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GEOLOGICAL APPLICATIONS OF OBLIQUE PHOTOGRAPHY

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MUCH has been written about the geological interpretation of aerial photographs, but most of it has referred to verticals, used either singly or combined as mosaics, or to overlapping verticals which can be studied under the stereoscope. Not so much attention has been given to oblique photographs and the geological uses to which they may be put.

The oblique photograph for the portrayal of landscapes has been much employed, and for that purpose it has many advantages as compared with the vertical picture—particularly a greater areal coverage and a more natural appearance of the terrain, and hence easy interpretation by the layman.

Nothing further need be said about such obliques. They are very useful to the geologist as records and for study, but such use is well known.

STEREOSCOPIC OBLIQUES

Stereoscopic obliques have not received as much attention as they deserve from geologists. They combine the advantages of stereoscopic vision with those of broad coverage of the terrain and of the possibility of seeing and assessing its relief features to even better advantage than can be done with overlapping verticals.

For geomorphic studies, stereoscopic obliques are especially advantageous as can be well demonstrated by the stereo-pair reproduced as Figure 1. This picture was taken with a miniature camera in the course of a flight on a regular passenger liner. A single picture of this pair gives no suggestion of the fact that the land of low relief in the foreground lies at the summit of a mountain mass and records a strongly-uplifted very old-age surface.

The possibility of seeing in one view the salient features of the geology as well as of the topography, and the relations between the two, is one of the great advantages of stereoscopic aerial obliques as a tool in geomorphic studies.

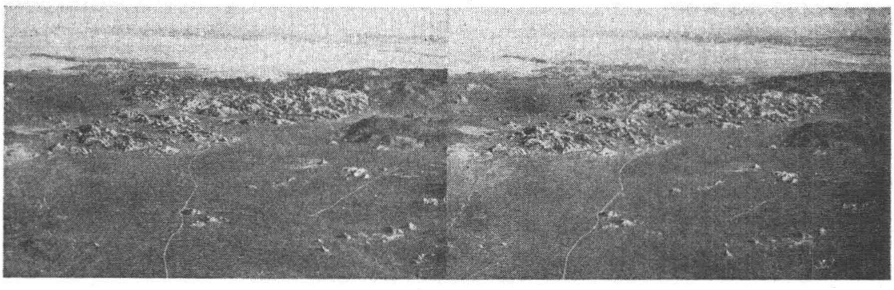

FIG. 1. Stereo pair illustrating advantages of stereoscopic obliques for geomorphic studies. Looking north over northwest end of Little San Bernardino Mts., Calif.

If a geomorphologist can arrange for the use of a plane for even a few hours, it will be possible for him to fly over an area that he intends to study, and by taking a few stereoscopic aerial obliques of selected spots, to make a record of the general geomorphology of the area, as well as of details of special features, and these records will show not only the topographic relations but also the geologic features on which they depend.

It would seem also that a few well-selected stereoscopic oblique pictures used as illustrations in a report might make the presentation of the results much clearer and more easily understood than would words alone, even though they might be supplemented by a topographic map.

The making of stereoscopic obliques is not difficult. All that is necessary is to take two pictures in as rapid succession as possible, pointing each of them at the same distant object.

For much of the world, stereoscopic obliques are already in existence, having been made as part of the trimetrogon photography done during and since the war by the Army Air Forces. How much of that will be available to the general public is a matter of Army policy, but, fortunately, in areas where aerial photography is now permitted, the geologist can go out and take his own pictures. In doing this he will have much less difficulty taking obliques than he would in taking overlapping verticals, which require the use of special equipment.

MAPPING FROM OBLIQUE PHOTOGRAPHS

Not only are oblique photographs valuable as records and for use in connection with geomorphic studies, but they can also be used for the making of maps and for recording or determining the map locations of various objects of interest.

In regions where a certain amount of control is available, the location of the camera position when an oblique picture was taken can be made with as much accuracy as with a plane-table by the three-point method of drawing rays from three objects whose positions are known, using either the Crone or the Army Air Force methods[1] of obtaining the true directions of those rays. Having two or more camera positions thus determined, it is easy to triangulate to any points of interest and to obtain elevations with considerable accuracy.

