THE USE OF AERIAL PHOTOGRAPHY IN THE HYDROGRAPHIC SERVICE

by
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(Translated from the Portuguese).

The assistance which aerial photography to-day lends to the Hydrographic Service in its different operations such as surveying, the compilation of charts, various methods of investigation and study, etc. has reached such proportions that it is not exaggerated to place it in the foreground of the different resources on which the Hydrographic Service depends to achieve its aims. For the last five years, during which it has been employed in an ever-increasing degree, its importance has become more and more evident.

As early as 1922 the Geographic Service of the Army published a map of the Federal District which, even in Europe, served to demonstrate the possibilities of aerial photography for surveying purposes; but it was only on 26th March 1933 that the benefits which might accrue to hydrography from this method were fully realized when, at the instigation of Professor Emilio WOLF and under his supervision, the aerial photographic survey of the whole of the Eastern part of Ilha Grande was carried out.

During this work, in which I took part as observer, 47 miles of coast were surveyed in 160 minutes of flight, from the take-off at Rio de Janeiro to the landing at Angra. At that time we were completing the survey of the zone now included in Chart N° 1604 — *Angra dos Reis e Jacuacanga* — an area which does not correspond to even a sixth part of the stretch which was photographed in those few minutes, and in which we had already spent some seven months in soundings and detail surveys alone.

Until then, the most expeditious method of coastlining was that which we call the "corrida da bandeira" (flag track) method, by which three or more observers, installed with theodolites at stations linked up to the triangulation, follow the track of a boat moving along the coast measuring angles from a fixed origin every time the boat hoists a flag, the intersections obtained being used to define a point of the coast-line. An officer in the boat selects the most appropriate points for the intersections, varying their interval according to purely local criteria; he also makes a rough sketch of the coastline between each two points so that it may be drawn in with all its intricacies on the plotting sheet.

It was also possible to lay off the shoreline by taking sextant angles from each selected point, fixing the positions by graphical solution of the Snellius problem. Those methods, however, were rarely sufficient, and in practice it was always indispensable to survey small stretches of the coast by means of tacheometry, in which case the shoreline has to be followed on foot by the operators laden with instruments, stadia, signals, etc.

The chief disadvantage of those old methods resides in the multiplication of computed or graphically constructed vertices and secondary points linked up to the triangulation until they resolve into a point for each 50 or 100 metres of shoreline; it was also necessary to land and to approach the coast at frequent intervals, a not always easy and sometimes impracticable matter. If acceptable results are obtainable by those methods in surveying bays or sheltered areas, on the other hand, where the coast is open and battered by the ocean, the same methods fail altogether.

Aerial photography has revolutionized hydrographic methods by surveying 150 kilometres of coastline per hour without the least obligation to take into account either its accessibility or inaccessibility and with greater faithfulness and the same wealth of detail whether on the most unprotected coast of the ocean, in the calm interior of a bay, or along the banks of a river.

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Aerial photography supplies directly an abundant number of ground marks of sufficiently accurate position, thus greatly curtailing the duration of the sounding operations. The photographed coast offers such a degree of accuracy and detail that soundings by simple alignments and direct reference to the shore line are greatly increased in practice.

Often the photograph itself indicates the existence of submerged shoals and reefs — colour, breakers and current movements being the chief elements of indication. The contours of shallow banks are well-defined. It was never our intention to apply aerial photography to this kind of investigation, for which special conditions of light, sea and wind are required, besides the choice of the most favourable times; but the photograph published in N° III of these *Annaes*, illustrating the description of Professor Emilio WOLF's "Stereograph", when compared with chart 1501 — *Cabo Frio* — shows the possibility of perceiving the gradation of tints for depths down to 8 metres.

It is unfortunately impossible, as is often demanded by those unfamiliar with surveying, to deduce from the photographs any concrete value as to the depth. However, this does not exclude that science may one day lead us to this result, which is of such incalculable importance for hydrography.

It is not only in the survey of the coastline and in the localization of the soundings that aerial photography renders inestimable services; its benefits extend to many other sections of hydrographic activity. While formerly it was necessary to effect a careful reconnaissance previous to disembarking in the area to be surveyed, to-day the survey is undertaken with a perfect knowledge of the coastal configuration and the main obstructions. A projected triangulation may be studied with full probability of its being carried out; in the draft the positions of the vertices may be laid off for the correct form of triangles and their intervisibility; the altitudes at which they will be located and the nature of the terrain are data known in advance; the most sheltered point for landing and the best way to the station of installation may be identified beforehand. From an inspection of the photographs the most suitable terrain for the measurement of the base with due regard, besides, to its correct amplification, may be ascertained. The movements of the ship and boats may be correctly effected from the outset, which considerably lessens the work. On arriving at Cape Frio, with the sole resource of the above-mentioned photograph we proceeded on the *Tte Lahmeyer* through the channel existing over the bank near the island, with scarcely half a metre more than the ship's draft.

