THE IMPACT ON OCEAN MAPPING OF THE POST WAR REVOLUTION IN MARINE GEOLOGY AND THE WORK OF SCOR WORKING GROUP 41

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Abstract

Following the second world war, marine geology expanded rapidly due to the wide variety of new techniques that were available for studying the ocean floor. This resulted in the development of new understanding of the mechanisms and processes by which it was created, and in the revolutionary hypothesis of plate tectonics. Geoscientists needed detailed bathymetric charts on which to base their research, and found that the GEBCO charts had failed to utilise these new ideas. As a result the demand for the 3rd and 4th Edition charts nearly ceased. Prompted by the LEPOR report of IOC in 1968, SCOR set up Working Group 41 to review existing series of world charts and to recommend how to address the geoscientists' needs. The recommendations of the SCOR WG 41 led to the reorganisation of GEBCO, which became a joint activity of oceanographers and hydrographers, and to the initiation of the successful 5th Edition of GEBCO.

The theme of this paper is the failure of GEBCO to keep in touch with the rapid development of marine geology in the post war years, and the subsequent reorganisation of GEBCO to produce, in the late 1970s and early 1980s, a 5th Edition of the world charts, which found its way to the walls of laboratories and lecture theatres around the world.

I was one of the lucky generation of oceanographers starting my career after the war when a whole armoury of instruments and technologies became available for studying the oceans and the floor beneath them.

The operation of, and the hunt for, submarines had encouraged the development and understanding of the use of sound in the sea. Sonar methods had become commonplace both for depth and side scan measurements, as well as telemetry. Lower frequency sound, generated by explosions, penetrated the earth's crust to give the subsurface structure. The small variations in the earth's magnetic field and of the gravity field of the earth that were used to detect the presence of submarines could now be used to tell us about the nature of the rocks of the sea floor.

Scientists who had been trained in research to support naval warfare were able to turn their attention to the academic study of the ocean, and once more ships became available for marine research.

The results of this activity rapidly led to an increase in the understanding of the processes which operate in the ocean.

The canyons in the edge of the continental shelf were shown to have been cut by sediments transported, sometimes violently, from the continents. Narrow canyons were found on the deep ocean floor where denser seawater, laden with sediment, meandered in rivers for hundreds of miles, down gradients as small as one in a thousand. Extraordinarily smooth abyssal plains were mapped and their origins attributed to turbidity currents originating from the continental margins.

Wide ranging expeditions demonstrated the existence of the largest mountain range on earth – the mid ocean ridge of some 50,000 km length characterised in places by a narrow valley

at its centre and in others by a narrow ridge. The improved network of seismic stations across the world, set up to detect nuclear explosions, showed that a line of shallow earthquakes ran along the centre of the ridge. The deep trenches of the West Pacific and elsewhere were characterised by lines of much deeper earthquakes.

The evidence from the ocean floor led in 1959 to the concept of seafloor spreading and later to understanding the formation of the ocean trenches by subduction of the oceanic crust. The enormous fracture zones, first mapped in the Pacific, were found to be the scars of old seafloor spreading and the concept of transform faults was developed. All these observations were to culminate in the hypothesis of plate tectonics which revolutionised not only geological theory under the oceans but also on land.

All of this was going on in the 1950s and 1960s.

To support this research was the need to define, much more precisely than hitherto, the shape of the ocean bottom, the morphology, from which so many clues can be derived about the mechanisms of seafloor evolution.

Most research ships carried deep-sea echo-sounders, although it was not until 1954 (Luskin *et al*, 1954) that precision depth recorders were developed, that enabled the incredible flatness of the abyssal plains to be recognised. As the ability to navigate slowly improved with the use of electronic aids, lines of soundings throughout the world accumulated and seafloor features could be better delineated. Although the hydrographic services of the world, notably in the USA, UK, France and the USSR, carried out systematic surveys of the deep ocean in certain areas of strategic importance for the cold war, most of these data were classified and unavailable to the academic community.

In the USA, the Lamont Geological Observatory of Columbia University, under the leadership of Dr Maurice Ewing, was a hothouse of marine geological research, largely in the Atlantic Ocean, and of new concepts in marine geology. A seminal publication by Heezen, Tharp and Ewing in 1959, "The Floors of the Ocean Part 1, the North Atlantic" (Heezen *et al*, 1959), described in detail the morphology of this region and was accompanied by the first of the now famous Physiographic Diagram series which were later developed by the National Geographic Society. This method of presentation was especially suitable where the sounding profiles were widely spaced and where the absolute position of features was disguised in accordance with restrictions imposed by the military.

