HYDROGRAPHIC SURVEYS: THE PURPOSE AND THE CHOICE OF SCALE

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The main purpose of a navigation chart is to show what lies under the water, in order, first, that a ship shall not take the ground unwittingly, and secondly, that observed changes of depth over identifiable features may be used to assist the determination of her position. The conventional method of showing this information in plan is by a selection of depths reduced to a common datum and they will usually be in greater profusion than the comparable spot heights of the land map. They are supported by contour lines, called fathom lines at sea, using symbols which are strengthened when they surround the shallower areas that need greater emphasis. These depths will invariably have been taken from the final drawing or « fair sheet » of the hydrographic survey of the area and each one will have resulted from an up and down sounding to measure the depth at that particular spot.

There is in fact no known way of determining the depth of a point on the sea floor other than by a vertical measurement from the surface above it; and as far as can be foreseen, the future does not hold any means of seeing through water, at least not in the sense of human vision with its capacity for discrimination and estimation, which is so valuable when more than one dimension is concerned. Even if this was not so, plane-table methods employing the intersection of points of detail on land would seldom be usable, since the sea floor is often covered by sediment which obscures minor detail, as may be observed at low tide at the sea shore especially near a river estuary.

Another type of sea floor may be likened to the Scottish Highlands in which outcropping rocks provide detailed features, although they will often not be recognisable, even when they are visible, from different directions. Such features, when they exist on the sea floor to one side or other of the ship, will be detected, within similar limitations, by Asdics. The Asdic method, which was originally developed for submarine warfare, has, like radar, a beam which is trained in azimuth to give a bearing and distance of an object, provided that it has a surface which will reflect back a sufficient part of the transmission directed at it. At still shorter ranges there is the new development of under-water television; but these methods have considerable limitations in many of the different conditions encountered under water.

Such a preamble seems unavoidable in any discussion of hydrographic surveying and is particularly important to the present aspect of it. It will sufficiently show why the accepted method of determining the topographical features of the sea floor is by traversing the area with parallel lines of soundings whose distance apart will determine how much is learnt and how much is overlooked. That some detail will be overlooked is inevitable, but it will be the less for the natural processes of smoothing over by sedimentation and the swallowing up of objects in soft sand or mud, or alternatively as a result of the use of Asdics and other methods in addition to systematic sounding.

In the naval surveying service it is standard practice to run the lines of soundings 0.2" apart on paper, as is shown in the bottom right-hand part of Plate I. This spacing has been adopted since it is convenient for plotting and numbering the fixes of the soundings that have been taken. It is the variation in the distance represented by 0.2" on different scales which is important.

It will be well next to look at the user's need for varying scales in the charts, which are the end product of the surveys, but it cannot be emphasized too strongly that the purpose of the survey is to find out about the sea floor, whereas the object of the chart is to portray it. The range of scales can be separated into four main divisions of navigation, *i.e.*, ocean, 1/1M to 1/5M or still smaller; offshore, 1/150,000 to 1/500,000; coastal, 1/50,000 to 1/100,000; harbour and approaches, 1/6,000 to 1/25,000. Generally speaking, the closer that a navigator wishes to take his ship to the land, whether below the keel or to one side of the hull, the larger must be the scale of the chart. In harbour work, the outline of the ship, the wharves and the ground tackle of moorings have to be of a size on paper that permits their proper appreciation and a larger scale than 1/6,000 may be needed exceptionally. Large scales are also required when an area has to be dredged and the amount of spoil to be calculated, although such surveys are more for use by harbour authorities than the navigator with whom this discussion is more concerned.

Clearly a limit to the largeness of the scale is simply and directly set by the size of instruments and chart tables; and a prospective customer may even have to be warned that the advantage of using a blunter pencil on a larger scale may be offset by the need to use a longer parallel ruler with which to lay off his bearings. It must also not be overlooked that the headlands and shore objects which should be included on the chart to give good fixing on it may, on too large a scale, lie outside the limits of the chart table, to which the British standard size of charts, 38" × 25", is conditioned. For example, when the scale is one inch to one mile and the standard dimensions become sea miles, the lengthwise two-thirds of a coastal chart which is likely to be sea area is readily worked with a parallel ruler having a convenient length of 18". Such a ruler will comfortably cover ranges of 12 to 15 miles at which objects at sea are often used.

Having stated that the purpose of the chart and the object of the survey are different, it is necessary to point out that the scale of the survey must not be smaller than that of the chart. By this arrangement, a first principle of chart compilation, which is to work from larger to smaller scales, will be maintained. This could mean that the survey is on an unnecessarily large scale for its main purpose of learning about the sea floor, but on the other hand it will satisfy the need to plot the positions of the under water features with the greater accuracy which the larger scale chart demands. In no other way should the needs of the chart maker, with a projected chart in view, dictate the scale of the survey, nor should they set the limits of the survey, since that might mean stopping short in the delineation of an important feature which extends beyond the limits of the chart. And a last word on charts would be to note that the coastal and larger scales are likely to be directly from surveys, whilst the offshore and ocean scales can be compiled from larger scale charts.

Turning to surveys, it is convenient to discuss first the effect of instrument and paper sizes on the scale to be used, since this has been referred to in relation to the scale of charts. It will be appreciated that the detail of a survey or, in other words, the position of the surveying ship at frequent intervals along her line of soundings, is plotted by station pointer from sextant angles. The three legs of a station pointer express the two horizontal angles which are observed simultaneously with sextants from the bridge of the moving ship, and the legs are laid alongside the three objects on the plot, a comparable but infinitely quicker operation to that of resection on a plane table ashore by drawing in three lines of sight. The largest station pointer made has a graduated circle 12" in diameter and legs which have an extended length of 48". It takes two men and a boy to work it, and the length of the rays involved does not make for accuracy unless extreme care is taken. That may be practicable when laying down additional sounding marks on the plot in the quiet of the chart room, but is hardly so on the bridge where rapid plotting is required so that the ship's course may be adjusted in good time. Consequently the stations pointers more commonly used have either a 6" or 8" circle, and legs from 24" to 32" in length.

It will be patently obvious that it is more accurate to fix on shore marks than on beacons in the sea which are swinging round or between anchors, and a coastal survey can be well within visibility distance of marks on shore when extending only 15 miles to seaward. A survey scale of 3" to a mile may be desirable and it is aggravating to be unable to use shore marks just because rays of 45" on paper cannot be handled. One solution is prior computation and plotting of circles of equal horizontal angle, but this means accepting the use of very few objects when in fact, if others were available, delays owing to the difficulty of taking sextant angles into the sun or a rain squall would be avoided. At the present time a fine radio solution to this problem is in prospect with the continuous-wave distance-measuring system of « two range Decca », provided that the trials recently carried out confirm the theoretical accuracy. Any area within its maximum range, which may be as much as 70 miles, can be readily prepared for plotting fixes by drawing, at whatever scale is required, the arcs of distance circles from the two shore transmitting stations; and the latter need not appear on the field plot.

Another factor which must directly exercise some control on the scale is that the smaller the scale, the more space will be taken up by each figure representing a depth; and the more difficult does it become to arrive at the true delineation of an under-water feature. An old textbook used to put it thus :

> « If the scale be one inch to a nautical mile and a square inch be divided into a hundred equal areas (suitable for a hundred figures) each sounding will occupy a space equal to about eight acres, *i.e.*, an area a little larger than the Horse Guards Parade and about twice the area of Trafalgar Square. »

Similar reasons will demand that the scale must be large enough to plot clearly the results of Asdic or wire sweeping operations.

Having disposed of considerations which, to say the least, should not be allowed to have too much bearing on the scale of the survey, attention may be turned to the main purpose of the majority of surveys, which is the delineation of the sea floor, having particular regard to features that may provide danger to navigation. To surface navigation a depth of 45 feet on an individual shoal or obstruction is regarded as potentially dangerous, whilst to submarine navigation it is difficult to set any limit. It is, however, reasonable to think in terms of carrying out detailed survey to include the 100 fathom line. This is often the edge of the Continental

Shelf, beyond which there are steep gradients to oceanic depths that are of much less concern either to under-water warfare or surface navigation.

What kinds of feature must be catered for in the, so to speak, blindfold search ? What gradients may be expected ? How far apart can the lines of soundings be and yet be sure of drawing attention to a need to look more closely ? To what extent will this vary with the depth ?

Some knowledge of geology will clearly be a help, but there is the usual difficulty of finding the time to acquire it; a hydrographic surveyor must necessarily also be a seaman, and will have a role to fill as a naval officer or alternatively as a harbour master or engineer. Fortunately, it is probably true to say that he can get by if he makes a common-sense appraisal of what he sees of neighbouring land features, especially the run of the valleys or faults. Alternatively, he may use his experience of previous surveys in comparable soundings, and in the fortunate case of the British Naval Surveyor this experience may be of world-wide extent.

He will seldom have found gradients under water to match those on land because there will have been deposits or sediments brought by currents which will have settled in the valleys and at the foot of cliffs, thus smoothing out the original form of such under water features. He will be alive to the effect of tidal streams elongating and maintaining the general shape of sandbanks and the deep channels between them. He is also likely to have encountered coral formation and be able to learn what to expect of them from a study of neighbouring areas.

