International Hydrographic Review, Monaco, LIV (2), July 1977.

THE GENERAL BATHYMETRIC CHART OF THE OCEANS

SEVENTY-THREE YEARS OF INTERNATIONAL COOPERATION IN SMALL SCALE THEMATIC MAPPING

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This paper was presented at the 8th International Cartographic Conference, Moscow, August 1976, and is published here with the permission of the Organisers and of the Dominion Hydrographer.

In November of 1975, the Intergovernmental Oceanographic Commission of UNESCO adopted a resolution which in part stated : "[The Commission] invites the Third U.N. Conference on the Law of the Sea to consider this, [The General Bathymetric Chart of the Oceans, (GEBCO)] the international world bathymetric chart coverage, as a positive technical contribution to the work of the Conference and the progressive development of a better geological and geomorphological knowledge of the oceans". This resolution and its adoption by the eighty-seven nations making up the Intergovernmental Oceanographic Commission (Table I) mark another milestone in the history of an international program to map the oceans of the world. This cartographic endeavor, initiated in 1903, provides an example of long term international cooperation in small scale thematic mapping that may be unique in cartographic history. In this paper an outline of the history of GEBCO throughout this century of unprecedented scientific and technological growth is presented.

Since early man first began to travel by water, its mysteries and terrors, its depths and hidden promises, its treasures and tragedies, have fascinated his imagination and exerted a relentless pull on his exploring, restless instincts. Whether this is an atavistic throwback to the times when some dim ancestors of man lived in the sea cannot be told. All we do know, as cartographers, is that the history of the explorations of the oceans and the history of cartography marched side by side through time. As men of different races set out to expand the limits of the world as they knew it, they recorded new coastlines on their maps with each succeeding voyage of discovery. These maps affected not only the way man thought about the world he lived in, but also the way he thought about himself.

The sea was, first, merely a highway to discovery; and the early explorers who drew coastlines on the maps thought of them as representing the edges of the land, not the edges of the sea. However, a certain knowledge of the sea was required in order to traverse it safely; consequently, a few measurements of currents, tides and water depths were made, as well as observations of the material making up the sea floor and the creatures living on it. Further, as man's thinking evolved to a point where he began to develop cosmogonies, he had to explain the sea's place in the great scheme of things. To do so he had to guess or measure the depth of the sea in some places. As examples, one notes Aristotle (384-322 BC) commenting on the relative depths of the inland seas of the earth, and Posidonius (First Century BC) reporting that the sea near Sardinia had been measured to about one thousand fathoms (quite an accurate measurement), the method employed being presently unknown.

These early examples of publishing what had been learned so that others might use the knowledge cannot be construed as being the general rule. All too frequently, information was kept secret, or made known only to select groups, for protection of trade routes or sources of trading goods. This was so in the case of the Phoenicians, whose remarkable knowledge of the oceans is largely lost today. The tradition was not confined to the ancients. For example, when the Portuguese discovered the sea route from Europe to India, they at first prohibited any of their captains from revealing the route to foreigners, under pain of death. Nevertheless, the overall trend has been toward the publication, and consequently a sharing, of knowledge about the oceans.

The particular item of knowledge about the sea which is the subject of this paper is the shape of the surface of the sea floor. This shape may be determined by measuring a sufficiently large number of depths — although the measurement of even a single depth was, until the 1930's when electronic echo sounders came into common use, an extremely difficult and time-consuming undertaking. In shallow waters, a weighted line was lowered to the bottom, and the length of line submerged taken as the depth. A measured depth was called a sounding. This process could be applied in deeper water but was complicated by the need for special winches and reels of line, and also by the fact that the line could be dragged sideways by currents as it sank through the water. In very deep water it was frequently difficult to determine when the weight actually reached the bottom. Several ingenious mechanical devices were developed, particularly in the nineteenth century, to help speed depth measurement in deep water, and to make it more accurate. Despite these advances, prior to the introduction of electronic echo sounders, a deep sounding could still take several hours to obtain. More important, a sounding was only a spot depth or in modern parlance an item of point data (fig. 1).