Even if no control is available other than the horizon line and one or more level or nearly level lines somewhere in the area to be mapped, it is possible by the method outlined[2] to make a reconnaissance map of fair accuracy.

Where trimetrogon photographs are available, maps on a scale as large as 5,000 feet to the inch (1/60,000) can be made of limited areas with considerable accuracy. This is best done by orienting the obliques by running as accurate a base line as possible by using the radial-line method on the accompanying verticals of the trimetrogon triplets, and orienting each oblique with respect to its corresponding vertical picture by lining up points on the principal line of the oblique with the corresponding points on the vertical photo. After the obliques have been oriented, points in the area to be mapped are located by intersection in the manner already described.

If a sufficient number of accurately-located control points can be seen in the area within which geological features are to be mapped from trimetrogon photographs, these may be used directly as control for the obliques, and the radial-line plotting of the associated verticals will not form a necessary part of the orientation procedure except for the areas covered by the verticals themselves.

[1] See page 619. Rich, J. L., "Reconnaissance Mapping from Oblique Aerial Photographs without Ground Control."

[2] *Ibid.*

DIPS, STRIKES, AND STRUCTURE CONTOURS FROM OBLIQUE PHOTOGRAPHS

In areas of considerable relief, where sedimentary rocks are conspicuously exposed, useful and surprisingly accurate dip and strike measurements can be made from oblique photographs tied together by adequate control such as that furnished by trimetrogon pictures or by ground control, or any other system which supplies control sufficient to make possible fairly accurate intersections.

The method is to select three points on a dipping bed; to locate each of them by intersection; and then to determine the relative elevations of each (absolute elevations are not necessarily or particularly desirable) of them by using the graphic method described in the paper last mentioned or any other satisfactory method such as that described by Landen.[3] After that has been done, dip and strike are determined by the well-known three-point method.

For representing structure on reconnaissance maps made from aerial photographs the writer, in the course of such mapping of the mountainous regions of southern Alaska, hit upon the idea of using form-line structure contours for showing the attitude of the rocks. The result is much more graphic than the use of dip and strike symbols alone. For each unit of area where dip and strike could be determined and where the stereoscopic photographs showed that dip and strike were essentially the same as at the spots where actual dip determinations were made, structure contour form lines were drawn trending parallel to the strike, and spaced as they would be for the scale of the map and the contour interval employed. (For the Alaskan work, where dips were steep, this was 500 feet.) No pretense was made of connecting these form-line contours from area to area so as to make a map showing actual structural elevations, but it was found that the method portrayed very graphically the known facts about the structure so that they could be comprehended at a glance.

Preliminary mapping of a difficult area by use of aerial photographs (in the Alaskan work trimetrogon photos were used) reveals the major geological features. It points up the problems to be solved and reveals faults and other discordant features which might require long and arduous brush work on the ground to decipher. It thus gives the geologist who goes into the area later on the ground all of the benefits to be derived from the aerial view of the terrain and of its geologic relationships, as well as reasonably accurate *locations* of the features observed and mapped from the air.

For the maximum benefit to be derived from the combination of reconnaissance mapping from the air followed by ground work, the ground party should take into the field not only the map made from the aerial photographs, but also the photographs themselves from which the map was made. On the map, each point which was intersected from the air should be plainly marked, and on the photographs a dot in brightly-colored ink should indicate each point so intersected. The geologist on the ground can then recognize each spot which formed the basis of the aerial geologist's interpretation and he can go directly to that spot if the interpretation should be questionable.

Also, in difficult country where mapping of large-scale accuracy is not required, the point locations made from the photogrammetry could serve as departure points for secondary ground traverses or for obtaining locations by intersection, and thus save much time and labor in traversing.

[3] Landen, David, "A Principal Plane Photoalidade for Oblique Photographs," PHOTOGRAMMETRIC ENGINEERING, vol. XI, No. 3, 1945, pp. 245–254.

THE AERIAL TRAVERSE[4]

The aerial traverse is a graphic record of a flight so arranged that the approximate locations of various points of interest or of the position of the plane when the photographs were taken are shown on a map as determined by the relations of time and distance during the flight.

