HYDROGRAPHIC SURVEYING IN THE ANTARCTIC

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The Antarctic is a vast but little known area of the globe which is assuming an ever increasing importance as man's frontiers of knowledge are pushed continually outwards. Since the signing of the Antarctic Treaty a few years ago all territorial claims have been frozen and the area thrown open to scientific work by all countries. About a dozen nations support bases, the British ones being mainly on the west coast of Grahamland, from which expeditions working further afield are mounted, and from which a considerable programme of static scientific work is carried out.

Fig. 1. — Boat sounding off Grahamland in late March. The formation of new pancake ice can be clearly seen, but this is no obstruction to the boat's passage.

These British bases are relieved and resupplied by the ice-strengthened Royal Research ships *John Biscoe* and *Shackleton,* backed up by the Royal Naval ice patrol ship H.M.S. *Protector,* who, though she is unstrengthened and unable to navigate in ice, nevertheless is able to lend valuable assistance to the various research programmes with her two Whirlwind helicopters. Included in the *Protector*'s complement in recent years has been a small naval hydrographic survey unit, who, with their own survey boat, are detached from their parent ship to work independently in Grahamland waters during the short Antarctic summer. This article is a result of the present writer's experience of two years in charge of this unit.

The first, and probably the hardest, lesson which the Antarctic teaches is that it is foolish to make firm programmes and timetables and then expect to be able to stick to them. An outline programme, for general guidance, is of course necessary, but the vagaries of the weather, and particularly the ice, require a constant flexibility of outlook and an immediate readiness to change and adapt the overall programme at short notice. In spite of years of research into the subject it is still impossible to forecast, except in the broadest terms, what general ice conditions will be like, and local conditions can vary considerably from hour to hour. There does, however, appear to be a seven-year cycle, with often a series of three or four good years followed by an equal period of bad ones. The contrast between the two can have far-reaching practical effects; for example Marguerite Bay was open to navigation by unstrengthened vessels during the whole of the first three months of 1963, while in 1964 the R.R.S. *John Biscoe* was unable to enter the bay until the beginning of March, and then only spent a week there for fear of being beset for the winter.

Surveying programmes therefore have to be drawn up with a wide range of alternative work, and it must be left to those on the spot to decide which particular jobs are to be undertaken, in the light of current ice conditions.

H.M.S. *Protector*'s southern season, generally of three or four trips south from her base in the Falkland Islands, is invariably a full one, with many scientific and other commitments for which she is particularly suited, and the hydrographic requirements have to be dovetailed in with everything else. Generally speaking one of these voyages, of about three weeks, is devoted to supporting the surveyors, mostly by using her helicopters for triangulation, while other hydrographic work (e.g. passage soundings, air and sea searches for dangers, and moving the survey party from one detached survey area to another) is fitted into her other trips as effectively as possible.

In a good ice year the R.R.S. *John Biscoe* completes her programme of relieving bases well before the end of the season, and she is then made available for sounding, a task for which she is well suited.

Weather

On a really fine day the Antarctic is superb : the sun shines down from a cloudless sky with enough warmth to dispense with shirts, while the snow and ice make a scintillating and dazzling contrast with the blackness of the smaller areas of exposed rock, and the incredible clarity of the atmosphere combines with the massiveness of the terrain to give a completely false and underestimated idea of distance. But such a day is bought dearly, at the expense of many wasted hours of fog, snow and gale.

Temperatures during the summer months at sea level generally average a degree or two above freezing, but in the last month of the season, March, the winter frosts start and the thermometer may register twenty degrees of frost or more. Snow falls frequently, but does not lie for long on exposed rock in high summer, and rain is not uncommon.

Ice

Ice is the worst hindrance, particularly when boat sounding; whilst it is possible for a properly protected boat to negotiate pack-ice up to densities of about eight-tenths, it is impossible to run straight and regular lines of soundings in more than about one-tenth. In a bad year some pack-ice may be present throughout the summer, and this will interfere seriously with the progress of the work. But changes in the wind or tidal stream can materially shift the position of ice fields in a few hours, so with patience, and by taking advantage of every area of open water, it is possible to make slow but steady progress.