On the west coast of the USA, Professor Bill Menard of the Scripps Institution of Oceanography published in 1965 his book on "The Marine Geology of the Pacific" summarising twenty years of research (MENARD, 1965). This book contained not only a bathymetric chart (in 18 segments) but also a physiographic diagram of the whole Pacific. He reviewed the extensive work done on oceanic trenches, abundant in the west Pacific, the great fracture zones running east-west in the eastern Pacific and demonstrated the formation of archipelagic aprons as volcanic structures loaded and depressed the ocean crust.

Both HEEZEN's and MENARD's books summarised the current knowledge and laid the foundations for subsequent detailed research on the evolution of the ocean floor.

Marine research in the USSR was also extremely active, although, because of the cold war and difficulties of translation, it was not nearly so well known in the west. Dr Gleb Udintsev, then of the Shirshov Institute of Oceanology in Moscow, was a leader in this field and later was to take an active part in the international research in the Indian Ocean. He was, and remains, a very active contributor to GEBCO.

In the UK, the scale of marine geological research was much smaller, but none the less influential, and centred on the Department of Geodesy and Geophysics at Cambridge under the leadership of Dr Maurice Hill. It was later taken up by the National Institute of Oceanography (NIO).

UK research cruises in the North Atlantic required more detailed charts of the sea floor, and in 1960 at NIO, I initiated a series of unpublished charts at a scale of 1:1 million of the North-east Atlantic based on the collected sounding sheets maintained by the International Hydrographic Bureau. These were to become the basis for a published series of bathymetric charts of the north-east Atlantic (LAUGHTON *et al*, 1975).

International collaboration in marine research received a huge boost with the International Indian Ocean Expedition (IIOE), between 1959 and 1965, when 34 ships from 11 countries concentrated their research on the least well known of the three major oceans. One product of the IIOE was the Geological Geophysical Atlas of the Indian Ocean, published in 1975 (Udintsev *et al*, 1975), which contained new bathymetric charts of the whole Indian Ocean at a scale of 1:5 million as well as detailed charts of special areas. The techniques for the presentation of these charts evolved from those of individual bathymetric specialists, from the USA, UK, USSR and South Africa, who used their collective understanding of marine geology to interpolate and interpret the limited soundings available.

The state of knowledge of marine geology in the early 1960s is excellently elaborated in Volume 3 of "The Sea – The Earth Beneath the Sea" edited by Maurice Hill of Cambridge (HILL, 1963). Nine chapters are devoted to Topography and Structure, including chapters on the continental shelf and slope, submarine canyons, abyssal plains, oceanic islands, guyots and atolls, the mid-ocean ridges and trenches.

I have described in some detail what was known about the ocean floor at the end of the 1960s since it is against this background that the marine geological community in 1973 assessed the then current 3rd and 4th editions of the GEBCO series of world charts.

The GEBCO committee, as you have already heard, did indeed have marine geologists as members when I joined it in 1966 – Prof P.L. BEZRUKOV and Dr Gleb UDINTSEV from the USSR, Prof André GUILCHER from France, Prof Bruce HEEZEN and Dr Bill MENARD from the USA – and it had an Editorial Committee chaired by Bruce Heezen, which was later joined by Dr Bob FISHER. By this time the contouring and the chart production was in the hands of the Institut géographique national (IGN) in Paris.

At the 1967 meeting of the GEBCO Committee (GEBCO, 1967), there were long discussions on the role of this committee. It was decided that the contours generated by the IGN should be reviewed by the Editorial Committee, guided by geological and geophysical data, and that the contours so derived should be indicated by dotted lines on the final charts. In his report to the Association Internationale d`Océanographie Physique in August 1967, the Chairman of GEBCO describes the Editorial Committee as "chargé d'assurer une interpretation cartographique correcte des concepts géologiques et géophysiques" (AIOP, 1967).

In the regulations for GEBCO published by the IHB in 1970 (IHB, 1970, para 9-1), the Editorial committee has "the responsibility for approving or indicating amendments to be made to the selection of soundings and the drawing of isobaths as proposed by the IGN". In other words, the final decision on the delineation of the contours rested with the Editorial Committee. This never happened.

The GEBCO Committee in 1967 wrestled with the problem of speeding up the completion of the 4th edition, but it was fighting a losing battle against the continually increasing volume of data and the lack of resources, both financial and manpower.

