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OCEAN CHARTING

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Note : The views expressed in this paper are the author's own and derive from his ten years' experience in charge of ocean charting in the UK Hydrographic Department : they do not necessarily represent the official policy of the Department.

ABSTRACT

The recent significant improvement in ocean charting is discussed and a comparison is made between the recently completed 5th Edition of the General Bathymetric Chart of the Oceans (GEBCO) and the new series of Small-scale International Charts. The recording of ocean bathymetric data is referred to with special reference to the GEBCO Plotting Sheet System and the increasing importance of digital methods for the recording and storage of these data. Despite their recent improvement, ocean charts are, for the most part, still based on sparse and inadequate data : there are probably many ocean dangers and shoals still to be found and charted, and most of those currently charted are based on old and sketchy reports that could well be erroneous or considerably in error. There is therefore a need for chart users to be aware of these deficiences in ocean charting, and for uniform procedures and standards to be adopted for the investigation and charting of ocean dangers and shoals. The need for the continued maintenance and improvement of ocean charts is emphasised, and the role of remote sensing from satellite observations as an aid to the detection of new bathymetric features in the ocean is referred to.

Introduction

The recent completion of the 18 sheets of the 5th Edition of the General Bathymetric Chart of the Oceans (GEBCO), with 16 of these sheets on a scale of

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1: 10 M (Mercator, 0°) and 2 for polar regions on 1: 6 M (Polar Stereographic, 75°) (see Fig. 1); and the near completion of the 79 sheets of the small-scale International (INT) chart series on scales of 1: 10 M (Mercator, 0°) and 1: 3 1/2 M (Mercator, 22°33′) (see Fig. 2 & 3), means that for the first time the oceans have been systematically charted from all available ocean sounding data to meet the needs of both oceanographers and mariners. These charts depict more accurately, and in more detail, than ever before, the general configuration and depths of the ocean floor world-wide. Thus it would now seem to be an appropriate time to assess and compare these two series of charts, and to consider future action to further improve ocean charting through the two series.

Before comparing the 5th Edition GEBCO and the small-scale INT chart series it would be useful first to consider the present situation as regards the collection and recording, and the availability and accuracy, of ocean bathymetric data; because these matters are of the utmost importance for the future maintenance and improvement of both these series of ocean charts.

The GEBCO Plotting Sheet System [1] [2]

The main method of recording ocean soundings world wide has been, until recently, the hand plotted GEBCO Plotting Sheet System, started in 1962 by the International Hydrographic Bureau (IHB). This system, based mainly on the British Admiralty ocean plotting sheet system, comprises 655 master sounding sheets on a scale of 1: 1 M which provide complete coverage of the oceans. The responsibility for maintaining the 1: 1 M master sounding sheets was undertaken by 18 Volunteering Hydrographic Offices (VHOs) of Member States of the International Hydrographic Organization (IHO) and the limits of the block areas for which each is responsible are shown in Fig. 4. This world bathymetric data service continues to this day and indeed the IHO has been designated the World Data Centre for Bathymetry within the Data Centre network which was originally set up for the International Geophysical Year in the 1950s, and which has subsequently been expanded considerably under the sponsorship of the Intergovernmental Oceanographic Commission (IOC).

Most ocean sounding data still being made available to the IHO for its role as World Data Centre for Bathymetry are hand plotted on the 1: 1 M master sounding sheets by the Volunteering Hydrographic Offices. Some VHOs, however, have changed, or are changing, from hand plotting to recording and storing ocean sounding data as digital bathymetry on magnetic tape from which soundings can be plotted out automatically for any particular area at the scale required (see section below on "Digital bathymetric data...").

The original purpose of recording ocean soundings on the hand plotted 1: 1 M master sounding sheets was to provide the source data for the compilation and maintenance of the General Bathymetric Chart of the Oceans (GEBCO), a task with which the IHB was originally entrusted in 1929, together with collating all sounding data outside the continental shelf. Hence the 1: 1 M hand plotted master sounding sheets are usually referred to as GEBCO plotting sheets, and the GEBCO Plotting Sheet System has until recently been regarded as the world base for ocean bathymetry.

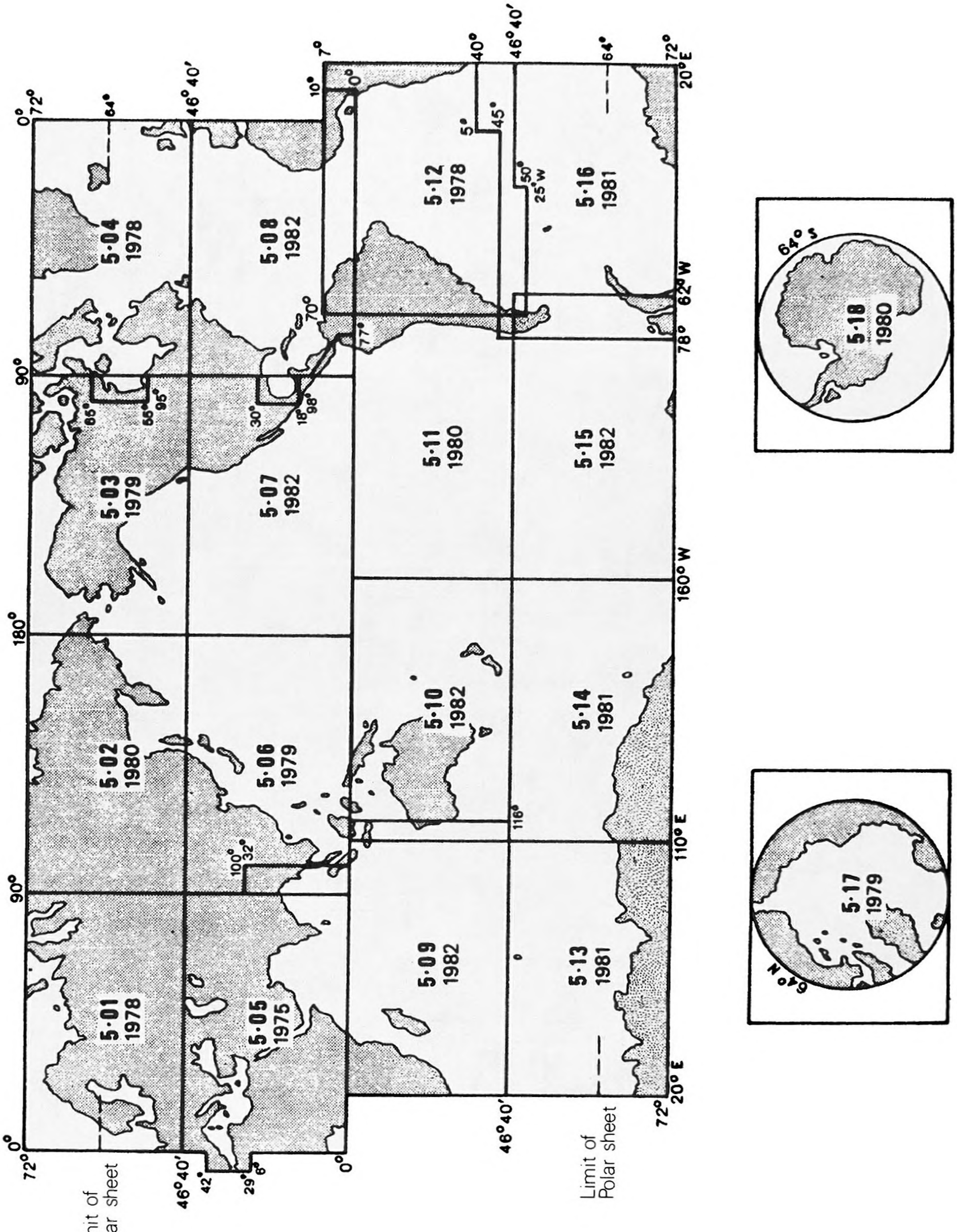

FIG. 1. — Assembly diagram for GEBCO sheets (5th Edition)