Icebergs are another hazard. They do not reach the same density as pack-ice, but inevitably some of them will lie on sounding lines, and it will be necessary to break off the line to go round them and carry on again the other side. Again they are moved by a change in weather conditions, and it will probably be possible to fill in the gaps left in lines a day or two later. Occasionally, however, a berg will ground at the height of spring tides and may remain in the same position for months, but normally their vast draught is sufficient to preclude the possibility of a dangerously shallow patch beneath them. However the chance of the berg resting against an almost vertical pinnacle of rock cannot be completely excluded, and soundings taken close to it on all sides are of little value as almost all bergs have protruding underwater shoes, which, of course, give an echo often indistinguishable from that of the sea bed.

Another hazard of icebergs is that they are continually obstructing the line of sight to sounding marks. But a good sextant angler soon gets used to making a habit of foreseeing this occurrence in time to take a fix just before the mark disappears, and then by fixing again as soon as it reappears the interval will not be too long. But if there are many icebergs around it is a good idea to erect and fix more sounding marks than would normally be required.

Icebergs are frequently calving (i.e. large pieces breaking off) and sometimes the whole thing will roll over and capsize, having been undermined by the waterline ice being eroded away and melted, so it is as well not to venture too close to them. The same thing, of course, applies to ice cliffs.

New ice, which the surveyor will meet in the last month of the season, forms an often unexpected hazard. Though a boat will break a path through new ice of two inches or more in thickness, the broken pieces get forced underneath the hull and cause so much interference that the echo gets completely obliterated. This only happens in a sheet of unbroken new ice, and not in pancake or brash ice when the pieces are pushed to one side and not forced underneath the hull.

Clothing

Provided a little thought is given to the subject, it is quite easy to be warm and comfortable at all times. A windproof outer suit is essential, as

is a waterproof suit for use in the boat. For under garments a string vest, thick shirt and woollen sweater, with long underpants and trousers, are ample on all but the coldest days. Two pairs of socks are recommended, and in a boat the best footwear is rubber vapour barrier boots of a size larger than normally worn. Gloves are mainly a matter of personal preference, some prefer mittens, some chamois leather with silk inners, and others plain woollen gloves for surveying tasks, but a pair of thoroughly waterproof outer gloves for the boat's crew is essential. A woolly hat for those who suffer from cold ears completes the ensemble. It is a good idea to keep a set of dry clothing in the boat for anyone who is unfortunate enough to fall over the side.

Camping Equipment

Whilst a hut would always be used in preference if available, there is no undue hardship in carrying out a boat survey from a tented camp. Proper double-skinned pyramid tents are recommended for sleeping, though the number of occupants should be slightly less than that for which they are designed to allow space for kit and drying clothes. An efficient sleeping bag and air mattress will ensure warmth and comfort under all conditions. For cooking, eating and survey work bigger tents are required, large enough to hold the whole party, though for the latter some form of artificial heating will be needed. These tents should be of a light-coloured material as it is galling to have to keep lighting paraffin lamps when there are twenty-four hours of daylight outside.

FIG. 2. — A Royal Naval Hydrographic Survey camp on Avian Island, Marguerite Bay, 100 miles inside the Antarctic circle. The four smaller pyramid tents are used for sleeping, while the two larger tents are for cooking, eating and survey work.

In the cold weather a larger ration allowance is required, and in particular the extra calories in an increased ration of fats and chocolate will be welcome. Consideration should also be given to the anti-scorbutic

value of the rations. Fresh meat is plentiful, and the occasional seal's liver or penguin breast makes a welcome change from tinned meats.

General Surveying Techniques

At the present time, off Grahamland anyway, the whole area is covered at least by small-scale sketch surveys, and there are enough soundings along the well-beaten deepwater tracks for ships to be able to navigate them in perfect confidence, even though the soundings may come from numerous sources and show considerable disagreement in places. But outside these main routes the soundings are generally pretty sparse. In more temperate climates this might be of little consequence in an area so little used by shipping, but in the Antarctic the ever-changing ice-fields frequently force the mariner off his chosen track into unsounded waters. In places the sea bottom is as precipitous as the land, and an echo sounder will give little or no warning of an approaching danger.

The type of shipping to be met off Grahamland has changed significantly in the past twenty years. Gone are the stoutly built wooden-hulled vessels, generally of under a thousand tons, and in their place are larger, deeper draught steel ships, some ice-strengthened, some not, but all of them requiring a higher standard of charting if they are to navigate these waters in safety.

