MAPPING FROM AERIAL PHOTOGRAPHS

Thesis for the Degree of B. S.

Edwin C. Whitney

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Map-drawing
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Mapping from Aerial Photographs

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Through the help of these gentlemen this thesis was made an instructing and interesting problem.

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Class of 1936

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Part I

Resumé of Aerial Photography up to the Year 1936

Mapping from Aerial Photographs

The science of aerial photographing and mapping had its inception on January 10, 1910, when a man by the name of Erickson made the first photograph from an airplane. The picture was an oblique (angle) photograph of San Diego Bay, and the event formed the first chapter in a new branch of photography whose growth parallels that of the automobile and the airplane itself in importance.

The World War lent impetus to this new science, and it was because of the accurate spotting by the aerial camera that artillery divisions were able to operate so effectively during the war.

After the war the activity along this line did not cease, but, to the contrary, new developments took place which lifted the work of the aerial photographer from crude, catch-as-catch-can work to that of a science which, with the help of the precision instruments now available, makes possible a high degree of accuracy in mapping.

The civil engineer was quick to seize the opportunity of improving his surveying by using the aerial photographs as a supplement, and it was not long before maps were being constructed directly from the photographs with the ground surveys serving but as a basis of primary survey. It is now possible to bring old maps up to date cheaply and quickly by the use of aerial photographs which show objects in their relative positions, and it would appear that the entire field of mapping has been revolutionized by the aerial camera. As a contemporary has said, "It is safe to say that aerial photography in its present status is the most valuable aid to map-making in general that has been devised in the last century".[1]

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[1]McKinley, Ashley C. , Applied Aerial Photography, p. 233

Primary Steps in Map-Making

The personnel of a mapping expedition consists of three distinct divisions; the pilot and photographer, the laboratory personnel, and the draftsmen. It is imperative that proper coordination exist among the workers of these divisions to insure the proper results.

The work undertaken by the above workers falls into the following seven steps, each of which must be done to the highest degree of accuracy;[1]

1. Primary survey by the ground crew. (This includes the studying of light conditions and obtaining of flying information.)
2. Photographing the area.
3. Developing the film.
4. Numbering the negatives.
5. Making the prints.
6. Making the index map.
7. Preparing the map with, or from, the prints.

Although, as has been stated, each of the steps is equally important, a complete study of the subject would entail volumes so we will concern ourselves principally with the last five steps, taking up the others in as brief a manner as possible when they become necessary to the understanding of the main subject.

The Aerial Camera

Aerial photography brought up many problems concerning the camera that were not encountered in ground photography. It was necessary to develop a fixed camera lens (one that did not need special focusing for varying object distances), and every action of the camera had to be one that could be positively controlled by the operator. All

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[1]McKinley, Ashley C. , Applied Aerial Photography, p. 2

springs and devices that depended upon gravity for their operation had to be discarded and an entirely new form of camera built up which resisted the vibrations of the airplane while in flight. No adjustments which depended upon the senses of feeling or of sound were admissible, and all levers and catches were made extra large in order that they might be handled with gloved hands. The film, or plate, capacity of the camera had to be enlarged, and the weight of the entire mechanism had to be kept as light as possible, preferably under one-hundred and fifty pounds.

The cameras are classified into self-explanatory divisions of non-automatic, semi-automatic, and automatic cameras, depending upon their method of operation. Up to recent years the cameras consisted of but a single lens, but, within the last few years, three, four, and even five lens have been added.[1]

The principles of the multi-lens camera were first enunciated by Captain Theodore Scheimpflug, an Austrian Army Engineer, who studied the problem with the aid of captive balloons. As a result of his experiments a tri-lens camera was invented by James W. Bagley, a pioneer in aerial photography, for the purpose of speeding up the taking of negatives by enabling a larger area of ground to be photographed at one time.[2]

The tri-lens camera consisted of one lens pointing directly downward and two supplementary lens pointing at an angle of thirty-five degrees to either side (Fig. 1). Upon developing the negatives, a supplement had to be used to project the side photos onto the plane of the center print. This required a change in the scale of the side photos as they were taken from an angle instead of from a vertical position.

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[1]For furthur information on multi-lens cameras consult <u>Applied Aerial Photography</u> by Ashley C. McKinley, p. 9

[2]Bagley, James W., "The Tri-Lens Camera in Aerial Photography and Photographic Mapping", <u>The Military Engineer</u>, vol. 12, p. 360