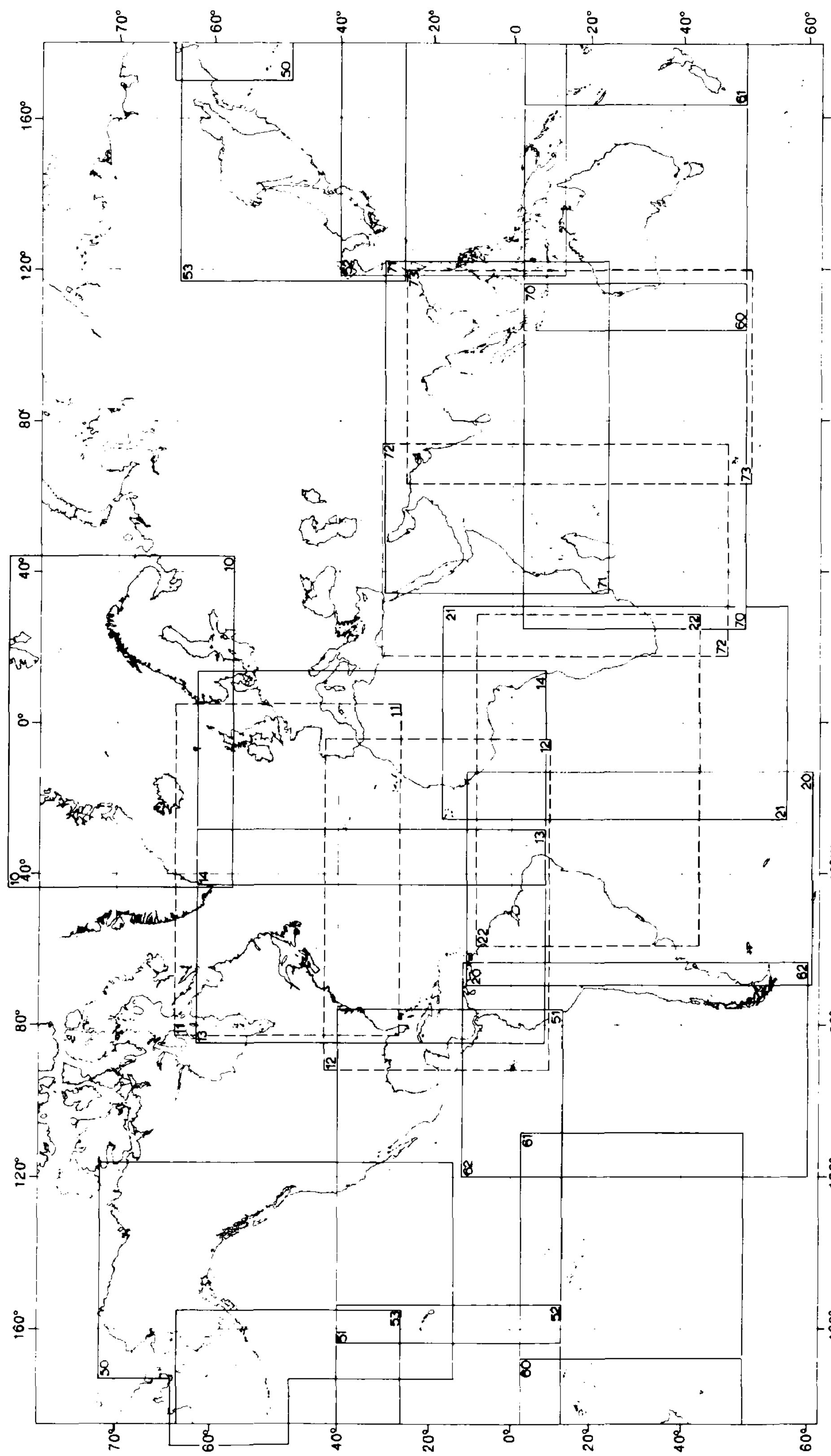

FIG. 2. — Scheme of small scale International charts on a scale of 1:10,000,000

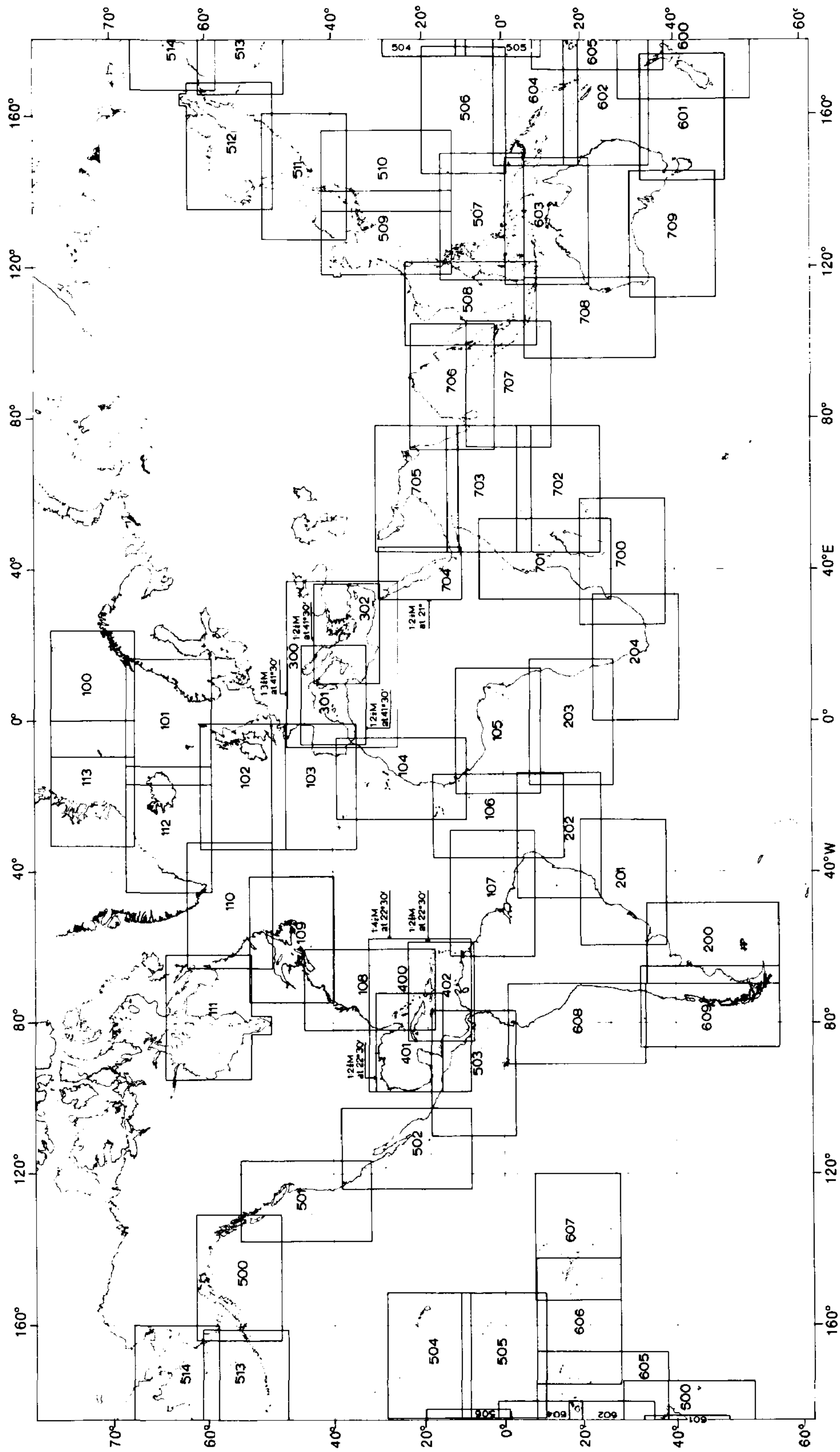

FIG. 3. — Scheme of small scale International charts on a scale of 1:3,500,000

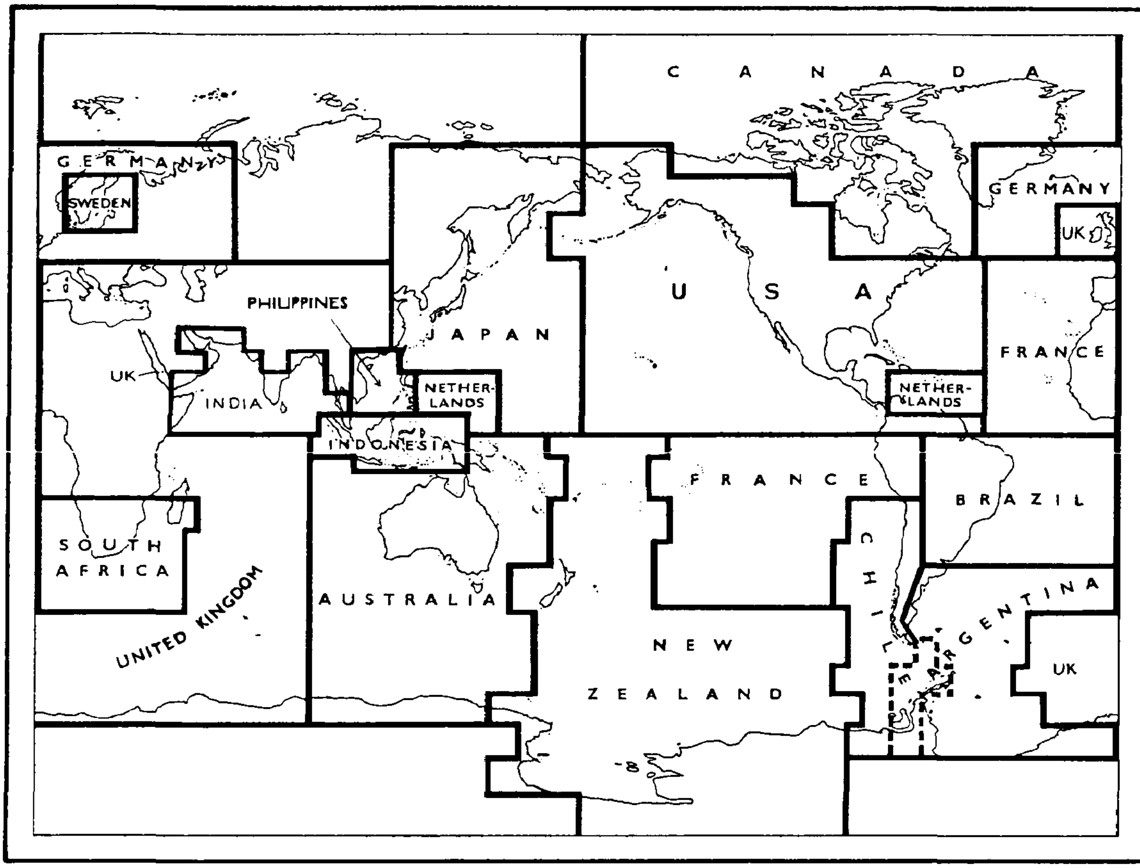

FIG. 4. — National areas of responsibility for GEBCO data collection

While most charts of the continental shelf are based on hydrographic surveys, albeit of varying age and quality, very little survey work of a systematic nature has been carried out in ocean areas beyond the edge of the continental shelf (200 m line). Thus nearly all ocean bathymetric data that have been recorded on GEBCO plotting sheets are random lines of soundings from a wide variety of sources — survey ships, research vessels, naval vessels, cable ships, merchant ships, etc. — and the soundings shown are therefore of varying reliability and accuracy. Most lines of soundings shown on GEBCO plotting sheets were fixed by astronomical observations and the average error in position of such lines has been found to be ± 8 miles [3]. Ocean soundings gathered since the introduction of modern ocean fixing aids, such as Satnav and Omega, have been positioned more accurately. However, despite this variation in reliability and accuracy, all ocean soundings shown on GEBCO plotting sheets have, *in general,* been regarded as equally acceptable both for the compilation of small-scale INT charts and the GEBCO 1:10 M sheets. Indeed, until such time as the oceans are systematically surveyed in the same way as continental shelf areas, the charting of the oceans will have to continue to be based largely on the random data available, and the interpretation of these data.

The reducing role of the GEBCO Plotting Sheet System

The role of the IHO as World Data Centre for Bathymetry based on the GEBCO Plotting Sheet System continues to be supported by the Member States of the IHO by way of the 'Annual List of Information Concerning Recent Ocean Bathymetric Data', whereby Member States advertise the ocean bathymetric data they have collected, usually from their own survey ships, during the previous year. The data are advertised under the relevant GEBCO plotting sheet numbers and this information is circulated by the IHB so that the VHOs responsible for the maintenance of the GEBCO plotting sheets can acquire the data for incorporation into the GEBCO Plotting Sheet System.

However, this Annual List has not been as widely used and supported as originally intended, particularly in recent years, mainly because of the changing methods of recording and storing ocean sounding data. When the GEBCO Plotting Sheet System was first established in 1962, most ocean sounding data available were recorded on hand plotted ocean sounding sheets and it was a relatively simple task for the 18 VHOs to incorporate these soundings by hand on to the GEBCO plotting sheets. This method of hand plotting ocean soundings on to ocean sounding sheets is still generally used by most hydrographic survey ships as well as naval vessels, cable ships and other traditional sources of ocean passage soundings.

Digital bathymetric data as the main future method of recording and storing ocean bathymetry

Today, however, many — if not most — new ocean bathymetric data are collected by marine scientists on research vessels and these data are no longer hand plotted but are recorded and stored as digital bathymetric data on magnetic tape, and usually remain stored in this form after being used for the particular project for which they were collected. These modern digital bathymetric data are generally more accurate and reliable than most of the hand plotted sounding data shown on the GEBCO Plotting Sheet System, as they have, in the main, been obtained by using modern ocean position fixing systems such as Satnav and Omega and modern deep ranging echo sounders, in particular precision depth recorders.

Much of the modern digital bathymetric data stored on magnetic tape is held at the World Data Centre 'A', Marine Geology and Geophysics (WDC 'A' MGG), at Boulder, Colorado, USA.

Unfortunately, most of this modern digital bathymetry collected by oceanographers and research vessels has not been made available to hydrographic offices for the compilation and correction of small scale nautical charts of the ocean, in particular the small scale INT chart series. The following extract from the report of proceedings of the XIIth International Hydrographic Conference, Monaco, 1982, is relevant in this respect : 'Professor SIMPSON (former Chairman of the Joint IOC/IHO GEBCO Guiding Committee) said that the Guiding Committee had realised, during the course of its work, that the findings of many individual scientists were never transferred to the IHO in its capacity as World Data Centre for Ocean Bathymetry. All members of the scientific community should be urged to send in their data...'.

Having been appraised of this situation, the recently re-formed GEBCO Sub-Committee on Digital Bathymetry addressed itself to the problem at its first meeting in April 1984 and steps are now being taken by the WDC 'A' MGG to provide information on the digital bathymetric data it holds to the IHB, and thence to the VHOs responsible for maintaining the GEBCO Plotting Sheet System.

The 5th Edition of the General Bathymetric Chart of the Oceans (GEBCO) [2]

In 1972 the IHO and the IOC decided to co-sponsor an entirely new edition of GEBCO, the 5th Edition, to be compiled by marine scientists employing the best available bathymetric, geological and geophysical knowledge of the ocean floor so as to meet the needs as well as possible of the many and varied present day users of ocean bathymetric charts.

Production of the series was supervised by a Joint IOC-IHO Guiding Committee for GEBCO, and the Canadian Hydrographic Service undertook the considerable task of fair drawing and printing the 18 sheets from compilations provided by the marine scientists.