If precise figures for gradients under water are sought, knowledge seems to be incomplete. In the case of unconsolidated material, the angle of rest may be as little as 5° or as much as 15° depending on whether it is mud, sand, gravel or shingle. If there is clay, gradients may increase to 30° although the latter is not commonly met. Bare rock is encountered comparatively seldom, but when it is, there will be no rules. Canyons with sides nearly vertical or with slopes of at least 60° and a smooth floor running down into deeper water may have held no sediment over the years and thus remain true to original shape. So do steep rocky shores or off-lying rocks, more especially when strong tidal streams keep them washed clean of sediment. Coral atolls in the later centuries of their growth may give gradients near the surface as steep as 40° to 45°, and this gradient may apply to submerged coral heads that are found standing solitarily within the 50 fathom line, meaning that their bases will be of comparatively small extent.

On the one hand then, slopes up to 30° will seem less than might be expected and on the other, coral heads and rocky outcrops present a special problem. In the case of the latter, however, their probable presence may often be suspected. Moreover, rocky formations at any appreciable height above the sea floor, are likely to be part of a large feature with slopes of 15° to 20° up to a summit above which there may be outcrops protruding for a few additional feet. Such features are most likely to be ridges having considerable length extending seawards perhaps from an above water headland, and an example is St David's Head in Pembrokeshire which runs out to the Smalls and beyond. Indeed, along this line there is a recent report of an under-water feature which was not found in the previous survey. That survey, however, was nearly 100 years ago and by modern standards would be dubbed as exploratory.

If exceptional cases of needle rocks rising to the surface were to be quoted, there would be Cook Rock in the deep waters of Cook Strait between the North and South islands of New Zealand; Avocet Rock standing in 40 fathoms in the

Southern Red Sea; and on the extension of the Peninsula south of Reykjavik in Iceland where the above-water islets are spectacularly sheer, there is a rock found during the last war by a ship which passed so close that the return from the weak sideways transmissions of the echo machine showed more strongly than that from the transmissions directed downwards. Its top is about the size of a card table and it is 11 feet below the surface. Its sides are sheer for at least 100 feet, and thereafter the gradients are very steep for another 80 feet to the sea floor. The venomous picture is completed by the fact that, rather exceptionally, no tide rips, breakers or discoloration betray its presence. However, such rocks provide particularly good Asdic targets and Asdics are being used with very good effect on a current survey off the Borneo Coast where many coral heads are being found.

Having shown reasons why under-water features may, on account of their gradients and shapes as well as their geological likelihood, be less difficult to find than might be supposed, attention is drawn to the illustration in Plates I to III of a shoal which is totally unexpected geologically and is circular rather than part of a ridge.

Plate I shows the method of covering an area by parallel lines of soundings. It will be seen how a spacing of five to the inch became four to the inch, and finally, two to the inch as the depths increase. This will have been on the principle that a feature rising to a dangerous height will be wider at its base as the general depth of the sea floor increases. In those days, sounding up to 18 fathoms was done by a mechanical contrivance for heaving an especially heavy lead so that it was let go forward and the depth line read aft when it came up and down, but the ship's speed had to be greatly reduced. In deeper water there was nothing for it but to stop the ship, and this will have been necessary for every one of the spaced-out depths on Plate I. Nowadays echo sounding, first adopted in 1928, gives a continuous record of depth at high speed, and a closer spacing of lines in deeper water is practicable.

Although no example of it is shown, it will be opportune to add here that additional lines are run whenever the presence of a feature is suspected. It is customary first to run one interline and, at half the standard interval of 0.2", it is possible to show legibly the additional soundings obtained. Thereafter, if the interval is again halved, there is room to plot the ship's track, but depth figures can only be inserted at the expense of previous observations. A further point is that lines of soundings are always oriented so that the general direction of the fathom lines is crossed at right angles and thereby there is less chance of missing the ridge formations which are so commonly encountered.

Plate II shows the location of Sea Green Shoal which was reported by a minesweeper fouling her sweeps on it during the war, and which was made the object of an investigation when an opportunity arose in 1946. Using echo sounding, a shoal was quickly found and indeed with the sun high up behind the observer, it could be seen at a distance of a quarter of a mile because of a green discoloration of the blue sea, hence the name. It was half a mile in diameter at its base and rose 120 feet to a rounded top, a tenth of a mile across at a depth of 50 feet below the surface. There is no geological reason for a shoal in such a position as for example there might be along the extension of the promontory on which Nelson Island stands, as shown in Plate II. It accordingly smacks of being wise after the event to draw attention to the seaward of two soundings of 30 fathoms shown in Plate I to lie on the edge of the shoal area as shaded in from Plate II. This sounding

Depths by lead line — 1/100,000 survey of 1920

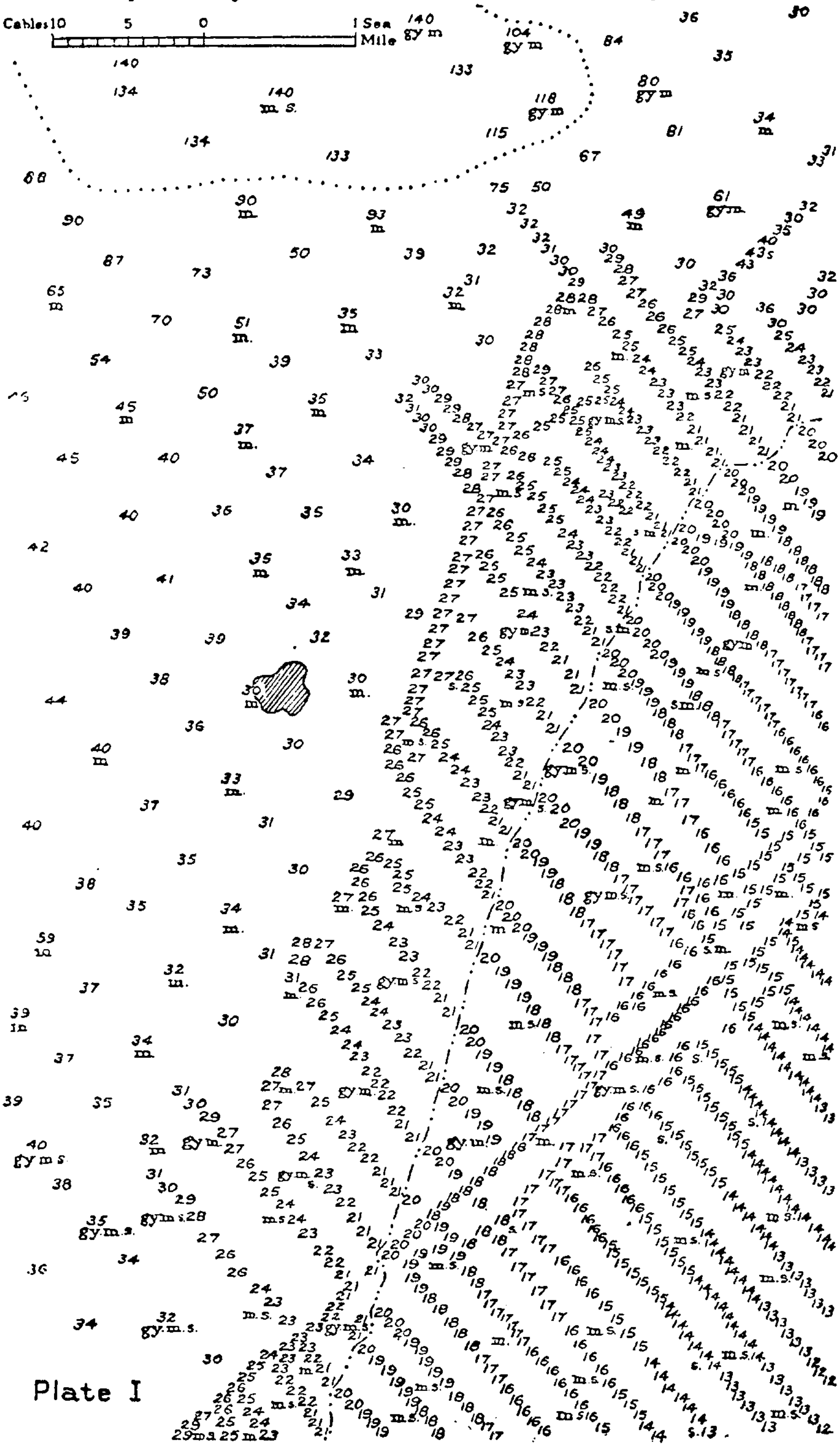


Plate I

would have been 35 fathoms had the slope seawards been uninterrupted, and it may be said with some certainty that had echo sounding been in use in 1920, its continuous trace would have given sufficient indication of a feature to cause its discovery by an interline. Quite probably the trace would in addition have shown the harder material of the shoal extending under the softer mud of the sea floor round its base, thereby demonstrating another advantage of echo sounding.

Using standard methods on a scale of 1/100,000, therefore, an indication of Sea Green Shoal was obtained. That shoal had slopes of only 10°, whereas 25° may be encountered, and accordingly on Plate IV, an illustration in elevation to show the efficiencies of different survey scales, a shoal with 25° slopes and a least depth of 42 feet has been used. The illustration draws attention to the cone into which the echo transmissions are focussed, so that a line of echo soundings is advantageously a great deal wider than the base of the superseded soundings lead, which was but a few inches across. The advantage is however lessened in deeper water when the cone tends to become pear-shaped. Plate V has been added to show that the echo trace can be misleading to the uninitiated in its distortion of the slope, and indeed the writer had not formerly appreciated the extent of the distortion.