So the present need in the Antarctic is for as thorough and accurate surveys as anywhere else; and these are achieved by almost exactly the same methods, the only difference being one of emphasis.

Preconceived notions of a regular 5-1/2 day working week should be forgotten, and the aim must be to carry out fieldwork on every day, Sundays included, when the weather permits. At the beginning of the season, in the better weather, this may mean working for perhaps a fortnight without a break, but later on there will be periods of several days on end when no work at all will be possible. In an average season a total of up to 60 full working days may be expected.

Coastlining by normal methods is impracticable in an area where some three-quarters of the land is fringed by crumbling ice-cliffs which are dangerous to approach from both seaward and landward. But most of Grahamland is now covered by aerial photography from which the coastline is generally taken.

For ship work, conditions for fixing by conventional visual means are not good : days of fog and poor visibility are frequent; the land in many places is covered by featureless snowfields on which there are no natural sounding marks; possible landing places for erecting artificial marks are few and far between; and floating beacons are impracticable due to ice. All these factors combine to make some form of radio fixing aid essential if it is intended to undertake a major off-shore survey.

Instruments

The normal range of hydrographic instruments is used, and few special preparations or precautions are needed. Theodolites and levels should be prepared for cold weather service by their makers, without which they are liable to freeze up in low temperatures. Sometimes chamois leather covers are fitted over the operating knobs, but this is not really necessary for normal summer use.

As far as possible optical instruments should be kept at a constant low temperature; a sudden drop in temperature is liable to cause condensation inside the telescope or optical system.

Snow plates should always be used if a theodolite has to be set up on snow or ice, otherwise conduction of heat by the tripod will cause thawing under the legs and put the instrument slightly off level. Aluminium plates, about a foot in diameter, and with a small central hole to hold the tip of the tripod leg, are ideal.

Wet paper echo sounders should be avoided, as the paper roll is liable to freeze into a solid block of ice in cold weather, and in some conditions a sheet of ice will form over the tank face in a very short time.

Triangulation

Though naturally one attempts to achieve normal standards of accuracy, the Antarctic terrain and weather will sometimes force acceptance of a slightly lower standard if the start of fieldwork is not to be greatly delayed. Methods, using theodolite and tellurometer, differ little from those in temperate climates, and the latter instrument works well in the low temperatures. A thorough initial reconnaissance is of great value, particularly in areas where their almost sheer sides make it impossible to establish stations on the mountain tops. Whenever possible rock sites are chosen, but at times a snow station cannot be avoided, even though it will only last for a year or two.

Undoubtedly the best method of undertaking triangulation is with the assistance of helicopters. Apart from their speed, they allow landings to be made at points where swell or ice conditions often prevent boat landings. But whenever parties are landed, whether by boat or aircraft, they must take tents, food, camping gear and wireless so that they can remain *in situ* for several days if necessary. Weather can clamp down and prevent flying or boatwork in a few minutes, and the author has spent eight days on one island waiting to observe one round of angles.

Sounding Marks

In some parts of the Antarctic the precipitous and sharp-peaked mountains and islands provide prominent natural marks for visual fixing, and it will be unnecessary to erect more than a few artificial marks. But

in most parts the land is covered in a flat featureless snow piedmont terminating in ice-cliffs a hundred or so feet high. In this type of terrain two courses lie open to the surveyor who is committed to fixing by visual means : he can erect his marks on the small low-lying islands which almost invariably fringe the coast; or he can build them on the piedmont itself.

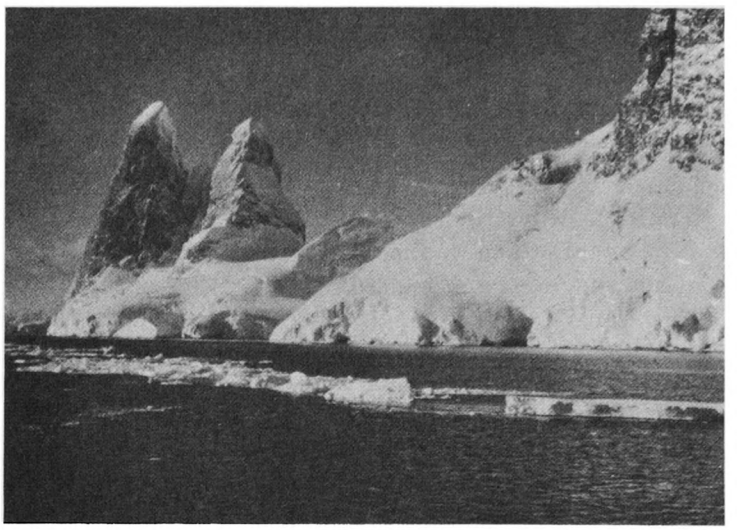

FIG. 3. — ' In some parts the precipitous and sharp-peaked mountains provide prominent natural marks for visual fixing ' — C. Renard, central Grahamland.

