NECESSITY IS THE MOTHER OF INVENTION

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1. To consider carrying out a hydrographic survey by making use of some of the instruments that gunners employ when aiming their guns is not perhaps to be recommended. Everyone knows that shells only very rarely score a direct hit. However, this is exactly what was done in 1953 by the French Survey Vessel *Beautemps-Beaupré* (here abbreviated to *B.B.*) off the coasts of Mauritania in French West Africa.

Because of local circumstances, a satisfactory survey could not be achieved by merely employing the conventional methods available to surveyors in the 1950s. We were therefore obliged to deviate somewhat from the classic approach by combining these conventional methods with a wholly original method which we devised bearing in mind that the *B.B.* mounted three guns and had adequate gun direction equipment.

2. We were required to survey an area of about 600 km^2 off a barren, featureless coast where a violent sand-laden wind blew almost all the time reducing the visibility to a few kilometres. The area to be surveyed stretched along about 45 kilometres of coastline seawards to the 10-metre line which was 15 km out beyond a submarine ridge thought to be coralline and likely to prove dangerous.

The coastal marks which had been set up and triangulated the previous year were not visible in the better part of the survey zone on account of the atmospheric impurity. Furthermore the area between this submarine ridge and the coast had to be considered dangerous, at least initially, since in 1935 the *Seminole*, a hydrographic survey vessel on an exploratory mission, would most certainly have foundered there if the presence of rocks submerged under only 2 m of water had not been revealed at the very last minute by an abnormally large swell.

3. In view of the *B.B.*'s tonnage, one could not plan to have the ship herself run the sounding lines. Unfortunately, that meant losing all her advantages, since without too much risk it would have been possible to profit from the ship's ability to maintain a steady course and provide a stable platform, navigating in good conditions, with frequent fixes using predetermined triangulated shore positions. Thus it was necessary to run the sounding lines with the ship's survey launches, and this in spite of the fact that they would be moving blind, as they could not see the

triangulation marks. Moreover their survey parties were usually unable to make accurate optical measurements on account of spray, and finally the platform they provided was unstable in the very choppy sea, with wave heights of up to 1.5 m.

4. One solution would no doubt have been to work only when atmospheric conditions were favourable, that is to say, on days of flat calm, since it was the trade-winds that produced both the poor visibility and the choppy sea. However, this would have delayed the survey work enormously, and naturally the survey was an urgent matter — as it nearly always is ! Its object was to allow a government service to choose a coastal site from which ores could be exported by sea. One of the possible sites (nowadays designated Tanat) was the one to be investigated by us. It could, we thought at first sight, prove of interest since the surf there is not too heavy which is exceptional on this coast. The site was also to be examined because it was in all likelihood that in this neighbourhood some 200 years ago there had existed a trading post known as Portendick, of which no definite trace remains but which prospered to such an extent that in times gone by it was taken by force of arms by several nations in turn. This history led to the belief that it would be possible to establish port installations in the area.

5. To return to my narrative — the hydrographic problem was to survey the whole of Zone C (see figure 1). Zone B had been sounded by survey launches which had fixed their positions according to classical methods on previously triangulated landmarks in Zone A, an area that extended a little inland. But there remained Zone C, and here the lack of visibility prevented the use of classical methods.

It was thus decided that for this zone the sounding launch positions should be primarily fixed by bearing and by distance relative to the *B.B.*, these two coordinates being supplied by the ship.

In order to do this the *B.B.* anchored in turn in positions P, Q, R, S, T, *etc.*, which were each about 10 km from the shore.

At each of these anchored stations the *B.B.*, thanks to her stability as a platform, could determine her position by reference to the landmarks, taking advantage of short periods of favourable visibility. A sandy bottom was chosen so that the ship did not drag anchor even when it was at long stay. Every day, the wind slowly changed direction from NNE to NNW, and blew steadily with the result that the *B.B.* did not yaw. Thus her amount of swing and consequently her position, could be considered unaltered for as much as an hour at a time.