In studying Plate IV it must be remembered that shoals are more likely to be ridged than circular; that interlines at 0.1" intervals are run in suspect areas; that there are considerable odds against a shoal lying exactly between lines of soundings; and that 25° is a steep slope.

It will be seen, however, that in areas where the sea floor is less than 10 to 12 fathoms down, something quite small rising only, as one might say, a handful of feet off the bottom, can be of importance and likely to escape notice under ordinary methods. If they are infrequent. Asdics find them, but if the floor is generally rugged, Asdics will be insufficiently discriminating. Then, recourse is had to sweeping or dragging a horizontally stretched wire across the area. This is a laborious business, costly in time, and is only used for such a purpose along a channel which valuable ships must navigate with but little water under their keels.

Having mentioned costs—and time is money—they can at once be dismissed with the accepted conclusion that since scamped work cannot be checked and may lead to disaster, surveys must not be costed at so much a mile, and a hydrographic surveyor's promotion must not be directly related to the number of square miles he covers. Experience shows that there is more than enough incentive to get results, and it is more likely that one of the responsibilities and anxieties of the surveyor in charge will be to ensure thoroughness.

Nevertheless there are opportunities to save time at the other extreme of surveys; *i.e.*, those covering smooth estuarial sea floors, which moreover may be subject to rapid changes. The Edinburgh Channel is an example and is at present being surveyed twice a year. Because it is narrow, the chart is on a scale of 1/12,500 and so the survey must be to that scale, although 1/24,000 would suffice to delineate the sandbanks. In such case the lines may be run at double the normal interval.

Reverting to the general from the particular, it can be held that surveys of 3" to the mile and larger scales will, in the majority of cases, teach all that matters navigationally about the sea floor by ordinary methods and will be executed to meet a need for a chart of a harbour or its approaches.

Choosing the scale, therefore, becomes the greatest problem in the case of coastal surveys which may have to extend many miles to seaward in order to

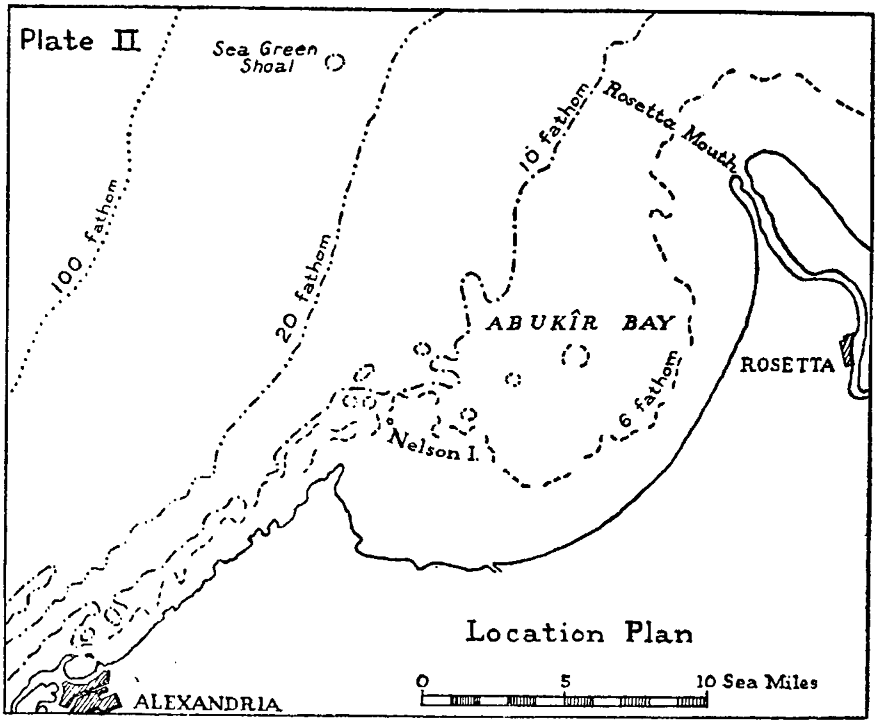
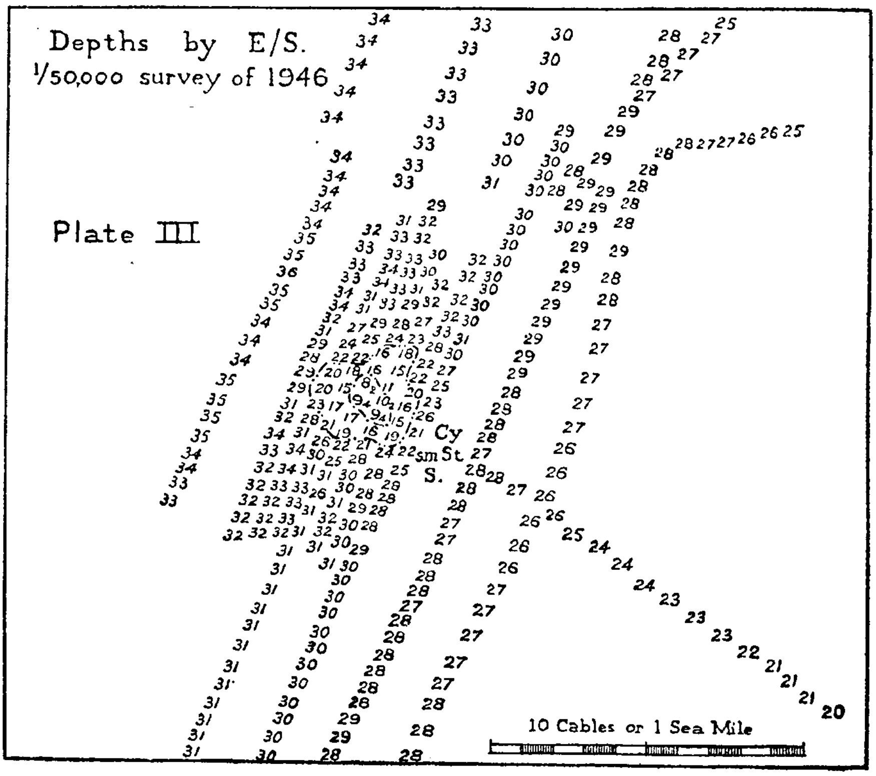


Plate II
Sea Green Shoal
100 fathom
20 fathom
10 fathom
6 fathom
Rosetta Mouth
ABUKÎR BAY
ROSETTA
Nelson I.
ALEXANDRIA
Location Plan
0
5
10 Sea Miles


Depths by E/S.
1/50,000 survey of 1946
Plate III
Cy
sm St
S.
10 Cables or 1 Sea Mile

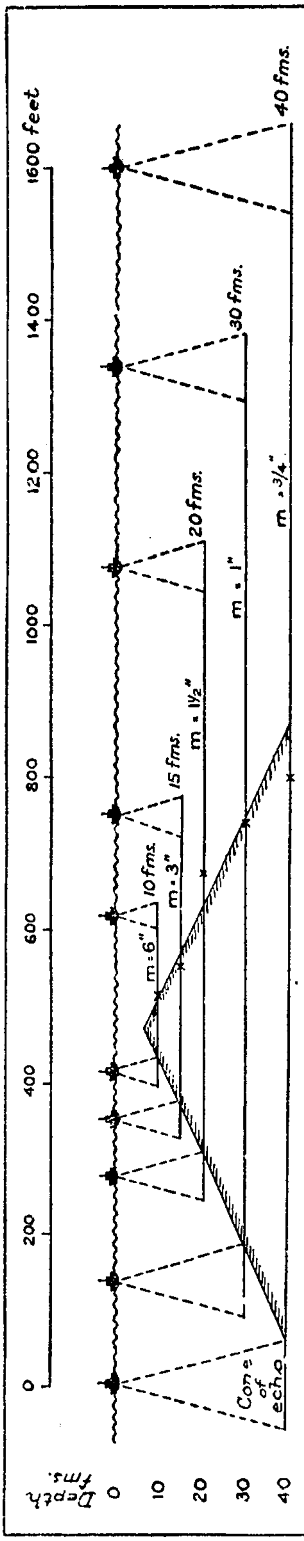


Plate IV Diagram showing at what depth, and at what scale of survey, the base of a 7-fathom shoal with a 25° slope will occupy approximately half the distance (×) between two lines of soundings plotted at a normal interval of 0.2 ins.

