Building the Fifth Edition: an exercise in cooperation

Dave Monahan,

Canadian Hydrographic Service

and Ocean Mapping Group at University of New Brunswick

Vice-Chair of GEBCO and Scientific Coordinator for five sheets of the Fifth Edition.

1. Setting the stage—the world during the production of the Fifth Edition

- Science: emergence of marine geology, and its findings, led to sea floor spreading, completely revolutionizing all of geology
- Technology: the vast promise of computers, improvements in positioning and data collection
- International relations: the convocation of the Third United Nations Conference on the Law of the Sea (UNCLOS III).
- The Cold War raged, and part of it was fought in the deep oceans by submarines.
- Organizational: International Hydrographic Organization (IHO) member states were becoming accustomed to working together in multi-national cooperative endeavors.

1.a Timeline

1959	Heezen and Tharpe relief map
1967	“Common Heritage of Mankind” concept introduced to UN TRANSIT positioning satellite made public
1968	Deep Sea Drilling Project begins
1970	Last sheet of the Fourth Edition published IOC establishes Group of Experts on Long Term Scientific Policy and Planning
1973	SCOR WG 41 recommendations producing world map April GEBCO Guiding Committee (IHO) endorses recommendations of WG 41 June Third United Nations Conference on the Law of the Sea (UNCLOS III) begins GLORIA surveys begin
1974	First meeting of joint IOC/IHO Guiding Committee
1975	First sheet of Fifth Edition (5.05) published by Canadian Hydrographic Service Sheet 5.05 presented to United Nations Conference on Law of the Sea
1977	Hot vents discovered on oceanic ridge
1980	Carters Echo-sounding correction tables published replacing Mathews Tables
1981	IHB publication B-6 'Standardisation of Undersea Feature Names' published IOC International Bathymetric Chart of the Mediterranean published First commercial GPS receiver sold, too late to be used for Fifth Edition
1983	United Nations Convention on the Law of the Sea signed Interpretations of NASA Seasat (flown 1978) altimeter data show seafloor
1984	GEBCO Fifth Edition publication completed
1985	“The relief of the surface of the earth” first computer- modeled relief map

1.b Scientific revolution and the evolution of knowledge of sea floor morphology—cause and effect intermingled

- Revolution in marine geology changed accepted view of the shape of the ocean floor
- Sea floor was related to geologic structure and history
- Existing bathymetric maps did not show such shapes
- Geologists began fitting natural surfaces to widely dispersed track data
- Out of this came support for seafloor spreading and credible bathymetric contours

1.c “Computer cartography”

- Data Interpretation Geophysicists began using computers to plot values on maps, but it was not long before computers were generating contours of potential field surfaces.
- But the seafloor was too rough, the data too sparse and the algorithms too crude to produce meaningful results for bathymetry, and the Fifth Edition was produced using human interpretation.
- Map Production Computers beginning to be used in cartographic production processes. CHS systems focused on the production of nautical charts.
- Consequently it was decided to use manual methods to draw the Fifth Edition.

1.d The United Nations Conference on the Law of the Sea

- Ownership of sea floor resources was a factor in the convening of the Third United Nations Conference on the Law of the Sea 1973-1982.
- Influenced the perception of the importance of oceans at many levels of Government worldwide
- Bathymetric mapping was looked on favorably
- Indirectly, the Fifth Edition benefited from these favorable conditions.
- Possible that the Fifth Edition influenced the framers of UNCLOS.

1.e Hydrographic antecedents to the Fifth Edition—setting the stage

- 1:1 000 000 Plotting Sheets developed during the Third Edition formed the first international data bank for bathymetry, and established the IHB as the world data center for bathymetry
- Volunteering Member States undertook preparation of the plotting sheets during the Fourth Edition, rather than having the plotting done at the IHB
- Clear Demonstration that the major Hydrographic Offices of the world were committed to oceanic hydrography and to cooperation on a world wide scale and had created an organizational structure to make this commitment a reality

Part 2 Launching the Fifth Edition

- By the end of the Sixties
  - more and better bathymetric data were being collected
  - a mechanism existed for assembling the data world wide
  - an understanding of the origin and evolution of the sea floor and of the processes active on it was developing
- Although these comprised essential components of a world series, no satisfactory world bathymetry map existed.
- An organizational solution had to be found.