The occasions on which an aerial traverse may be used are either flights in a regular scheduled airline passenger plane or special, straight point-to-point flights for purposes of surveying or geological reconnaissance. The purpose of an aerial traverse is to fix the locations of the objects observed during the flight or of any pictures which may be taken. The essential procedure for recording the traverse requires noting the following: the time of take off, the time of the end of the climb, the time of the beginning of the descent and the time of landing; the time of passing objects whose map positions are known—towns, railroads, etc. (those which are to be used as control points); and the time when each object to be recorded is passed or photographed.

The chief difficulty about locating points on an aerial traverse has always been in adjusting the time-distance relations for the control points and for the various rates of speed. This originally was done by the writer by use of the principle of proportion applied by means of a slide rule, but that method required rather laborious procedure in adjusting to control points. Recently a graphical method has been developed which makes the work of adjustment much simpler and more rapid than it had been previously. In the graphical method, a graph, Figure 2, is prepared, using two rectangular coordinates—one representing elapsed time and the other representing distance traveled. On the time coordinate, beginning, for convenience at the left, the time in minutes is plotted to scale. On the distance coordinate, distances are plotted to the scale of the map being used as a base.

A straight line on the graph connecting the starting point with the ending point of the traverse represents the average speed of the plane, and if the speed of a flight were to be uniform throughout, this line (which we will call the flight curve) would permit the accurate location of the plane along the line of flight at any instant of time.

But as a rule, the flight speed is not uniform. It is generally slower than average during the climb for altitude, and may be faster than average during the descent for a landing. It is therefore desirable, if possible, to fit the flight curve to control points of known position along the flight line.

The position of the curve at a control point is found at the intersection of a line drawn at right angles to the time coordinate from the point representing the time when the control spot was passed with a line drawn at right angles to the distance coordinate from the point representing the air-line distance of the control point from the starting point. To express the same thing in another way: the position of the control point on the flight curve will lie along a line drawn at right angles to the time coordinate from the point representing the time when the control point was passed, and it will be distant along this line from the time coordinate by an amount equal to the distance from the starting point to the control point, expressed to the scale of the distance coordinate.

As an example, on Figure 2 the position of the Midland control point passed at 1.56 7/8 P.M. lies at the intersection of a perpendicular to the time coordinate at the point representing 1.56 7/8 and a perpendicular to the distance coordinate

[4] Rich, John L., "The Aerial Traverse—An Application of Aerial Photography to Geographic Studies," Ohio Jour. Sci., vol. XLI, No. 3, May, 1941, pp. 212–224.