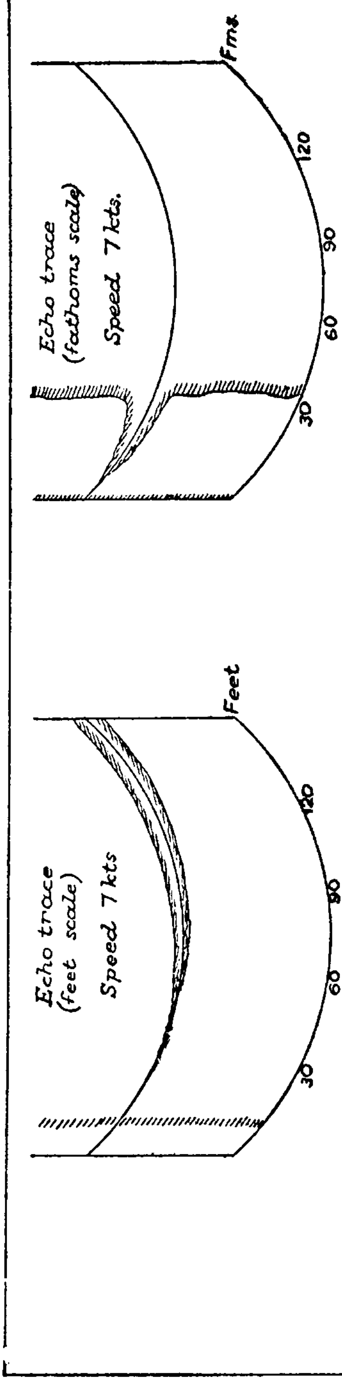


Plate V How a typical E/S recorder would trace the shoal in Plate IV given a speed of 7 Knots across it. (2/5th Scale) include the 100 fathom line. There is an immense amount to be done if the old lead line surveys are to be replaced, as they should be, and if sparsely sounded areas are to be covered. The smaller the scale the quicker will the work be done, but the purpose of the survey must be satisfied. In a task of such magnitude priorities must be taken into account, and first will come the safety of shipping wherever it may reasonably expect to navigate. Sometimes it will be economical to include the inshore areas or the shallower parts through which in fact the survey may find safe routes. At other times, when such secondary areas have been covered by a previous lead line survey, those results may be allowed to suffice for the time being. Taking all things into consideration a scale of 1/72,000 seems most suitable and anything smaller is likely to be inadequate. But if charts on a larger scale than 1" to 1 mile are a navigational requirement, it will usually be wise to go to a yet larger scale for the survey, and especially so in rockbound or coral waters, in order to be sure of matching up to the confidence which users of all kinds will place on the large-scale chart.

And so, references to the chart conclude, as they began, this dicussion of scales of surveys, but it is necessary to bring in the surveyor once more, particularly the surveyor-in-charge. He accepts responsibility for the results of his survey. He must have latitude to enlarge the scale which has been ordered should he think it necessary, or report if this is deliberately not done for some reason that he will advance. Alternatively he may open out the lines to save time whenever it can safely be done. If he employs Asdics he has to assess the degree of reliability basing it on the operating conditions and the type of target.

On the surveyor's reports the chart maker is ready to insert explanatory notes for the benefit of the chart users. Chart users are advised in various ways and places how to assess a chart and stress is laid on the date of the survey quoted in its title. This is sound but it increases the responsibility of the chart maker as advised by the surveyor to say so, when, for example, an insufficiently large scale has been used for parts of a modern survey on which the modern chart is based. Captions are then used, as « Unexamined, » « Less water may be encountered, » etc. On the other hand, a chart may show an important channel through dangerous waters which has been surveyed on a larger scale than that of the chart, and also perhaps than that used for surveying the surrounding waters. In such a case, and there is an example in recent surveys and charts of the Persian Gulf, then an appropriate caption will rightly increase the confidence of the mariner.

Mariners must see a good deal of evidence of out-of-date surveys on their charts, but they may take comfort from the care and devotion brought to their task by the surveyors of the last century. Their soundings were sparse so that their work would be classed as exploratory by modern standards, but their keen powers of observation, supported by masthead lookouts and the cross-examination of local seamen has meant that, on the many coasts they covered, they missed but few shoals dangerous to surface navigation.

My tribute to them I will follow up with my thanks to all those, mostly in the Hydrographic Department, who have helped me in the preparation of this Paper.

PRESENTATION OF PAPER AT R.I.C.S. 12TH MARCH. 1954

It has occurred to me, without perhaps any great conviction, that we should make a bid to the Council, so that on these Hydrographic evenings, we can have some appropriate stage effects. Nothing so violent perhaps as rocking the boat but a gentle heave and a roll and pitch would show that we have gone to sea for the evening. However, as a more practical alternative, I hope to provide the right atmosphere with my first three slides.

Slide No. 1

(1) The first is of the new surveying ship *Vidal* which has not quite finished her trials, and you see one of the first photos to be taken of one of Her Majesty's surveying ships with a flight deck and a helicopter upon it. She was built at Chatham Dockyard, and after a shakedown cruise on the West Coast in the coming Spring she is to cross the Atlantic and resume surveys in the West Indies where we have not had a ship since the 1930's.

Slide No. 2

(2) The next slide is a surveying launch. These craft make very useful tenders to ships preferably working in pairs. The latest arrangement is that the four in Home Waters are forming into a group to cover the East Coast from Winterton to South Foreland. In these parts there are many sandbanks not far offshore and they are continually changing.

Slide No. 3

(3) The third slide is of a motor boat of the latest improved design. It is 30 ft. long and the larger ships carry three of them. You can see the after plotting and steering compartment where the space is required and where the echo sounding recorder is fitted.

Slide No. 4

(4) The next slide is of an air photo — any air photo — and with this as well as the three preceding photos I want to rub in that you cannot see through the surface of the sea. This happens to be a photo of Suva Harbour in the Fiji Islands where the water is clear. Although you can see a very shallow reef formation which has a beacon on it, there is no trace of any detail of the bottom where the water is 12 feet deep as it is inside the reef, or 12 fms. as it is in the left bottom corner of the area.

Perhaps I can emphasise the point by quoting the song that « you join the Navy to see the sea and what do you see? You see the sea ». And this notwithstanding all the brains and efforts that during the war went into the problem of determining gradients off the enemy beaches on which we wanted to land. I think the most fantastic idea was to have one aircraft dropping a stick of bombs over the sea in towards the beach and another aircraft taking oblique photos of the splashes caused by the explosions. It was said that the height of the plumes would vary with the depth of water. As you will appreciate, it was hardly a clandestine method and must, I suppose, have relied on double bluff.

I wonder if you saw a photo in the Press the other day of the St. Lawrence waterway project. For a moment I thought the ground had gone from under my feet or perhaps I should say the wind had been taken out of my sails by the picture of a helicopter over a narrow part of the river where the water was shallow and too violently disturbed for boats. The caption said that the helicopter carried a depth finding device. I wondered various things and thought it most likely that it lowered some echo set on a wire to the surface but I was lucky just then to have a visit from an Officer of the Canadian Hydrographic Department. He gave me the surprising explanation that the helicopter from time to time lowered a measuring pole vertically into the water until it touched bottom where upon observers on shore with theodolites took cross bearings for position and read off the depth on the pole. A highly ingenious application of a helicopter.

Slide No. 4a

(4a) Anyway, the point is that we normally have no recourse but to run lines of soundings in ships and boats across the area in which we want to learn the bottom topography, and this slide illustrates that. It is a typical arrangement where the lines open out as the water gets deeper. At their closest where they are five to the inch, soundings can be shown legibly but there is comfortable room to plot another line in between and this is done whenever suspicions are aroused.

The larger the scale of the survey, the closer can we run and plot the lines, and the more may we learn about the sea bed. The question is, how far we should carry this in practice.

Slide No. 5

The next slides are of charts on which of course the results of the surveys appear. The scale of the chart will vary with its purpose which may at one extreme, be to take a ship alongside a wharf, and at the other, to plot a course from one side of an ocean to the other. The more intricate the navigation, the larger must be the scale of the chart, and whenever new ground is being broken the scale of the chart must wait the results of the survey.

An important principle is that a chart cannot be accurately compiled from surveys which are on smaller scales.

And a governing factor is the size of paper which general convenience has established at 38"×25" in British Admiralty practice.

The slide is Portland Harbour on a scale of 1/8,000 or 10" to a mile. The outline of a ship is of H.M.S. *Vanguard,* and to give you a dimension, the parallel ruler is 18" long. In this case the Harbour Master will want the large scale so that he can measure off lengths of moorings and the distances between buoys. He will also want to know safe distances to a matter of feet from a buoy to dangerous underwater features. The survey must be on a large scale to give the positional accuracy that is needed and not to make sure of the topography of the bottom which in this case is smooth and gently sloping.

Slide No. 6

Next is a slide of the Edinburgh Channels on a scale of 1/12,500 or 6" to 1 mile. The ships outlined are the big tankers that are nowadays plying to the Isle of Grain and Thameshaven and again there is an 18" parallel ruler for size, There is not much room to spare for big ships and they need a large scale chart In such waters there must be no risks taken and the limits of the dangers are marked by buoys.

These dangers, however, consist of sand which forms into banks rising from deep water with comparatively easy slopes. Here a survey on a smaller scale than the chart could learn enough about such features and fix their comparatively indefinite limits with sufficient accuracy.

What we must do in this case is to open out the distance apart of our lines of soundings in order not to waste our efforts. And this is particularly important because we are having to survey these channels twice a year owing to the movements of the banks. You can see the shapes of the banks and their extensions and in fact the North Channel appears to be breaking through, whereas the South Channel now in use tends to be getting narrower.

Slide No. 7

(7) Next there is a chart of Lowestoft and Yarmouth Roads on a scale of 1/50,000, 1½" to a mile. Again the area is one with a sandy bottom where the banks form parallel to the coast and along the direction of the tidal streams. They are continually changing.

In this stretch of water there are important channels inside the sand banks from off Lowestoft to Winterton. The chart is on hardly a large enough scale for these but it is too large for the deep waters outside the banks.

