costly apparatus and a very great amount of ground control are required. Brock & Weymouth Inc. of Philadelphia state that they have developed equipment which enables them to draw contours on the photographic plates and they claim an accuracy of plus or minus one foot. In a survey of the Tennesee River by the War Department, the photographs were taken into the field and by using them as plane table sheets, the contours were drawn in. It is my opinion that a better method is to use the pantographed map as a plane table sheet in the field and the map can then be checked while the contours are being drawn.

ADVANTAGES. The principal advantages of this system of mapping are speed and economy. This is not a cheap method of making maps but where the area to be surveyed is large enough to justify an aerial survey and where a map of this type will serve the purpose for which the survey is made, it will be found that a remarkable saving in time and money may be effected.

PHOTOGRAPHS. Securing the necessary photographs for a map constitute one of the major items of cost. For this reason the flying should be done if possible when weather conditions are best suited for flying and photography, thereby reducing to a minimum the time the plane or planes will be in the field. A study of local weather conditions will indicate the best time for this part of the work. Clear days are required for taking photographs and only the hours when the light is strong enough can be utilized. Photographs must be clear enough to readily admit of interpretation and should overlap 60%.

Either vertical (single lens) or composite vertical (multiple lens) photographs are suitable for aerial mapping. The verticals will not have as much distortion as the composite verticals while the latter will embrace a larger area.

When planning an aerial survey it will be an advantage to know the approximate area covered by each photograph. Knowing the size of the picture and its approximate scale the area covered by the picture can be easily computed. A simple formula for arriving at a rough approximation of the scale of the pictures is H/f where H is the elevation of the camera in feet and f is the focal length of the lens in inches. With the camera at an elevation of 14,000 feet and a focal length of 10 inches the approximate scale of the pictures will be 1 in. = 1,400 ft. $\frac{14,000}{10} = 1,400$.

In order that all the photographs shall have approximately the same scale there should be no variation in the elevation of the plane while photographs are being made.

DISTORTION. Due to perspective, the images of elevated points will always be displaced when they are located away from the centers of the photographs. There will also be displacement of images whenever the camera is tilted, and it is very important that the camera be held in a vertical position. Where the overlap of photographs is 60% the images of points will appear on three photographs. This allows the location of the points by the intersection of three lines drawn from the centers of the photographs on the control sheet and the true positions of the points are thus established. The distortion of the photographs caused by perspective and tilt is therefore corrected on the map.

GROUND CONTROL. Maps made from aerial photographs are dependent on a network of ground control. The accuracy of the map can be no greater than the accuracy of the control. Ground control can be established by triangulation, transit traverse, or a combination of the two. It may be established either before or after the photographs are received.

Establishing ground control is a major item of expense and should be reduced to a minimum compatible with the desired degree of accuracy of the map.

MAP COSTS.

The United States Engineer Office at Kansas City is compiling a topographic map of the Missouri River from Yankton, South Dakota, to the Mouth, a distance of approximately 900 miles. This map will not be contoured. (See illustration.)

The contract for supplying the photographs was awarded to the Fairchild Aerial Surveys of New York, who completed the work during the period October 7 to January 24. The photographs were taken from an elevation of 14,000 feet, and owing to weather conditions, only 25 days of the 109-day period of the flight could be utilized for this work. The flying days were distributed as follows: ten in October, four in November, four in December and seven in January.

As the entire map has not been completed to date, complete cost figures are not available at this time. However, the "Kansas City-Mouth" section of the map, covering a distance of 400 miles and embracing an area of 800 square miles, was completed in February, and the itemized costs are as follows:

Contract, one set of photographs and films	$7,188.46
Office, drafting and materials	2,164.25
Field, establishing ground control	1,163.19
Total cost	$10,515.90

Cost per river mile $26.30
Cost per square mile 13.15

The above figures afford an excellent basis for estimating costs on surveys of this class. It should be borne in mind however, that the ground control established at a cost of $1,163.19 was only a small part of the ground control required for the map. The additional ground control needed was obtained from office records in the form of previous ground surveys.