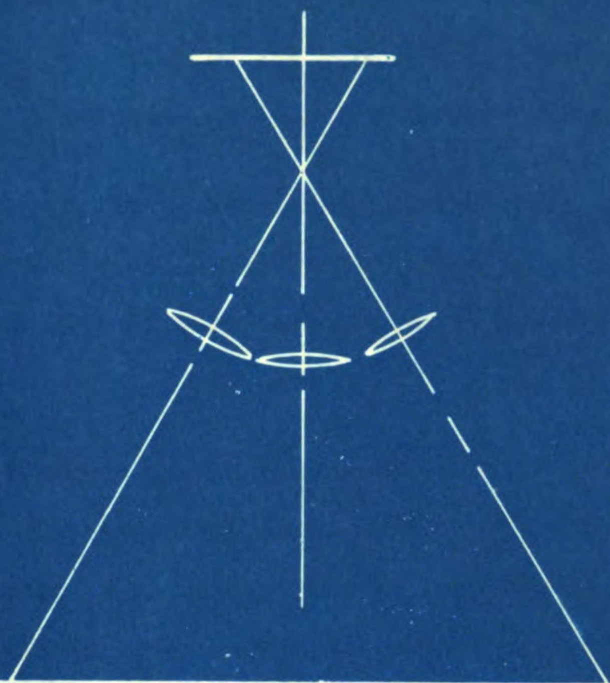

Fig. 1-a Arrangement of the lens in the tr-lens camera

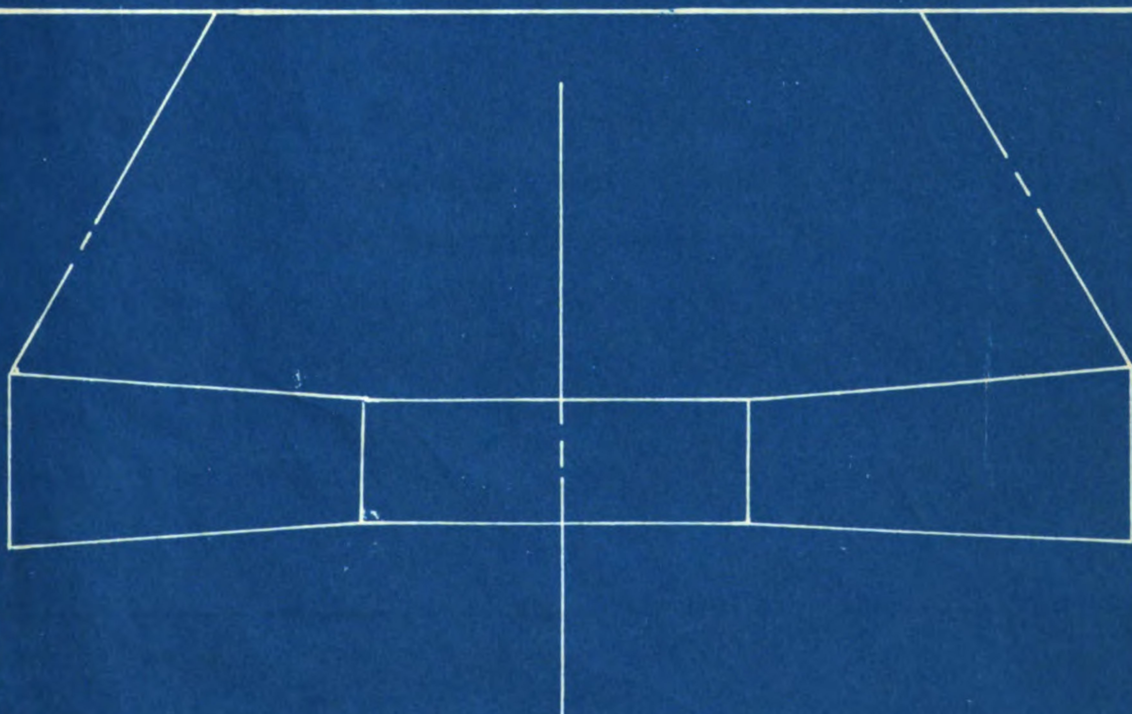

Fig. 1-b Form of photograph taken, one exposure, tri-lens camera

The required camera supplement was designed, shortly after the design of the cameras, by Mr. F. H. Moffit of the U. S. Geological Survey,[1] and since that time the tri-lens has gained rapid favor because of its speed and because it reduces the number of ground controls necessary.

The four and five lens cameras failed to gain popular favor until very recently. Latest developments along this line, however, point to the possibility of their acceptance as a successor to the tri-lens.

Although photos can be made more rapidly with a multiple-lens camera, (fifty to one hundred miles of territory being mapped in one hour) the cameras are found to be susceptible to moisture in the air and are easily affected by haze which spoils the negatives easily.[2]

Types and Results of Photographic Errors

Were a photograph to be taken of a terrain of nearly equal relief (altitude above sea level) from a plane flying at a constant altitude, and with the camera in a true vertical position, the map constructed from this photo would be an exact representation of the underlying ground. These ideal conditions, however, are very rarely encountered. Variations in the relief of the territory being photographed, aerial haze, and distortion of the camera lens cause errors whose correction is essential before a true representation of the territory can be made.

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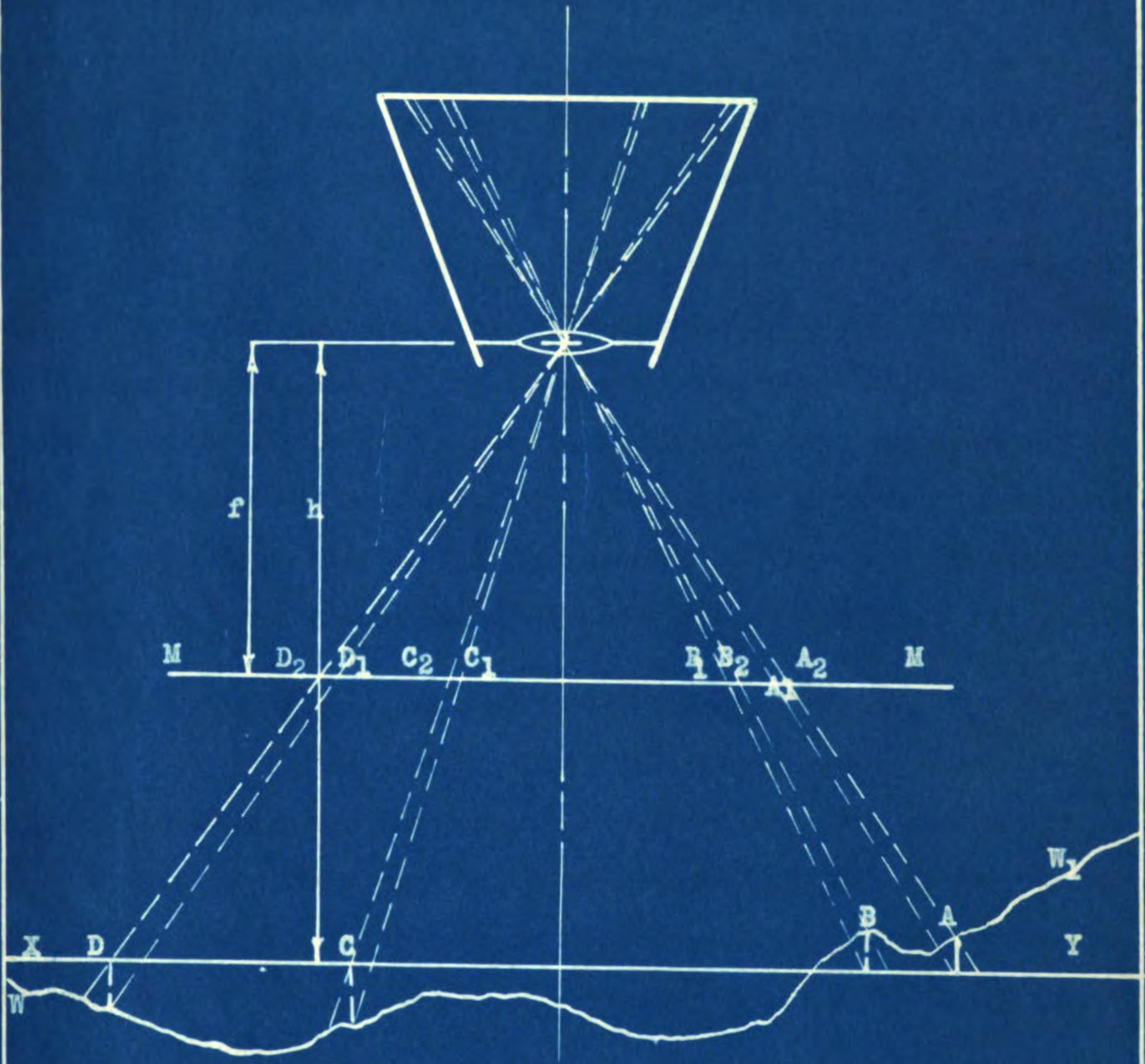
[1]Bagley, James W., "The Tri-Lens Camera in Aerial Photography and Photographic Mapping", The Military Engineer, vol. 12, p. 360

