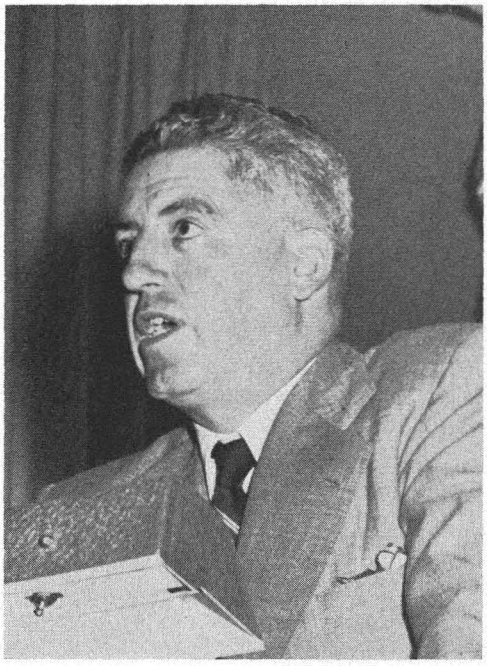
THE MULTIPLEX, KELSH PLOTTER AND WILD AUTOGRAPHS*

A BRIEF STUDY OF THEIR *C* FACTORS, ECONOMY AND PRACTICAL APPLICATIONS

Luis Struck, Compania Mexicana Aerofoto S. A., Mexico, D. F.

IN CHOOSING the paper which we feel honored to deliver before the Society, we have taken into consideration the interest that exists among photogrammetric engineers, contractors, surveyors and government offices to know and get acquainted with the three types of the best known and versatile photogrammetric instruments that offer within their principles and applications the possibility of accurate restitution of photogrammetric maps from aerial photographs.

In our Company we have had the opportunity to use very extensively the wide angle Multiplex from Bausch & Lomb for 6″ metrogon lens, as we operate four bars with a total of twenty-seven projectors. We have had in operation a Wild A5 Autograph for about three years. For about one year we used a Wild A6 Autograph; this was later exchanged for another Wild A5 which arrived about five months ago. The Wild factory very kindly lent us an A6 until we could take delivery of an additional A5. We have had in use one Kelsh Plotter for about eight months and an additional one for about five months. Therefore we have had the opportunity to study and learn of the possibilities and economy of these three different types of apparatus. We would like to mention right away that although our purpose is to show their advantages and possible disadvantages, we consider them all to be excellent.



LUIS STRUCK

As a matter of fact, the modern photogrammetric instruments for restitution are so precise that they have outrun the possibilities of the lenses and of the practical altitudes to be attained by our most modern commercial aircraft. This is the case when we consider the most economical altitudes at which we could fly to obtain maps with 20 or 30 meter contour intervals with scales of 1:50,000. For this purpose the flying scale is only limited by the resolution power of the lenses and the fineness of the emulsion which should permit a correct appreciation of the necessary detail for a full interpretation of the photograph. The picture scale is also governed by the practical altitude at which the photographs can be taken. For a conventional *C* factor of 1:750 for 20 meter contours,

* Paper read at Eighteenth Annual Meeting of the Society, Hotel Shoreham, Washington, D. C., January 9 to 11, 1952.

for instance, the economical flight altitude would be about 49,000 feet. This corresponds to more than the present practical altitude limit of commercial photographic flying. In the case of 25 and 30 meter contours, we obtain an economical flying scale corresponding to practically the highest altitude attained even by the most advanced jet propelled military aircraft. It is therefore now a question of improving the resolution power of lenses and fineness of film emulsions as well as the possibilities of high altitude flying, to take advantage of the full precision possibilities of our modern photogrammetric instruments.

In the U.S.A. the best known of the three types mentioned is very likely the Multiplex. In our opinion the best name that could be applied to the Multiplex in photogrammetry would be the photogrammetric "Work Horse." It is a work horse in every sense of the word. It will take the most severe work, will do it well enough and will do it economically. Its operation is extremely simple and easy to understand even by people who are not familiar with the more advanced principles of photogrammetry. It offers a unique possibility of convincing a possible customer interested in a photogrammetric job of how well and how accurate and easy this can be done as compared to standard ground methods. This alone gives it a definite value for selling purposes which in the case of a commercial mapping organization can be of tremendous importance.