WAR DEPARTMENT
CORPS OF ENGINEERS, U.S. ARMY
NEW FRANKLIN
HOWARD COUNTY
SLAUGHTERHOUSE BEND
FRANKLIN ISLAND
BOONVILLE
COOPER COUNTY
MISSOURI RIVER
MOUTH TO KANSAS CITY
REVISION FROM AIRPLANE PHOTOGRAPHS
OCT. 14 & 21, 1926
In 31 Sheets, Sheet No. 19, Mile 203.0 To Mile 215.8
MADE UNDER THE DIRECTION OF
Major G.C. Gee, Corps of Engineers, U.S.A.
U.S. Engineer Office, Kansas City, Mo.

RELATION OF AERIAL MAPPING TO MINING ENTERPRISES.

Maps made from aerial photographs can often be used in engineering projects related to the mining industry, especially where operations are carried forward on a large scale. An aerial survey should only be utilized however where the desired map has a magnitude sufficient to justify this type of survey.

TOPOGRAPHIC MAP. Where a topographic map of a mining district or an undeveloped area is desired, it may be procured with a minimum of time and expense by an aerial survey.

GEOLOGIC MAP. The topographic map may be used as a base for a geologic map.

HYDRO-ELECTRIC POWER & WATER SUPPLY. These items are often of major importance in mining projects and aerial maps will aid in a solution of these problems.

RECONNAISSANCE FOR RAILROAD LOCATION. An aerial survey affords a means of rapid preliminary surveys for the location of railroads, when transportation is one of the problems relating to a mining project.

TRANSMISSION LINE RIGHT OF WAY. Where transmission lines are needed in connection with mining operations, an aerial map will aid in a decision regarding the most desirable locations for the lines.

NOTE: It should be borne in mind that the photographs are always on file and can be used in conjunction with the map, for details of topography.

The following description of the method used for aerial surveys at the United States Engineer Office at Kansas City, Missouri, was not written by me but is on file at that office.

AERIAL MAPPING.

Description of Method used at the U. S. Engineer Office.
Kansas City, Mo.

PRELIMINARY OPERATIONS.

The arrangement of the map sheets is laid out on the base map from which control is to be obtained, the map sheet numbers becoming an important part of the index system as soon as the photographs arrive.

It is important that the photographs be checked for gaps, overlap and tilt, as soon as they arrive, in order that a reflight may be made if found necessary, while the plane is in the vicinity.

The photographs are laid out in order as taken by matching features of topography; when laid out in this order base and parallel flights are in position. The overlap of photographs and flights will be evident, and any area not covered by the photographs will be noted.

Tilt can be expected in any flights not flown in straight lines. Sufficient overlap and the elimination of gaps and tilt are very essential to good results in mapping and these factors should be carefully studied. The ship crew should be notified at once of defects in any of these points. Features of topography should appear on at least three photographs necessitating a 60% overlap of photographs in the direction of flight. A 40% overlap of parallel flights is required. After carefully checking the layout as described above, the next step, while the photographs are in position, is primary control.

PRIMARY CONTROL.