The compilation of each sheet was undertaken by scientific co-ordinators who were experienced marine scientists selected for their specialist knowledge of the bathymetry and sea-bed morphology of the ocean areas covered by the sheets which they compiled. These scientific co-ordinators were responsible for the acquisition, evaluation and selection of ocean sounding data used for the compilation of their 1:10 M GEBCO sheets. From these sounding data they compiled bathymetric contours that best fitted both the bathymetric data available and their theories and knowledge of the ocean floor morphology of the area concerned; bathymetric contours were extrapolated to portray in as much detail as possible the most probable shape of the ocean floor for areas where little or no sounding data were available. As these 5th Edition GEBCO sheets have not been designed and produced for the purposes of ocean navigation, the scientific co-ordinators have been able to exclude, if they so wished, after careful analysis of all the data available, the many doubtful dangers and shoal depths, and anomalous depths, that have been reported in ocean areas.

The 5th Edition GEBCO sheets are thus scientific documents for the use of marine scientists and the increasing numbers of others interested in the ocean who now need an accurate bathymetric chart of the oceans for their various purposes. The main requirement of the General Bathymetric Chart of the Oceans has been described as 'the closest approximation of the truth that can be made from available data and the existing knowledge about the sea floor' [4]; and the 5th Edition GEBCO has been drawn with this requirement very much in mind.

Fortunately, an important innovation on the 5th Edition GEBCO sheets has been the depiction of the sounding control which has been used on the face of each sheet. Discrete soundings appear as grey dots and echo sounding tracks as grey lines in the background to the contours. Areas which are 'saturated' with lines of passage soundings and those which have been fully surveyed are shown in boxes and cross referenced to a note in the border. These 5th Edition GEBCO sheets thus provide a useful, and currently the most complete world-wide graphical index of available ocean sounding data; and they are therefore also the most useful single guide to the amount of sounding data not at present recorded on the GEBCO 1:1 M plotting sheets.

With their specialist knowledge of ocean floor morphology, and with the extra ocean sounding data they have acquired in addition to that shown on the 1:1 M GEBCO plotting sheets, the scientific co-ordinators have achieved a more accurate and detailed depiction of ocean bathymetry on the 5th Edition GEBCO sheets than would have been possible from using the sounding data on the 1:1 M GEBCO plotting sheets alone; and there are many new significant bathymetric features in ocean areas shown on the 5th Edition GEBCO sheets which should be included on small-scale INT and other ocean navigational charts.

In his report to the International Union of Geodesy and Geophysics meeting in Hamburg in 1983 Dr R.L. FISHER, a member of the GEBCO Guiding Committee, stated that 'the 18-sheet 5th Edition GEBCO series, at 1:10 M Mercator (0°), very likely will become the overall world sea floor standard for at least the next decade or two'.

The compilation sheets prepared by the scientific co-ordinators of the 5th Edition GEBCO 1:10 M Sheets

These compilation sheets were mainly prepared in the middle and late 1970s by the scientific co-ordinators from all the sounding data they could obtain for the 1:10 M GEBCO sheets they were compiling. The two main sources of ocean sounding data that were used were the 1:1 M GEBCO Plotting Sheet System and the digital bathymetric data held in the date base at WDC 'A' MGG, but other sources of sounding data, known to the scientific co-ordinators with the specialist knowledge of their areas of responsibility, were also used. Legends listing the sources of all sounding data used are shown on the published 1:10 M GEBCO sheets.

The scientific co-ordinators' compilations, which were a mixture of sounding collector sheets and contoured sheets, thus comprised the best world-wide large scale graphical record of ocean bathymetry; and they were compiled mainly on the same scale as the 1:1 M GEBCO Plotting Sheet System. It is therefore to be hoped that copies of these scientific co-ordinators' compilation sheets — both sounding collectors and contoured sheets — will be made available, wherever possible, to the VHOs responsible for the maintenance of the GEBCO Plotting Sheet System and for the production and maintenance of small-scale INT charts.

The continuing need for a world-wide graphical record of ocean bathymetric data

Despite the reducing role of the GEBCO 1:1 M Plotting Sheet System, there is arguably a continuing need for ocean sounding data stored as digital bathymetry on magnetic tape to be plotted out graphically on the same 1:1 M plotting sheet system so as to provide an immediate and visual record of all available ocean sounding data world-wide. Indeed the revised GEBCO Regulations will need to take account of both systems of recording and storing ocean sounding data — the GEBCO 1:1 M Plotting Sheet System and digital bathymetry held at WDC 'A' MGG — and how they can best be used together : the 1981 report of the GEBCO Sub-Committee on Digital Bathymetry stated that 'for some time into the future both graphical and digital data will be part of a world-wide data base for bathymetry'.

The continuation of a graphical record of ocean bathymetry, similar to the present GEBCO Plotting Sheet System, would help hydrographers and oceanographers to deal promptly with immediate queries concerning depths in ocean areas, to plan their ocean surveys and passage soundings, and to identify areas of special interest.

A most important role for such a comprehensive graphical record of ocean soundings will continue to be that of providing the base data for the compilation and correction of ocean charts.

In addition to this proposed world-wide graphical record of ocean sounding data of digital bathymetry stored on tape, it is already possible to obtain plots of digital bathymetry for any ocean area at any particular scale required.

Small-scale International (INT) Charts

In the early 1970s, when the GEBCO 5th Edition was being planned, work was also under way on the 79 charts comprising the Small-scale International Chart Series on scales of 1:10 M and 1:3 1/2 M which provide complete nautical chart coverage of all ocean areas except the polar regions (see Fig. 2 and 3). The task of producing these charts, now nearly completed, has been shared by 17 of the Volunteering Hydrographic Offices responsible for the maintenance of the GEBCO plotting sheets with, in general, these hydrographic offices producing the small scale INT charts that fall in their areas of responsibility for GEBCO plotting sheets.

The small-scale INT charts have, for ocean areas beyond the edge of the continental shelf, been compiled almost solely from the data on the 1:1 M GEBCO plotting sheets. Therefore, from the standpoint of Hydrographic Offices, the most important role of GEBCO 1:1 M plotting sheets has been to provide the main source data for the production and maintenance of small-scale INT charts, and other small scale nautical ocean charts.

Small-scale INT charts are, in the main, cartographic generalisations of the sounding data shown on the GEBCO 1:1 M plotting sheets and, as stated above, there is much information on the 5th Edition GEBCO 1:10 M sheets that could usefully be incorporated into these INT charts; in particular, the general run of bathymetric contours depicting the major morphological features of the ocean, suitably generalised for the use of the mariner, and the many new significant bathymetric features in the oceans not currently recorded on the GEBCO 1:1 M plotting sheets.

The large scale compilation sheets referred to above that were prepared by the scientific co-ordinators showing soundings and/or depth contours should, where possible, be obtained and used in conjunction with the GEBCO 1:10 M sheets for the correction of small-scale INT charts.

All significant new bathymetric features shown on the GEBCO 1:10 M sheets should be inserted together with spot soundings to indicate the shoalest depth, where these soundings are available from the GEBCO 1:10 M sheets or the scientific co-ordinators' compilation sheets. Where soundings are currently not available these significant new bathymetric features will have to be shown by depth contours only, taken from the GEBCO 1:10 M sheets, to be augmented later by soundings, when available.

For deep ocean bathymetry it may also be necessary to insert depth contours from the 5th Edition GEBCO sheets without the supporting spot soundings normally shown on nautical charts, particularly where depth contours have been extrapolated by scientific co-ordinators for areas with no available sounding data.

There is a need for this improvement of small-scale INT charts from the 5th Edition GEBCO sheets to be carried out as soon as possible before the scientific co-ordinators disperse their compilation material, and because, as stated above, the 5th Edition GEBCO is likely to remain the 'overall world sea floor standard for at least the next decade or two'.

The generalisation of contours depicting deep ocean bathymetry on small scale INT charts is quite acceptable because mariners using these charts do not require a meticulously accurate portrayal of the deep ocean floor; this is in contrast to oceanographers and other marine scientists using the 5th Edition GEBCO who require the deep ocean floor shape to be shown in as much detail as possible. Generalised bathymetric contours at 1 000 m intervals, together with a suitable selection of spot soundings, adequately portray the amount of information required for navigational chart purposes in deep ocean areas.

Furthermore, while variable blue layer tinting for the many different ranges of depths helps to improve the depiction of ocean bathymetry on the 5th Edition GEBCO, this widespread use of layer tinting is less suitable for nagivational charts, as a generally white background is preferred for the plotting of courses and fixes, and the overprinting of lattices such as Omega, Loran-C, Decca, etc. There is also the need for small-scale INT charts to be in the traditional simple format of nautical charts for ease of production, maintenance, correction and frequent reprinting.

The generally white background for the water areas on small-scale INT charts and the enhancement of the 30 m and 200 m depth contours on these charts with blue tint sufficiently emphasise the features of particular significance to the surface mariner, such as the edge of the continental shelf, and dangers and shoal depths — both confirmed and reported — which rise suddenly from deep water.

Reported and unconfirmed shoal depths and dangers must always be shown on navigational charts for the safety of shipping until they have been confirmed or disproved by an adequate search and survey. It is also important to chart newly reported isolated anomalous depths — usually reported depths not dangerous to surface navigation but markedly shoaler than charted surrounding depths — as these anomalous depths are often the first indication of significant new bathymetric features, such as seamounts; these newly reported anomalous depths thus serve as a warning to mariners that lesser depths may exist in the vicinity. There is no requirement to show doubtful data on bathymetric charts used by oceanographers and scientists as these charts are not used for navigation. Hence, doubtful data are usually omitted from bathymetric charts particularly if they do not fit the existing and most probable pattern of bathymetry in the vicinity.

There is a need to show clearly what have been termed 'signposts of the ocean bottom' [5] — the major morphological features of the ocean floor — on small scale navigational ocean charts. The depiction of these features serves as an aid to navigation in much the same way as the sea bed topography of the continental shelf has been used for centuries by mariners as an aid to navigation off-shore. Perhaps more importantly, now that position fixing in ocean areas has been made so much easier and more accurate with the use of electronic aids such as Satnav and Omega, and with further improvements from new global satellite navigation systems such as GPS Navstar likely soon, the depiction of these 'signposts' now serves as a guide and a warning to mariners by helping to indicate where uncharted shoal depths and dangers are most likely to occur in the ocean : for it is important to chart as clearly and fully as possible those areas where shoal depths and dangers are most likely to occur — such as mid-oceanic ridges with associated fracture zones, isolated seamounts and seamount chains, oceanic island arcs with contiguous shoal areas which frequently include dangerous shoals, and coral areas where dangerously shoal coral pinnacles rise sharply from deep water.

Most shoal depths and dangers in ocean areas that are currently charted, in particular those hazardous to shipping, have still to be positioned accurately and fully surveyed for least depth and extent, and there are doubtless others still to be discovered and charted. This very important factor concerning the sparseness and inadequacy of ocean bathymetry should always be borne in mind when using small scale ocean charts and is referred to more fully below.

A good example of the sort of area where unexpected shoal depths are likely to occur is the Southwest Indian Ridge : the complexity of the morphology, and the rapid and large variations in depth over very short distances, are well illustrated in Figures 5, 6 and 7 which show part of this ridge as depicted on BA 4072 (1:10 M INT chart 72), GEBCO 1:10 M 5th Edition sheet 5.09 and 1:1 M GEBCO plotting sheet 463. It will be seen from Figure 7 that, even in this relatively well sounded area, there are some significant gaps between the lines of soundings where shoaler soundings than those circled, the shoalest so far found, may well exist.

The sparseness, and inadequacy and inaccuracy of ocean bathymetry : with particular reference to the detection and charting of ocean dangers

Most existing ocean bathymetric data are from random lines of soundings and almost the entire area of the ocean has still to be systematically surveyed to obtain an accurate and definitive portrayal of the ocean floor. In particular, this applies to those areas of potentially critical depths for navigation, such as mid-oceanic ridges and summits of seamounts. The many such features presently charted only from random sounding data may well, after being fully surveyed, be found to require considerable amendment for least depth, general extent and geographical position.