The idea of joining the spot depths or interpolating between them and drawing depth contours or isobaths appears to have originated in the eighteenth century. MURRAY (1895) credits Buache with producing the first bathymetric map in 1737, but at the same time mentions in rather contradictory fashion that Cruquius produced a bathymetric map twenty years earlier. More recently, ROBINSON (as reported in WOODWARD, 1976) reports discovering a 1715 map by Blackmore which utilizes isobaths. These early examples were from small relatively shallow areas and it was not

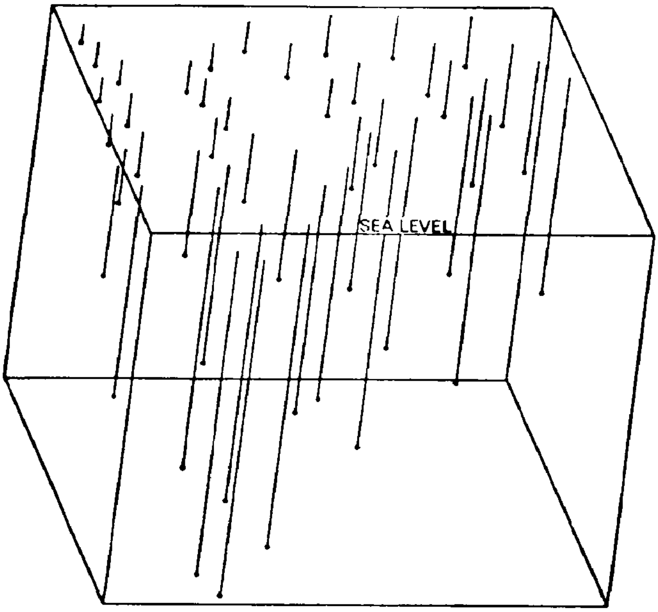

FIG. 1. — Spot depths measured from sea level as single soundings.

until 1854 that a bathymetric map of a major ocean was produced. MAURY, a U.S. Naval officer, assembled all the deep soundings (less than 200) from the North Atlantic, most of which had been measured on his orders, and produced a coloured "Bathymetrical Chart" of that ocean. This was the first of several produced before the turn of the century. BENCKER (1952) provides the following list:

1854 M.F. MAURY, U.S.N. — *Map of the Basin of the North Atlantic.* Cf. The Physical Geography of the Sea (1860).

1874 J. PRESTWICH. — *Planisphere of the Oceans* (Philosophical Transactions of the Royal Society of London, 1874, p. 674).

1886 Sir John MURRAY. — *Physical Charts of the World,* Annex to the *Challenger* Expedition (1872-1876) : Summary of Scientific Results, London.

1895-99 Dr. BARTHOLOMEW. — Kept Murray's charts up-to-date at a scale of 1:40 000 000.

1893 REICHSMARINEAMT of Berlin. — *Weltkarte zur Uebersicht der Meerestiefen* (World Map of the Depths of the Oceans).

1899 Dr. SUPAN. — *Chart of Ocean Depths,* scale 1:80 000 000 (Petermanns Geographische Mitteilungen, Gotha).

Throughout the period from MAURY's work until the turn of the century several facts began to emerge, all of which reached a culmination in the proposal to produce the GEBCO. The first fact was an appreciation of the actual size of the ocean. Although the explorers of the second half of the nineteenth century could point with justifiable pride to the number of soundings they had collected as a result of their herculean labours, they began to realize, or at least suspect, that many, many more would have to be collected in order to adequately cover all the world's oceans. Coupled with this was the growing realization that the sea floor was considerably rougher than had hitherto been generally believed. This again meant that a greater number of soundings would be required to accurately depict the seafloor's relief.

With this growing awareness of the vastness of the sea and the magnitude of the task at hand came the realization that no one expedition or even single nation could legitimately expect to properly map the world ocean. The immense effort and cost to obtain even a single sounding effectively scuttled that idea. However, the pragmatic and energetic hydrographers and oceanographers of the age were not nonplussed at the thought: rather, they sought a means of cooperating and coordinating the resources at their disposal. One such cooperative venture was proposed at the VII International Congress on Geography held in Berlin in 1899.

In the late 1890's, a committee of the leading oceanographers of the day, comprising Prince Albert I of Monaco, Professor KRÜMMEL, Admiral MAKAROFF, Dr. MILL, Sir John MURRAY, Fridtjof NANSEN, Professor PETTERSON, Professor SUPAN and Professor THOULET under the presidency of Baron RICHTHOFEN had been working on problems of nomenclature of the oceans and the ocean floor. A group of such dynamic and perceptive men did not confine itself to nomenclature; it realized the need for a world series of bathymetric charts and recommended to the VII International Congress on Geography held in 1899 that such a series be established. The series would attempt to bring together data from all cruises and expeditions, regardless of their national origin. The Congress accepted the proposal and turned the project back to the same committee for its actualization. The committee studied the matter in depth and met again in 1903. It was decided to produce a series of 16 sheets between 72°S and 72°N on the Mercator projection with a scale of 1:10 000 000 at the equator. A further 8 sheets on a gnomonic projection would cover the polar regions. Prince Albert, one of the most generous benefactors oceanography has ever had, agreed to produce the series. Under the direction of his Scientific Cabinet, seven draftsmen produced the first edition of GEBCO in seven months. The series was presented to the hydrographic and oceanographic community in early 1904.