The map can be no more accurate than the network of control used. Extreme care must be exercised and every available check made to insure that the point marked on the photograph is the same point marked on the base map. Well defined features of topography, as bridge piers, road corners, railroad crossings, etc., that can be identified on the base map and on the photographs are marked for primary control and form the network of control. A convenient method of marking the points is a double circle around the point, designated by the number of the photograph on which the point is first picked up with a sub-number showing the weight of the point as $\frac{536}{1}$ or 540/2, indicating that 540 is not to be used when first weight points are available and, if used, the results are to be carefully noted by the pantograph operator. It is important to have primary points near both ends of all base flights. Poor results will always be obtained in mapping beyond the control. Notations for the future guidance of the draftsmen are made during this operation, while the flights are all in position. See that the base flight has the proper control. Next determine what control parallel flights have. In some cases, auxilliary flights will not be parallel and will connect with the main flight between primary control points only. In this event, a secondary point will be selected that is common to both flights, marked with a single circle and given the number of the photograph on which the point is picked up but will not be given a sub-number. This point is marked on photographs in both flights and will become a primary for that end of the side flight; control at the other end, only, will have to be selected from the base map. Control should be marked on all the flights that will be used on a map sheet including the flight extending into the next sheet. When this is done take the photographs up in flights, covering the first map sheet, as they will be worked in this order in all future operations. On the backs of the first and last photographs of each flight, mark the flight with the number of the first and last photographs, the map sheet number, and any notations necessary to the future operations as "536-546, Map sheet 1, Establish point 541 by pantograph." The next step introduces the filing system.

FILING SYSTEM.

The following method has given good results. Put a rubber band around the photographs in each flight and place all flights to be used on one map sheet in an envelop marked with the sheet number. The photographs are then indexed on a small scale map by using a templet, drawn to scale. Draw the outline of the first and last photographs on the map, connecting the indicated photographs with a straight line marked with the number of the photographs included, as 536-546. The outline of the map sheets are also shown on the index map. If the photograph that shows a certain dike is wanted, by referring to the index map the dike is located and a glance will show the sheet number and the flight number in which the desired photograph will be found.

SECONDARY CONTROL.

Second ry control points in aerial mapping correspond to marked points to be established by cuts in ground surveys. Any well defined features of topography that appear on three or more photographs may be used. As many as eight secondary points should be marked on each photograph. These points should be distributed over the sides of the photographs, marking features that are to be mapped such as roads, railroads, etc; points established in the zone of lens distortion are not as reliable as points not as close to the edge of the photographs. This distortion is most pronounced in the outer one-inch of the photographs; points on or very near the line of flight are of no value as the rays will parallel or cross at so small an angle that the point can not be defined. In the beginning, at least, it is well to number at least one point on each side of each photograph as identifying points in later operations. Points are marked with a single circle, and given the number of the photograph on which they first appear.

STRAIGHT LINE METHOD OF CONTROL.

The object of any method of control is to enable the draftsman to place the successive photographs under the control sheet in exact orientation with the preceding photographs. If black ink has been used in marking primary and secondary control points the base line points should be marked with circles in a different color, to insure against mistaking points and to hasten the operation of setting the photographs in their true positions.

The system consists of establishing two base lines approximately at right angles to each other. The azimuth base is selected well toward the top of the first photograph with as wide a base as can be conveniently obtained without entering the zone of lens distortion. This base is approximately normal to the line of flight. The second base is approximately perpendicular to the azimuth base or parallel to the line of flight. Points selected for these base points must be small and well defined, care being taken to mark exactly the same point in succeeding photographs. Three points are required for the two bases; the points on the azimuth base are base are toward the edges of the photograph, the other point is located about midway between; these points must be marked on the succeeding photographs. On the last photograph on which this set of base points will appear, new bases are established and this photograph will then have two sets of base points. After the bases have been selected throughout the flight, draw sections of the azimuth base line about an inch long outward from the circles, with the same color ink as the circles. The lines must be very thin for accurate settings and would pass through the center of the points if extended. There is no line drawn through the center base point on the photographs. After marking the base points throughout the flight the next step is the skeleton control sheet.

THE SKELETON CONTROL SHEET.