I have put an 8" station pointer — it is the circle which is 8" and the unlengthened leg is 18 inches long — in a position on the chart as it might be used for surveying at the eastern edge of the area if one must do it on 1/50,000.

Winterton Church, a fine upstanding tower, apparently built for the benefit of Hydrographic Surveyors like so many on the coast of Norfolk, can easily be seen 20 miles away in clear weather. Yet it is difficult to plot accurately when the extensions of the station pointer legs have to be used, and one certainly cannot plot quickly if one sends for the next size up, the largest of station pointers, which needs a man and a boy to work it. As usual I am drawing on personal experience, and I can remember our difficulties in this area some years ago. Opening out lines of soundings won't help this difficulty and a review of the charting would I think show that there should be two charts with one on a scale of 1/75,000 for the outer waters and the inner waters on a larger scale. Then both surveyor and navigator could use the normal size of plotting instruments.

Admittedly, the surveyor can extend the triangulation out to sea with floating marks, but so long as he can see shore marks it will be more accurate to use them and tantalising if one cannot, just because of the instrument problem. Accurate plotting on large scales from distant marks can of course be done on a previously constructed plotting sheet showing arcs of equal horizontal angles between selected objects, even though they are outside the limits of the sheet. There are various limitations and one doesn't get over low visibility. Much is accordingly hoped for from the adaptation of an electronic aid — the Decca system — in which the master is carried on board and gives accurate ranges of two slave stations on shore simultaneously up to 70 miles or more. Trials have been carried out but results are still being examined. Then we should be able to vary the scale without difficulty.

Slide No. 8

(8) A last chart is a coast sheet on 1/75,000, 1" to 1 mile, Beachy Head to Dungeness, one headland to another, which is the ideal arrangement for the mariner and again there is a 18" parallel ruler for size.

Hereabouts there are offlying shoals, the Royal Sovereigns for example, but there is no occasion for other than small craft with local knowledge to go inside them. 1" to a mile is sufficiently large for the mariner navigating outside them and his 18" parallel ruler will cover his requirements comfortably. For instance Dungeness and Beachy Head lights have visibilities of 16 to 17 miles, which is of course 16 to 17 inches on paper at this scale.

Similary surveys on 1" to a mile can use normal instruments whilst in sight of the land. Evidently a most handy scale to work on unless small features are likely to be encountered.

I would like you to note how the underwater features hereabouts are in long ridge-like formations and they are not only of sand.

Charts on smaller scales than this on one inch to one mile are provided for long distance open sea navigation. They will obviously be compilations from the larger scales and I have no examples to show.

Slide No. 9

(9) Next then is a slide of Sea Green Shoal off the coast of Egypt to show what may be encountered in bottom topography. It rises out of 30 fathoms to within 50 ft. of the surface with 10° slopes — 1 in 6. It was reported during the last war by a minesweeper who fouled her sweeps on it and remarked that it was uncharted. You will see that there is no geological reason for a shoal in such a position as there might have been had it lain on the extension of the Peninsula which has Nelson Island standing on it. I would however draw attention actually on the next slide to a very marked indentation in the Continental Shelf as shewn by the 100 fm. line, and I was much struck when I was turning up details of a similar feature to this, one which rises dangerously near to the surface and is well known to mariners in the southern Red Sea. Its name is Avocet Rock. There I again found a big dent in the 100 fm. line and possibly such a chasm in the Continental Shelf indicates a one time geologically unstable area. Perhaps whenever this happens one should look out for unusual soundings. At the head of this chasm depths seemingly increase remarkably from 50 to 115 fathoms but the slope is only 10° or 1 in 7.

I surveyed Sea Green Shoal in 1946 on my way back from the Middle East in the survey ship *White Bear,* but I did it with mixed feelings since, 25 years previously, I had been the junior officer of the surveying ship that had covered the area and not found the shoal.

Slide No. 10. *Slide as* 4 (a) *slide*

(10) The next slide shows a piece of the 1920 survey. It was on a scale of 1/100,000 and, as you will realise, done with a lead and line. Each one of the spaced out soundings in the deeper water will have meant stopping the ship to get an up and down cast. Nowadays, echo sounding gives a continuous record however fast the ship is going.

Looking carefully at the soundings, and of course it is knowing where to look when the limits of the later survey are superimposed, as it is here, you can see that even the infrequent lead soundings showed along one line an interruption in the normal slope towards deeper water. There are two soundings of 30 fms. and one of them could have been expected to have been 32 or 33. There is little doubt that had we had an echo sounding record in those days to study at the end of the day's work, it would have been clear that there was something needing further examination. But even on that lead line survey the scale of 1/100,000 was in fact large enough to give a sign of the feature. The shoal can be seen if looked at in the right direction at the right time since the sandy patches reflect light and the water on the surface is discoloured green.

Slide No. 11

(11) Next comes the slide showing diagrammatically an elevation of a circular shoal like Sea Green Shoal that we have been looking at. It has much steeper gradients 25° or 1 in 2 and rises to a greater height, that is, to 42ft. below the surface, a depth which is considered potentially dangerous to deep draft ships.

I have shown a number of cross sections of different depths where at a given scale of survey the position of the shoal occupies approximately half the normal distance between lines of soundings.

I am not sure that the diagram really means an awful lot but it is quite illuminating. I have not worked out the odds against such a shoal lying between and clear of two lines of soundings, but they must be quite heavy. What makes the picture much less gloomy in practice is that topographic features are so seldom circular and one can often choose the direction of the lines of soundings so that they will be across the expected fathom lines.

The diagram shows I think that when the general depth is 10 fms. or less, quite small features with average gradients will be dangerous. Where important routes lie through such waters at some distance from the shore special measures may be necessary. If large scales such as three inches to a mile or larger are not practicable, there is the alternative of sweeping. When I started surveying we used to tow a kite astern at a given depth, if it struck a shoal it tripped, rose to the surface and rang a bell on the bridge. It was known as the Submarine Sentry. Later there was developed the method of dragging a horizontal stretch of wire through the water as in minesweeping and this can still be the final arbiter even nowadays when Asdics may be used for searching sweeps.

I am not going to be drawn into a discussion of Asdics. I was not brought up on wave lengths, frequencies and power outputs. It shall be enough to say that Asdic transmissions like those of echo gear go out in the form of a 30° cone as shown on this diagram, but they will of course be horizontal.

Certain types of echo gear will be better on shoals of fish, although they may get confusing returns from layers of water of different temperatures. Other types will give an idea of the nature of the bottom and the thickness of mud over rock.

So with Asdics. Some targets will be easier located than others and some sea floors will give more confusing reverberations than others. At some ranges and depths a target may be under the beam of transmissions. An object may lie hidden behind a ridge and so on.

Asdic sets like echo sets can be designed differently for different purposes and the one fitted in a survey ship must consequently be a compromise. The surveyor must realise its limitations and how these vary under different conditions of sea and sea bed.

In the Persian Gulf, a coral bottom gives too many reverberations for shoals to be located by Asdics, and only a few weeks ago one of our ships touched a shoal rising to 12 feet from 60 feet. The shoal probably had no steeper slopes than on this diagram but although the ship was only doing 7 knots there was only just time to bring her up as she scraped over. The representation shewn here of an echo trace of the diagrammatic shoal above it, is really included to show the distortion of scale on the recorder, but when you realise how frequently the pen makes a mark, it conveys the urgency of the action needed on board a ship although she may only be doing 7 knots.

Slide No. 12

(12) Lastly. I have a slide covering the area of the search for the Comet wreck near the Isle of Elba. Besides being currently topical, this search can be made to illustrate some relevant points. It has been conducted by the Commander-in-Chief, Mediterranean and the Admiralty has not butted in with any advice. I have not yet seen a detailed report how it was conducted since, although one of the first signals referred to the possible need for a surveying ship, there was not one within several thousand miles.

One method of carrying out a search is to sweep with several vessels on a broad front and having another ship laying dan buoys to mark out the area covered or the obstructions that are located. This does not require very accurate fixing or plotting. There can be a good overlap between sweeps. The buoys show the result and fixes by compass bearing and radar ranges will suffice.

The surveying method would be to fix by sextant angles which can be done with an accuracy of ± 30 feet provided they are to shore objects. An accurate record of objects found would be kept.

In the first method more ships are used so that a quicker result is obtained and this has been adopted in looking for the Comet. The disadvantage is in the use of buoys. They can get in the way and in the deep water they have long moorings so that they are not very accurate markers. And of course may drag or sink in bad weather meaning all the sweat of re-locating the target, lying as it may be, amongst a number of others.

The survey method on the other hand is more held up if there is bad visibility and in any case I have assumed although I have not checked up that the surrounding islands do in fact provide good fixing marks. It reuired specialist personnel so that fewer ships can be used. There is a fair amount of preparatory work making plotting sheets on very large scales of promising areas where curves of equal angle between shore marks would be needed. Given these things however the position of a piece of wreckage would be accurately recoverable even after an interval, perhaps of rough weather causing casualties to buoys.