The first edition of GEBCO was the first truly international series of bathymetric charts, since it was based on data from several nations. Primarily, however, British Admiralty charts were used but they were supplemented by reports from as many expeditions as had made their findings public. Since every sounding was so valuable, not only in terms of time and costs of obtaining it but also in terms of the tremendous contribution each one made due to the paucity of data, every effort was made to ensure that no soundings, whatever their source, were omitted from the series. This precedent established the intent of the series to this day.

Prince Albert, never one to rest on his laurels, initiated production of the second edition in 1910. A second edition was desired because of the great number of new soundings which had become available and which were continually being made available to the world at large. The second edition was not produced as speedily as had been the first since it was interrupted by the First World War. Shortly after production resumed following World War I the series received a further setback with the death of Prince Albert. The second edition was eventually finished in 1930 but lacked the brilliance and originality of the first edition. The second edition also overlapped a new era in the mapping of the oceans, since by the mid-twenties echo sounding was replacing earlier methods of obtaining water depths.

The advent of the echo sounder changed the mapping of the seafloor in a spectacular fashion. Instead of taking hours, individual soundings could be obtained by the echo sounder in seconds. The happy prospect of an abundance of data made the future of the GEBCO appear sunny. All was not as good as it appeared at first blush, however. Echo sounders work on an assumption of the velocity of sound in sea water, and not enough was known in the early days about the velocity to make the echo soundings accurate. Further, the deep scattering layer was a virtually unknown phenomenon, which could and did return spurious echoes. Attendant with these physical problems was the need to develop new techniques and new methodology to deal with the vast amounts of new data. Unfortunately this was not done for some considerable time — yet another example of a technology being developed in advance of the capability to process the results of that technology.

These technical problems were overshadowed by the economic and social problems of the period. In 1921 the maritime nations of the earth had banded together to form the International Hydrographic Bureau, whose prime function was to help in the development of safe charts and related documents for international maritime commerce. Each participating nation paid membership dues proportional to the tonnage of their mercantile fleets. With the stock market crash of 1929, the following world-wide depression and its attendant decline in registered tonnage, funds available to the International Hydrographic Bureau in the early thirties were very small. Consequently, when the third edition of GEBCO was undertaken by the International Hydrographic Bureau only one draftsman could be assigned to the task. Under these conditions it is hardly surprising that the third edition progressed extremely slowly and was far from being an overwhelming success.

For the production of the third edition a new approach was taken to hopefully accommodate the vastly increased number of soundings being collected. A series of 1:1 000 000 plotting sheets was developed in the IHB and data were plotted on these sheets when provided by the Hydrographic Offices of the member nations. However, proportionally less and less data were being provided to the Hydrographic Offices from sources within their own countries. This situation had two causes. First, those scientific expeditions that did receive financing in the thirties wished normally to publish their results themselves, and only after they were published would they be made available to the Hydrographic Offices. Secondly, much of the data being collected was considered to have military value, and consequently nations were reluctant in those uneasy times to release data from their Secret lists. Despite this, the 1:1 000 000 plotting sheets formed the basis of the first truly international data bank for bathymetry, and firmly established the International Hydrographic Bureau as the world data center for bathymetry, a function it fulfills to this day.

The Third Edition struggled on through the thirties, until production was interrupted by World War II. World War II had far more widespread effects on hydrography and oceanography than the interruption of a chart series. Research into underwater acoustics, seismology, magnetics, sedimentology and long-range navigation, primarily directed at marine warfare, paid huge dividends in the instrumentation available or potentially developable after the war. This had repercussions for GEBCO in two directions. First, echo sounding was improved to the point where continuous profiles across the seafloor could be obtained (fig. 2). Such profiles contain a wealth of information not obtainable from the measurement of individual points (fig. 1) enabling — providing always that proper interpretation is performed — the production of a far more realistic and meaningful map of the seafloor. Secondly, the modern science of marine geology was built using the instrumentation developed or refined in World War II. From this science a description of the origin and evolution of the seafloor and of the processes active on it began to emerge. This both permitted and required a more realistic description of the seafloor to be made.