Lay the flight out in order by matching topography. When all photographs are in position, place the tracing paper over the photographs in the position desired and register the first photograph so it can later be put back in the same orientation. Take up the flight arranging the photographs in order as they will be required. Replace the first photograph under the control sheet, setting on the register marks; secure the tracing paper in place with weights and draw thin ink lines over the base lines and passing through the point, ie., the azimuth base as drawn on the photographs is traced on the control sheet. Next draw a fine pencil line (on the control sheet) through the center base point (on the photograph) approximately at right angles to the azimuth base. Both bases have now been transferred to the control sheet. Next set a map pin in the center of the photograph and draw short radial lines (on the control sheet) radiating from the center, through the control points on the photograph. The center of the photograph corresponds to the instrument station on a ground survey. Mark the center of the photograph on the control sheet including the number of the photograph. These centers correspond to the instrument stations on a traverse line. Replace photograph No. 1 by No. 2. Place the azimuth base on the control sheet, directly over the azimuth base on photograph No. 2. This places the photograph in orientation but does not center it. To accomplish this, shift along this azimuth base until the pencil line on the control sheet cuts the center base point on the photograph; when all lines cut the center of their respective points, the photograph is set and the radial lines will be drawn from the center as before, forming the first intersections. This method is continued with each photograph in the flight. All primary and secondary points numbered on the photographs should be numbered the same on the control sheet and all notations on the back of the flight should be made on the control sheet, as instructions to the pantograph operator. Very transparent tracing paper is necessary for the control sheet. Avendale No. 155 gives good results.

CHECKING THE AZIMUTH OF THE SKELETON CONTROL.

This method of checking requires three or more primary points on the control sheet. Checking the azimuth before, instead of after, transferring the topography from the photographs, will sooner or later save much loss of time. The method of checking consists of selecting a pivot point on the control sheet and the base map. On the base map draw lines from the pivot point to the rest of the primary points included in this flight; place the skeleton control on the base map, centering the pivot point; orient the control sheet until one of the primary points falls on the respective line on the base map. When so oriented the remainder of the primary points on the control sheet should fall very close to their respective radial lines on the base map. In the event one of the points falls considerably off the line this point is marked in error, and the pantograph will not use the point for a setting. Where there are several primary points on the control sheet, different settings will enable the draftsman to locate and eliminate erroneous points before the map is started, thereby saving much time and trouble.

TRANSFERRING TOPOGRAPHY.

In transferring the topography from the photographs to the control sheet, much depends on "horse sense". In most all flights there will be photographs out of scale or that have tilt. With experience the draftsman will soon learn to identify these photographs by the results shown by the intersections on the control sheet. A tilted photograph will give a triangle or error instead of an intersection. This will be evident while the control sheet is under construction. The tilted photograph should be marked at that time and if new base points have been picked up on this photograph they should be disregarded and the new base established on the preceding photograph. A photograph that is out of scale will be recognized by the points established by intersection not falling on the point on the photograph. These photographs, by this method of control, can be eliminated, in fact with the proper amount of overlap two consecutive photographs can be eliminated and all of the topography obtained from the remaining photographs. The first photograph in the flight cannot be used with much accuracy as the points are not defined by intersections. The second photograph will have intersections on the upper part. In transferring topography set roughly on the base settings; carefully study the evidence as shown by the intersections on the control sheet and the corresponding point on the photograph; if the scale is different to an extent which will complicate the operation, try the next photograph. With this method of control very little shift will be necessary, the operation being largely one of tracing. However, very good results may be obtained with photographs that are out of scale by taking the necessary time and care. The procedure is to center the intersection on the control sheet on the corresponding point on the photograph, being careful to keep the photograph in proper orientation. The topography around the centered point is then transferred and the next point centered. In this manner all topography on the photograph can be very accurately transferred when necessary. Interpretation must be learned by experience; some general principles can be explained that will be of assistance, the most important of which is to check the interpretation by the base maps and all other available information at all times. An error in interpretation is generally a violation of some law of nature. Trail a feature of topography from the beginning to the end and find out what it is doing before naming it. There is little difference, in many cases, between a levee, ditch, and a wire fence grown up in weeds; all cast about the same amount of shadow or reflect the light in much the same manner, but the missions of the three objects are entirely different. A ditch will empty into a stream at the earliest opportunity; a levee will parallel the water course; neither a ditch nor a levee will have right angle turns but a fence will not run long without a square corner. It must be borne in mind at all times that interpretation is generally a study of light and shadow, and objects which we see habitually are seen horizontally. We are therefore not familiar with objects as seen by the aerial camera. The position of the camera must be constantly borne in mind until interpretation is learned. A magnifying glass and stereoscope will often prove advantageous when interpreting photographs.