Both methods would have started with Asdics without which the initially huge area of search could never have been covered and both concluded with echo sounding and wire drag sweeping, underwater T.V. and a diver. A smooth muddy bottom and good seawater conditions have meant that Asdics were most efficient. This indeed made the operation possible — as for instance was not the case off the Scottish coast where an R.A.F. Shackleton was recently lost without hope of recovery. The asdic sweep of an individual ship probably had an effective width of 1/2 to 3/4 mile and I expect sweeps had to be made in more than one direction across the area since some wreckage would be a better target looked at one way rather than another.

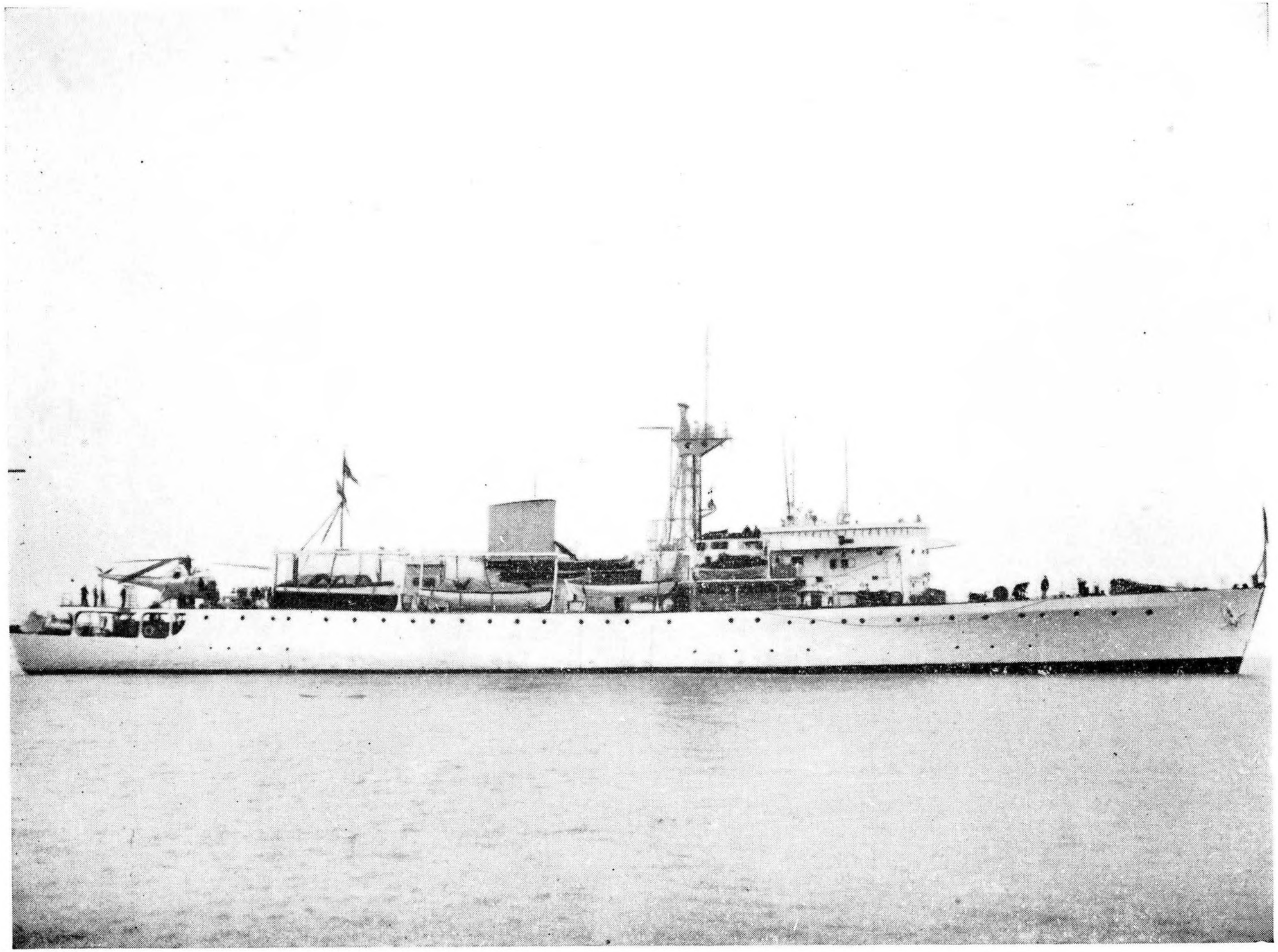
The wire bottom sweeps from the Italian trawlers in formation may have covered 1/4 mile at a time. These have proved most valuable and have no real equivalent in the surveying method, which does not as a rule dispose of many ships. The record of objects found cannot have been easy to keep. One part of the area had been mined during the war and that meant there were a number of mine mooring units lying about the bottom. And one promising target turned out to be a wreck, I suppose an old Greek schooner since the television saw amphorae — presumably a most valuable cargo of wine. A plot on a scale of at least 1" to a mile, four times that of the available chart, must I think have been designed and of course very large scale diagrams for each quadrilateral of mooring buoys inside which a salvage vessel manœuvres to pick up pieces.

Fixing and positioning difficulties in either method would have been solved by electronic methods and at one time a portable Decca navigator system was considered. Three stations set up on the islands with their transmissions all over sea would have given extremely accurate results and any ship could independently have placed herself over a known piece of wreckage within a few feet.

Other methods however were by that time showing signs of success and you will know from the Press what success has been achieved in this fantastically difficult operation.

It is not an exact example of the surveying problem since for one thing the accurate geographical position of the pieces of wreckage is unimportant. It will have illustrated however what has to be done to locate or examine a shoal or obstruction at some distance from the shore.

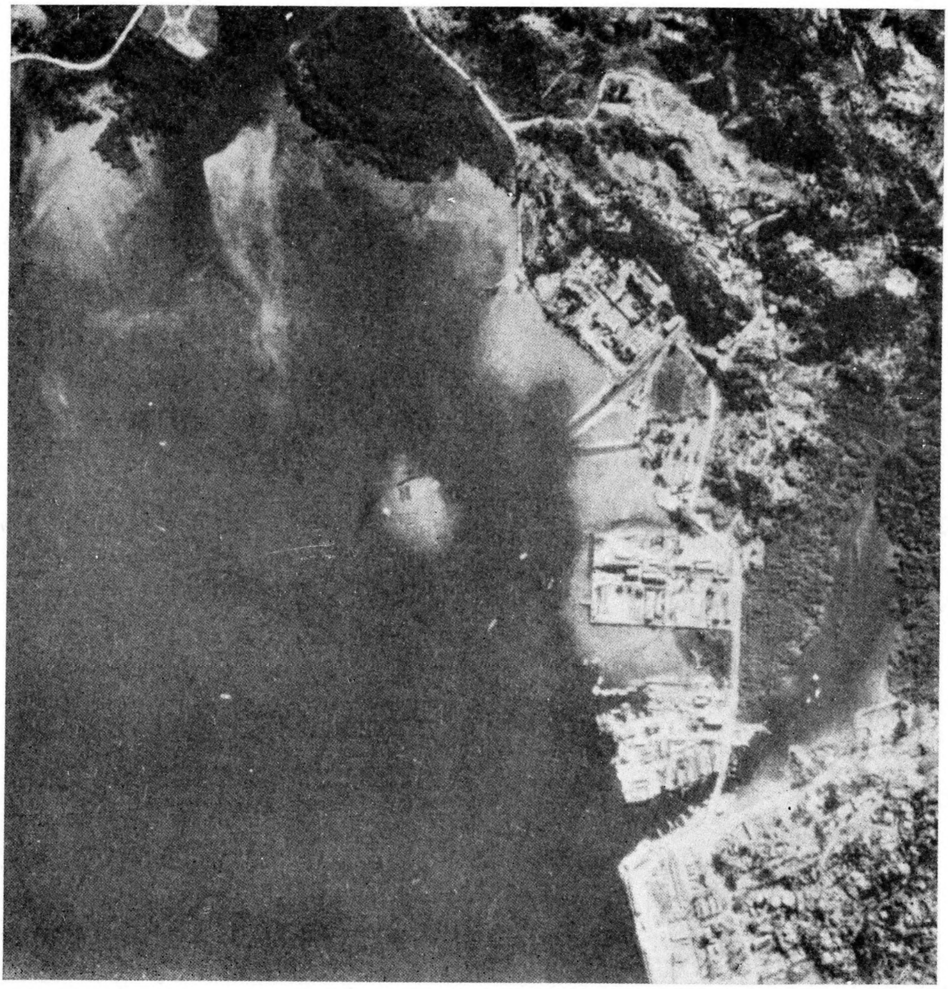
And to show that I have not wandered far from my subject one of the first questions will be « What will be the best scale to work on? ».