In April 1972, during the 10th International Hydrographic Conference in Monaco, an informal meeting of GEBCO met under the chairmanship of Ingénieur-Général Marc EYRIES, who had recently taken over as Chairman of GEBCO. Since this was held at a Hydrographic Conference, only hydrographic members of GEBCO were present. The minutes of this meeting (GEBCO Working Group, 1972) were to spark an explosion which nearly killed GEBCO altogether. A proposal was made that the observations and theories of geologists "could only be taken when the next edition of the appropriate sheet was being prepared". This could and would, of course, take many years.

At about the same time the Editorial Committee of the Indian Ocean Atlas was preparing its own bathymetric charts, and there was some common membership between this and the GEBCO Editorial Committee. Drafts of these charts were sent to the Chairman of GEBCO and to the IGN for use in the preparation of the 4th edition GEBCO charts of the Indian Ocean, (sheets A IV and A' IV) but were rejected as "too imaginative".

The interpretative work of marine geological specialists in the Indian Ocean was roundly criticised by the GEBCO informal group, and a decision was taken by the Chairman of GEBCO and the President of IHB, which was reported in the minutes of the June 1973 full meeting of the GEBCO Committee, "not to submit the compilations to the Editorial Committee, as a temporary measure to speed up the work" (GEBCO Minutes 1973).

Questions were raised at the informal meeting in 1972 as to whether it was preferable to generate the GEBCO charts from the new 1:3.5 million scale INT charts being prepared by the national hydrographic departments. A paper by L.N.PASCOE formalising this proposal was published in the International Hydrographic Review (PASCOE, 1972). At the same meeting the IGN reported that the commercial possibilities of marketing the GEBCO charts were very poor, and that since 1965 there had been an annual deficit in the IGN contract with IHB of 80,000 FF (£530).

The report of the April 1972 informal meeting was very badly received by the scientific community, and gave rise to some strongly worded correspondence. The scientists had already become disillusioned with the GEBCO products, and so were not buying them, but nevertheless needed a good global bathymetric base for their research programmes. This had already been recognised by the Intergovernmental Oceanographic Commission (IOC) in their report in 1968 (IOC 1968) on the "Long-term and Expanded Programme of Oceanic exploration and Research (LEPOR)", one of whose aims was the morphological charting of the ocean floor.

The Scientific Committee on Oceanic Research (SCOR), which was the international voice of oceanographers, took up the challenge and created a Working Group (41) on "Morphological Mapping of the Ocean Floor" to review the current situation and to make recommendations to SCOR, and hence to IOC, about how best to proceed. SCOR WG 41 was initially chaired by Dr Johannes Ulrich of Germany and later by me.

WG 41 first met in August 1972 in Montreal prior to the 24th International Geological Congress, and almost simultaneously with the 6th International Cartographic Conference, the regular meeting of the International Cartographic Association (ICA), in Ottawa.

Together with my colleagues David ROBERTS and Ray GRAVES of NIO, I had prepared a paper for ICA on "Deep Ocean Floor Mapping for Scientific Purposes and the Application of Automatic Cartography" (LAUGHTON *et al*, 1973), in which we detailed the need for improved charts, reviewed a comprehensive list of currently published charts, including the GEBCO 3rd and 4th edition charts, and set out ideas on how global charts could be improved. This paper was written, partly, in response to that by PASCOE proposing that the needs of

oceanographers could be met by the publication of contours already drawn for the 1:3.5 million INT charts.

The paper became the basis for the second meeting of SCOR WG 41, held at the National Institute of Oceanography in the UK in April 1973, which was attended not only by members of the working group but also by representatives of the IOC, ICSU, ICA Working Group on Oceanic Cartography, IHO and the UK Experimental Cartography Unit.

A few weeks prior to this meeting, an informal meeting at UNESCO in Paris between Rear Admiral G.S. Ritchie (President of the IHO), F.W.G.BAKER (Secretary of ICSU and of GEBCO) and D.P.D.SCOTT (Secretary IOC) had proposed that the current series of the 1:10 million GEBCO sheets should be abandoned as a scientific global base chart of the oceans, and secondly that the structure of the GEBCO Committee should be changed to become a joint IOC/IHO body on which both oceanographers and hydrographers should be equally represented (Ritchie *et al*. 1973).

For the second SCOR WG 41 meeting, all members had been circulated with the results of a questionnaire prepared by WG 41 asking members to evaluate the listed charts, in the scale ranges of 1:12 to 1:6 million, 1:5 to 1:2 million and 1:1 to 1: 0.4 million. Most of these charts were displayed around the walls of the meeting room.