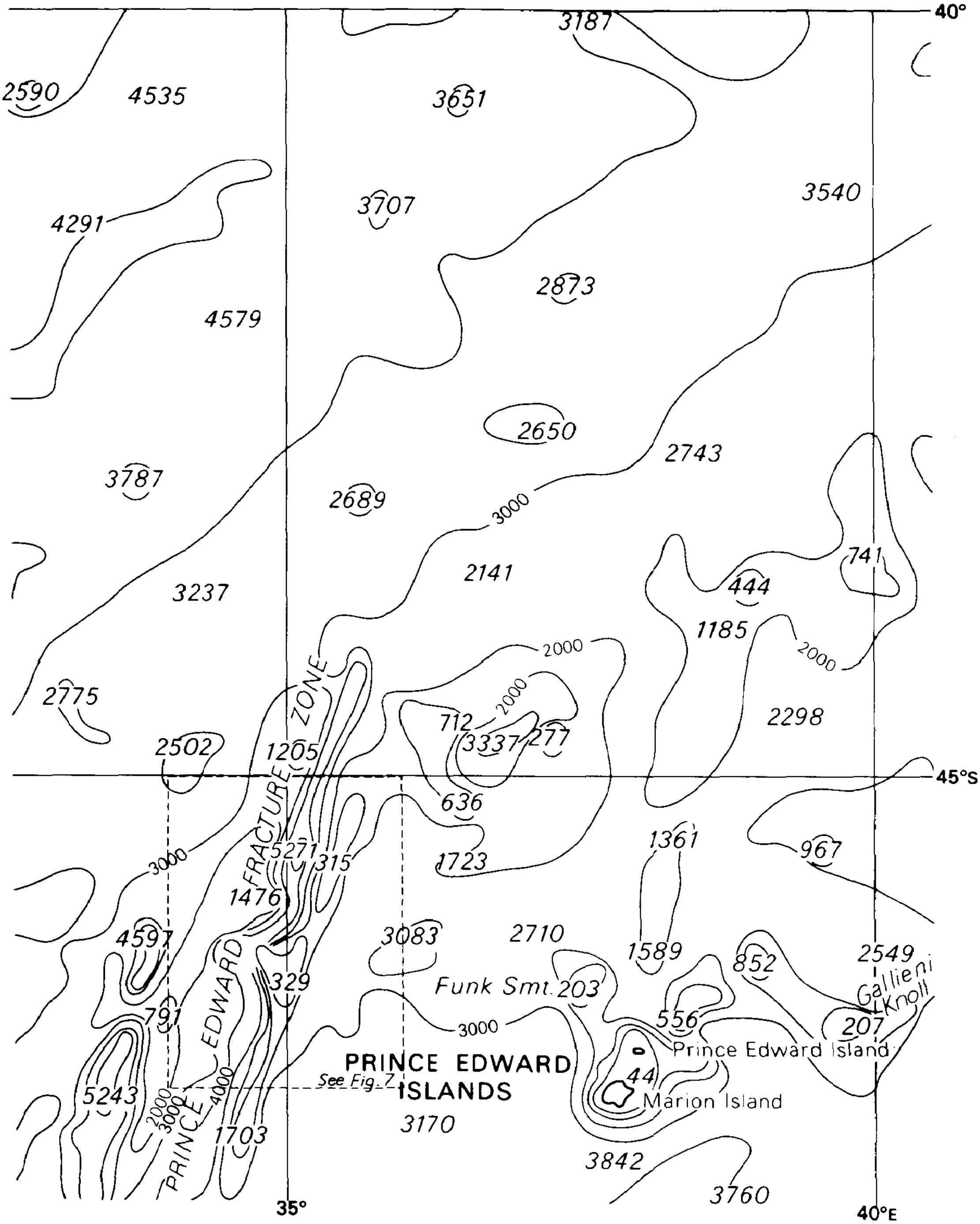

FIG. 5. — Part of the Southwest Indian Ridge from B.A. Chart 4072 (INT. 72). (photo enlargement)

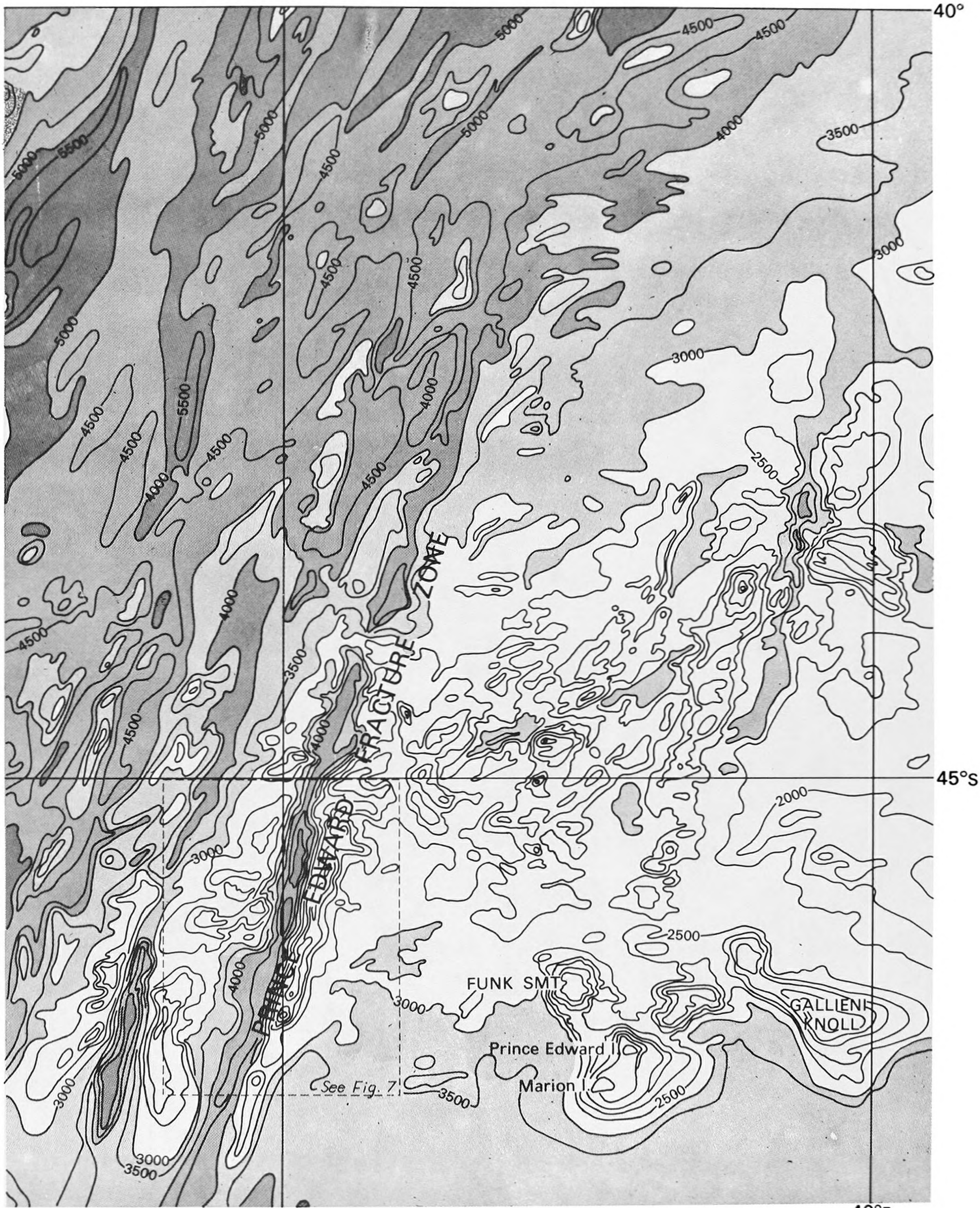

FIG. 6. — Part of the Southwest Indian Ridge from GEBCO 5th Edition sheet 5.09 (photo enlargement)

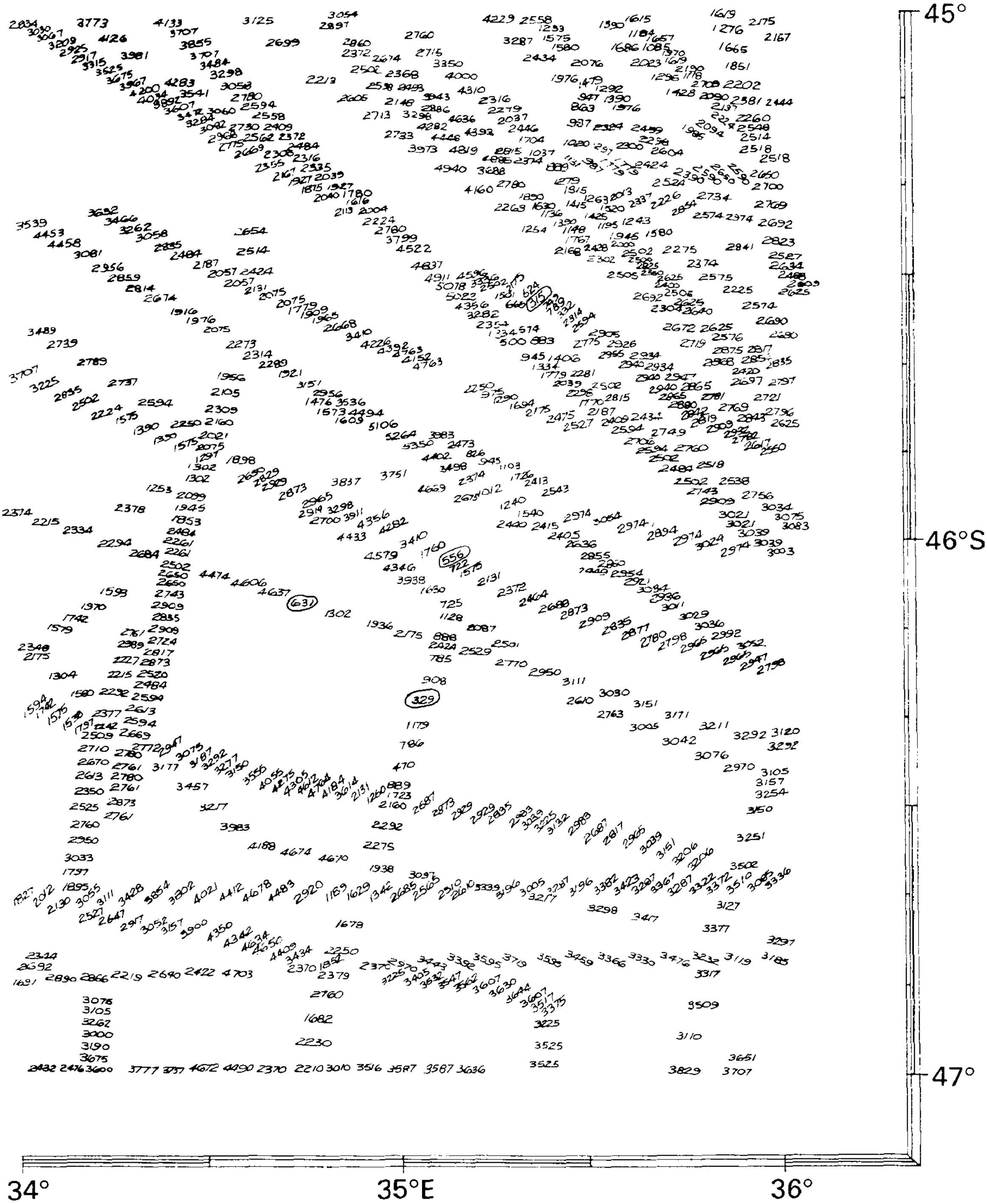

FIG. 7. — Part of the Southwest Indian Ridge from GEBCO plotting sheet 463

It is important for the mariner to bear this in mind when navigating in the vicinity of charted ocean dangers and shoals, as many of these have been inserted from old and sketchy reports which may be considerably in error, especially as regards geographical position (see section below on "the investigation of reported dangers and shoals in ocean areas"). Such reports of ocean dangers have been received and charted by hydrographic offices since the first half of the nineteenth century, when small scale nautical charts providing world wide coverage of the oceans were first published for mariners. Many ocean dangers first charted from these early reports have remained unchanged in their depiction on ocean charts throughout the years to the present time, despite the age and shortcomings of the original reports.

