

used for the taking of the photographs are used in the stereoscopic apparatus, the problem of placing all the individual photographs in the same relative positions as they occupied in the camera with which they were taken presents such great difficulty as to be insoluble, except by methods which would be too inconvenient and too laborious in actual practice. If on the other hand the individual pictures obtained at each exposure are rectified and brought together on a single plate, the rectification itself imposes demands of a very high order. The complete picture can then be used with a single camera of longer focus, but the relative positions in space of two such complete pictures must be calculated before they can be utilized. The process is only suitable for mapping on very small scales.

The manifold difficulties and complications mentioned above as arising in the use of multiple cameras indicate that the solution of the problem should be sought for in another direction. From what has been said it will have become evident that there is no object in widening the angle of field too greatly. It must be conceded that angles of  $50^{\circ}$  for extended photogrammetric surveys from the air involve a relatively large number of exposures, and therefore also a relatively large number of control-points, unless the series-connection of the different photographs is utilized in some way. But also for series-connection a larger angle would be desirable, though it ought not to have to be achieved by the round-about way of multiple cameras.

Quite lately it has been proved that air-camera objectives can be constructed with a much larger aperture-angle than any of the objectives heretofore used in cameras for survey purposes, without having to sacrifice any of the requirements as to freedom from distortion. Herein, it would seem, lies the correct path to sound further development. It is now certain that distortion-free objectives of  $90^{\circ}$  aperture-angle can be made, with which the area that can be covered is four times as great as with objectives of  $50^{\circ}$  angle. From what has been said above, it is not worth while to attempt to extend this new limit very greatly.

Of course the apparatus for mapping from air-photographs will be made capable of utilizing the wider angle, and will then present advantages hitherto undreamed of in regard to cheapening and simplifying the processes of air-photogrammetry. That will be true for mapping from single photographs as well as for air-triangulation, for very exact mapping as well as for the rapid preparation of general plans in which a lesser degree of accuracy is required.

In offering these remarks, I do not seek in the least to belittle the great value of the publication to which I have referred, but rather to emphasize that value. For we must all be grateful to the authors of all these valuable contributions for providing us with a basis for further discussion and research, and thus contributing in a high degree to the further development and clarification of the most important photogrammetric problems of the present day. I cannot conclude without expressing my thanks to the American Society of Photogrammetry for their extremely interesting and stimulating publication.

#### DISCUSSION OF MR. BERCHTOLD'S PAPER BY LIEUTENANT O. S. READING

Mr. Berchtold deserves the thanks of the American Society of Photogrammetry for his very interesting discussion of the May-June 1935 "News Notes." Everyone echoes Burns' sentiment, "O, wad some power the giftie gie us To see ourselves as ithers see us," and Mr. Berchtold has very kindly complied. Every student of photogrammetry will do well to weigh and consider carefully each statement of his remarks, for they represent the viewpoint of one of the leading men of one of the leading instrument concerns of the world, the Wild Surveying Instruments and Supply Company of Switzerland. Insofar as his remarks are interpolated between his experience, they are entirely sound and very accurately represent the facts. Thus his discussion of the relative advantages of photo mosaic and line maps and of the difficulties of obtaining a reasonably accurate scale in specially ratioed mosaics of terrain having much relief is quite correct.

As to his discussion of multi-lens cameras, particularly the nine lens, I have a little different viewpoint than he, and I hope I see a little further than he in certain items, though doubtless not so far in others.

The difficulties involved in the construction of multi-lens cameras which he mentions are present all right, but we do not believe they are insoluble by any means. In fact we are rather grateful to him for mentioning them, for it gives a better excuse for the time used in getting the various parts of the camera up to specification, getting it built and adjusted. The building of the camera required about 17 months, and the adjustment has taken five. As a result of what we have learned, we believe that a second camera could be built in six months and adjusted in two without working overtime. The best answer to his misgivings will be the resulting photographs.

The main purpose of the nine lens camera is to make possible the highest graphic accuracy in planimetric line maps with a minimum amount of ground control. A century of experience in the Coast and Geodetic Survey has taught us that there is only one right place on any map for any object that appears on it. Accuracy always pays, because, if this country continues to exist, there will be many other surveys and revisions to be coordinated with the base map. If the nine lens camera facilitates, with its wide field, the more accurate orientation of its photographs, it will pay for itself many times over for very close spacing of control is particularly expensive along the coast of this country. We confidently expect to gain the advantages illustrated by the third figure on page 6 of the article to which he refers.

In regard to the limitation of the effectiveness of a stereo base to 1:3 or 1:4, I think Mr. Berchtold does not give enough weight to the million or so square miles of land in this country so flat that five and ten foot contours are required. Such areas are somewhat analogous to the roof of the house he mentions. For these areas the base of 12:7 made practicable by the nine lens may be useful. For the steeper areas it will be very simple to take more photographs reducing the base as much as may be advisable, since the cost of photographs is usually a minor part of the cost of mapping. This is assuming that we are successful in holding the adjustment of the camera and transformer so well that the composite photograph will have the requisite accuracy for contouring. As mentioned before, the camera was designed for increasing the accuracy of planimetric maps with a minimum amount of ground control. Any contouring we may be able to do with it will be so much advantage in addition to its main purpose.

With respect to the new lenses covering a 90° field without distortion, they have the limitation of the decrease of the light with the fourth power of the cosine of the angle from the axis. However, when they become available, they will make practicable smaller and more efficient multi-lens cameras. More promising still, in my opinion, is the lens now being designed by Dr. I. C. Gardner of the National Bureau of Standards in this country. This lens intentionally gives a large amount of negative distortion to its image in order to minimize this falling off of light at the margins. On the other hand, if fields of the magnitude of those made possible by multi-lens cameras are attempted with such lenses, the enlargement of the compressed images at the margins when reprojected to make the distortion free positives may present difficulties which may leave a sphere of usefulness for multi-lens cameras for many years to come.

In thus extrapolating beyond our experience both Mr. Berchtold and I are likely to be mistaken in our evaluation of the many different factors, which when integrated by actual trial in the future, will determine the course of progress. Yet such extrapolations and actual construction of the apparatus resulting from them are necessary if there is to be any progress. Nothing so handicaps progress as the assumption that because a proposed development is difficult, it cannot be accomplished or is not worth a trial. But by the free interchange of views we all have much to gain and nothing to lose. We all hope Mr. Berchtold will continue to send us such comments as he may care to make on the progress of photogrammetry in the United States and that we may have correspondence with photogrammetricians of other countries.