But besides the above, the most unique feature of the Multiplex in our opinion lies in its possibilities for bridging. We recall one occasion in which due to unfortunate circumstances the intermediate ground control was lost, and we had to bridge six photographs with four points in the first pair and only one point in the last pair. The plotting scale was 1:10,000 and contour interval five meters. There was no time to obtain additional ground control, and so our Chief Multiplex Operator was requested to make the map using the ground control available plus whatever topographic interpretation could be taken advantage of, to obtain the map. Fortunately we had a river running through all the photographs with a very even grade of descent (Figure 1). The job was done although it taxed the abilities of our operator to the utmost. But it was done in time and to the satisfaction of our customer within the specified accuracy specifications. Needless to say that our operators were not on speaking terms with us for quite a few days afterwards.

The average production from operating four Multiplex plotters on one shift and three on a second shift, that is with seven operators, has been of about 125 square kilometers or 50 square miles a week, plotting five meter contours at the scale of 1:10,000 on extremely difficult and rugged mountainous country. This included the necessary orientation and all preliminary preparations for the restitution.

We have used the Multiplex for maps to be done at a final scale of 1:2,000 with two meter contours. In our opinion, however, this is stressing the possibilities of the instrument as it is most economical and most advantageous for scales up to 1:5,000 with five meter contours. Beyond that, it is our experience that a restitution can be done more economically and much better with the more precise instruments such as the Kelsh Plotter and Wild Autographs. For 1:2,000 mapping with two meter contours we found the Multiplex to produce about one third of the amount of work that can be done with an A5 machine. Besides this disadvantage in production the interpretation of the topography and planimetry is not nearly as good and correct as with the A5. The contour lines take a very rounded appearance in the Multiplex while in the A5 they follow a typical photogrammetric pattern.