The report of SCOR WG 41 (SCOR, 1973) reviewed the existing chart series, in particular noting the deficiencies of the GEBCO 1:10 million series:-

(i). "the series hardly constitutes a current world series since publication dates of sheets range from 1923-1970 and only 8 out of 24 were published after 1960,
(ii). the contouring of sounding data has not been done with due regard to the existing state of knowledge of sea floor morphology or of the geological and geophysical processes active on the sea floor. Because of this erroneous data has not been identified and rejected. (N.B. contouring by geoscientists of the same data is in no way a generalisation. Where contours cross sounding lines they must be consistent with the data. The difference between the geoscientists approach and the cartographers is in how to interpolate between sounding lines),
(iii). no use has been made of the large variety of special surveys contoured at larger scales or of previous work of geoscientists in contouring the collected sounding sheets. (the WG regretted the decision of the GEBCO Committee to reject, during the preparation of the 4th edition, the contoured Indian Ocean charts prepared at 1:2 million for the IIOE Atlas),
(iv). there is no indication of the reliability of the contours or of the data on which they are based,
(v). the scattered sounding values do not add to the usefulness of the chart unless they represent isolated high or low points,
(vi). the contour interval is too wide and the contours too generalised,
(vii). the charts do not indicate whether soundings are in corrected or uncorrected metres."

The report endorsed the valuable role of the IHB as a specialised World Data Centre for Bathymetry and the contribution made by the Volunteering Hydrographic Offices (VHOs). Further it welcomed and accepted the proposals put forward by Ritchie *et al* at the UNESCO meeting in its paper on "The future of GEBCO"

Among the 15 recommendations, SCOR WG 41 noted that the 1:10 million GEBCO charts as prepared at present "do not fulfil the needs of marine scientists because the contouring of the collected soundings has not responded to the advances of earth science", and recommended that a full time Geoscience Unit "be set up to handle the task of preparing an

acceptable final compilation of bathymetry for subsequent cartographic drawing, printing and distribution".

This report, together with its recommendations, was endorsed by the SCOR Executive, in May 1973 and transmitted to IOC for their consideration.

The existing GEBCO committee met for the last time in June 1973 to discuss both another questionnaire that its Secretary, F.W.G. Baker, had circulated about the usefulness of the current GEBCO, and the report of SCOR WG 41.

All 15 recommendations were endorsed by the GEBCO Committee, including the immediate cessation of work on the 4th edition. It recognised that the present GEBCO series "no longer meets the present needs of oceanographers" and recommended that " a Guiding Committee for the new General Bathymetric Chart of the Oceans be formed by the IHO and the IOC after consultation with SCOR, IAPSO and the CMG" (GEBCO Minutes, 1973). The old GEBCO Committee was then disbanded.

Thus was born the mechanism for the integration of oceanographers and hydrographers into a new GEBCO organisation which first met in April 1974. This was to generate new standards for the bathymetric charts and initiate, and see through to completion, the production of the 5th Edition, which was to take a further eight years to complete. Funds were never found for the full time Geoscience Unit that was envisaged, so other ways of working had to be devised to include a significant contribution from geoscientists knowledgeable in the ocean floor.

There is no doubt that the SCOR Working Group 41 provided the impetus for a regeneration of GEBCO after its slow decline in the production of the 3rd and 4th Editions. The chart specifications discussed by the WG, and already used by many geoscientists, formed the basis for the new specifications developed by the Joint IOC/IHO Guiding Committee for GEBCO for the 5th Edition. Because of the extensive work already done, the charts of the western Indian Ocean prepared for the IIOE Atlas, based on extensive geological and geophysical studies, were to form the first sheet, 5.05, of the new edition of GEBCO.

At last the bathymetric charts of GEBCO were catching up with the explosion of marine geological knowledge and the understanding of the processes generating and moulding the ocean floor, and providing the much needed base for future research.

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Author's biography

Sir Anthony LAUGHTON, Ph.D., F.R.S., became a member of the GEBCO Committee and its Editorial Committee in 1966. In 1974 he became a member of the Joint IOC/IHO Guiding Committee for GEBCO and Chairman in 1986, a post he still holds. He was the second Chairman of SCOR WG 41. He joined the National Institute of Oceanography (later to become the Institute of Oceanographic Sciences) in 1955, and was Director from 1978 to 1988. His research was in marine geology and geophysics of the deep ocean floor.

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