2.a Solution

- Intergovernmental Oceanographic Commission (IOC) of UNESCO Group of Experts on Long Term Scientific Policy and Planning in 1970 examined morphological charting of the sea floor and recommended production of a world bathymetric map, bearing in mind that the IHB was the most experienced body in this field
- Working Group 41 of the Scientific Committee on Oceanic Research (SCOR) studied producing a world map and recommended how to be achieve this
- Joint IOC/IHO Guiding Committee for GEBCO established
- Mandate to create a totally new approach to GEBCO.

2.b Strategy

- Balance: the introduction of new approaches while maintaining the most valuable elements of the preceding years.
- Impatience: a proper map of the world ocean was needed urgently.
- Use sense of immediacy: to attract new players and new data sets.

2.c Coordinators

- One or More Scientists assumed responsibility for the interpretation of the data within a map sheet
- Scientific Coordinators to some extent staked their scientific reputations on the contents of the map in the same way they would with a paper published in a refereed journal.
- Data Interpreted as samples of a complex geomorphologic surface
- Editorial (Peer) Review of sheets prior to publication

2.d Partners and partnerships

- Many partners contributed to the success of the Fifth Edition
- Data was collected and submitted by partners
- Home Organizations of the members of the Guiding Committee, its sub-committees, the scientific coordinators and advisors were all partners.
- Groups who supplied information or the land portions of the map sheets were all partners.
- All deserve credit for successful completion of the Fifth Edition. There were so many that they cannot be listed : many are listed in the booklet that accompanied the Boxed Set.

Part 3. The Maps

- Canadian Hydrographic Service volunteered to produce the map sheets of the series.
- Coordinators produced contour sheets, which were submitted to peer review process, and sent to CHS who transformed the draft documents into thousands of copies of the paper charts.
- For coordinators who worked with little institutional support, the CHS transformed the draft material to a common scale and projection to produce a draft of the entire sheet prior to peer review.

3.a Shoreline and topography

- Institut Geographique National shoreline and topography from the Fourth Edition
- American Geographical Society Arctic and Antarctic shoreline
- Scott Polar Research Institute, Cambridge University, under-ice contours for the Antarctic and updates to portions of the Antarctic shorelines
- Elektromagnetics Institute, Technical University of Denmark under- ice contours for Greenland

3.b Depth portrayal

- Contours interpreted by marine geoscientists
- Spot Soundings few were to be shown
- Depths Corrected for the varying velocity of sound in seawater by Mathews tables
- Contour Intervals appropriate to scale, morphology and amount of data
- Generally, shallowest contour was 200m. After that, the interval switched to every 500m. Variations in this plan were necessary in places: for instance, in areas of steep continental slope, the 500s are occasionally omitted, and in the Arctic Ocean data density permitted only the portrayal of 1000 m contours.

3.c Reliability –uncertainty indicators

- To allow readers of the maps to judge how much faith to put in them for every portion of the seafloor, the reliability of the contours was indicated by showing the ships' tracks along which data had been collected as a thin gray line, or in the case of a comprehensive survey too detailed to be shown at map scale, as an outlined box.

3.d Projection

- Mercator's appropriateness debated at length, recognizing that all projections distort, and any choice would be a compromise.
- Transforming 1:1M Mercator plotting sheet data to another projection would have introduced an extra step into the production stream.
- Reproduction material available from the IGN consisted of land topography, drainage and shoreline registered to a Mercator grid.
- Mercator coverage extends to 72 degrees North and South
- Polar regions mapped on stereographic projection extending from the poles to 64 degrees North and South.