6. The method consisted essentially, then, of running sounding lines made up of a network of star patterns each of which was centred on one of the *B.B.*'s anchored positions.

To this end we set up trainable transit marks on the ship by erecting a wooden framework on the barrel of one of its guns. This framework was 12 m long, and at each end we fixed two large reflectors fitted with electric lamps of sufficient power to pierce the opaque atmosphere. An experienced gunlayer aimed the gun — and consequently the alignment

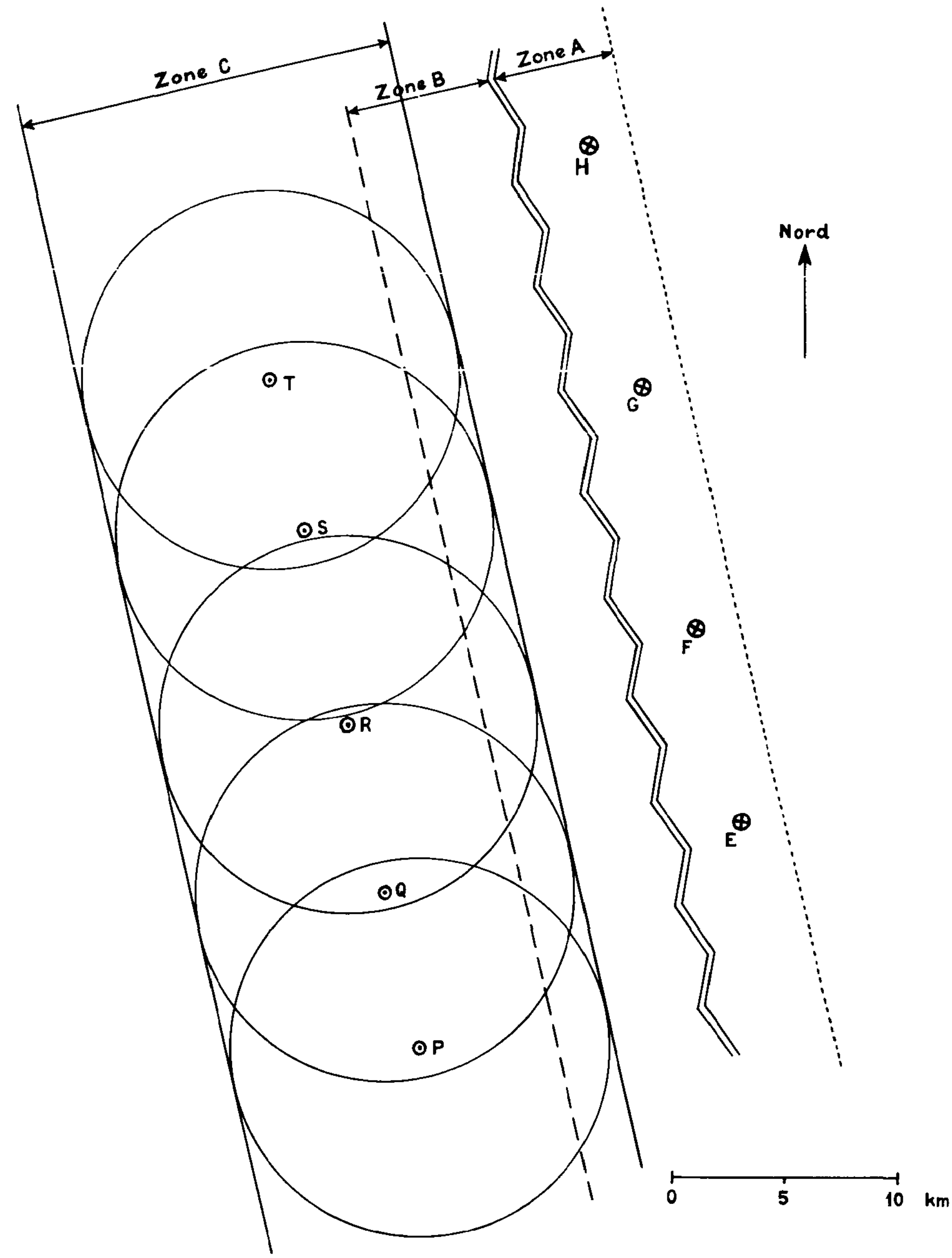

FIG. 1

Coastline.

