or *freedom from industrial barriers.* Varying the field-angle, aperture, focal-length, picture size and shape seems to make possible challenging combinations.

To make a long story short, two remarks only will be added:

(1) Taking as term of reference, on the left side of Figure 2, a $f=6''\text{-}9''\times 9''$ *convergent* camera instead of the single $f=6''\text{-}9''\times 9''$ camera does not change the main conclusions significantly. One has to fly so much lower in order to secure adequate stereoscopic interpretability and the accuracy of the settings in the critical model corners,* that all the advantage that better intersection angles secure over worse scale transfer angles, and weakened stereoscopic settings, is lost again.‡

(2) The traditional doubts about accuracy and cost of handling *composite* photography are no longer justified. With extensive calibration areas available, and doing aerial triangulation on stereocomparator and electronic computer, the actual (random) inner geometrical relationships of multilens aggregates can be taken into account in a matter of seconds per pass point, with extreme accuracy. A condition for this is however using a flexible and economical method of computation, like the one recently developed for the Royal McBee LGP-30 electronic computer. As for plotting when a quadruple aggregate is used, each triangulated model happens precisely to be conveniently halved.

* A map cannot be trusted better than its systematically worse sections.

‡ W. A. Brucklacher, Bildmessung & Luftbildwesen, July 1956.

A System for Projecting Prints for Controlled Mosaics on Steep Slopes[1]

CORTLAND P. LOHR,
and
WM. WADE

INTRODUCTION

SINCE many difficulties arise in the construction of mosaics, due to photographic distortion and differences in scale between the individual photos, many methods have been tried to overcome them. Even when a radial template laydown has been made and a number of control points have been obtained in correct geodetic positions and with correct scale and distances between them, there still remains the difficulty of making projection prints so that the points on these prints will exactly fit all of the control points, to say nothing of portions of the prints which may be distorted between control points. It may be said that no mosaic can be made with complete accuracy if there are many changes of elevation in the area photographed, without using an exorbitant number of control points.

A method has been developed by the U. S. Geological Survey for making prints which are free of distortion, by a series of photographic strip exposures made in conjunction with a stereoscopic plotting instrument. (See *Development of the Orthophotoscope*, PHOTOGRAMMETRIC ENGINEERING, *September 1955, Page 529.*) It is a remarkably ingenious method, but in its present state of development the cost of prints is so fantastically high that it is impractical to use the prints for the great majority of mosaics. Improvements in the future may make this method less costly. It has the advantage of rectifying all portions of a photo-model instead of only a few controlled portions.

[1] This method was developed by Cortland P. Lohr and described by Wm. Wade, both of the Cartographic Unit, Soil Conservation Service, Portland, Oregon.

The most suitable method, so far, for projecting prints to fit control points, is by means of a rectifying projector. This instrument is equipped with an easel which can be so tilted that the projection can be reduced or enlarged in any part of the photo, thereby distortion of scale due to change in elevation or tip or tilt in the original negative can be corrected. Of course the print is rectified in relation to the given control points, but not necessarily in relation to every portion of the photo as was mentioned in the preceding method, which is entirely too expensive for such refinements.

Although the cost of the method of using a rectifying projector is not excessive, the projector itself is very much more expensive than an ordinary photo projector. For this reason of cost the majority of photo laboratories do not have the rectifying projector, but rely simply on the ratioing of photos to make an approximate fit to the control, through using the much less expensive photo projector—about one-third the price.

Many cartographic offices have tried various methods of ratioing and projecting photos without a tilting easel. The accuracy of results has varied. One of the most troublesome jobs is where the terrain rises steeply from a shore line or valley and the ascent continues for a long distance. In such cases the contact prints will be larger in scale on the uphill side than on the downhill side. The usual effect of this in laying a mosaic is for

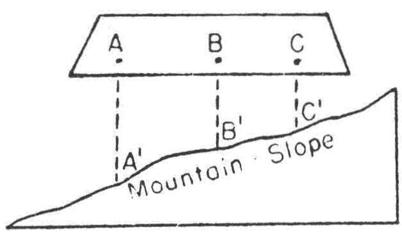

FIG. 1

the prints to fan out larger as they are laid uphill and to cause a straight ridge parallel to the shore to form a bow with its concave side toward the shore line. It has been very difficult with the usual methods of ratioing to correct this or even to get the prints to match reasonably well.

Such a condition existed when a mosaic of the Kapapala Ranch[2] in Hawaii was to be laid. The same problem occurred for a mosaic in the northern part of San Mateo County, California.[3] In both cases the land sloped steeply up from the Pacific Ocean. These two jobs were the cause of an experiment and the development of the new method described in this write-up. This method was used successfully for the east side of Davis County, Utah area for a National Soil Survey Mosaic.[4]

A New Method

It is well known that, in ratioing photos for laying a mosaic, the ratio for one side of a photo is often not the ratio needed for the other side due to the elevation of the ground being higher on one side than on the other.