Slide No. 1

Slide No. 2

Slide No. 3



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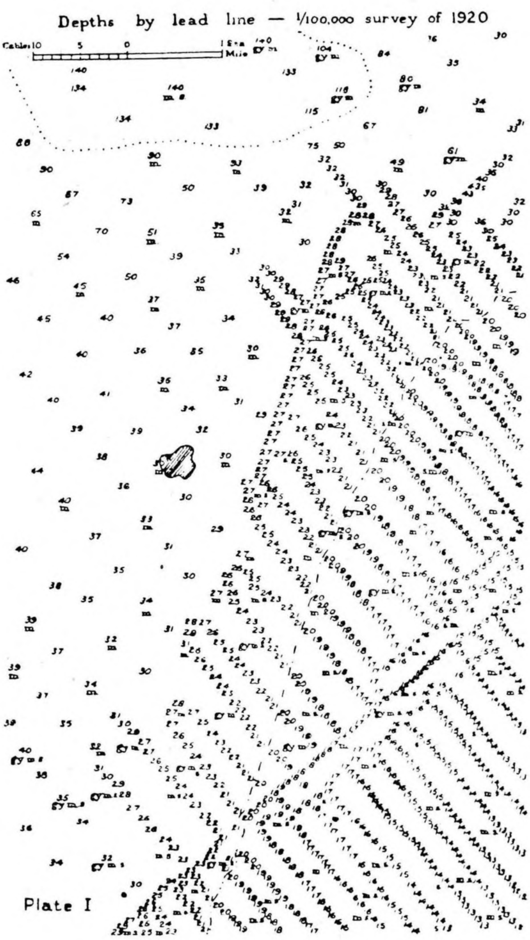

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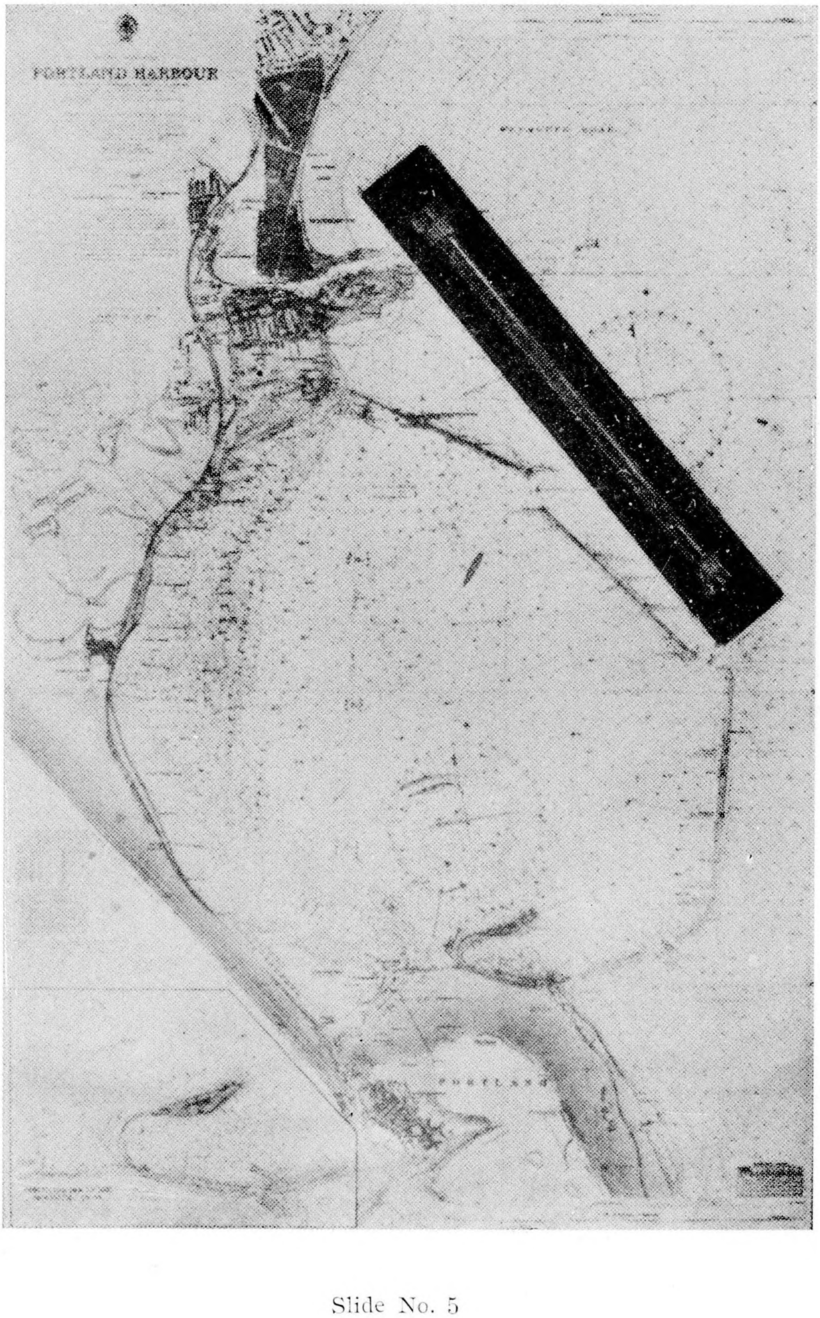

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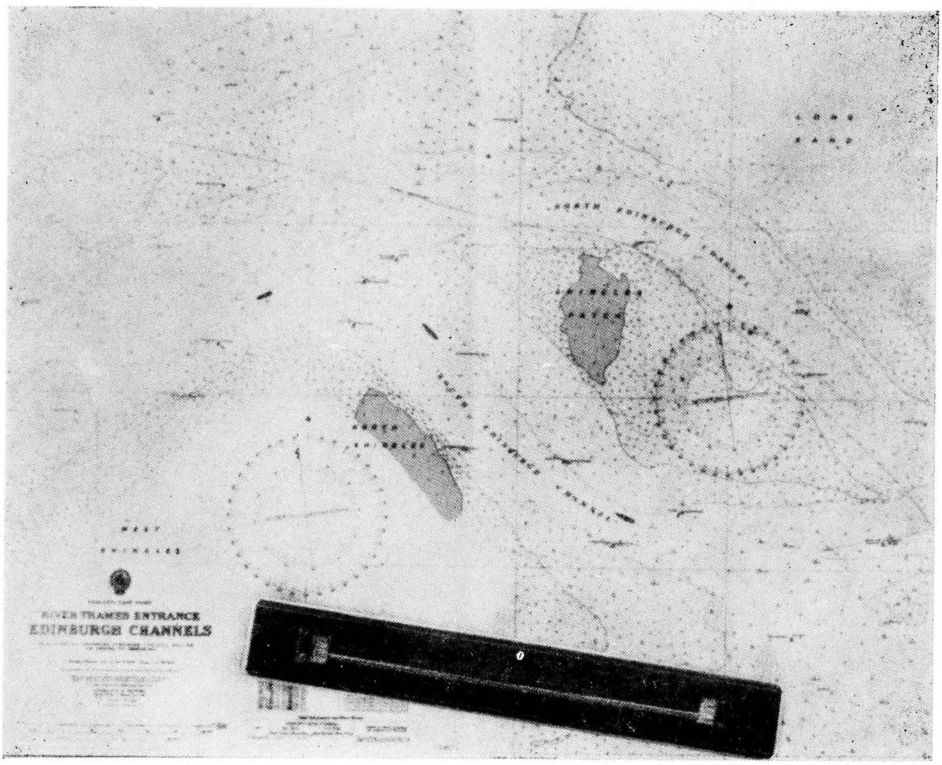

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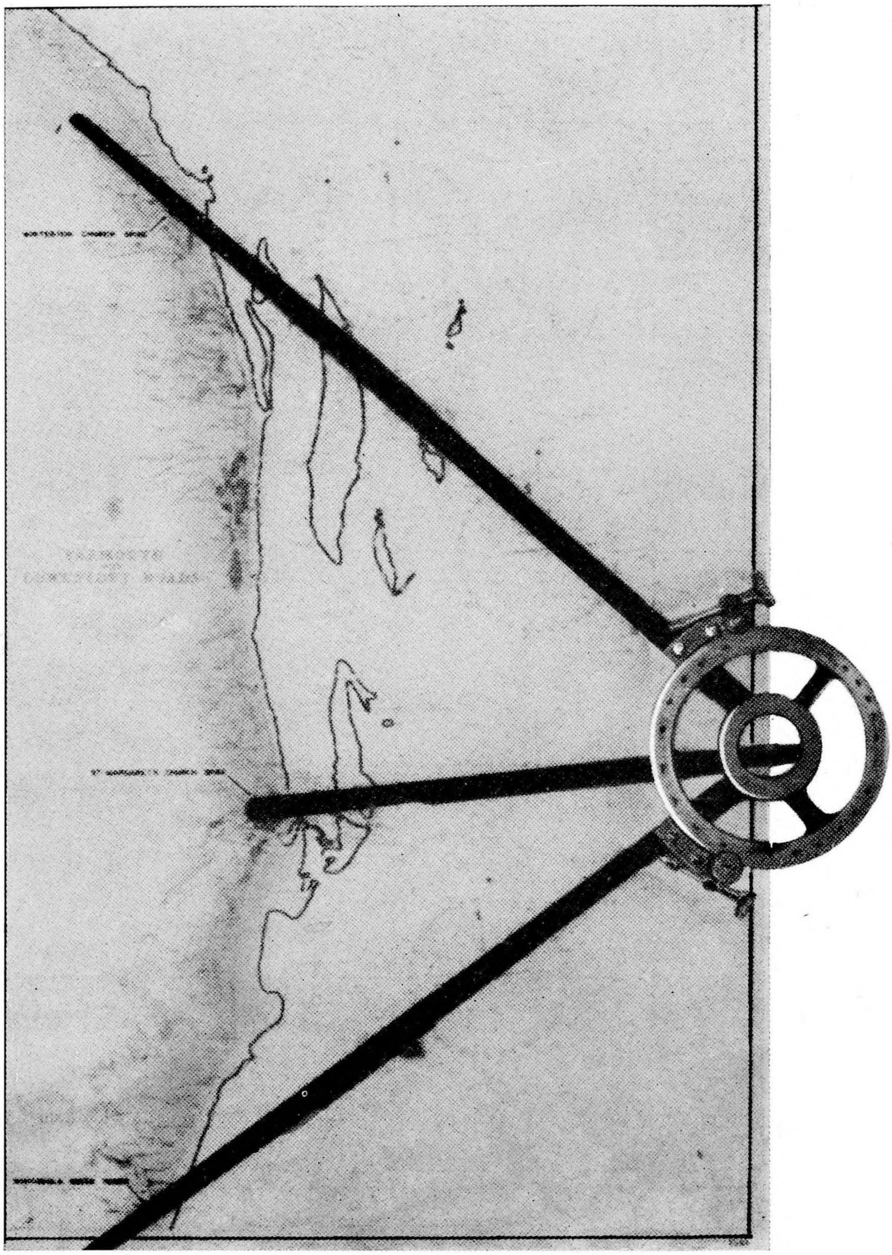