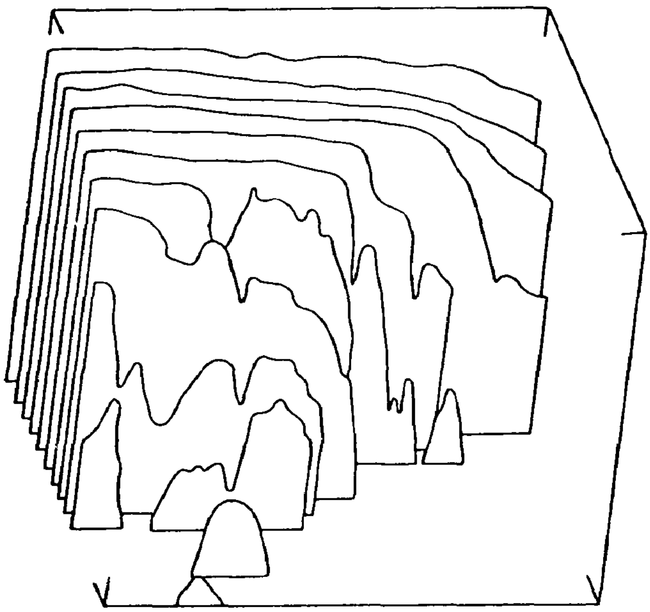

FIG. 2. Profiles across the same area as in figure 1, as measured by echo sounder.

The Third Edition of GEBCO appears to have been totally untouched by these developments. When production resumed after World War II it still followed the same guidelines which had been laid down in 1929. Echo sounding profiles were not treated as profiles but were broken into discrete "soundings" — almost without exception the shallowest points on the profiles — and plotted as such. This had the effect of artifically smoothing the seafloor by filtering out shorter-wavelength features. Further, no attempt was made to relate what was being discovered about the morphology of the seafloor to the shape of the contours shown on the map sheets. The third edition was thus out of date long before 1955, when the edition was declared finished despite the fact that three Polar sheets were published later (1968-9) and three others remained untouched.

If the Third Edition was out of date, the fourth was a veritable anachronism, since profiles were still broken into discrete soundings and interpretation performed by untrained people. Several changes were made in the production procedure, however. First, each of the volunteering Member States undertook the preparation of the 1:1 000 000 plotting sheets for a certain area of the world. These sheets were submitted to the IHB for review; after acceptance they were forwarded to the Institut Géographique National (IGN) in Paris for drawing of the contours and the production of the final 1:10 000 000 map sheets. This procedure had both good and bad points. The 1:1 000 000 plotting sheets benefited from more immediate input from the countries most directly concerned and became the standard data collection document for oceanographic bathymetry. The 1:10 000 000 series moved in the opposite direction, however, to a point even further removed from its source. Though the IGN is renowned for the quality of its land maps, it had little experience in marine work and consequently the 1:10 000 000 sheets were not considered of comparable standard.

Marine scientists were thus faced with an unhappy and frustrating situation in which more and better data were being collected, a mechanism existed for assembling the data, better interpretations of the data were being performed, but no satisfactory world bathymetry map existed. The need for such a map was recognized by numerous groups and committees but no decisive action was taken for about fifteen years.

In 1970, the Intergovernmental Oceanographic Commission (IOC) of UNESCO set up a Group of Experts on Long Term Scientific Policy and Planning. Among its activities, it examined morphological charting of the seafloor and recommended that the Commission participate in the production of a world bathymetric map bearing in mind that the IHB was the most experienced body in this field. To achieve this end a working group of the Scientific Committee on Oceanic Research (SCOR) was formed to study the methodology involved in producing a world map of the oceans and to present its findings to the Meeting of the International Cartographic Association in Ottawa, Canada, in September 1972. The recommendations were not formalized at that meeting; however, a paper was presented by a member of the group which was fairly damning of GEBCO as it stood at that point in time. The working group did make its formal recommendations in April of 1973. In June of 1973, at a meeting of the GEBCO Guiding Committee, the recommendations of the SCOR working group were endorsed. Thus the 1:10 000 000 sheet became a joint publication of the International Hydrographic Organization and the Intergovernmental Oceanographic Commission.