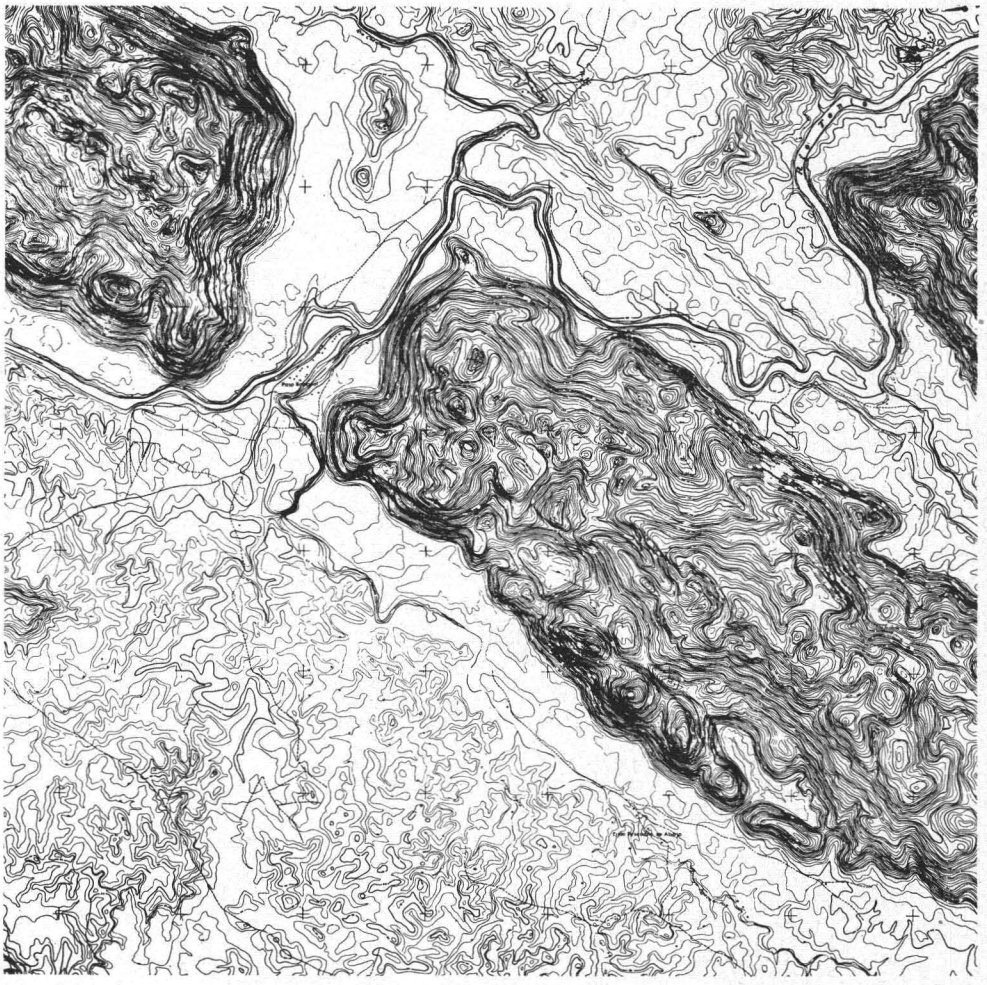


FIG. 1. The location of the Papalopan River Dam, one of the largest under construction in the world. The project can be compared to that of the TVA of the American Government. The map was made through the use of the Multiplex to compute the capacity of the reservoir. The tremendous amount of small hills and depressions will be noticed. These would have made work extremely difficult by ordinary ground surveys. The dam is being built at the lower left part of the slide where the Tonto River breaks through the ridge formation. The map scale was 1/10,000 with five meter contours, and the flight altitude 12,500 feet.

We have heard of cases where the Multiplex was used to make contour maps of two foot interval at the scale of 1″ equal to 100 feet. In our opinion it is a wrong application of the instrument. This type of mapping should at least be done in a Kelsh Plotter which shows a decided improvement over the Multiplex in definition and accuracy of observation, offering as well the advantage of a larger working scale, because the map can be drawn up to around five times the negative scale.

The Kelsh Plotter is a typically American instrument. It is sturdy, simple, and essentially practical in its operation. We have used it mostly in preparing photogrammetric maps of cities at scales of 1:2,000 with one and two meter contours. As far as the flying altitude of the photographs is concerned, we have been able to use practically the same C ratio as we use for the A5, that is about

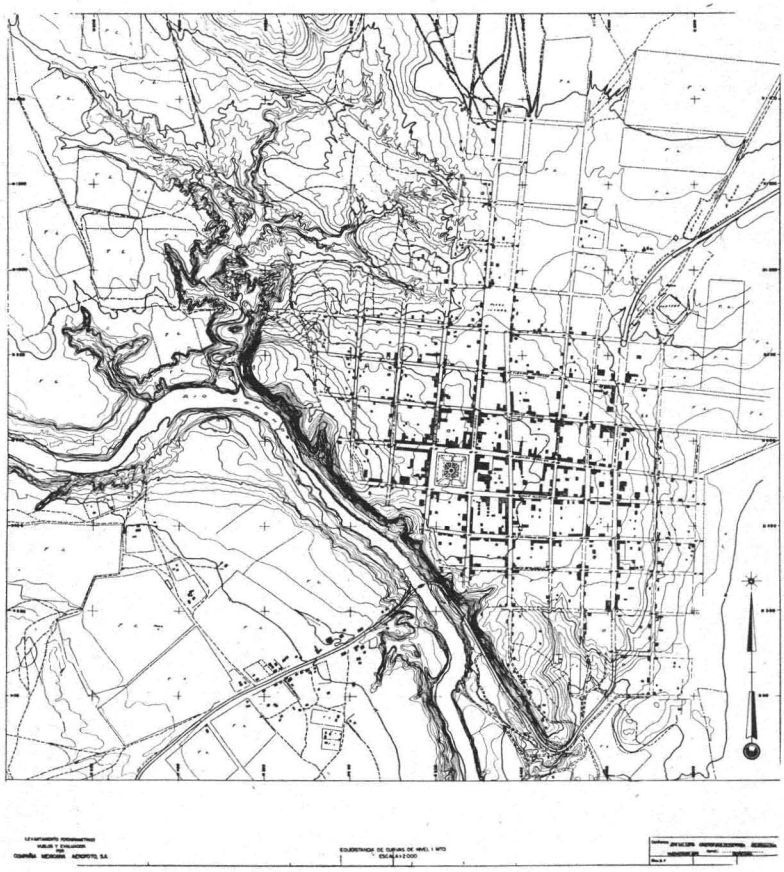


FIG. 2. The town of San Fernando in northern Mexico. The map was made for the installation of drainage and water facilities. The original was made at the scale of 1/2,000 with 1 meter contours, by the Kelsh plotter. Flight altitude 3,500 feet.