[2]Jones, Col. E. Lester, "The Airplane in Surveying and Mapping," The Military Engineer, vol 12, p. 32



Errors of Relief

Fig. 2 This represents a cross section of a camera that has been properly leveled for an exposure. Line XY is the datum, or sea level, plane. WW_1 represents a cross section of the terrain being photographed. The line MM represents a map, scale f/h, onto which WW_1 is represented. ABCD are points on the ground. The effect of the varying elevations of these lines is shown on MM. For example: A_1 shows the position of point A as it should be represented on the map, while A_2 shows the position whose inaccuracy is caused by relief. Although points A and B are at approximately the same elevation, the distance of A from the center of the photograph makes the error more pronounced.

(Reproduced from Applied Aerial Photography by Ashley C. McKinley, p. 242)

Of these errors, relief and camera tilt form the majority, distortions of the lens and shutter being negligible except when doing very large scale work. When the two errors are combined it is very difficult to distinguish between them and many complications arise which demand skilful computations for their correction.

Errors of relief are caused by the height of the photographed object. A photograph taken from directly above an object will show it in its correct position but objects three hundred feet high and five inches from the center of the photograph are displaced approximately sixty feet from their actual position (Fig. 2) while those of the same height and one and one-half inches from the center of the photograph are displaced about thirty feet from their actual position.[1]

Camera tilt errors are usually caused by the motion of the plane in flight because most of the aerial cameras now used are fixed rigidly to the airplane and cannot be moved by the operator. Camera tilt of less than one degree is not noticeable, but tilt at any greater anlge than that figure tends to vary the form of photo taken, enlarging it on one side and reducing it a corresponding amount on the opposite side (Fig..3).

This type of error tends to distroy the uniformity of the scale of the photos and entails extra work in the preparation of a map from the pictures.

The process of eliminating these errors is too long to consider at this point.

Another obstacle to the taking of good photos is aerial haze,

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[1]McKinley, Ashley C., Applied Aerial Photography, p. 241

[2]For information on the correction of errors in photographic mapping see Aerial Surveying, by B. M. Jones and J. C. Griffiths, p. 140 Also refer to Applied Aerial Photography by Ashley C. McKinley, p. 236

an "optical turbidity of the atmosphere"[1] which arises from particles of dust, smoke, or water vapor being present in the atmosphere. There are two types of haze; that which clings to the ground and that which extends uniformly to great heights. The former is caused mainly by water vapor around marshy lands, while the latter is caused by particles of solid matter in the air.

Numerous camera filters have been tried in an effort to eliminate the effects of haze, but so far progress along these lines has not been entirely satisfactory.[2]

Types of Aerial Maps

Aerial maps are divided into three classes according to the accuracy of their detail and scale. The mosaic map is the most common and also the least accurate of these types. It consists of strips of overlapping vertical photos, taken with a single lens camera, laid and pasted in a mount in a matched position. A composite picture of the entire photographed area is obtained in this manner.

The photographic map is constructed in the same manner as the mosaic map except that it is accurately scaled on a base on which have been plotted accurately obtained control points (see appendix). Relative relief may be drawn on a map of this type.

The third type of map is the topographic or line map. It is not essentially an aerial map, but it is mentioned here because topographers are coming more and more to depend upon the aerial photograph to enable them to place objects accurately on the line maps. Either single

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[1]Definition from Aerial Haze and its Effect on Photography from the Air, Bulletin Number 4, Eastman Kodac Company Research Laboratory, Rochester, New York, 1923.

[2]Ibid.