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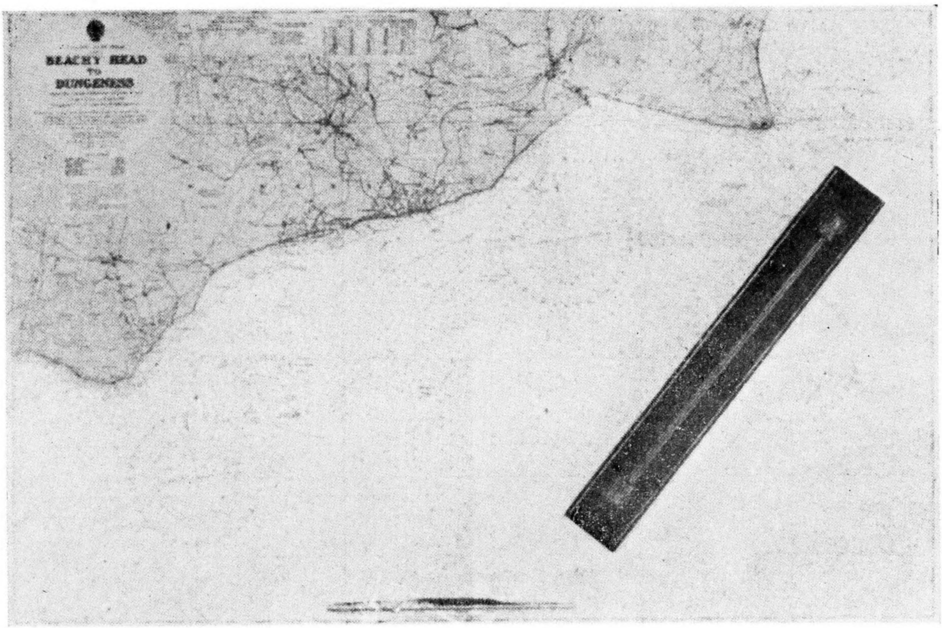

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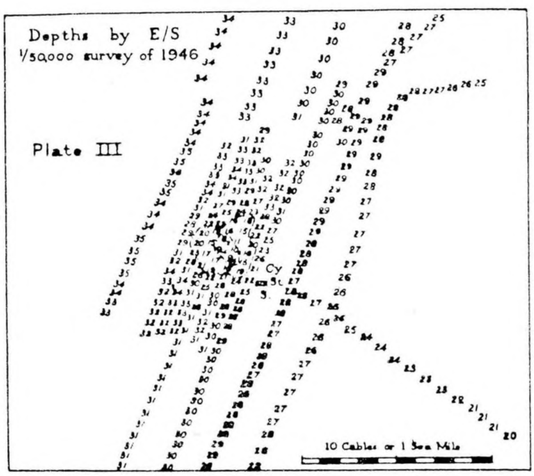

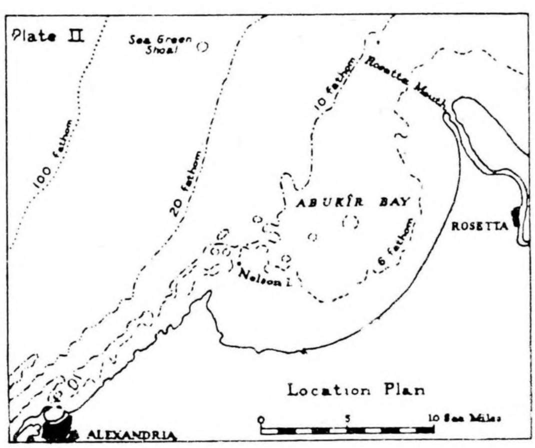

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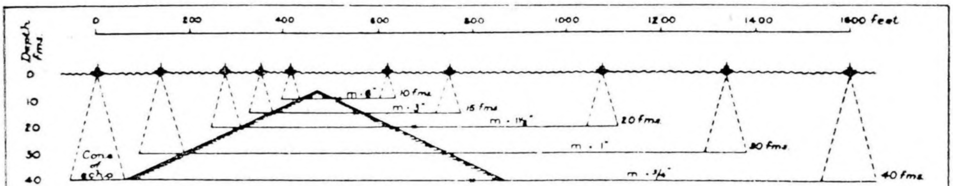


Plate IV Diagram showing at what depth, and at what scale of survey, the base of a 7-fathom shoal with a 25° slope will occupy approximately half the distance (×) between two lines of soundings plotted at a normal interval of 0·2 ins

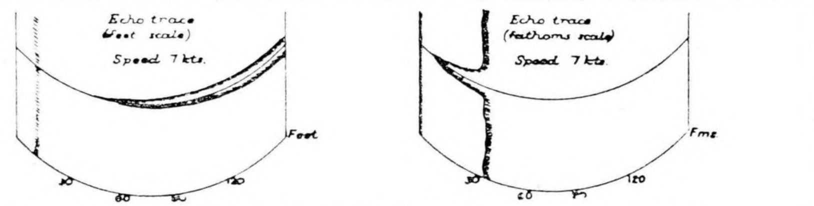
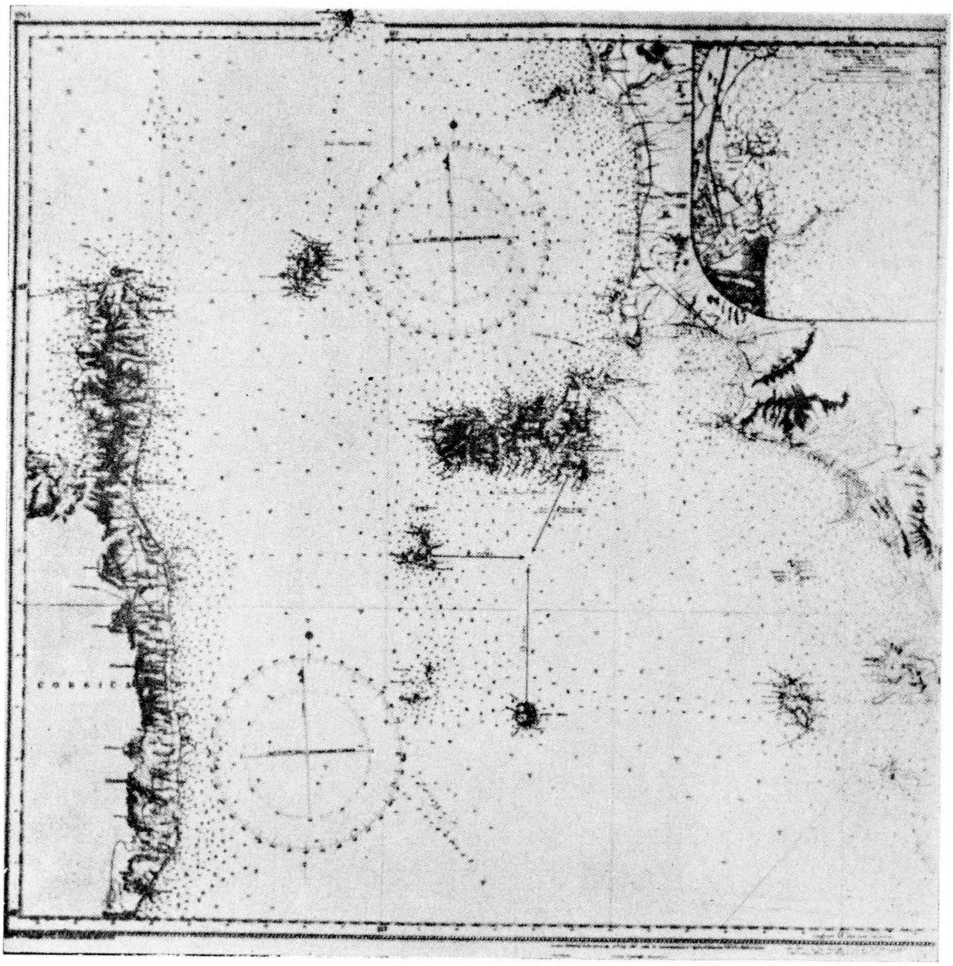


Plate V How a typical E/S recorder would trace the shoal in Plate IV given a speed of 7 Knots across it (2/3th Scale)

Slide No. 11



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