1:1,000 and up to 1:1,200 (Figure 2). Its output in our experience is about one half of the one corresponding to the Wild A5 Autograph.

For its possible improvements we suggest the convenience of providing scales and graduations to measure and record the tilts, crab, etc. of the stereoscopic pair after it has been adjusted. This would be a tremendous advantage whenever necessary to replace the stereoscopic pair for any subsequent correction or completion of the map. At the present there is no possibility of recording the data of adjustment; this is a serious disadvantage for such cases as just mentioned.

After writing this paper the author had a chance to see at this meeting a new device installed on a Kelsh Plotter. This consists of level bubbles with reading diagram scales. This will very likely be a great improvement towards the solution of the deficiency mentioned above.

Another disadvantage is the impossibility of working at less than four times. nor more than five times the scale of the diapositive; this necessitates a laborious reproduction procedure to bring the final maps to the desired scale. The use of a pantograph on an adjoining table might be a possible solution. However, we believe that this might lead to a loss of accuracy. The Italian firm of Nistri has recently put on the market a patented device to allow for electronic con-

version of the restitution scale to the final map scale, but this is still a rather expensive equipment, although it may prove to be a development towards the right solution in this connection. It is advertised for use with Multiplex equipment, but could very likely be adapted to the Kelsh Plotter as well.

The same disadvantage of course applies to the operation of the Wild A6 which we found to be a good instrument for medium scale plotting with contour intervals as low as one and two meters. In other words, in our experience the A6 has a very accurate possibility of measuring altitudes, but it is rather restricted