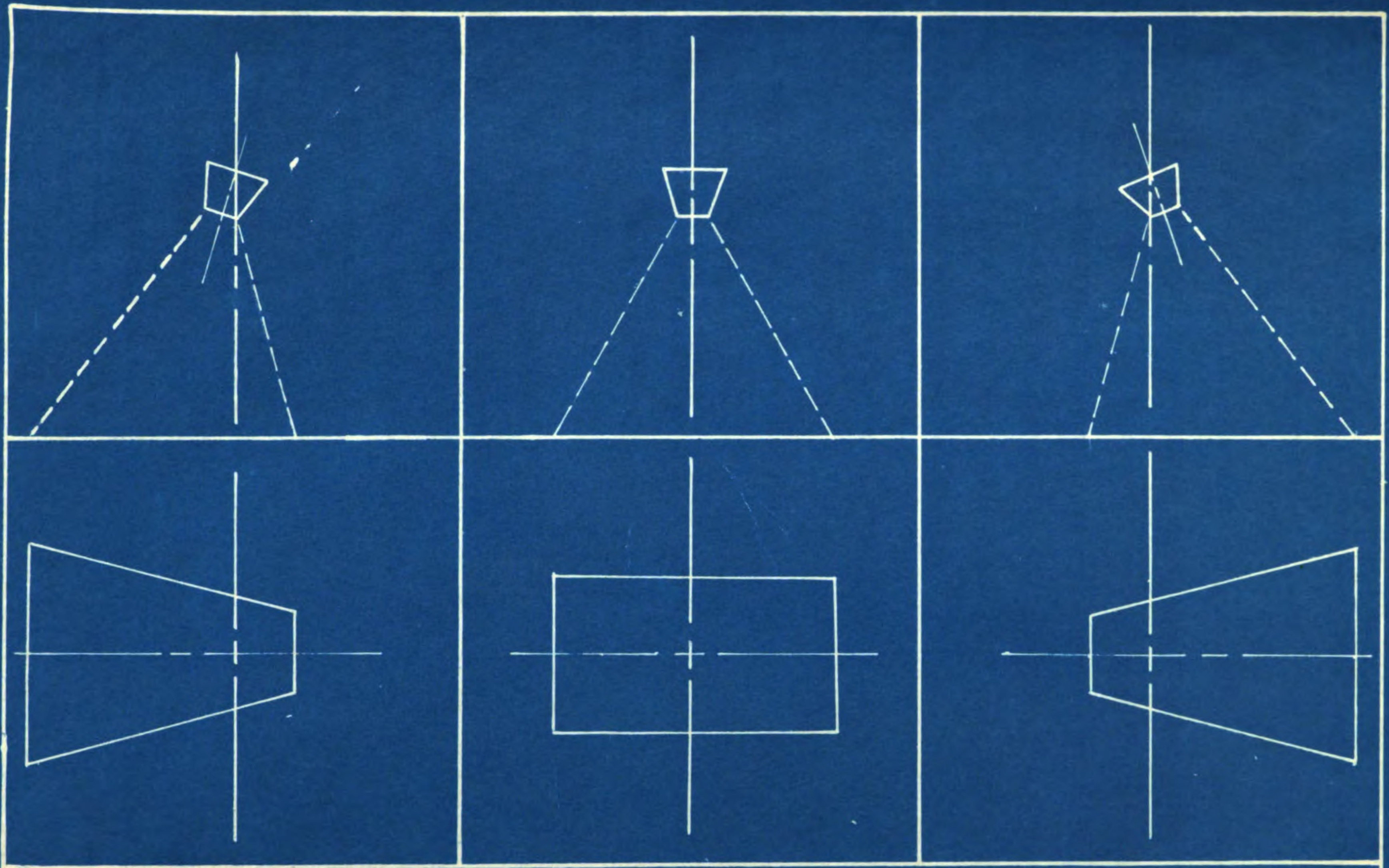

Fig. 3 Distortion of the Photograph caused by camera tilt

lens or multi-lens cameras may be used for this work, the main features of the photos being transferred from the photographs to the line map by the use of tracing cloth or paper.

An aerial map will be accurate in proportion to the number of control points used and the methods by which these control points were obtained. It is possible to construct a map with much greater accuracy than can be easily read, for example; on a photographic map with a scale of 1:15,000, the dot made by a pencil in taking measurments will cover an area of approximately fifteen square feet. This error will be transferred throughout the entire calculations.

Most authorities, up to the time of 1929, thought that the maps made from aerial photographs had to be carefully checked by ground surveys in order to insure accuracy. So much progress has been made in the establishing of control points and in the using of these points that now the aerial surveyor, "can detect as many errors in the work of the ground surveyor as the ground surveyor formerly could in the work of the aerial photographer."[1]

Preparation of the Prints

After the prints have been developed they are sent to the drafting room where they are numbered in the order in which the print was taken. Additional information such as the altitude from which the picture was taken, the time, and any other data that might be deemed important, are sometimes added.

The prints are then laid in piles, each pile corresponding to a strip of territory covered by the plane during one trip over the

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[1]Talbert Abrams, President of the Abrams Aerial Survey Corporation, made the quoted statement in a recent interview.

corresponding territory. These strips are then assembled into a primary map, known as an index map, which serves to show any part of the project that may have been omitted, or, in work on large engineering projects, serves as a record of the work as it progresses.

The index map is arranged by taking one strip of the prints and laying it out so that it will overlap as accurately as possible. The second strip is then laid adjacent to, and overlapping the first strip. Using the first strip as a basis, the remaining strips are built outward from both sides, the best photo being used in each case to overlap the preceding picture.

Methods of Assembling the Mosaic

There are two main methods of assembling mosaic maps from photographic prints, the paper traverse method and the straight line method. The steps in the construction of a map by the paper traverse method are as follows:

First assemble a rough mosaic (index map) by matching images in the zone of overlap, and select about nine points, widely distributed over the map, for use in primary control. These points should be easy to identify and suitable for easy field control. The photos containing the selected points are then turned over to a field party which controls the points from the ground.

Next select and mark two points on the first photo of each strip. These points must also appear on the adjacent photos of the same strip. For example: The first point is taken near the center of the first print, and, due to overlap, appears also on the outside of the second print. The second point lies near the center of the second print and near the edge of the first print. The remaining prints of the strip, and all other strips, are marked in a like manner.

A sheet of tracing paper is then placed on a drafting table and the first photograph of the first strip placed near the corner. a small hole is punched through the photograph and paper at each selected point and numbered, on the tracing paper, to correspond to the number of the print. If a control point is contained in this photo it is also numbered.