A good example of such an early reported danger still currently charted is Owen Bank, with a depth of 34 metres (19 fathoms), situated some 60 miles west of the Chagos Archipelago in the Indian Ocean in general depths of 3 000 to 4 000 metres. This bank was reported and sounded over by Lieutenant W.F.W. OWEN, RN, in HMS *Barracouta* in November, 1811 while on convoy duty from Batavia to Bombay. Quite by chance the bottom was clearly sighted and soundings of 19 and 20 fathoms were carried over the bank for some half an hour; however, none of the other ships in the convoy had soundings. Lieutenant Owen subsequently had a notable surveying career and, as Captain Owen, was responsible for surveying most of the coast of Africa for the first time. Based on this report, the bank has since been shown on British Admiralty charts, until very recently, as a firm depth of 34 metres (19 fathoms) with the name 'Owen Bank'. Owen's report has now been reappraised against the GEBCO plotting sheet of the area which shows depths in the vicinity of 3 000 to 4 000 metres from lines of soundings, albeit widely spaced : because of this, and the likely considerable error in the position of Owen's 1811 report, this feature is now shown on the modern 3 1/2 M and 10 M BA INT charts of the area as a doubtful 34 metres depth with the legend 'PD (1811)'.

A further example of a charted confirmed ocean danger based on old report and survey is Durand Reef, south east of Loyalty Islands off New Caledonia in the South-west Pacific. This reef was first reported in 1794 and is still charted from a survey and investigation by Captain DENHAM, HMS *Herald*, carried out in 1856. Figure 8 shows this survey and despite the position of the centre of this reef being quoted to the nearest second in the title it could well be several miles in error, considering the date of the survey. The depth information on this sketch survey in the vicinity of the reef is very sparse and an extract from Captain Denham's letter of 14 May 1856 to Captain WASHINGTON, the then Hydrographer of the Navy, reads as follows '... it was not until the 16th of January that most anxious night and day peerings detected its sleepy brake. Having, however, once sighted it, and hung about it till satisfactory astronomic observations and intersections were obtained, I am enabled to record that this most insidious danger of all I have had to deal with in these seas, from its sunken character, lies in 22°2′24″S, and 168°39′34″E, that it is subject to occasional break, which would overwhelm a ship though she were lifted above its submersed rocky heads, while for long intervals of tranquil surface in moderate weather a vessel upon an erroneous course might plump right upon its 9 feet points, which, however, occupy but a circle of two thirds of a mile diameter. The lead will not warn approach to Durand Shoal, as 210 fathoms, coral grit, lie within half a mile of its breakers' [6].

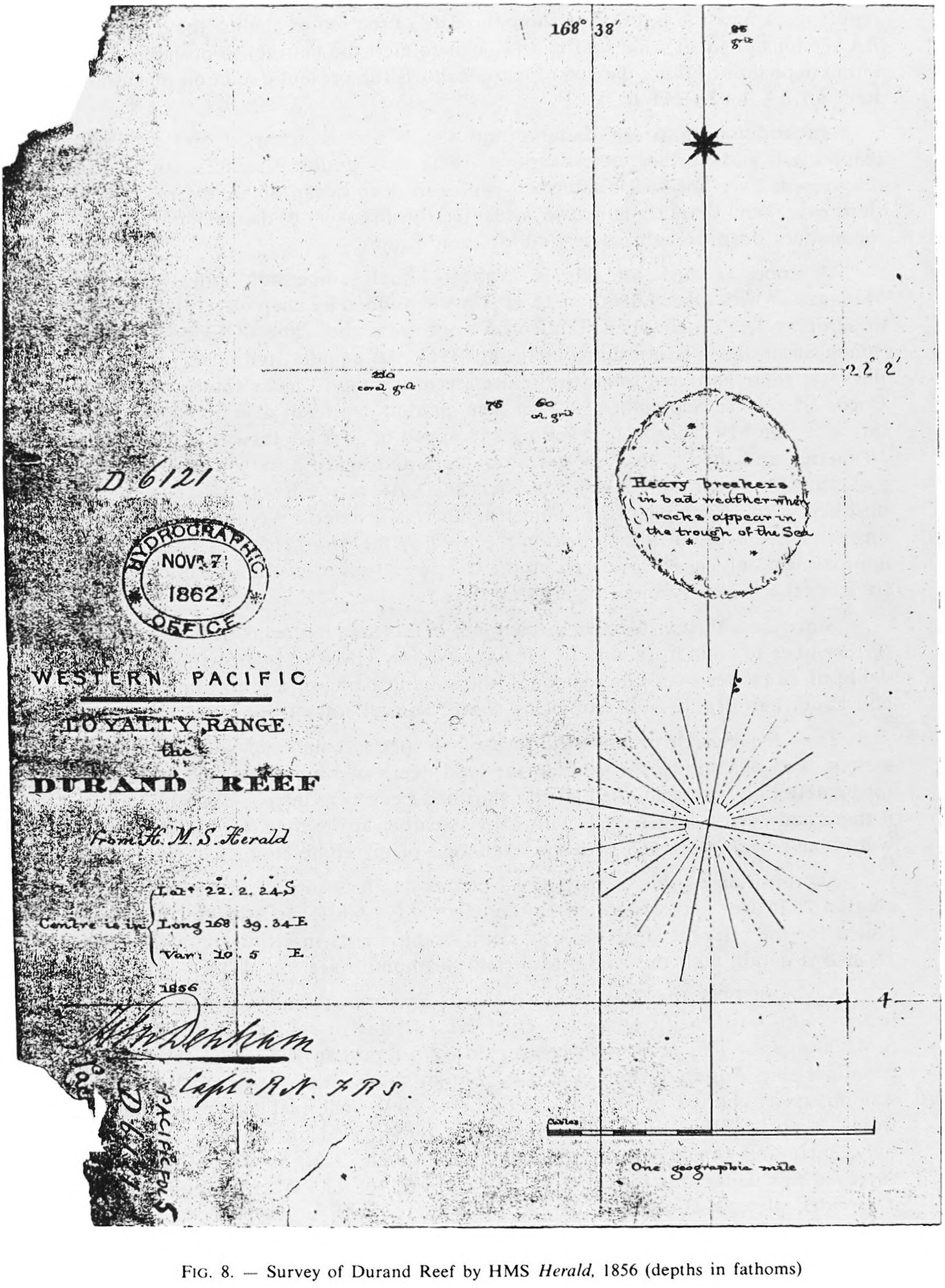

FIG. 8. — Survey of Durand Reef by HMS *Herald*, 1856 (depths in fathoms)

Where charted ocean dangers are based on old (mainly nineteenth century) reports, it is now the practice to show the date of the report against the danger on BA versions of small scale INT charts, so as to alert the mariner to possible errors in the depiction of these dangers. Figure 9 shows the present depiction of Durand Reef on BA 4602 (INT 602).

In addition to ocean dangers and shoals already charted and requiring reappraisal and further investigations, there are doubless others still to be discovered. Even for well established routes in deep ocean areas, the passage of ships over many years has not always ensured the discovery of dangers, particularly for modern deep-draught vessels, along these routes.

A good example of this is Walters Shoals some 450 miles south of Madagascar with a least depth of 15 metres surrounded by deep water; this danger to shipping lies on the well frequented route from the Cape of Good Hope to Sunda Strait and was not discovered until 1962. An equally significant danger on the same route has been found still more recently some 75 miles south-west of the Cocos Islands. In September 1973, in then charted depths of over 5 000 metres in this area, the MV *Muirfield*, travelling at a speed of 13.5 knots, with a draught of 16 metres and in a 2 to 3 metres swell, reported striking an 'obstruction' and sustaining considerable damage to her keel. As a result of this a reported obstruction of 16 metres (8.5 fathoms) depth was inserted by Notice to Mariners on the charts affected in the position reported by the *Muirfield* : this position was approximate only, as it was based on the course and speed of the ship and a visual fix from the Cocos Islands some hours later (see Fig. 10).

Since then, the existence of a seamount in this area has been established from further lines of soundings, and in 1983 a survey by HMAS *Moresby* found a least depth of 18 metres over this seamount, the summit being of a level plateau shape and about half a mile in extent rising sharply on all sides from deep water.

Thus the draught of the *Muirfield* of 16 metres combined with the 2 to 3 metres swell was almost the same as the least depth of 18 metres, so that the ship fortunately only just grounded. If the ship had been of a deeper draught and/or if there had been a larger swell with heavy weather at the time, far more damage would have been sustained with the likelihood of the complete loss of the vessel.

The position of this confirmed 18 metres depth is some 5 miles NE of the charted 16 metres depth reported by the *Muirfield*; a Notice to Mariners has been issued for the relevant small scale nautical ocean charts inserting this confirmed 18 metres depth, with the name 'Muirfield Seamount' (see Fig. 11).

Again, in 1984, the French Survey vessel *Estafette* searched for Antiope Reef in the South-west Pacific some 100 miles NE of Niue in charted depths of 3 000 to 4 000 metres. This search was prompted by a report in 1983 from the French container ship *Rostand*, which was using Satnav for position fixing, that this reef was not in its charted position of 18°14'S, 168°20'W. The reef had been charted from a report by the British ship *Antiope*, in 1886, based on visual observations only, including breakers, with no soundings taken. The *Estafette* found and surveyed this dangerous reef in position 18°15.1'S, 168°23.6'W and found it to be a circular plateau about 400 metres in diameter with a least depth over of 9.5 metres, rising sharply on all sides from surrounding deep water. It was fortunate that this reef was charted as a confirmed dangerous reef from *Antiope's* original