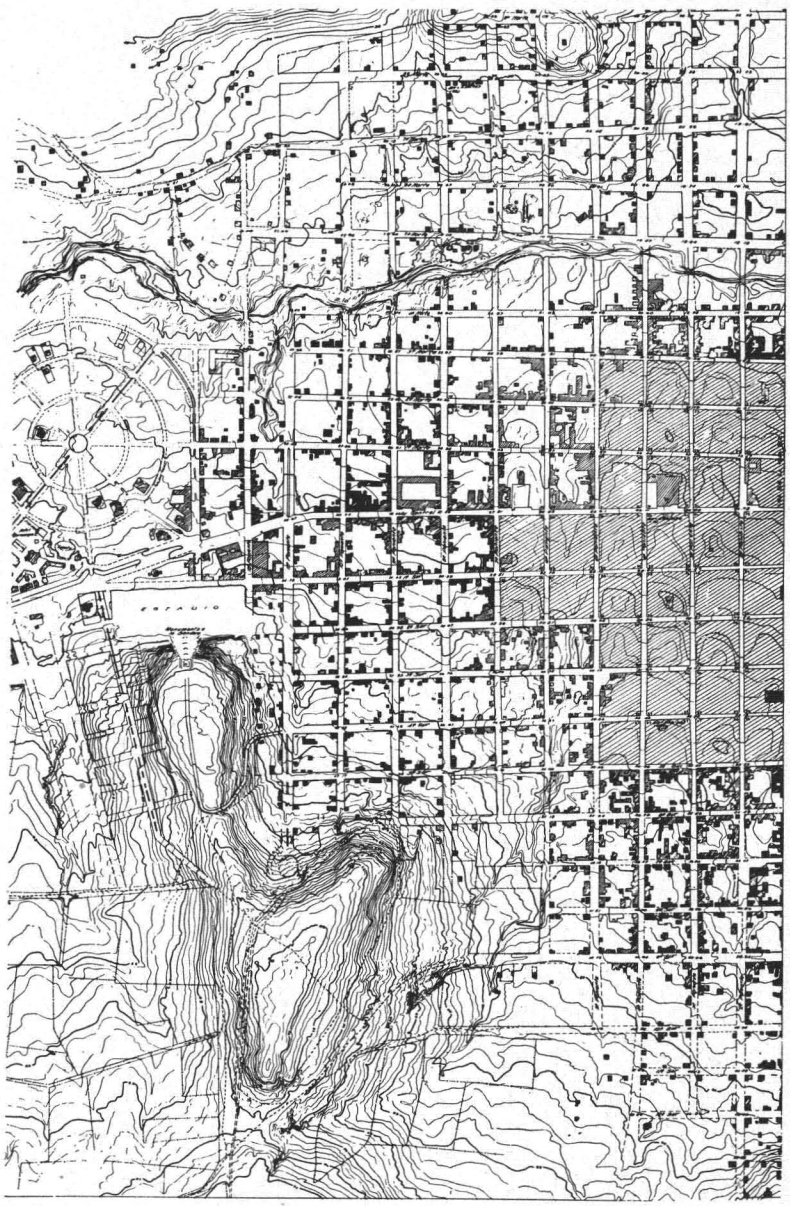


FIG. 3. The town of Tuxtla Gutierrez in the SW part of Mexico. At the same scale and contour interval of 1/2,000 and 1 meter, flight altitude 2,500 feet and done for the same purpose as mentioned with the Wild Autograph A-6. The shaded areas correspond to the blocks of built up areas.

in its possibilities of plotting large scale maps due to the necessity of producing enlargements which necessarily greatly reduces the planimetric precision.

There is one feature in the A6 that in our opinion is superior to any of the other instruments mentioned, even the A5. This is the clearness of its optical observation system which permits the drawing of contour maps in terrain of extremely little contrast, such as desert country where the Multiplex, the Kelsh Plotter and even the A5 might fail. It is an excellent plotting instrument for vertical photographs when it is desired to produce medium scale topographic maps of high precision. We found its output to be about 65% of the one corresponding to the A5.

If in the family of photogrammetric instruments the Multiplex could be named the "Work Horse," and the Kelsh Plotter and Wild A6 could be called "Working Gentlemen," the A5 is undoubtedly the "Aristocrat." It is the universal plotting machine that will do anything that the other instruments can do and do much more, more accurately, much quicker and deliver the final map at the desired scale without any necessity of further reproduction or enlargements and without restriction to vertical or tilted photographs, aerial photo-