Landward limit of Zone A (triangulated area of coast).

Seaward limit of Zone B (area of classical shallow sounding).

Limits of Zone C, the area sounded with the method described in this article.

Limits of the various sounding networks centred on the *B.B.*'s positions.

⊙ The *B.B.*'s anchored positions.

⊗ Triangulation marks utilized for obtaining reference azimuths and for calibrating the *B.B*'s telemeter.

of the attachment — in a constant bearing $c^\circ = a^\circ + b^\circ$, relative to a reference bearing a°, which was obtained by continuously sighting from the *B.B.* on a triangulation mark. Angle b° was adjusted during the course of operations, according to the course the launches were to follow for their sounding lines. For each particular case one of the reference signals (E, F, G, H, etc.) was chosen in terms of its greater distance from the vessel and its position in a quarter where the visibility was the least unfavourable.

The "Black" launch (she flew a large black flag), thus guided, could follow a straight course controlled precisely by this alignment. To expedite the work two other launches, one "Red" and the other "Green" worked abreast of the first, each following a course at angle of d° from the "Black" launch's course.

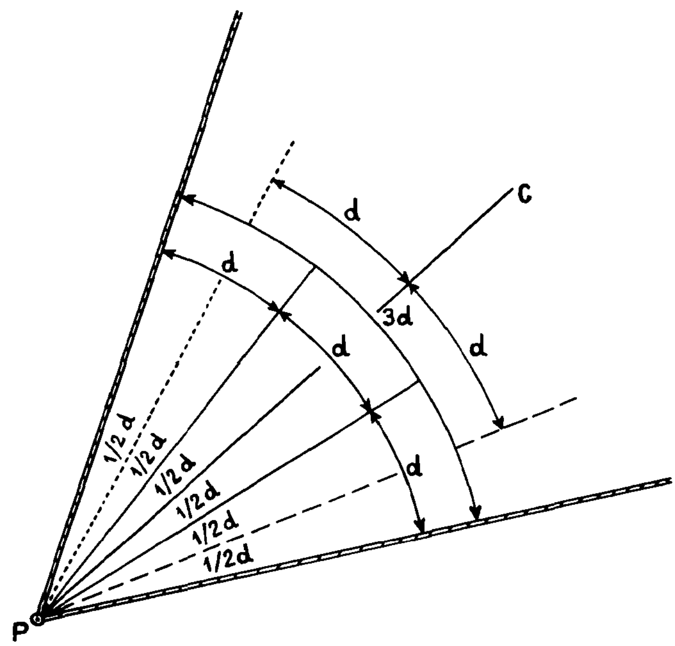

FIG. 2. — Diagram showing a sector whose width is covered by the three launches at each change of alignment.

(hatched line)	Limits of a sector covered by the three launches.
(solid line)	Track of "Black" launch.
(dotted line)	Track of "Red" launch.
(dashed line)	Track of "Green" launch.
c :	bearing of alignment.
d :	angle of divergence of the launch tracks, and also the width of the sector covered by each launch.

The sector sounded thus had a $3 \times d^\circ$ spread for each change in the alignment (see figure 2). The return trips of the three launches thus led to soundings over a spread of $6 \times d^\circ$ since the central bearing was altered by $3 \times d^\circ$ when the launches arrived at the far end of their track before turning back.

7. The bearings of the launches were controlled from the *B.B.* by observations in azimuth using the target indication sight located on the bridge. This instrument was automatically set on bearing $c°$, and it was possible to shift it at will to $c° \pm d°$.