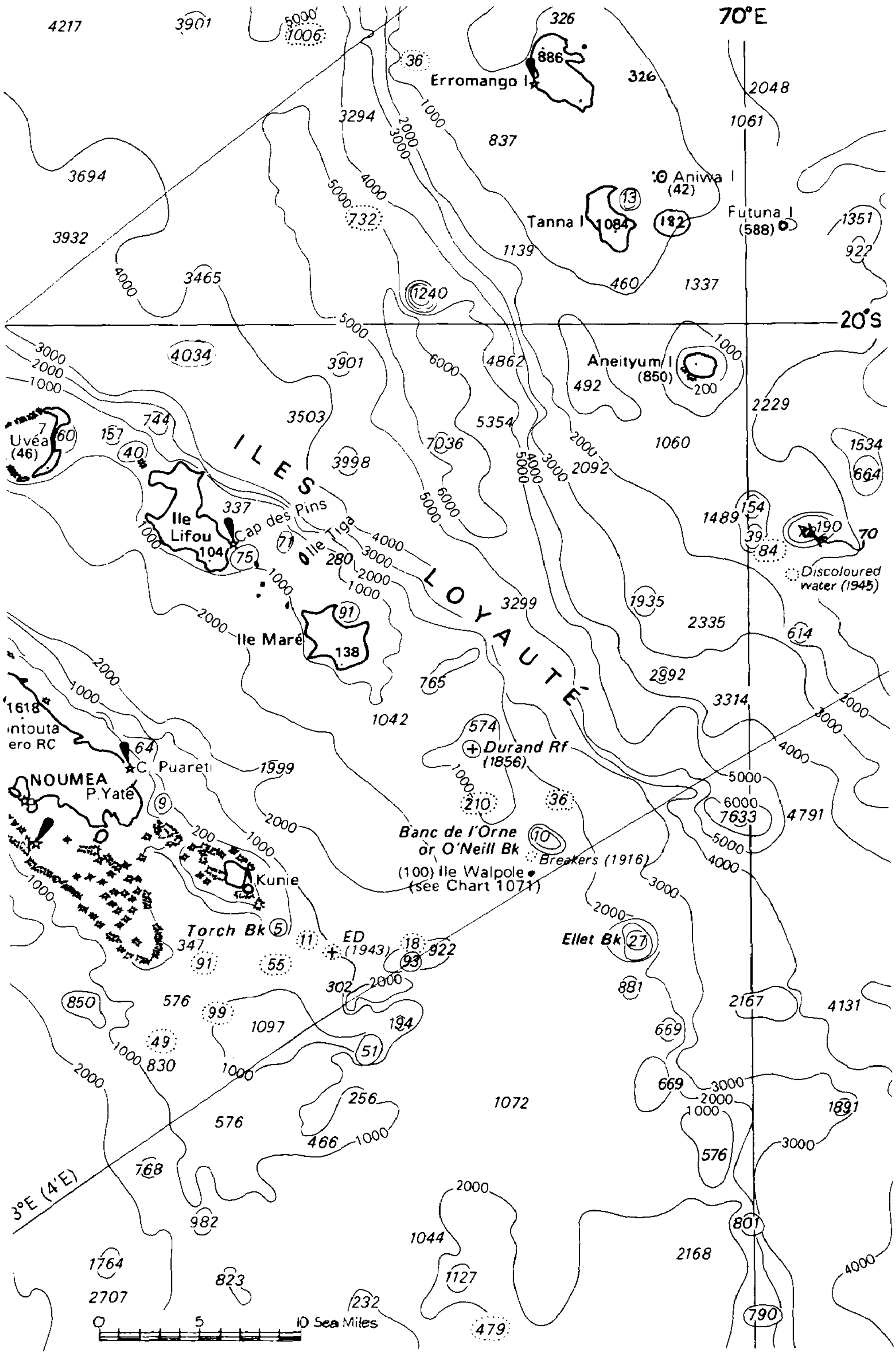

FIG. 9. — Depiction of Durand Reef on B.A. Chart 4602 (INT 602)

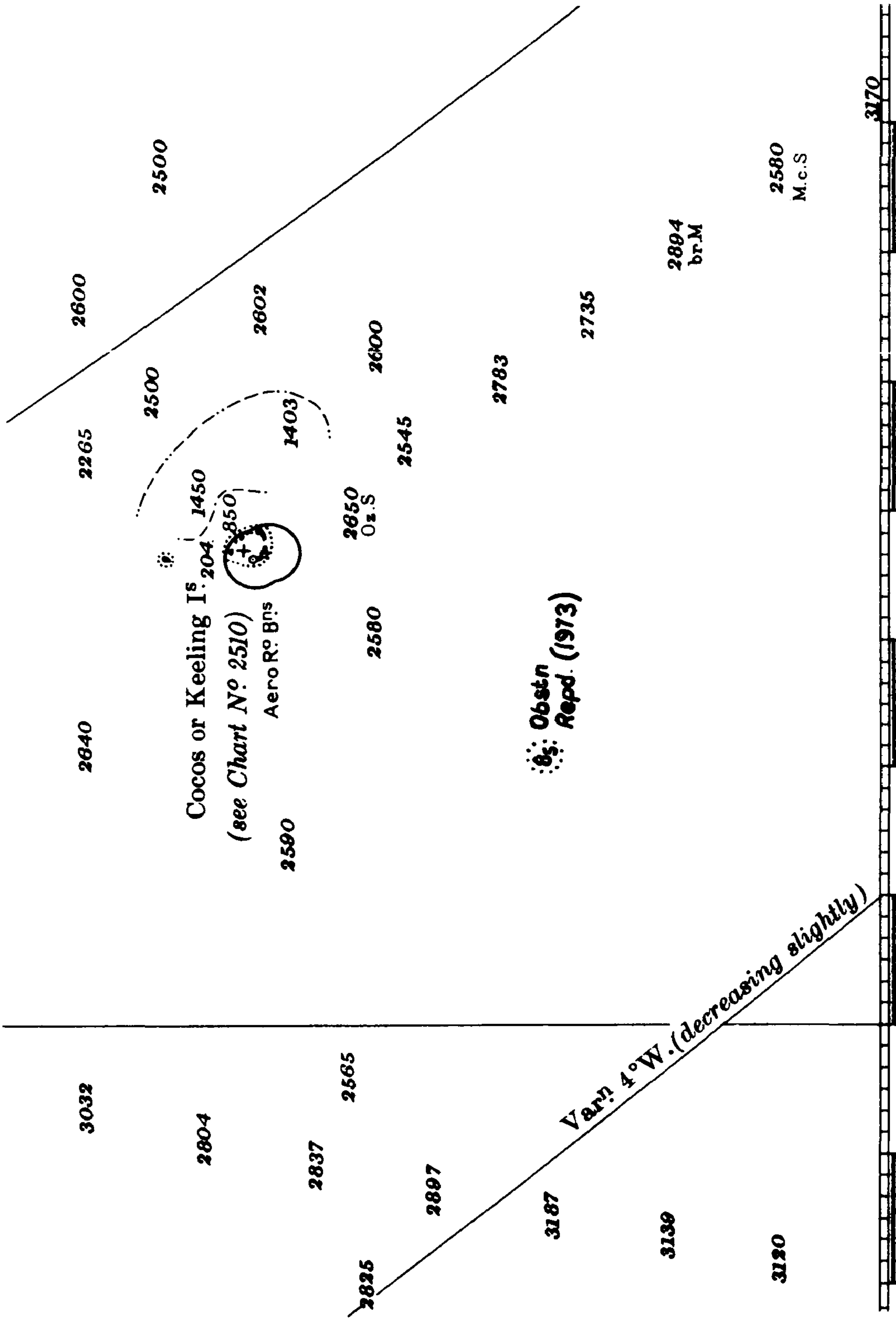

FIG. 10. — Part of former B.A. Chart 90 showing reported obstruction in 1973 S.W. of the Cocos Islands (depths in fathoms)

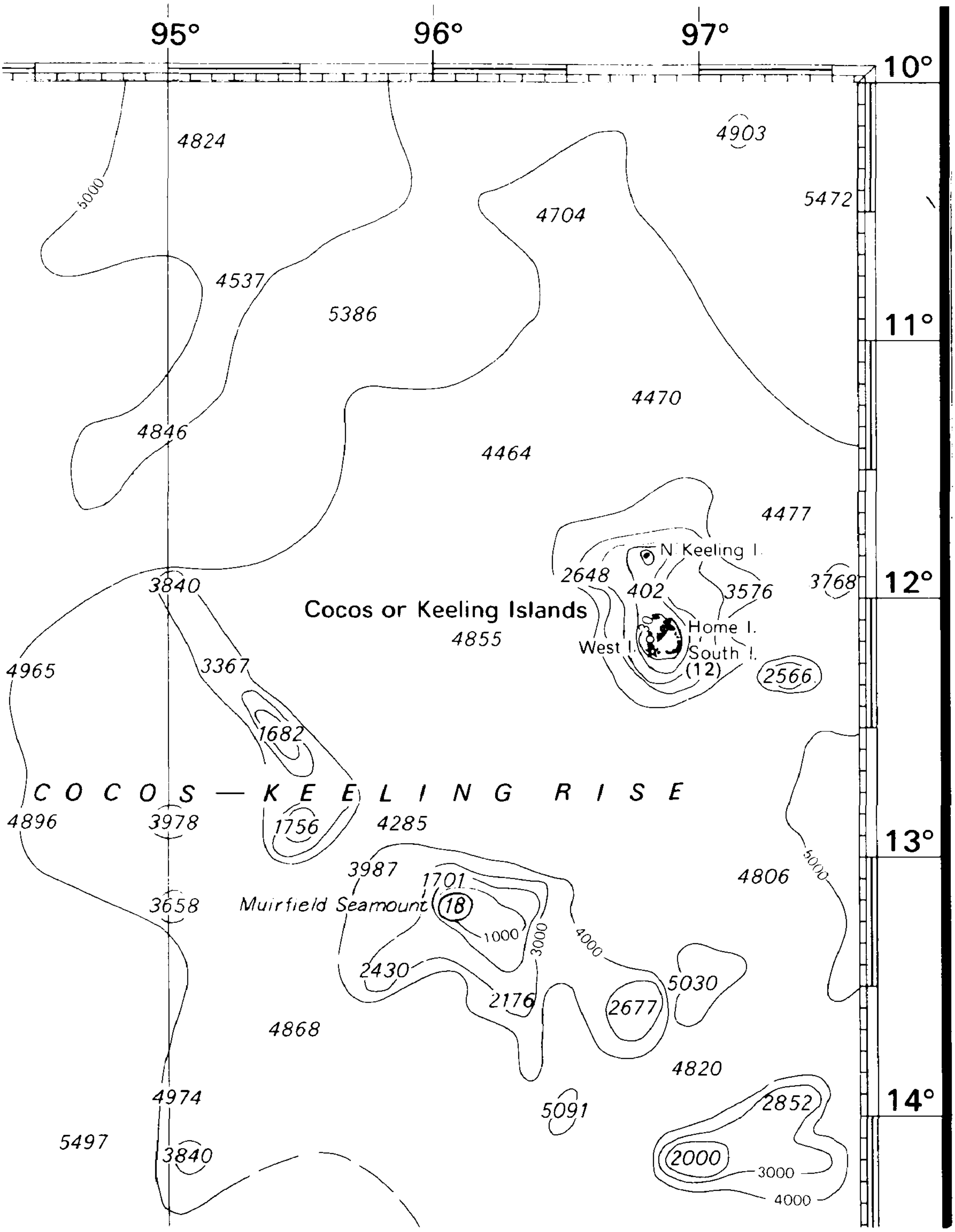

FIG. 11. — Part of existing B.A. Chart 4714 showing Muirfield Seamount S.W. of the Cocos Islands

report. Furthermore, although *Antiope's* position for the reef differed by some 5 miles from the correct position, it could well have been 15 or more miles in error considering the date of the report.

The above examples of ocean dangers show how hazardous these are to ocean going shipping. These dangerous pinnacles of rock or coral are usually found cresting the summits of seamounts and oceanic ridges and rise steeply from surrounding deep water with little or no warning given from soundings in their approaches. Because of the small overall extent of their summits and their steep-to approaches, it is likely that many of these dangerous pinnacles have still to be found and charted in the oceans. The detection of such dangers in time to take avoiding action is extremely difficult for modern deep draught ocean going vessels travelling at their normal speed and equipped with the average commercial echo sounder having a maximum range of only 800-1 200 metres. A dangerous shoal can exist about two cables from a sounding of 1 000 metres or five cables from a sounding of 2 000 metres (see section below on "The investigation of reported dangers and shoals in ocean areas").

Small scale nautical ocean charts are currently littered with reports of breakers and dangers in ocean areas, particularly in those areas where coral reefs and islands abound. There is a need for all these charted reports to be investigated as soon as possible.

The lack of bathymetric data for the compilation of ocean charts has already been referred to in an article in the *I.H. Review* [7]. In 1976 an analysis of the then latest GEBCO plotting sheets found that for only 16 % of the oceans was there sufficient data to determine the sea floor topography with reasonable accuracy; for a further 22 % the data were only sufficient for showing major sea floor features, while for the remaining 62 % the data were considered too sparse to determine the sea floor topography. The situation is still very much the same today, as relatively few soundings have been added to the GEBCO plotting sheets since 1976; and although, as explained above, there is a considerable amount of ocean sounding data that has not been incorporated on the GEBCO plotting sheets, the overall general sparseness of ocean bathymetry for most of the oceans can readily be seen from an examination of the 5th Edition GEBCO sheets which are currently the most complete graphical index of ocean sounding data world-wide.