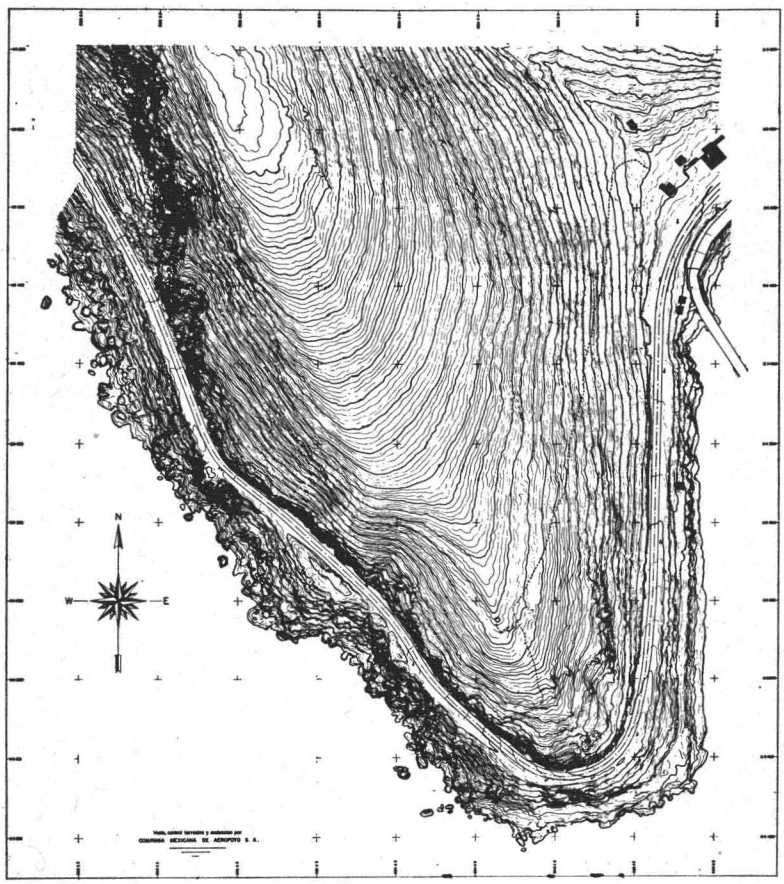


FIG. 4. A survey at the scale of 1/500, 50 centimeter contours of a peninsula in lower California for a harbor construction project. The Wild Autograph A-5 was used. The flight altitude was 2,000 feet. Illustration was reproduced from a blueprint. Note the cliffs on the Western side of the peninsula, that made an accurate terrestrial survey almost impossible. A few days after this map was finished a large part of those cliffs was blown up with dynamite for the construction.

graphs or terrestrial photographs. In other words, it is the universal plotting machine to be used for any kind of photogrammetric work that can be encountered in practice. It solves the orientation problem of one stereoscopic pair in a most accurate way, and it also provides excellent bridging possibilities.

The A5 is suitable for the production of aerial photogrammetric maps up to scales of 1:500 with 50 centimeter contours. We had a chance to do a job like this of a peninsula in connection with the study and construction of harbor facilities. The accuracy was of the highest importance because the map was to be used as a base for the computation of rock excavations and all the construction work in connection with it, which involved a considerable amount of money to be paid to the contractors. The photographs were obtained at an altitude of about 2,000′ and we used small white circles of 50 cms. diameter painted on the ground for control. They showed up remarkably well on the photographs and the map was produced to the entire satisfaction of our customer and drawn directly at the scale of 1:500. See Figure 4.

We used the A5 extensively in connection with railroad location throughout some of the most inaccessible and rugged country in Mexico, for the study of the new railroad between Durango and Mazatlan. This study was done for the Bank of Mexico which employed as consulting engineers the firm of Ford, Bacon and Davis who subcontracted the services of the well known firm of Coverdale and Colpitts. This latter company sent one of their best and most experienced engineers to Mexico to make extensive studies, and under his recommendation it was decided to study an alternate location of the railroad following the Presidio River with a gradual rate of descent from the highest part of the Sierra Madre mountains of about 11,000′ altitude to practically sea level. The Presidio River cuts through the mountains in a series of tremendous canyons and vertical cliffs where any other kind of survey method would have necessitated an enormous amount of ground topography and a considerable length of time for the compilation of the necessary maps.

Our company did the job exclusively by photogrammetric methods and all the plotting was done with an A5 machine at the scale of 1:2,000 and two meter contours. The differences of elevation within one stereoscopic pair reached sometimes more than 4,000 feet which will give an idea of the character of the ground. Ground control was established by a series of triangulation points located practically all on the top of the river canyons which were much easier to reach than the bottom of the river. The country was completely uninhabited and we had to provide radio facilities for each field party and one main radio station in Durango which was in touch with the various camps twice each day. This was the only means to give the engineering parties doing the ground control, the possibility of keeping in touch with the outside world for any emergency. In our opinion this survey was one of the most difficult railroad location surveys that have been carried out anywhere, and it was done to the entire satisfaction of our customer by the use of the Wild A5. Its tremendous possibilities and magnificent accuracy could not have been demonstrated any better (Figure 5). The paper location on these maps determined the abandonment of this route in favor of another one that had been studied, and recommended by the engineers of the Ministry of Communications, and which resulted in a considerable saving in construction cost. The maps for the line were also provided by our company by photogrammetric methods but since the terrain was not as precipitous and the facilities for establishing ground control were quite better, it was possible to use Multiplex equipment.

When one has to consider differences of elevation of the kind mentioned above, the matter of *C* factor becomes a rather undetermined quantity. As a

FIG. 5. A part of the Presidio River Survey for the location of the railroad between Durango and Mazatlan. Extremely difficult terrain full of inaccessible cliffs and tremendous differences in elevations will be noted. The Wild A-5 was used with 1/2,000 scale, 2 meter contours and an average flight altitude of 8,000 feet above the ground. A terrestrial survey of the area could have been made only with a tremendous amount of survey parties and would have necessitated great mountain climbing ability; the time of the job undoubtedly would have been several times longer.

matter of fact, we have found that *C* factor is a very vague denomination, because in our experience it can vary to a great extent depending on the character of the ground, the quality of the photography, and the prevailing weather conditions. In cases where one deals with terrain of considerable contrast with little vegetation, and when the photographs are taken in ideal weather conditions with a practically clear atmosphere, the *C* factor for any photogrammetric instrument will likely be twice as high as when a terrain of little contrast has to be mapped or when the photographs are taken through a layer of smoke, dust particles or haze.