Aerial photography, besides the aid which we already know it to bring to planimetric surveys, serves with no less efficiency in altimetry, through the stereoscopic study of superimposed plates. For the recently published chart N° 1701 — *Porto de Santos* — not one single levelling operation was carried out in the field during the survey, all the altitudes having been measured and all the contours drawn by means of stereophotogrammetry.

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Among the Hydrographic Offices themselves the mode of application of this wonderful auxiliary differs both in method and intensity of use. With us the photographs are always made in advance so as to permit the preparation and study of the hydrographic expedition for which they are intended. During the development of an expedition the aerial photographs are furthered and completed in order that they may be consulted one year beforehand. By arrangement with the Naval Air Force, the latter supplies the plane and pilot, whereas the camera operator is from the Hydrographic Service; this is the best combination by which the photographs obtained may serve the purpose intended.

The cameras used are always of the single-lens type, ZEISS or WILD, focal length approximately 21 cms, format 18 × 18 cms. Obtaining photographs from a single-lens camera is easier and more accurate, although in some cases this procedure may require more flying time.

With regard to scale, we never consider obtaining less than 1:20 000, which represents on an average 4,200 m. altitude of flight. All ground details are sufficiently well defined by the use of this scale which has been adopted for all ordinary cases of survey. When the plotting sheet must be compiled to scale larger than 1:20 000, as in the case of ports and rivers, the photography is effected so as to correspond to the necessary scale.

The photographs once obtained, a simple mosaic of the whole of the photographed region is constructed, the photographs being pasted directly on sheets of paper, orienting them solely from the common portion of terrain which appears in them. During the flight care is taken that this overlapping is about 60 % in the direction of flight and 20 % for the parallel strips.

With modern cameras which permit photographs to be easily obtained with less than 2° inclination from the vertical, (the plane being equipped with a statoscope guaranteeing a constant altitude of flight and thus uniformity in the scales), the flight having been carried out according to a pre-established programme, the assembled mosaic answers all requirements. With the scale to which work is normally carried out, an assemblage of photographs pasted in mosaic on a sheet of paper of ordinary size (1.00 × 0.80 m.) will seldom show distortions exceeding the limits ordinarily allowed in the graphical construction of the chart.

As an accurate triangulation of the terrain has been made which enables one to place the survey in its true position duly proportioned to the surface of the Earth, one has the possibility of rigorously determining the scale of the photographs and of verifying the mosaics, correcting them for any possible imperfections.

For this it is sufficient that the triangulation contain at least two points indispensable for its employment. In plotting the vertices, identified points on the photographs or ascertainable from the latter should be selected. On occupying the vertices for the measurement of the angles, all possible sights around the horizon should be taken, in order that all islands, peaks, etc. may have their positions checked by tangents. Nothing else is necessary for sketching-in the whole shoreline on the chart.

The density of the triangles naturally varies in accordance with the scale of the survey, but it may be asserted that their number never exceeds half a triangle per square mile in large-scale surveys. In operations along the coast, the normal scale of which is 1:100 000, they may have sides as great as the nature of the terrain allows, provided the linking up with the mosaic, confirmed by tangents and intersections from the vertices, satisfies perfectly the accuracy of the graphical construction. This has been established by comparison between the direct mosaics and those constructed with the rectified photographs.

In our case, in which the sets of charts are on a maximum scale of 1:300 000, continuous triangulation would not be necessary if it had not to serve also for various other scientific purposes. One determination of geographical position, say every twenty or thirty miles, would provide a sufficient check on the mosaics. It is true that in the very mountainous zones where we have been working until now, deviations of the plumb line exceeding a dozen seconds such as we have frequently met with, would perceptibly affect the construction; but this error might be reduced by appropriate selection of the terrain. It is always much easier to link up a few geographical positions so as to be able to accept as less than 2" their error of deviation from the vertical, (which would not be taken into consideration in the graphical construction), — than to establish a rigorous and continuous triangulation along coasts which offer almost insuperable difficulties from stretch to stretch.