During 1974, specifications for the Fifth Edition were developed. The scale and projection remained the same, with shoreline and topography being provided by the IGN. Depths were to be shown by means of contours interpreted by experienced marine geoscientists. Few spot soundings were to be shown; only those which reveal significant depths were to be included. The reliability of the contours was indicated by showing the ships' tracks along which data had been collected as a thin grey line, or in the case of a comprehensive survey, as an outlined box. These modifications effectively modernized the chart presentation and satisfied the requirements of ocean scientists.

A scientific co-ordinator was appointed for some of the sheets of the Fifth Edition, and Canada volunteered to produce the first four sheets of the series. It was further decided that application would be made to UNDP for funds to establish a small International Geoscience Unit consisting of three geoscientists (one from a developing country) who would prepare those sheets in this series which had no scientific co-ordinator. That application is still before UNDP; however, the present economic climate is not particularly healthy.

The first sheet of the series — sheet 5.05, scientific co-ordinator Dr. A.S. LAUGHTON from Great Britain — was published by the Canadian Hydrographic Service in time for presentation to the delegates at the International Law of the Sea Conference in Geneva in 1975. It incorporates the data from the United Kingdom, India, United States, Union of Soviet Socialist Republics and France. The second sheet, 5.04, is in drafting while sheet 5.01 should be completed summer 1977. This series is thus well and truly launched into its Fifth Edition.

The long history of GEBCO has been a stormy one. It has survived two world wars, several periods of economic depression, and a complete technological revolution. The important thing is that GEBCO has survived for seventy-three years. The message that GEBCO brings is that international cooperation in small scale thematic mapping, or in any other type of mapping, is not easy. It is extremely difficult. However, if a task is worth doing, if there are people who believe in that task fully and who work at that task fully, then it will be done, despite the odds. GEBCO has been fortunate to have such people throughout its history. Other international cartographic exercises can hope for no more.

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THE LONG-STOP

The recent relief of Rear Admiral van Weelde by Rear Admiral Kreffer as the Hydrographer of the Netherlands reminds me of my first post as a Commander in the U.K. Hydrographic Office and the help I there received from their illustrious predecessor Rear Admiral Baron Th. K. van Asbeck (1950-1961). It was like this :

I was responsible for preparing the British Admiralty Notices to Mariners, and at first was somewhat over-awed by the immense care needed to avoid mistakes. "Never mind", said my Assistant who had many years experience in the Branch, "there's always the Long-Stop". For the British, this is a position on the cricket field far behind the wicket, where a player is posted to stop balls which have escaped the other fielders from reaching the boundary. My Assistant was referring to Baron van Asbeck in The Hague, who closely scrutinised the published Notices to Mariners of Britain and of every other country whose Notices his office received.

When Admiral van Asbeck found an error of fact or of proof-reading, as he too often did, he would send a naive but polite enquiry to the Hydrographer concerned. My own Hydrographer had something to say to me when too many balls were retrieved by the Long-Stop !

G.S. RITCHIE

TABLE I

Member States of the Intergovernmental Oceanographic Commission

Algeria
Argentina
Australia
Austria
Belgium
Brazil
Bulgaria
Cameroon
Canada
Chile
China
Colombia
Congo
Costa Rica
Cuba
Denmark
Dominican Republic
Ecuador
Egypt, Arab Republic of
Ethiopia
Fiji
Finland
France
German Democratic Republic
Germany, Federal Republic of
Ghana
Greece
Guatemala
Haiti
Iceland
India
Indonesia
Iran
Iraq
Israel
Italy
Ivory Coast
Jamaica
Japan
Jordan
Kenya
Korea, Republic of
Kuwait
Lebanon
Libya, Arab Republic of
Madagascar
Malaysia
Malta
Mauritania, Islamic Republic of
Mauritius
Mexico
Monaco
Morocco
Netherlands
New Zealand
Nigeria
Norway
Pakistan
Panama
Peru
Philippines
Poland
Portugal
Qatar
Romania
Senegal
Sierra Leone
Singapore
Somalia
South Africa, Republic of
Spain
Sri Lanka
Sudan
Surinam
Sweden
Switzerland
Syrian Arab Republic
Tanzania, United Republic of
Thailand
Togo
Tonga
Trinidad and Tobago
Tunisia
Turkey
Ukrainian SSR
Union of Soviet Socialist Republics
United Kingdom
United States of America
Uruguay
Venezuela
Viet-Nam, Socialist Republic of
Yugoslavia