The first print is now removed and the second print placed to correspond to holes punched in the paper. The second point is obtained from this print, punched through to the paper, and used as a guide for the third photo. The strip is completed and a lateral traverse made in the same manner so that all points on the map are finally punched through to the tracing paper in their respective positions.

In order to obtain the tentative scale of the mosaic, measurements are made, on the tracing paper, of the distances between two control points. The actual distance between these points is then taken from ground surveys.

A polyconic projection[1] is now plotted, and all of the control points are accurately plotted from the field notes. The final scale is worked out in this manner, and a proportion obtained between the final scale and the tentative scale. The controls are replotted to this final scale by drawing lines from the origin of the projection[2] to all control points, measuring the distances from the origin to these points, and

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[1]For a definition and description of the method of taking a polyconic projection see the appendix.

[2]The origin is the central meridian of the projection.

increasing or decreasing their distances in accordance with the proportion obtained between the tentative and the final scales.

After the control points have been adjusted to the new scale, the prints are cut (only the centers being used, the overlap being discarded) and pasted[1] over their corresponding points, thus completing the map.

Due to the fact that the straight line method is not as commonly used as the paper traverse method it will not be described at this point.

A third method of assembling mosaics has been devised by B. M. Jones and makes use of the fact that the separate strips will have been taken in approximately straight lines. This method is used when speed, rather than accuracy, is the essential factor. Data on this method will not be considered here but may be found by consulting the book, Rapid Survey Methods by B. M. Jones.

Contours from Aerial Photographs

As has been previously stated it is possible to obtain relative relief from aerial photographs. This fact leads to another important possibility in the use of aerial maps, that is the drawing of contours directly from the photos.

Several complicated instruments have been developed for use in the drawing of contours. Some of these are the Stereocomparator, the Steroplanigraph, andthe Aerocartograph. Their operation is too complex to be considered in a paper of this type.

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[1]Gum arabic and rubber cement are two of the adhesives used to secure mosaics to their mounts.

Perhaps the best method of constructing contours from photographs is by the use of the mirror steroscope (Fig. 4). This instrument makes use of the fact that two pictures of the same object, when projected onto one another, will show relative relief. It is quite simple to make comparisons of elevations by this method and, by joining the points of equal height, to show contour lines.

The value of the aerial photograph for showing relief depends upon the following factors: The magnifying power of the steroscope, the stereoptical vision of the operator, the skill used in adjusting the prints, the quality of the prints, the altitude from which the photo was taken, the amount of relief and the scale of the two adjoining prints.

If two or more altitudes are known (vertical controls) it is possible to sketch inthe contour lines at regular intervals. The magnitude of the stereographic effect is proportional to the length of the base on which the two photographs were taken, the length being the distance the airplane covered between exposures.

The Future of Aerial Mapping

In 1920 James W. Bagley made the following statement, "There are many miles of our outlying coast lines about which we need accurate information, and there are vast areas of our frontiers, such as the valleys and plains of Alaska, of small relief, which probably will remain for a century almost as little known as at present unless a more rapid and economical method of mapping them can be devised."[1]

Since that time many of these frontiers have been mapped with the aid of the aerial camera. Noticeable among these recent conquests

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[1]Bagley, James W., "The Tri-Lens Camera in Aerial Photography and Photographic Mapping", The Military Engineer, vol. 12, p. 359