Thus, although small-scale INT charts are for first time providing the mariner with a systematic and much more detailed depiction of the bathymetry of the oceans than hitherto, they still represent no more than a 'best guess' in their portrayal of the depth and shape of the sea floor for large areas of the ocean. It is therefore being proposed that a note should be inserted on these small-scale INT charts emphasising the sparseness of ocean sounding data on which they are based, similar to the note already shown on small scale INT charts produced by New Zealand, with an additional reference to the unreliable charting of ocean dangers, as follows :

DEPTH CONTOURS AND OCEAN DANGERS

The depth contours shown on this chart have been interpolated from all available information which, in ocean areas, is insufficient for an accurate portrayal of the sea bottom. In particular, charted ocean and shoal depths are often from old and imperfect reports and have seldom been fully surveyed; they could therefore be considerably in error as regards position, least depth and extent. In addition other ocean dangers and shoals have still to be found and charted.

There was less need to warn against the sparseness of ocean soundings on most old-style small scale ocean nautical charts which usually showed quite distinctly and separately the random lines of soundings that were available, and did not use depth contours to link them and apparently fill the gaps in between; thus, unlike their modern metric replacements, they avoided giving the impression of more data being available than was actually shown.

The use of remote sensing from satellite observations as an aid for determining ocean bathymetry

Remote sensing from satellite observations can provide complete and uniform world-wide coverage of the oceans and this is its great advantage over traditional ship borne observations which, as stated above, currently provide sufficient bathymetric data for only a relatively small part of the oceans. Remote sensing is therefore of particular significance for those ocean areas where sounding data are sparse to determine bathymetry with any reasonable degree of accuracy.

Since 1972, Landsat imagery has been available from which sub-surface features down to depths of 20 to 25 metres can be detected *in optimum conditions* with a minimum feature size of 80 m^2 approximately, and new Landsat Thematic Mapper imagery will be able to identify a minimum feature size of 20-30 m^2. This facility is a useful aid in helping to identify and chart shoal depths and dangers, particularly in offshore areas [8].

The main drawback in the use of Landsat for ocean areas is the difficulty in determining the position of visible sub-surface features from Landsat imagery with any degree of accuracy away from land areas. Where no land is shown on the Landsat imagery, positional errors are of the order of tens of miles. Where land is shown on the image, positions can be fixed, at best, to ± 60-70 metres if the land mapping is accurate; with a lower order of fixing accuracy as the quality of the land mapping decreases and the distance from the land increases. Charted shoals and reefs in ocean areas away from the land can also be used to help position new uncharted sub-surface features which are shown on Landsat imagery in the same way as described below for Spacelab photography.

Recently the Spacelab Metric Camera experiment, completed in December 1983, was the first use of a calibrated mapping camera from space. The photography is of a high standard and has potential for nautical charting at scales of 1:100,000 and smaller [9].

Resolution of fine detail is generally better than might have been expected from space imagery. Coastal features are particularly distinct and water penetration in shallow areas is good, allowing the accurate mapping of submerged features. The use of the American Large Format Camera and future Metric Camera missions taking advantage of image motion compensation will yield further improvements.

A flying height of 250 km gives a photo scale of 1:820,000 and a ground coverage of 192 km × 192 km. This makes possible the correct positioning of islands and shoals a considerable distance from land, and a planimetric accuracy of ± 30 metres has been achieved.

Photo coverage of sea areas where no land is shown can also be a useful charting aid if charted shoals and reefs can be identified on the photo coverage, as these can be used to control the fixing and plotting of similar features shown on the photography in the same area but which are not charted. However, the planimetric accuracy of such photo plots may well be considerably in error, especially if the identified charted shoals and reefs, used for controlling these plots, have been positioned from old and inaccurate surveys. The charting of such areas as the South China Sea, which are littered with shoals and reefs, could benefit greatly from Spacelab photography as well as Landsat imagery.

An important practical advantage of Spacelab photography for hydrographers and oceanographers is that it can be processed using traditional stereo plotting equipment, whereas Landsat Multispectral Scanner (MSS) imagery requires specialised image processing facilities which may be beyond the means of many hydrographic and oceanographic establishments.

Seasat observations are even more significant as a source of information for the bathymetry of the oceans. Seasat operated only from 3 July to 10 October 1978 when, unfortunately, it suffered a total power failure; had it completed its planned mission, it would have sampled the sea surface along a dense grid of orbital paths with adjacent tracks separated by less than 20 kilometres. The premature demise of Seasat left tracts of unsampled sea floor up to 200 km wide so that interpolation of data to cover the areas in these widely spaced tracts has been necessary. Despite the short life of the spacecraft, the Seasat altimeter data collected consists of more than 4 million observations world wide along nearly 1000 sub-orbital paths distributed between latitudes 72°S and 72°N.

The radar altimeter on board Seasat was capable of measuring the shape of the ocean surface to ± 0.05 metre, and this accuracy was sufficient to detect the 0.2 metre swell that would be associated with a seamount 50 km wide at its base and 500 metres high; newly discovered features from Seasat observations vary from this size to seamount ranges which rise 4 000 to 5 000 metres above the sea floor and fracture zones which can be traced for 1 000 km or more.

The analysis and reduction of Seasat data has led to the development of Geotectonic Imagery (GTI) or maps depicting gravity field variations over the oceans [10]. GTI provides an ideal means for assessing visually the information obtained by Seasat, and promises to advance significantly our knowledge and understanding of the nature of the sea floor.

However, the correlation between gravity and sea floor topography is by no means uniform or straightforward. For example, because mid-oceanic ridges are underlain by a zone of low density upper mantle material, their influence on the gravity field is lessened; thus the East Pacific Rise, the dominant feature in the southern and eastern equatorial Pacific and some 3 000 metres in elevation, is almost invisible on GTI. In contrast, areas of thick flat lying sediments can be associated. Again, seamounts of identical size, but of different age, can have gravity deflections that differ by a factor of 2 or more.

Recently, some field tests have made to evaluate the reliability of Seasat predictions of uncharted bathymetric features in sparsely sounded areas. Four such studies were carried out in the Pacific and Atlantic Oceans and the detection of uncharted seamounts associated with Seasat anomalies occurred in only about 50 % of the cases tested. Thus the Seasat detections appear somewhat less reliable than most investigators had thought [11].

Furthermore, sometimes features on the GTI are the results of components of the sea surface that are not due to gravity perturbations, e.g. the effect of the Gulf Stream on sea surface levels in the western North Atlantic adjacent to the North American continental margin.

The radar altimeter will figure prominently in several future planned satellite missions and hopefully methods and equipment in this field will improve with time so that this form of remote sensing should be a promising and significant source of information for helping to determine ocean bathymetry in the future, despite the problems in interpreting the data referred to above.

A coloured world map on a scale of 1:46,000,000 showing the gravity fields of the world's oceans recovered from Seasat altimeter data has recently been published [12].

An even more detailed depiction of the Seasat altimeter data has now been produced in the form of 32 overlays for sheets 5.01 to 5.16 of the GEBCO 5th Edition 1:10 M Series [13]. In sparsely sounded areas a number of significant new features not shown on the GEBCO 1:10 M sheets have been found. These overlays should, therefore, act as a useful guide for the planning of bathymetric surveys for the investigation of these new features.

Doubtful hydrographic data in ocean areas

The XIIth International Hydrographic Conference in 1982 decided that IHB Special Publication No. 20 listing all doubtful hydrographic data in the oceans should no longer be maintained. This was because the small-scale INT chart series now provides an adequate continuing record of such data, particularly as there is a special symbol used on these INT charts to identify these doubtful data.

It is important, therefore, that all producers and printers of small-scale INT charts should take consistent action for the assessment and charting, and the verification or disproval, of these doubtful data.

Doubtful and confirmed dangers and anomalous depths in the ocean

The following Technical Resolution A 5.4. was adopted by the XIIth International Hydrographic Conference, 1982 :

1. — It is resolved that the world ocean chart cover on 1:3 500 000 or 1:10 000 000, supplemented by the records of the data in question held by each producer nation, to which enquiries for information can be made, shall constitute the IHO record of doubtful and confirmed dangers and anomalous depths in the oceans.

a) Insertions, deletions and amendments of reported and confirmed dangers and anomalous depths of less than 750 metres in ocean areas should be promulgated by Notice to Mariners by all producer and printer nations of the two small-scale series of INT, and national, charts.

b) All hydrographic offices should pass copies of relevant new information in these categories to the producer nation responsible for the sheet which the new information affects.

Note : United Kingdom is requested to conform to this procedure in respect of the supplementary 1:3 500 000 mid-ocean charts or 1:10 000 000 Southern Ocean charts produced in its national series.

2. — It is further resolved that the following items of new information, for ocean areas outside the continental shelf, should always be promulgated by Notices to Mariners.

a) All newly-reported dangers and anomalous depths of less than 750 metres (400 fathoms approximately) with brief details of the source, e.g. survey ship, research vessel, merchant ship.

b) Deletion of such items, and the reasons for the deletion, in cases where the existence of a charted danger or anomalous depths, whether shown as doubtful or confirmed, has been disproved as a result of a search by a survey ship, or by other reliable means.

c) Amendments to depths and/or other details, and the reason for such amendments, in cases where a search has confirmed the existence of a charted danger or anomalous depth, and established with certainty its position, depth and extent.

The assessment of newly reported anomalous depths in the oceans

Nearly all new doubtful data now being reported in the oceans are anomalous depths from ships' reports, usually with accompanying echo-traces. It is desirable that these reports should be assessed in a consistent manner by all hydrographic offices — particularly the producer and printer nations of small-scale INT charts — so that a common policy is adopted for the charting of newly-reported anomalous depths, which will avoid cluttering charts with erroneous information but, at the same time, will seek to ensure that such reports are not lightly discarded, as the safety of the mariner is dependent on the accurate assessment and charting of such reports.

Anomalous depths are isolated unsupported soundings, usually from a single report, which are significantly shoaler than other depths in the area shown on charts and GEBCO 1:1 M plotting sheets. Such anomalous depths should always be treated with suspicion. New depths rising from substantially greater charted depths should only be shown as confirmed depths if they are from a good quality echo-trace which clearly rises from deep water — from depths comparable to those already charted — and falls again on the other side back to deep water. Where such anomalous depths are from a genuine echo trace and are charted as confirmed depths they should, where possible, be shown with a selection of adjacent depths from the same echo trace rising from, and falling again to, the general level of existing charted depths — so as to give as good an indication as possible of the extent of the feature on which they occur, enhanced where appropriate by contours drawn in from these soundings.

False echoes — due to faulty or incorrect phasing of the echo-sounder, to reflections from the deep scattering layer or sharp temperature gradients in the water column, or to faults within the echo-sounder — are the main reasons for the reporting of anomalous depths.

Extreme care, therefore, needs to be taken in the evaluation of echo-traces purporting to show new anomalous depths in ocean areas, and where it is decided that the echo traces are possibly not genuine, these newly reported depths should be regarded and charted as doubtful. If the trace can positively be evaluated as false, particularly in relatively well-sounded areas, no chart action should be taken on the report because it is important to avoid cluttering charts with anomalous shoal depths which, once charted, should only be removed after careful search by a survey ship.

When a ship's report of a new oceanic shoal sounding is received without any accompanying evidence, in particular the echo-trace and position fixes, every effort should be made to obtain this information from the ship for examination before chart action is determined.

IHO Technical Resolution A 5.4, referred to above, on the charting of anomalous depths in the oceans, states that all newly reported anomalous depths of less than 750 metres should be promulgated by Notice to Mariners. Anomalous depths greater than 750 metres should also be included at the first opportunity on new charts or new editions, especially if they rise sharply from deep water, as such depths may be a first indication of hitherto undiscovered shoaler depths nearby.

The investigation of reported dangers and shoals in ocean areas

It is important that common standards and similar methods are adopted for the investigation of reported dangers and shoals in deep ocean areas. This matter is currently under consideration by the IHO and in response to CL 47/82 the UK Hydrographic Department provided comments on which the following paragraphs are based.