The latter course is strongly recommended if practicable, and presents no problems if helicopters are available. Otherwise, due to the sparsity of landing places and the dangerous crevassing up to half a mile or more inland from the cliffs, dog teams or motor sledges would be essential in order to cover the distances involved. But given the necessary means of transport, snow cairns, draped with black hessian or bunting, are quite easily erected, long lasting, and visible over surprisingly great distances.

The alternative method is very much a second best, though often unavoidable. Unless marks are well above sea level they very quickly become obscured by bergs and large floes, so that a great number of them will be required. Flags are about the only practical marks in these circumstances, and even when well set up on stout poles with wire guys they do not last very long.

The Sounding Boat

An Antarctic sounding boat must be well found and solidly built, as she will have to stand up to a considerable battering from ice. In size she should be as small as possible, compatible with seaworthiness, and be able to accommodate the sounding crew and cooking facilities in reasonable comfort. One or two sleeping berths may be fitted if practicable, but the size of the boat should certainly not be increased on this account. A small boat is easier to manœuvre and manhandle through thick pack ice; is

lighter and therefore less susceptible to damage on hitting ice or rocks; is a more practical size for beaching to deal with underwater damage; and has a shallower draught, thus easing the problem of her moorings. In the author's experience a 25- to 30-foot boat, with a displacement of about 5 tons, is ideal.

The hull must be well protected against ice, and for this wooden sheathing extending from the gunwales to just round the turn of the bilge is required. It should be covered by heavy-gauge copper sheathing, an added protection against scores and scratches from ice. Protrusions below the waterline, such as cooling pipes, should be kept to a minimum, but if unavoidable should have a protective fairing at the leading edge.

The stem, which bears the brunt of all collisions with small pieces of ice, needs to be encased in a really stout steel or brass shoe, and should have a reasonably sharp cutwater. This is the most vulnerable part of the boat and must be able to stand up to a constant hammering.

Also very vulnerable, particularly when going astern, are the screw and rudder. Surveying motor boats in the Royal Navy all have Kitchen Rudder steering gear, and this has been found to stand up to the wear and tear of use in ice very well, and the increased manœuvrability which it gives is very valuable when in thick pack. When going astern the buckets, being closed behind the screw, give it almost complete protection, making the manœuvre quite safe, whereas in a boat with a conventional rudder it is very hazardous.

When steaming through brash ice, large pieces often get forced right under the hull and hit the screw or buckets; this can largely be prevented by fitting a tubular framework round the whole Kitchen gear, but the forward members of this framework must meet the keel at a narrow angle so that they are struck a glancing blow by these blocks of ice. Too broad an angle will result in the framework itself being bent back and eventually fouling the buckets of the Kitchen gear.

FIG. 4. — Carrying out temporary repairs to the survey boat after being holed by ice above the waterline. In the background is the British base on the Argentine Islands.

The canopy should be continuous over the whole boat as far as possible, to give the maximum protection to the crew from the weather, whilst still leaving room for sextant angling.

A diesel engine is preferred to petrol, and has worked perfectly satisfactorily in the low temperatures, though ether or other cold start mixture will probably be needed. High speed is not desirable — it means that ice will be hit that much harder — and six knots or so is perfectly adequate, but the more power that is available for pushing through pack-ice the better.

An inflatable life-raft, secured in an out-of-the-way but easily accessible rack, gives an enhanced feeling of security when working in these cold waters. A light dinghy will be required for ferrying between the boat and the shore, and in ice an outboard motor has been found to be more effective than oars.

