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*

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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

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appears to be a recording barometer. This last actually is the profile recorder. In addition, there is a 35 mm. camera equipped with a principal point mark. The hyperbolic reflector and this camera are so mounted as to point straight down, as nearly as possible, when the airplane is in operational flight.

The easiest way to describe anything is to compare it to something with which we are familiar. The system of the APR closely resembles that which has been in use by the Coast and Geodetic Survey for many years, in its hydrographic work. A ship carrying electronic sounding equipment sails along the surface of the water, which establishes an almost perfect datum reference plane. A radar beam is directed towards the ocean floor below, and the returning impulse is recorded within the ship. The water surface datum is almost absolute, but there are certain minor deviations. The phase of the tide must be taken into consideration, and for close work the magnitude of the waves should also be considered. Lastly, there must be equipment in the ship to indicate the position of any sounding, so that each sounding can be correctly plotted on the map or chart.

In the air we have no such convenient datum. The nearest we have to this is an isobaric surface, or surface of equal air pressure. If there is no movement of the air mass, we can fly a level line by maintaining a constant reading on a sensitive altimeter. If there is movement of the air mass, to fly such a level course, or to reduce the results of maintaining a constant pressure altitude to such datum, requires a pressure correction somewhat similar to correction for tide. As the profile lines are flown, a record of the amount of crab necessary to keep the plane on its designated course is kept, and from this a correction is worked out for the resulting rise or fall of the plane due to keeping to an "*equal pressure*" altitude.

As a further comparison with the water-borne sounding device, the plane, even in still air, cannot maintain a completely horizontal course. It bobs up and down by as much as 50 to 150 feet. To take care of this weaving, an additional instrument called a datum stabilizer is included in the general equipment. This automatically corrects for minor deviations, so that the recording tape of the profile recorder shows a uniform, and correct line, in spite of such weaving.

Lastly, to obtain a record of points along the profile so that these may later be positioned on the map, the 35 mm. camera is operated during flight, taking photographs with 55% to 60% forward overlap.

It must be understood that the initial elevation of the plane is secured completely independent of any barometric pressure measurement. Before starting a line, the ship first flies over a known elevation, usually at a height of about 5,000 feet, which is enough to rise above the usual turbulence area. The radar beam transmitter is turned on, and the distance between the plane and the ground is determined. With present equipment, this distance is probably correct within something less than ± 10 feet. The barometric pressure at that point is then read and recorded, and the ship is now ready to fly a course.

As this was a completely new experiment, we first laid out a test figure "8" within the general area which we proposed to cover, during the season, with this method. This area lay just south of Fairbanks, Alaska. Along the perimeter of this figure "8" were certain known elevations on lake or other water surfaces. To this, additional water level elevations were added.

In the field we quickly found that it was not possible to complete satisfactorily the test on this figure "8." To get from the north to the south half of the figure required flying over mountain passes, through a region of completely different aerological conditions. As an indication of the general conditions in these passes, one of them bears the very descriptive name of "Windy Pass."

We therefore revised our test to cover just the upper circle of the figure "8," the perimeter length of which was about 300 miles. This test area lies completely in the central valley area of Alaska; however, this does not mean that there were no material differences in elevation. Test point elevations ranged from 300 to 2,100 feet in altitude. Our test conditions provided that repeated flights over these test points should not vary more than ± 20 feet in the elevations determined from the airplane, thus demonstrating repeatability of reading. Furthermore, in absolute elevation the mean results in feet, of three or more determinations, should not differ from true elevation by more than $\pm(10+\sqrt{M})$, where M is the distance in miles from the initial point. The results submitted were pleasingly surprising. The actual elevations of nine test points were determined on this perimeter by ground methods of surveying. The following comparisons were obtained:

Point	Miles from initial elevation control	True elevation	APR	Diff.
1	40	313	306	− 7
2	56	333	323	−10
3	74	343	343	0
4	96	550	544	− 6
5	114	1,757	1,780	+23
6	146	2,116	2,110	− 6
7	148	1,790	1,792	+ 2
8	70	841	837	− 4
9	48	715	725	+10

Six additional test points were included in two horns extending to the south of this perimeter but on the same side of the mountain ranges. Equally good results were obtained.