The methods to be used for investigating reported dangers in the oceans are laid down for the UK Hydrographic Service in Chapter 3, Part 6, of Volume 2 of the Admiralty Manual of Hydrographic Surveying [14]. When planning such investigations it is important to evaluate not only the accuracy and reliability of the original but also its likely positional accuracy. There are obviously significant differences in the probable positional accuracy of these reports depending on their date; those deriving from the 19th and early 20th centuries could well be many miles in error even if the danger or shoal depth has been correctly identified. The nature of the report — be it lead line sounding, discoloured water, breakers, or echo sounding trace — must also be considered in the light of presently available oceanographic and bathymetric knowledge of the area. Only by carefully considering all these factors can the appropriate extent of the search required be properly estimated.

Whilst it is difficult to generalise about positional accuracy in terms of the date of the report, this must be done in order to bring some sort of uniformity to the survey criteria required to be used for searches for reported dangers and shoals in ocean areas. Radio time signals were introduced in the early 1900s and it can be assumed that from the 1920s onward most ships were correcting their chronometers at sea. This would allow them to obtain astro fixes of ± 2 to 5 miles, but figures of 8 to 10 miles seem more realistic.

Nineteenth century fixing, particularly when the chronometers themselves were less accurate, in the early part of the century, could have been as poor as ± 50 miles. However, the following table has been devised from assessments made in the UK Hydrographic Department, and elsewhere, of the aids available for ocean navigation throughout the years.

Date of report of danger or shoal sounding	*Probable error in position to be assumed*
prior to 1830	± 20 miles
1830-1900	± 15 miles
1900-1930	± 10 miles
1930-1950	± 7 miles
1950-1970	± 5 miles
post 1970	± 4 miles

In order to disprove or confirm a reported danger or shoal, the radius of *the area to be surveyed should be twice the probable error in position,* e.g. for a shoal reported in 1960, a circle of 10 miles radius should be searched. This may appear to constitute an excessive amount of work, but in fact the lines of soundings may be opened out considerably as laid down in Figure 12.

Where the general depths are less than 200 metres, dangers may sometimes exist which rise almost vertically from the sea bed. Slopes of 60° from the horizontal have been found in general depths of just under 2 000 metres. Thus a dangerous shoal could exist about two cables from a sounding of 1 000 metres or five cables from a sounding of 2 000 metres. Below 3 000 metres the slope of the sea bed is not very likely to exceed 15° from the horizontal. Figure 12 has been constructed using these assumptions [14].

It should be noted that whilst sounding lines at the spacing shown in Figure 12 above have to be run to disprove a reported danger or shoal, the chances of detection will be considerably enhanced if either gravity or magnetic observations, or both, can be made concurrently, as dangers and shoals in ocean areas usually

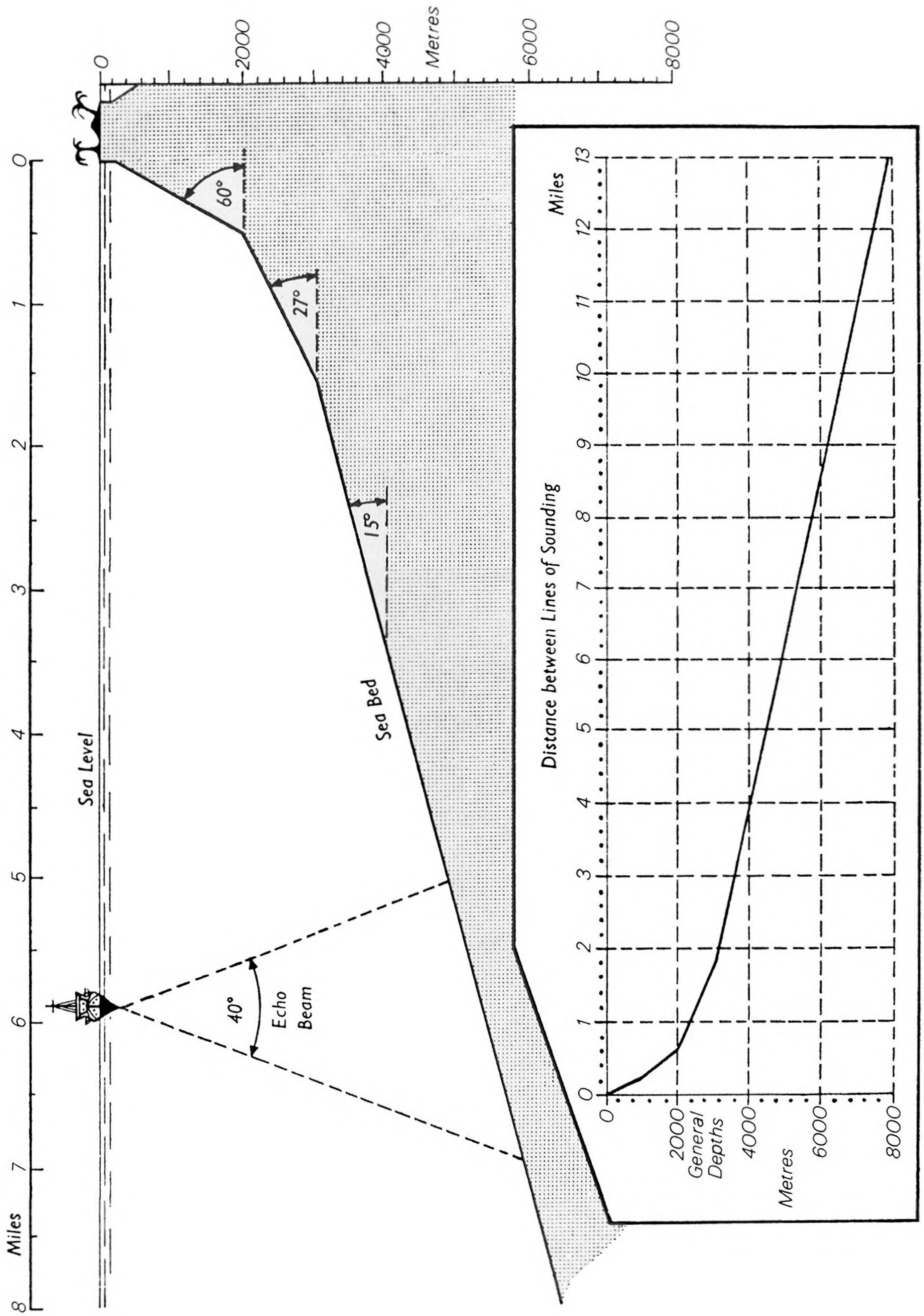

FIG. 12. — Searching for shoals : distance apart of lines of soundings

give rise to considerable geophysical anomalies. The use of bathymetric swath sounding systems and long range sidescan (e.g. GLORIA), and hull mounted sonars, can also assist considerably in the detection of the shoals and increase confidence in searches which disprove them. All these methods should be encouraged.

It is considered that the absolute accuracy of the navaid used to control the search should be better than ± 0.5 mile wherever possible.

The future maintenance of small-scale INT charts

The near-completion of the small-scale INT chart series prompts the question of the future maintenance of these charts.

The interval between new editions for the updating of small-scale INT charts is not laid down in the Specification for small-scale INT charts : there is thus a danger that the frequency of correction by new edition will vary among the different producer and printer nations and this will cause, among other problems, overlapping areas of this homogeneous series of charts no longer to agree.

There would therefore seem to be a need for producer countries of small-scale INT charts to update these charts at common specified intervals. The ideal interval would be every five years when the magnetic variation curves on these charts are updated for each new magnetic epoch.

There is a wealth of new information now available on the 5th Edition GEBCO sheets and this can be incorporated on small-scale INT charts by the methods proposed above — particularly as the 5th Edition GEBCO will be the 'world sea-floor standard for at least the next decade or two'.

The beginning of the 1985 magnetic epoch would seem to be an opportune time to start a systematic programme of new editions of small-scale INT charts so as to improve them from the 5th Edition GEBCO, and the scientific co-ordinators' compilations where these are available.

The value of small-scale INT charts as source information documents on ocean bathymetry

The correction of small-scale INT charts from the 5th Edition GEBCO sheets and the large scale compilations prepared by the scientific co-ordinators will do much to enhance the value of these INT charts, not only as ocean navigational charts, but also as source information documents for the bathymetry of the oceans, in the same way as larger scale nautical charts of coastal areas are used as source information documents for the bathymetry of the continental shelf.

Furthermore, if an agreement is reached so that WDC 'A' MGG will act on IHO's behalf as the World Data Centre for Digital Bathymetry of the oceans, all such data held at the Centre will be available for incorporation in small-scale INT charts, and this will further enhance the value of these charts as regards the depiction of ocean bathymetry.

However, small-scale INT charts, even if they are so improved from the 5th Edition GEBCO sheets and additional ocean sounding data available from WDC 'A' MGG, can never be regarded as adequate ocean bathymetric charts for oceanographers and other marine scientists, because their format and content is designed for their primary role as navigational charts. Nevertheless, small-scale INT charts could be a useful aid to oceanographers and others interested in ocean bathymetry if they are updated and improved from the 5th Edition GEBCO and WDC 'A' MGG digital bathymetric data.

Further points in favour of these small-scale INT charts as source information documents for ocean bathymetry are that they provide extensive coverage of the oceans on a scale of 1:3 1/2 M (three times the scale of the 5th Edition GEBCO), they are readily available world wide from chart agents, and they are kept corrected for all new ocean sounding data made available to the VHOs responsible for maintaining small-scale INT charts both by new editions at regular intervals and by Notices to Mariners for newly reported significant depths in the ocean.

SUMMARY AND CONCLUSIONS

The completion of the GEBCO 5th Edition 1:10 M series and the near-completion of the small-scale International chart series on 1:3 1/2 M and 1:10 M represent truly significant advances in ocean charting during the past decade.

The need now is for oceanographers and hydrographers to work together to maintain and improve both series for the continuing benefit of the many and varied users of these charts. In particular, for producer and printer nations of small scale INT charts, future action should take account of the following requirements :

1. The amendment of small scale INT charts from the 5th Edition GEBCO sheets, together with the scientific co-ordinators' compilations where these are available, so as to achieve the best possible depiction of ocean bathymetry on this most important series of navigational charts of the oceans for the information of the mariner.

2. World Data Centre 'A', Marine Geodesy and Geophysics, to act on the IHO's behalf as the World Data Centre for Digital Bathymetry of the oceans, and thereby all such data held at the Centre will be made available for incorporation in small-scale INT charts; this will further enhance the depiction of ocean bathymetry on these charts for the benefit of mariners.

3. The IHB and Volunteering Hydrographic Offices responsible for the maintenance of the 1:1 M GEBCO Plotting Sheet System to establish a close co-operation with WDC 'A' MGG so that all newly received ocean bathymetric data in both graphical and digital form are effectively recorded and disseminated for the benefit of both hydrographers and oceanographers, and for the effective maintenance of ocean charts.

4. The insertion, deletion and amendment of reported and confirmed dangers and anomalous depths of less than 750 metres in ocean areas by Notice to Mariners, in accordance with IHO Technical Resolution A5.4; and the acceptance

of common standards and procedures for the investigation of reported dangers and shoals in ocean areas as laid down by the IHO.

5. The regular updating by new edition of small-scale INT charts so as to include the latest available ocean bathymetry for the maintenance and improvement of this series of charts, not only for ocean navigation, but also as source information documents for ocean bathymetry.

If action is taken in line with these requirements, the small-scale INT chart series should provide the mariner with the best possible ocean chart coverage, and will comprise a homogeneous series of ocean charts, drawn to common specifications and standards, and effectively maintained from all available source data. Furthermore, the revision of the GEBCO Regulations, which has now been put in hand, should ensure that the IHO is firmly re-established as the World Data Centre for Ocean Bathymetry.

Finally, it is especially fitting that the small-scale INT chart series, the first series of International nautical charts to be published under the auspices of the International Hydrographic Organization, provides chart coverage of the oceans together with the General Bathymetric Chart of the Oceans, which is the Organization's oldest and still best known publication : and that both of these series of ocean charts carry the seal of the International Hydrographic Organization.

Acknowledgments

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