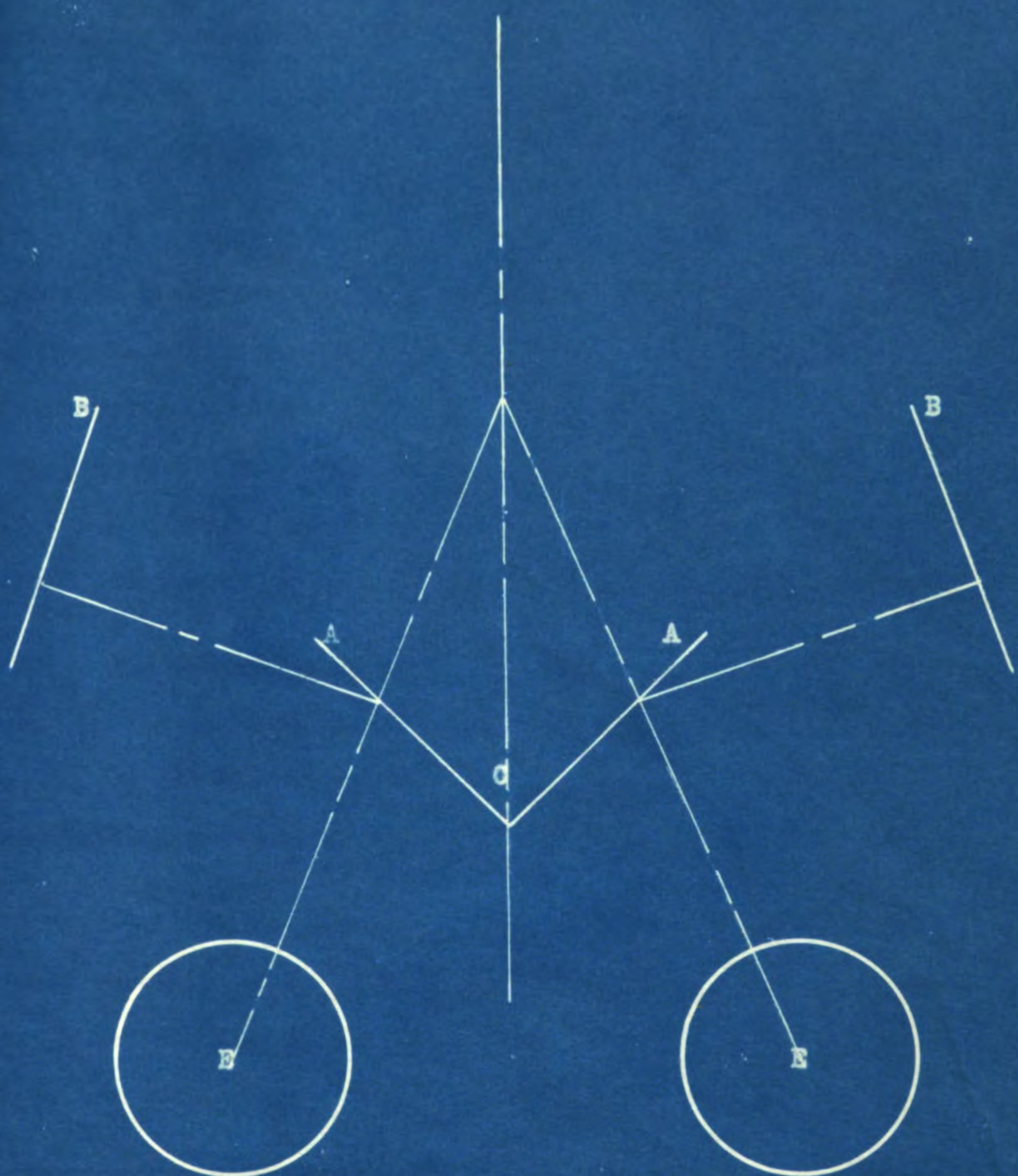

Fig. 4 Diagram of the mirror stereoscope, used for showing relief when drawing contours from aerial photographs. AA are two vertical mirrors. BB are the photographic prints, placed on either side. EE is the point of vision, or eyes, of the operator. The point of convergence is controlled by the angle C between the mirrors.

is that of the upper Amazon River, a territory in which ground surveys were found to be very inaccurate and inadequate. Isle Royale, in Lake Superior, has been mapped within recent years for the U. S. Government, and the U. S. Geological Survey is making tremendous steps toward even greater perfection of the photographic system.

City mapping will probably play a major role in this work due to the fact that cities usually grow much more rapidly than do their maps when made from ground surveys. As an example of the efficiency of aerial mapping in this respect, let us mention that the City of Paris was mapped in one day's actual flying time with the taking of eight-hundred exposures. The City of Washington was photographed in two and one half hours with less than two-hundred photographs.[1]

Air photos can also be used to advantage in archaeological surveys and in the location of timber, while their use in the location of submerged and hidden objects along our seacoasts makes them an important aid to navigation.

Although aerial mapping has been known for several years it has only recently become universally recognized: So we may say of aerial photography, as Kipling did of aviation, that, "We are at the opening page of the opening chapter of the book of endless possibilities."

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[1]Ives, Herbert Eugene, Airplane Photography, p. 412

Part II

Special Problem

Mapping from Aerial Photographs by Intersection

The Problem

Although contemporary works give many ways of constructing a map from aerial photographs (the most important of which are noted in Part I of this paper) all search through available material failed to show any method of plotting a topographic map from aerial photographs by means of intersection, not could any reliable information be obtained as to the accuracy of a map so constructed. It was therefore decidded to obtain prints of a nearby area which had been accurately controlled and to construct a map of this type, checking it as accurately as possible with available information.

Material

Through the courtesy of Mr. Talbert Abrams, President of the Abrams' Aerial Survey Corporation, Lansing, Michigan, ten overlapping photographs were obtained which covered an area E N E of the City of Lansing, Michigan, from the Fair Grounds (just north of M-16), east to the Lake Lansing Road, and from the Fair Grounds north to the Haslett Road (or Saginaw Street).

Each photograph was to the scale of 1:9600 (1" = 800') and covered an area 5600 feet by 7200 feet.

One of the photographs, covering from the Fair Grounds north a distance of approximately 7200 feet and east (from the Fair Grounds) a distance of approximately 5600 feet, was selected as a basis for the topographic map.

Another copy of this same photograph was obtained, from Mr, Abrams, printed on single weight paper, the first ten prints being on double weight paper.

Data as to the coordinated of the bench marks available within this area was obtained from Mr. C. M. Cade, Professor of Civil Engineering at Michigan State College and director of the U. S. Coast and Geodetic Survey work which covered this area.

As a permanent map record was desired it was decided to substitute tracing cloth for tracing paper in the construction of the map. This enabled blue prints to be taken of the completed map (one of which is enclosed in this thesis) and was more easily preserved as the original work.

It was found that the use of a T-square of triangle in constructing intersecting lines was slow and arduous so two intersection arms were devised.

These arms were of isinglass, twenty-one inches long and one-half inch wide, their edges carefully straight-edged, and so constructed that a pin, placed through a hole al ong the edge and punched through a control point on the photograph, would serve as a hub for this rotating isinglass arm, enabling a straight line to be laid off in any direction from the control point. Two of these arms were constructed for simultaneous use over two control points.

Procedure

The method of procedure followed resembles that described in <u>Higher Surveying</u> by Breed and Hosmer, Chapter VI, on Photographic Surveying (ground).

The description of the bench marks contained in the photograph was obtained and, after a study of the photograph under a mirror stereoscope, these points were pin-pricked on the photo.

These points are described in the manuscript <u>Bench Mark El-</u>

evations and Descriptions, Ingham County, as determined by C. W. A. Projects under the supervision of the U. S. Coast and Geodetic Survey, as follows:

15 B. - Located 2 mi E'ly of Abbott Road, E. Lansing, Ingham County. It is on the E side of gravel road on the E 1/8 line of Sec. 17, T 4 N, R 1 W, Meridian Twp. It is situated in triangle formed by driveways to Prof. C. M. Cade's house, 23.8' S of end post of N & S fence; 20.2' E of CL of N & S gravel road; 37.6' NE'ly of 12" hickory tree; 73.25' SW'ly from telephone pole, and 119.2' NW'ly from NW corner of Prof. C. M. Cade's house. To reach station go 2.0 mi E of Abbott Road in E. Lansing, on US Highway 16 (Grand River Ave) and 0.6 mi. N on gravel road. A standard disc set in top of concrete post.