In the test just described, however, it should be noted that the test points were water surfaces; hence, spreading of the beam, or slight tilt of the plane and/or equipment, would only have a minor error producing effect; nor would there be any possibility of echo from points other than the one indicated by the principal point on the photograph taken over the target. Incidentally, the relative positioning of the 3.5 mm. photograph, with relation to the profile, is secured by a tick mark which is automatically registered on the profile tape as the exposure is taken.

With this test successfully completed, we then proceeded on a regular profiling of the desired area with lines spaced at 16-mile intervals, flown in a general NE-SW line pattern. About 70,000 square miles were covered during the comparatively short season, indicating the speed with which such reconnaissance elevations may be secured by this method.

Because the profile lines require datum correction, it would be most desirable to fly between known elevations. Then, as with a ground traverse, a straight line adjustment of the closing error could be made. But this, of course, is not always possible, and with the very scarce control in this particular area, it was not possible at all. Consequently, perimeter flights around the area were made which, although broken in direction, did proceed from one known control point to another, although the distance between these points was very considerable. Thus, for example, on the north side of the area a meandering line was flown down the Yukon from the known elevation at the Canadian border to Tanana on the same river, and these data were used to adjust the "spur" flights to the Yukon from known starting elevations at or near Fairbanks.

I have reported the excellent results obtained over water surfaces. The next problem is—how accurate can the results be over varying land conditions? We quickly found that the increased intensity of the returning signal beamed to water resulted in an apparent rise of the water surface by some 10 to 20 feet. Also, narrow as the beam is, it covers about 150 feet with a flying height of a mile, and much of the flying had to be done at an altitude greater than that, due to the amount of ground relief. As a result, a returning signal from a sharp peak may actually come from a point down the slope, and vice versa from a sharp ravine. Any tip or tilt of the airplane adds materially to the possible error, since the camera and transmitter-reflector are fixed in position.

Ground cover affects the recorded distance.The beam appears to penetrate only a proportion of the tree heights, even in wooded areas of moderate density.

A frank statement voluntarily offered by the contractors, to the effect that APR results must be interpreted and evaluated, for maximum usability, should not, however, be considered as a serious reflection upon the value of this system. If we do not attempt to use the profile as such, but on that profile pick points where the factors contributing to possible error are manifestly held to a minimum, a series of elevations can be obtained which, within the general limits of the system, may be accepted, and used with confidence.

At this time, in the Geological Survey, we are in the process of making a templet assembly of a portion of this Alaska area, having used spot elevations obtained from this APR work as a basis for scaling, by Multiplex extension, the Trimetrogon verticals previously obtained over this area. The templet assembly, of course, covers both the verticals and their wing pictures, and from the horizontal positions which we are thus obtaining, we expect to obtain additional elevations by use of these wing pictures in the Wilson photoalidade, and finally to make a contoured map at a 1:250,000 scale, with 200-foot contours, of a small area recently covered by ground methods, so that the end product can be directly compared.

During this office test period, we have been learning to better evaluate, and to select, elevation points of desired characteristics. Definitely we can say that we have been able to pick out enough points along the profiles to establish the validity of this system in securing spot elevations, in a sufficient number, to be of very real use. Present indications are that the range of error on these points was somewhere between ± 20 to 35 feet.

While the office work has been in progress, considerable equipment improvements have already been attained. The reflector and camera are now gyro-stabilized. Control of variations of intensity in the returning signal has been worked out, so that there is no longer a jump in the record as water surfaces are crossed. The original curvilinear profile recorder has been replaced by a larger, rectangular coordinate recorder, which permits closer reading. The 35 mm. camera has been retained in the system, although possibly a larger picture size might have additional value; but the camera has been equipped with a considerably larger magazine. More general knowledge of the problems has been acquired. This includes opinion as to the desirable length of lines. It is now felt that where possible these should be limited to somewhere between 100 to 150 miles. But, in view of the considerable number of variables still not eliminated, it is felt that most of these improvements have so far tended to make the data secured more reliable within the 20 to 35-foot range, without greatly reducing that range.

Unquestionably there will be additional improvements, and the APR method should take a definite and valuable place in the field of reconnaissance mapping.