In planning a photographic flight for a photogrammetric project, it is therefore of the utmost importance to give due consideration to the above circumstances when selecting the flight altitude. In general, our experience has been that the *C* factors of 1:750 for Multiplex, 1:1,000 for A6 and Kelsh Plotter, and 1:1,200 for A5, are conservatively suited for favorable terrain and normally good quality of photography. They can be increased at least 30% for the best possible light conditions and the most favorable ground, and have to be decreased at least 30% whenever ground of little contrast such as desert country and highly wooded country are concerned, or when any atmospheric haze is encountered when taking the photographs.

Of great interest in the evaluation and study of the different possibilities of the photogrammetric instruments has been the matter of a photogrammetric camera. We have used for all of the above described work two Fairchild Carto-

graphic Cameras furnished with 6″ metrogon lenses. These cameras have proven to be reliable in their operation and have given us negatives that served their purpose for the plotting of maps within the required accuracy. This corresponded in general to standards as set forth by the American Society of Photogrammetry. For the Multiplex they have been transformed through the conventional reduction printer while for the use of these negatives with the Wild A5 and A6 we obtained from the Wild Factory the special transforming apparatus which corrects the distortion curve of the Metrogon lens through the use of a compensating plate. For the Kelsh Plotter the diapositives are obtained by contact prints from the negatives and the distortion curve is taken care of by the special cam devices provided for this type of lense.

The author is grateful for the opportunity to describe the experiences and possibilities of the most modern photogrammetric instruments and their application in Mexico. It is hoped that the descriptions will prove of some value to all photogrammetric institutions faced with similar problems.

REPORT ON AIRBORNE PROFILE RECORDER*

Harry T. Kelsh, U. S. Geological Survey, Washington, D. C.

ONE of the many problems with which the Geological Survey is faced, is to find a means of reducing the field costs of supplemental vertical control for our mapping work, in view of the ever-mounting labor cost. As a result, we are extremely interested in any development which in any way promises reduction in this cost. In the summer of 1950 we conducted an experiment to determine the possibility of obtaining reconnaissance vertical control from the air. It was decided to combine the experiment with an actual project, in an area large enough to furnish a good basis for evaluation of the results.

This experiment involved the airborne profile recorder.

Not too long ago we used to say that the miracles of yesteryear were the commonplaces of today. But today the wheels of progress have so speeded up that it is difficult to complete an experiment, and report upon it, before we have not only accepted the miracle as a commonplace, but in the meantime have even demanded improvements and actually have obtained them. As a result the report usually lacks "punch." We are no longer talking about something new. Furthermore, today's electronic developments, while wonderful, are not as spectacular as many of the previous developments. We all know how much more exciting it is to watch an old-time steam locomotive tearing down the rails than it is to see the much more efficient diesel engine of today go by.

The airborne profile recorder system uses a regular airplane (a twin-motor Hudson Lockheed was used for this experiment) and nothing outside the plane and, indeed, very little inside, indicates that it is anything but a routine airplane in flight. It doesn't even have a long string with an egg on the end of it trailing astern, such as we see in magnetometer surveys.

Underneath the belly of the ship is a hyperbolic reflector, four feet in diameter, at the focal point of which is a $\frac{1}{2}$″ broadcasting antenna, designed, when in operation, to radiate a narrow beam of energy towards the earth. The cone width of this beam is about $1\frac{1}{2}°$. But this reflector is within the body of the plane and is enclosed by a plastic cover streamlined into the general shape of the ship. Inside the plane itself we have a few instruments in box form, looking like ordinary shoran equipment, with a number of the usual dials, and what

* Paper read at Eighteenth Annual Meeting of the Society, Hotel Shoreham, Washington, D. C., January 9 to 11, 1952. Publication permitted by U. S. Geological Survey.