15 C. - Lodated 2 mi NE'ly of intersection of US Highway 16 and Abbott Road, E. Lansing, in Ingham Co. It is situated in the NE quadrant of the X of Haslett Road and N & S 1/8 line of Sec. 8, T 4 N, R 1 W, Meridian Twp. 45.8' N of CL of Haslett Road and 32.4' E of CL of N & S Road; 20.2' SE'ly of traffic sign; 25.9' SW'ly of 6" maple tree (twin). To reach station, go 2.0 mi E of Abbott Road in E. Lansing on US 16 (Grand River Ave.) and 0.6* mi N on gravel road. A standard disc set in top of concrete post.

15 D. - Located 2½ mi. NE'ly of X of US Highway 16 and Abbott Road in E. Lansing, in Ingham County. It is in Sec. 9 on N side of Haslett Road the abandoned X of Trunk Line Road M-78, 0.4 E of B.M. 15-C and approx. ¼ mi E of the Sec line common to Secs. 8 & 9, T 4 N, R 1 W, Meridian Twp. 21.5' E of stub of pavement of abandoned X, and 28.0' N of CL of pavement of Haslett Road. To reach station from traffic light at Abbott Road and US 16 in E. Lansing, go E 2.0 mi on US 16, 1.5 mi. N to Haslett Road and 0.4 E to monument. A standard disc, set in top of concrete post.

Although there were three bench marks contained in the photo only two were used for the major portion of the mapping work (B.M.'s 15-B and 15-C) as only two photographs of this area were available. The third (B.M. 15-D) was used to check the position of certain points in the final transit check.

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*Probably should read 1.6 mi instead of 0.6 mi.

The North and South Road past Professor Cade's house and shown down the center of the photograph, was chosen as the primary line of orientation. Accordingly a line was drawn down the center of a sheet of 18" x 24" detail paper and the positions of B.M.'s 15-B and 15-C were accurately located to the scale of 1:3600 (1" = 300') with this line serving as the center line of the North and South Road.

The detail paper was secured to a drawing board by means of thumb tacks and the two photographic prints placed in position over the two control points. The location of BM 15-B was pricked through the photograph and into the detail paper through the position of the point taken as the position of BM 15-B on the detail paper. The second photograph was now taken and the position of BM 15-C was located in its correct position in the same manner. The prints were now swung, using the pins through the control points as the hubs, until the picture of the North and South Road paralleled the corresponding line on the detail paper. The prints were now considered oriented.

Using a paper mucilage the prints were glued securely to the detail paper in this oriented position. The sheet of tracing cloth was now placed over the prints and detail paper and held in position with thumb-tacks.

The isinglass intersection arms were now placed in position, one with its end over one control point, the other with its end over the second control point. A pin was then pricked through the intersection arm, through the tracing paper, through the control point on the photo, through the control point on the detail paper and firmly into the drawing board in each case. These pins, securely imbedded, formed the initial points in the location of all other points.

The construction continued as follows:

A point was picked on one of the photographs. The intersection arm for that photograph was placed so that its edge ran directly through this point as shown on the picture. The same point was located on the second photograph and the intersection arm of the second photo was passed so that its edge passed directly through the point. The point at which the two intersection arms crossed was marked on the tracing cloth and represented the point chosen on the photographs but now shown, on the tracing cloth, to the scale of 1:3600 instead of to the scale of 1:9600 as shown on the photographic prints.

Work proceeded in this manner until the map was completed.

As a check on the accuracy of mapping by intersection, a brief transit survey was made of the area. Several shots were taken from the bench marks and the points plotted accurately on the completed map by means of angles and distances. A copy of the notes taken during this work is shown on the following page.

Conclusion

The points that were located by means of a stadia traverse are shown as dotted lines on the map. It will be noted that quite a bit of discrepancy is noted on about fifty percent of the points that were plotted.

The first eight points that were plotted (numbered 1 to 8 on the map) show the most error of the entire group. This is easily explained. When in the field the tree taken as the line of zero azimuth seemed very conspicuous and one which would be easy to locate on the photograph. Once at the drawing board, however, it was found that the tree showed up only in vaguest outline. An approximate position of

Notes From Stadia Traverse

Transit at	Sta.	Az. Angle 0° on tree NW Cade house	Observed bearing	Dist.	Vert Angle	Remarks
BM 15B	1	116°02'	S14°W	435'	0°	N Corner Barn
	2	117°00'	S13°W	465'	0°	S Corner Barn
	3	233°40'	N75°E	290'	+1°	Cade Barn
	4	221°46'	N88°E	280'	0°	Cade Barn
	5	221°20'	N88°E	312'	0°	Cade Barn
	6	221°18'	N88°E	169'	0°	Cade Garage
	7	214°00'	S84°E	168'	0°	Cade Garage
	8	00°00'	N50°W	812'	0°	Check on 0° Az. tree
BM 15C	9	00°00'	S83°E	502'	0°	C-L Road, 0° Az. Line
	10	1°10'	S84°E	492'	0°	Culvert
	11	1°13'	S84°E	510'	0°	Culvert
	12	98°13'	N02°W	696'	0°	C-L Road (N&S)
	13	102°15'	N05°W	223'	0°	Culvert
	14	116°38'	N10°W	228'	0°	Culvert
	15	190°05'	S87°W	1060'	0°	Back of Culvert
	16	190°15'	S87°W	1020'	0°	Front of Culvert
	17	189°22'	S87°W	1050'	0°	Edge of Road
	18	189°30'	S87°W	1040'	0°	Edge of Road
	19	275°15'	S32°W	1360'	+4°	C-L N&S Road

the tree had to be drawn in by intersection and the line from BM 15-B to this point taken as the line of zero azimuth.

The shots taken from 15-c were, in general, very good. Only two of the points were badly out of position, points 10 and 11 being displaced about twenty feet north.