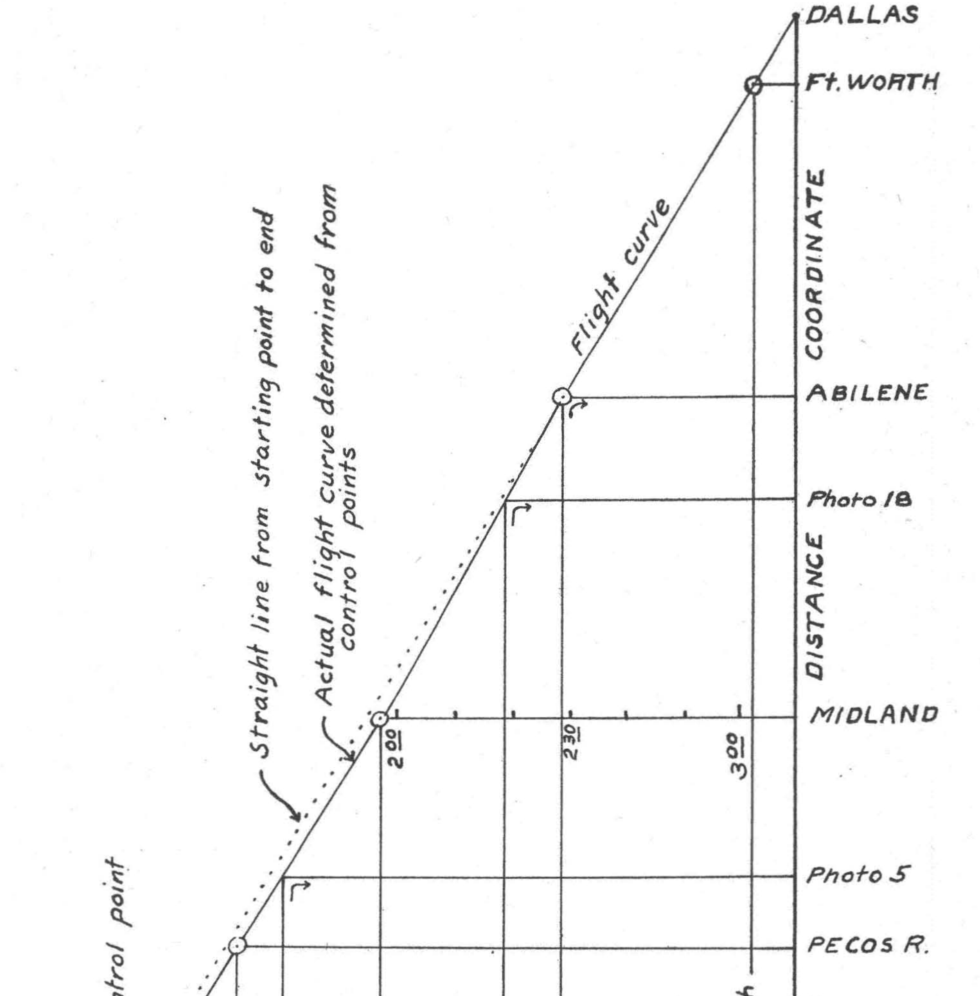

FIG. 2. Graphic chart for plotting an aerial traverse. Actual graph of a flight from El Paso to Dallas.

at a point representing the distance, along the line of flight, from El Paso to Midland.

The position of the flight curve is thus found for all control points.

In the absence of any control between the beginning and the end of a flight it is best, in drawing the flight curve, to make reasonable allowance for a slower-than-average speed during the climb, and, perhaps, for a greater-than-average speed during the descent (the pilot's air-speed recorder should be useful in this connection).

Having prepared the flight curve, it is a simple procedure to locate along the flight line any point where observations were made or photographs taken. For example, see Figure 2. Photograph 5 was taken at 1.40 P.M. A perpendicular from point 1.40 on the time coordinate to the flight curve and thence a perpendicular dropped to the distance coordinate locates the point along the flight line where Photo 5 was taken. It is not necessary to use the starting point for each of these distance determinations because each control point in succession can be used in a similar way.

By the graphic method here described, adjustments to control are very easily made because it is necessary only to alter the shape of the curve to fit any new control observations. One then scales off the distances easily and automatically from the graph.

An aerial traverse controlled in this way can be surprisingly accurate as to distances, because under ordinary conditions the rate of flight of a plane is very uniform, and with a reasonable amount of control on an ordinary good-weather flight there is no reason why a point should be out of position by much more than a mile, and the error in many instances will be less than that.

ADVANCES IN THE USE OF AIR SURVEY BY MINING GEOLOGISTS

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THE majority of geologists, particularly those in mining, have not kept up-to-date with developments in air survey. It is only since this last war, as they did after the first, that geologists and mining engineers returning from air survey and intelligence work in the Services have sought to promote its increased use in their peacetime tasks. This is evident in the courses for mining and geology students that are beginning to appear in the Universities of the United States, Canada and England. A few mining exploration companies have been using air photographs extensively in the newer unmapped areas as rough guides or maps, but the majority of geologists are still not in possession of a stereoscope or any pertinent facts. Especially the possibilities of detailed mapping at large scales from air photographs in lieu of pace and compass traverses, plane-table and transit surveys, have not been reconsidered in the light of present-day photography and mapping techniques.

It is therefore, up to the few geologists who have used air photographs in their work, to disseminate the information gained in order that further research may be done, and that this economical and practical aid to geological survey be used now in the acceleration of post-war development.

The purpose of this paper is to add to the present published knowledge of what has been done recently. Part I is an account of recent and proposed applications of aerial photography in Canada, where there is a definite need for all types of air survey. Part II is a description of the course of instruction that has

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