PANTOGRAPHING.

After the topography has been transferred to the control sheet it is ready to pantograph. The pantograph must be of the type with a vernier setting to the nearest decimal point. A pantograph graduated to 1/4s, 1/2s etc., is not adapted to this work. The operator of the pantograph will check on all available points and follow the instructions noted on the control sheets relative to primary points. A wrong control point will usually result in an unusual setting of the panto-graph and will also be in evidence by jogs where the topography from different pantograph settings joins and by land lines swinging out of direction. Much of the results in the map depend on the pantographing. All work should be thoroughly checked, and the completed map should be checked with the photographs and on the gronnd at every opportunity.

DEMONSTRATION MAP & CONTROL SHEETS.

STRAIGHT LINE METHOD. In substantial compliance with this method as used in the U. S. Engineer Office at Kansas City, Missouri, I have used the appended photographs as a basis for making a demonstration.map of the vicinity of Boonville, Missouri. In order to demonstrate the successive steps in mapping operations attention is invited to the control sheet with topography traced from the photographs, the work sheet on which the topography was pantographed to scale, and a tracing of the finished map.

RADIAL LINE METHOD. For full description of this method see War Department Training Regulations 190-27, dated January 23, 1925.

For purposes of comparison I have made a skeleton control sheet by this method. Control sheet is appended.

INTERSECTION METHOD. For a description of this method see Course P. Lecture 3: "The compilation of maps from aerial photographs". This lecture was one of a course of twelve delivered by T. I. Pendleton, Chief of Photographic Mapping Section, U. S. Geological Survey, Washington, D.C., at the School of Photography, Chanute Field, Rantoul, Illinois, February, 1925.

For purposes of comparison I have also made a skeleton control sheet by this method. Mr. Pendleton says to determine an approximate scale for all the photographs and using this scale, make a projection and plot the primary control points on tracing paper which will be used for the control sheet. I did not plot the primary control points on the control sheet because I do not believe an approximate scale can be determined for all the pictures and at the same time be accurate enough to be of much value.

In making these control sheets I started with photograph No. 465 and worked backwards. This is mentioned so the reader may check up on this operation.

REMARKS.

A comparison of these three control sheets will show that there is very little difference in scale or azimuth between them.

These three control sheets however, do not allow ~~of~~ a conclusive comparison between the three methods. This particular set of picutres was "hand picked" for this demonstration of aerial mapping and aside from insufficient overlap between some of the pictures they are ideal for this purpose. If a longer flight having several turns in it had been used, it is probable that the result would have been a greater variation in the control sheets.

Every mapping project will present new obstacles which will have to be overcome.

The "radial line" and "intersection" methods have been widely used by the Army and the U. S. Geological Survey respectively and have given good results.

All of these methods have been tested in the U. S. Engineer Office at Kansas City, Missouri, and the straight line method has proved to be the most satisfactory.

When making control sheets by the "radial line" and "intersection" methods, the pictures are partly oriented by setting over intersections. As this operation is largely a matter of judgment, the "personal equation" enters into the operation. This is not true of the straight line method where orientation is accomplished by setting over two straight lines which are approximately at right angles to each other. By this latter method two draftsmen can each make a control sheet from the same group of pictures and there will be practically no variations in the two results.

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I N D E X.

PHOTOGRAPHS.

These aerial photographs were used in making the appended map and control sheets.

Photographs were taken from an elevation of 14,000 feet.

Black circles, white circles and white lines apply to the "straight line" method of control.

Black circles, red lines and red figures apply to to the "radial line" and "intersection" methods of control.


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