A good many of the errors can be laid to the lack of technique of a college senior. An expert could probably make a reasonably accurate map, suitable for most purposes, by means of intersection from aerial photographs. For the best work, however, the other types of making maps from aerial photographs are strongly recommended.

Part III

Appendix and Bibliography

Method of Plotting a Polyconic Projection[1]

Polyconic projection is based on the fact that when a number of cones are placed tangent to some parallel, with their apex falling over the pole, the data at this point of tangency, and for some distance on each side of the point of tangency, can be projected on the cone.

Numerous calculations are involved which are made simple in Bulletin 650, published by the U. S. Geological survey.

When laying a polyconic projection, the construction will proceed as follows:

1. Find the central parallel and meridian of the area of which the projection is to be drawn. Refer to bulletin 650 for the desired scale, and lay off accurately the desired distances given in the table.

2. Draw two lines at right angles to each other and through the center of the mosaic mount, then, by referring to Bulletin 650, the value of inches for a minute of latitude of the area of which the projection is being made can be determined at the desired scale.

3. Refer to the table and find the required offset. Plot these distances to the north or south.

4. Refer again to the table in Bulletin 650. The distances of curvature for the meridians are found and can be laid off from south to north along each construction line.

5. Control points are then plotted along the projection.

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[1]Method quoted from Applied Aerial Photography by Ashley C. McKinley

Controls

Controls are all data employed in accurately fixing points on which to construct a mosaic or map. They are always related to some point of the earth's surface and are of two types; the horizontal control, which is the horizontal distance between two pointson the earth's surface, and the primary control which consists of belts of triangulation an accurately measured bases across the country from coast to coast and from the Great Lakes to the Gulf of Mexico. The primary controls are determined by astronomical positions. These positions are permanently fixed by using a concrete pier to which is attached a tablet with the desired information.

Secondary control is any control taken especially for the photographs themselves.

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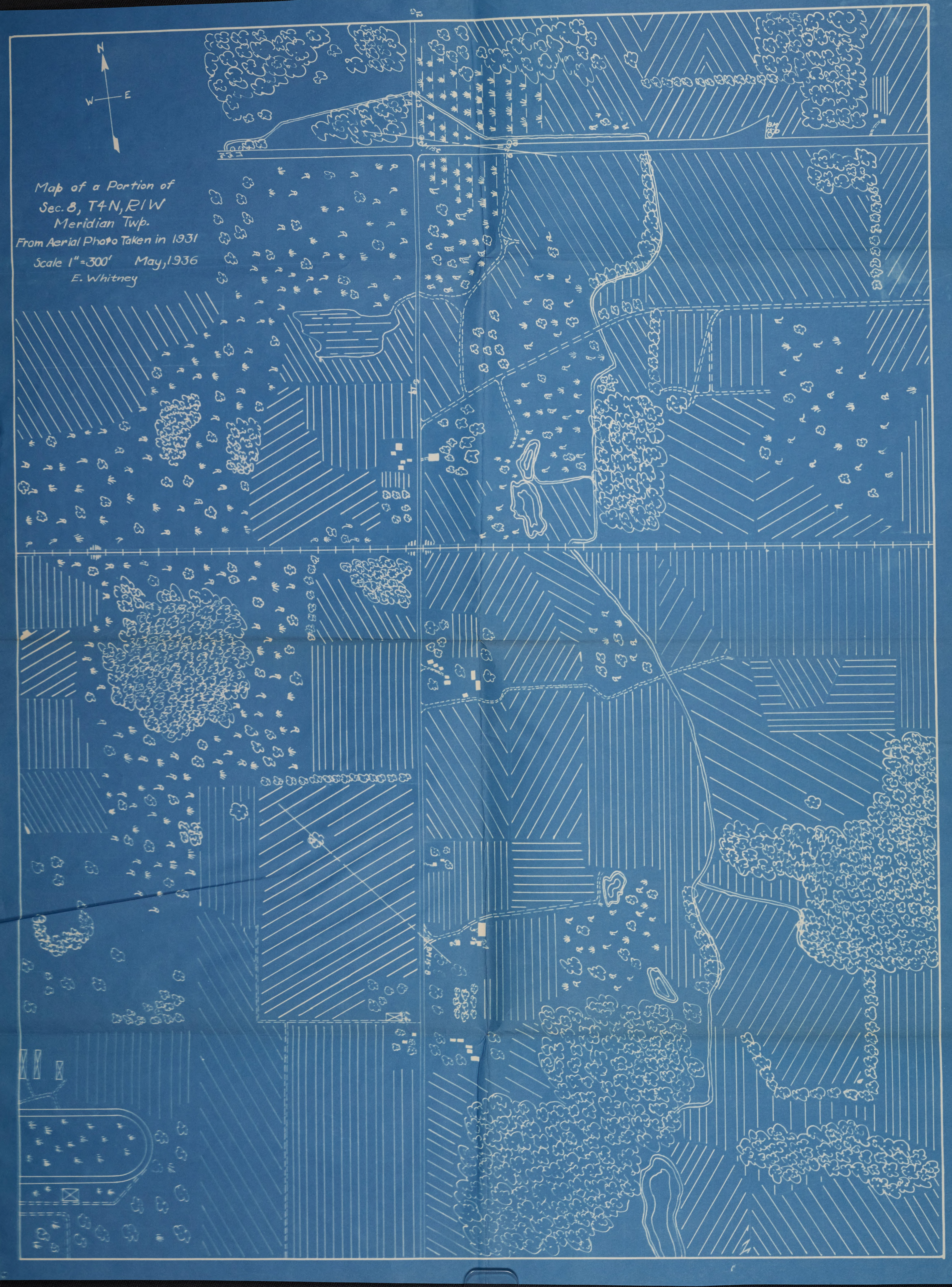

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Map of a Portion of
Sec. 8, T4N, R1W
Meridian Twp.
From Aerial Photo Taken in 1931
Scale 1" = 300'
May, 1936
E. Whitney

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