For the stereoscopic realization of the photographs our Service uses chiefly a modification introduced in 1933 on the Stereocomparator, an instrument primarily intended for the study of plates from photo theodolites and which was altered for use with films produced by aerial cameras.

Knowing the principle and construction of the Stereocomparator, its utility for photographs taken from aircraft is obvious. Instead of measuring with its index mark distances to the phototheodolite, close on the horizontal, we now measure vertical distances from the plane to the ground; — allowing us to trace the altitude contours continuously.

The changes introduced are briefly as follows: — removal of the graduation and vernier of the y axis; increase of the path of the microscope support so as to reach the extremities; removal of both plate-holders with their screws and circular-motion verniers; enlargement of the plate-holder support frames on both sides to the size of 18 × 18 cms; removal of the plane table and support; welding of four metal sectors on the supports of the new plate-holders in order to adapt metal pieces as supports for the new plate-holders; making of two metal pieces similar to the plate-holders of the radial triangulator, with two steel pivots for these plate-holders; adaptation of two plate-holders of the radial triangulator for work on the Stereocomparator, cut so as to permit their introduction and operation above the support of the periscope; adjustment of the metal pieces so that they may revolve in easy frictional contact and in perfect fit on the welded sectors, and exactly about the centre defined by the rotation of the steel pivots, mounting of two endless screws to operate the circular motion of the plate-holders, working in open racks in the metal pieces; various adjustments, placing of stops, etc., in order to allow the easy rotation of the whole and its introduction and operation over the periscope support; increase towards the left of the special travelpath of the left-hand plate-holder to permit the use of overlapping from about 20 %; adaptation of new 18 × 18 cm. drawing board; modification of the pencil device to write freely.

The principle of the stereocomparator as laid down by Professor Emilio WOLF in Volume III of the *Annaes* is the same as that on which the modified stereocomparator functions; also the discussion of the results and errors committed in the heights are applicable to our instrument, with the advantage in the latter of more precise construction enabling the parallaxes to be measured and the altitudes to be determined straight away.

When working with the modified stereocomparator it is necessary to measure the base, *i. e.* the distance between the centres of the plates on the graduated scale of the *xs* of the instrument, as a function of the scale of the photographs obtained with the mosaics. The altitudes may be calculated by the fundamental formula :-

$$h = \frac{bf}{a}$$

for the peaks and different points when it is desired to increase the accuracy of the results. Between the points of determined altitude, the parallax is then caused to vary in proportion to the altitude.

The correction curves for errors arising from the tilt of the optical axis are drawn as explained in the article cited concerning the stereograph, which facilitates reduction to sea level to which the photographs are perforce connected; the instrument is thus rendered independent of this sole important cause of error.

In spite of the disadvantages of great weight — of little importance since the instrument is not required to be a portable one — and of high price, as being of special construction, the modified stereocomparator affords several advantages of operation. For instance :-

(*a*) It is possibile to work either with the negative films or with positive paper prints.

(*b*) The placing of the photographs in the plate-holder adapted to the radial triangulator is effected exactly as with this apparatus; when working with negatives as in the usual case, it is unnecessary to determine the centre of the plates, this operation being done automatically and with the maximum of accuracy by the plate-holders themselves.

(*c*) The orientation of the plates is rigorous and graphically facilitated by the possibility of giving them a rotation without modifying the position of the centres; as in the radial triangulator, when the centres are placed in the alignment of the microscopes by the rotation of one of the plates, the maximum stereoscopic effect is obtained in the centre of the other. The plates remain rigorously oriented by the base without necessity to mark in one of them the centre of the other, or to effect any other graphical work. The microscopes also are by construction rigorously aligned with the base.

(*d*) The possibility of making the orientation rigorous, stereoscopically, remains even if the centres are over the sea and when it is not possible to mark them on the opposite plates, even if the overlapping is less than 50 % and when there is not on one of the plates the projection of the centre of the other.

(*e*) By the graduation and the vernier of the *xs* of the stereocomparator, the measurement of the base is rigorous whatever the overlapping of the plates.

(*f*) The adjustment of the vertical parallax may be freely accomplished during work, thus allowing the best stereoscopic effect to be obtained for each point.

(*g*) The microscopes are of great magnifying power (× 10) offering at the same time perfect contact of the mark with the ground ; very good perceptibility of detail.

(*h*) The drawing is made on separate paper of any kind, and may easily be changed.

The charts of Cabo Frio, Porto de Ilhéos, Porto de Itajahy and Porto de Santos, published by the Brazilian Hydrographic Service, are examples of altimetric surveys made entirely with this modified stereocomparator.

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