The *B.B.* maintained constant radiotelephone contact with the launches, and this meant that they could be guided from the target indication sight's observations in azimuth. This guidance was not in fact essential for the "Black" launch (the one using the improvised transit mark). For the other two launches it was indispensable, even though they quickly became able to judge the distance they should keep from the "Black" launch as their distance from the *B.B.* varied. All that was required was frequently to tell the two outside launches whether they were very little, a little, or too far right (or left) of their course.

Time signals were radioed every 3 minutes : at minute x for the "Black" launch, and at $x \pm 1$ for each of the other two. At each "mark" the *B.B.* measured the angle between the relevant launch and the landmark being used for the reference bearing.

This then was the way in which we determined one of the coordinates of the launches' position, i.e., their bearing or azimuth from the *B.B.*

8. To determine the other coordinate — the distance between the launch and the *B.B.* — we used the ship's stereoscopic visual rangefinder. This was an optical instrument with a 3-metre base whose instrumental error was 20 m at 5 km and 80 m at 10 km (taking into account the visual acuity and training of a competent operator). The error was in fact less in practice. As the three launches were moving in company their distance from the *B.B.* was the mean of three rangefinder measurements. Also as their speed was very nearly constant it was possible to determine fairly accurately the distance they ran between two stations. Finally the instrumental errors arising from the fact that rangefinders are influenced by atmospheric conditions were almost entirely eliminated, since the instrument was calibrated before, during, and after each series of soundings against a known distance of about 10 km between the *B.B.* and the reference landmark ashore, a distance accurate to within several metres. This was done for each sea station occupied by the *B.B.*

9. In actual fact angle $d°$ (the divergence of the sounding lines) was usually fixed as either 9° or 6°, but sometimes less (in areas where the sea bed seemed uneven), and the sounding lines were between 4 and 6 km in length.

However, whatever errors the coordinates (bearing and distance) might contain, the accuracy of the method proved satisfactory in the eyes of the hydrographer in charge of the technical work of the survey (after the data obtained at the intersections of the lines belonging to the various networks had been cross-checked). As to the length of time required to complete the work, less than 2 months sufficed to survey the whole of Zones B and C. It was therefore possible to deliver to the requesting agency the 1/50 000 scale sheet that they desired.

10. It may be helpful to add to the essential information given above a few remarks concerning some of the methods actually used.

(*a*) Anchorage positions were taken up at P, Q, R, S, and T in turn. In this way the *B.B.* could move from one station to the next without any hazard, since she was always navigating within an area that had just been sounded.

(*b*) Radiotelephone contact between the directing vessel — the *B.B.* — and the sounding launches was essential, as this permitted the transmission of a time check to fix the exact time for each station. Also it made it possible for the launches to report any information they thought necessary, and in particular to indicate the instant at which they crossed the submarine ridge, which they had to do in order to reach safe ground. Finally, thanks to this link the *B.B.* could give the launches new instructions at the far end of each line.

(*c*) The end of the outward course was determined by rangefinding, and, for the lines to seaward, in addition by the reports of the launches announcing that they had crossed the submarine ridge. At a given signal all three launches were ordered to take a 90° turn. The central bearing was at the same time altered by $3 \times d°$. When this had been done the "Black" launch could determine its return course on the new alignment without further help. The *B.B.* notified the other two launches individually when they arrived at $\pm d°$ of the return alignment. All three launches then turned towards the *B.B.*

11. The crews of the launches obviously had some very bumpy rides, but this did not present great difficulties since they were accustomed to navigating in such conditions. For them the big advantage of the method was that they were only required to make simple and fairly sparse observations, and this avoided their having to remain too long exposed to the spray outside the shelter of the forecastle. The crews were always sufficiently fresh and enthusiastic to work long hours each day, and they had the additional encouragement of the warm welcome given them by the ship's company of the *B.B.* each time they neared the vessel. In fact the spectacle — at least for those who were not directly involved in the operation — had all the attraction of a circus act, so picturesque was the simultaneous arrival of the trio of launches, their flags snapping and spray flying around them as they ran in towards the ship — for all the world like porpoises speeding in past the bows in a moonlit and phosphorescent sea.