In Figure 1 assume that a photo is taken vertically of a mountain slope and that the height of the camera gives the correct scale at the center point, B, on the photo. This point is projected from B' on the ground. Then, naturally, the scale at point A will be too small since A' on the ground is farther away from the camera. In the same way the scale at C will be too large because C' is closer to the camera.

Figure 2 shows how the points A, B, and C

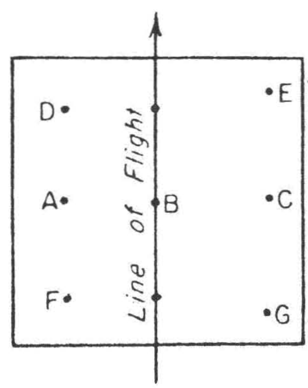

FIG. 2

appear on the photo along with the usual wing points D, E, F, and G, used for radial control in the side-lap areas of the adjacent photos to the left and right. Assume that the transparent radial control sheet (with the correct geographic positions of the points) is laid over the photo with the center B coinciding with the control center.

Let the correct positions D', A', F', E', C' and G' be marked with an x as in Figure 3.

Since the scale of the photo is too large at C, or between E and G, the points E', C', and

[2] Form SCS-19, #8835 dated 12/19/56. Kapapala Ranch, Hawaii—File No. F-7065. 3 sheets.

[3] Form SCS-19, #10922 dated 4/12/57. N ½ San Mateo County, Calif.—along the coast.

[4] Form SCS-19, #16190 dated 8/22/57 for National Soil Survey—East side Davis County, Utah, adjacent to Great Salt Lake.

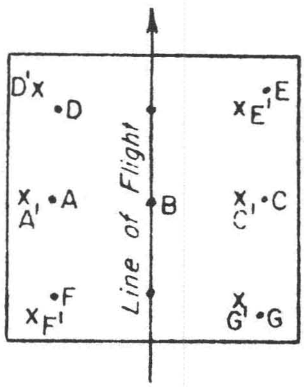

FIG. 3

G' on the control sheet will be closer together and nearer the center than E, C, and G. In like manner the correct control positions of D', A', and F' will be farther apart and farther from the center because the photo scale is too small.

Consider adjusting to the control only the right hand side of the photo shown in Figure 4.

A print is projected (using a regular photo projector) on to a tracing of the board control, reducing it so that the points of the triangle BEG on the print will very closely fit the points of the triangle $BE'G'$ traced from the board control. The tracing is then removed and replaced by sensitized photo paper, exposing it and making the projection print.

In like manner a print is projected to fit the left hand side, as shown in Figure 5. In this print the triangle DBF is enlarged to fit the control points approximately in triangle $D'BF'$.

This print is then laid with its center at B with the correct distance $D'F'$.

It has been found in practice that the small errors of adjustment can be taken up by the stretch in the paper and by tearing away portions of the prints to make the best match lines.

It is also known that the method works equally well whether the line of flight is parallel with the slope or across the slope. In either case the wing points used for projection are the two down-slope ones and the two up-slope ones for each half of the photo.

The principal feature of the method is that only one-half of each photo is approximately corrected at a time.

Many mosaics have been laid in which much of the distortion was corrected by simple ratioing of the prints, without consciously thinking of any particular method. It can be understood, as was explained in the beginning,

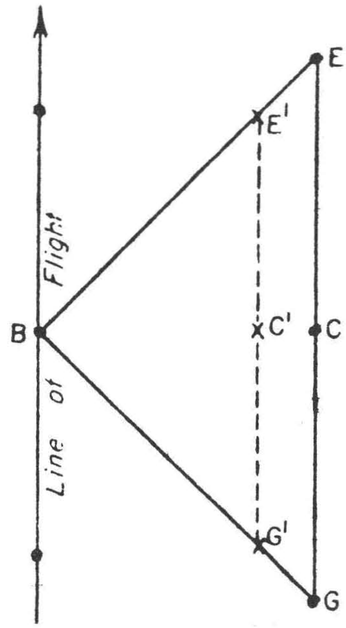

FIG. 4

that using only this method was bound to produce difficult mismatches, because ratios cannot be carried successively from one part of a photo to the next photo when slopes are steep enough to make the scale different on one side of the photo that on the other.

This method is useful where long steep slopes exist, like those which constitute a large percentage of mosaics in the western states.

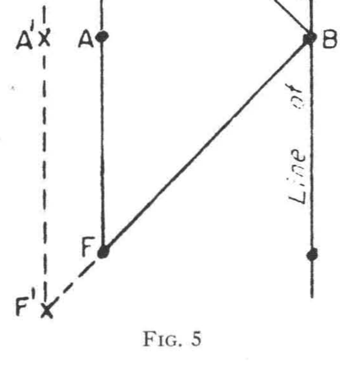

FIG. 5