Boat moorings are always a problem in an area where the holding ground is generally poor — mostly rock. Sometimes it is possible to stretch a wire or chain across a narrow creek and moor the boat in the centre. Otherwise a three-hundred-pound stocked anchor, with a two-hundred-pound sinker secured on the moorings a few feet from the ring of the anchor, has been found to give adequate holding power.

Ice has never threatened the safety of the boat at her moorings; their large draught is sufficient to keep all but the smaller growlers and brash ice away from the boat, and these do little more than bump gently down her side. Sometimes, if on a lee shore, she will be completely surrounded by ice, but this has the effect of damping the swell and sea, and she will ride happily, though if it is a calm and cold night the brash may freeze together and make it a slow and hard job to break a passage out into open water the next morning.

Airborne Hydrodist

A surveying technique which has recently been developed for use in the Antarctic is that of using hydrodist airborne from a helicopter. It is particularly suitable for fixing isolated rocks and reefs on which it is impossible to land, and can also be used to increase the range of the instrument by means of the increased height of the aircraft.

A special aerial mounting is required which allows 360° of hand training when it is in position below the aircraft, but which can be retracted inside the fuselage when not actually in use.

The procedure is to land the remote stations on two trig. points or other known positions. The master is installed in the aircraft where two operators are required; one on the set itself and the other to train the aerial and to give the countdown and fix. The aircraft is then lined up on the transit between one of the remotes and the target, but about a quarter of a mile downwind of the latter. Meanwhile contact will have been made with the remote, and while the aircraft is flying slowly towards the target (into wind so that groundspeed is at a minimum) the first operator will have time to line up his coarse patterns. All the time the second operator

will be giving a countdown of range, and the pilot should approach the target flying as slowly and as low as possible so that the second operator can judge the 'On Top' instant accurately. Two or three runs will be required with each remote, and they should agree to better than five metres. Of course some form of optical sight would greatly increase the accuracy of this method, as virtually all the errors are in the correct judgement of the 'On Top' instant.

For communications between master and remotes a transistor amplifier needs to be fitted in the incoming speech circuits of the master instrument to overcome aircraft noise, and a double earphone headset with a noise-cancelling microphone should be used in the aircraft. When not actually speaking this microphone should be disconnected, as aircraft noise is liable to interfere with the measuring circle. Normally, of course, the operator will be on the aircraft intercom, only switching over to the hydrodist circuit when required.

Conclusion

No mention has been made so far of the prolific wild life which abounds in and around the sea — seals, penguins and birds — all of them with very little fear of man. Thanks to them a day's surveying, whether in a boat or ashore, is never dull or devoid of interest.

For all its vicissitudes surveying in the Antarctic is a fascinating and engrossing task. Though there will be many periods of frustration when patience will be sorely tried, they will eventually add to the sense of accomplishment when the job is completed, and this, allied to the comradeship and sense of purpose of all who work in the Antarctic, of whatever nationality, make an experience which is not soon to be forgotten.

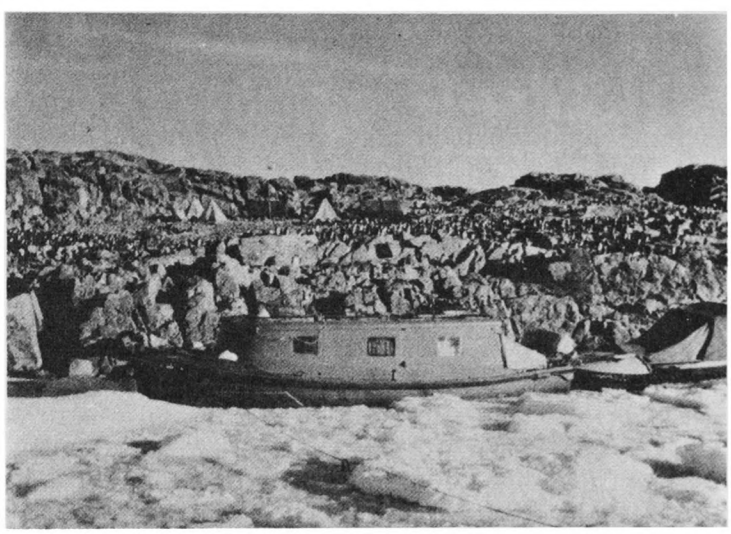

FIG. 5. — The survey boat at her moorings off the camp on Avian Island, with a penguin rookery between the two. The boat is moored to wires stretched across the creek.