3.e Sheet Layout

- Seek balance between portion of the earth that could be covered by a printable map sheet and the fact that a particular area of the sea is bounded by physiographic features which did not always coincide with map sheet boundaries.
- Fourth Edition was 16 sheets extending 90 degrees longitudinally starting from Greenwich
- Fifth Edition coverage of the southern hemisphere was improved by shifting the sheet boundaries 20 degrees east.
- Seven sheets enlarged to cover a small extra area, like the west coast of Hudson Bay, that would otherwise result in the user needing two sheets.
- Polar Sheets and World Sheet added

3.f Languages used

- English for water names, and French for land names used in first print run in keeping with the cooperative nature of the endeavor
- Russian, Spanish and Chinese in subsequent press runs

3.g Boxed set

- Boxed Set of all sheets produced to enable individual users to conveniently store and have access to GEBCO
- Included was
- a legend printed separately for use when the 1:10 000 000 sheets were trimmed and wall mounted,
- a booklet containing a general description of the project, credits, references and sources for each sheet , Guidelines for Geographical Names and Nomenclature, description of the International Hydrographic Organization as the World Data Centre for Bathymetry

3.f Nomenclature

- Sub-Committee on Undersea Feature Names
- researched the background of specific names appeared on the published GEBCO sheets
- produced a comprehensive listing of generic terms IHB publication B-6 'Standardisation of Undersea Feature Names' and a gazetteer (IHB publication B-8).
- developed a new name submission process and supporting documentation.

4 Transforming data into information by drawing contours.

- Drawn “by hand” guided by the brain and eye of the scientific coordinator.
- Could only have shapes that conformed to real geologic surfaces at map scale
- Benefited from information that was not contained in the numerical soundings and could not have been dealt with by the software of the time.

4.a The Coordinator’s Task

- To interpret the shape of something that had never been seen, from data
  - positioned incorrectly by up to several miles
  - included different echo sounder beam-widths
  - included depths selected in different ways,
  - whose methods of collection were unknown
  - arranged in a random relationship to the seafloor
  - detected features whose horizontal wavelength was very short along track compared to that across track
- The scientific coordinators were armed with their knowledge of sea floor processes, some ancillary geophysical and physical oceanographic information, an understanding of the limitations of the data, a sense of appropriateness, and a great deal of enthusiasm.

4.b Process

- Coordinators began with data that they had collected for part of the map area.
- Next assembled data from other available sources.
- Not all institutions had submitted their data. However, the coordinators were usually aware of all data “in the pipeline” and were well placed to influence the holders of the data to allow it to be incorporated immediately into GEBCO .
- The positive response to these requests was another indication that the international science community wanted a world bathymetric map.

4.c Each sheet covered a vast portion of the earth

- Small sub areas were covered by cohesive bathymetric data sets that used the same positioning and sounding instruments, were self-checking through having numerous crossovers and were laid out to optimally.
- These were very much the exception.
- The great bulk of the map sheet was covered by a random distribution of tracks collected over a number of years using different positioning methods with different accuracies and different sounding methods, with the velocity of sound only poorly understood, had varying numbers of crossovers and whose pattern was rarely related to the sea floor morphology.

4.d Checking

- Check for blunders including errors introduced by plotting metres and fathoms together, plotting depths corrected according to different assumed velocities of sound, reading the wrong phase in the echo-sounder, reading deep scattering layer for bottom...
- In theory, detected blunders can be corrected or rejected, but totally rejecting data from a sparse data set was often impossible. The shape information was still useful to some degree and was salvaged if at all possible.
- Systematic errors and random errors were largely accounted for during interpretation and by the difference between working and publication scale

4.e Original Echograms versus Posted Soundings

- Returned trace is virtually continuous and can be used in its raw form when it exists
- Soundings are samples of the returned echo at discrete locations
- Soundings were plotted manually: relationship between plotting sheet scale and the size of the numerals dictated the wavelength of features captured from the echograms.
- Depths plotted were not selected in a consistent manner. Capturing the shape of the profile vs shoal biasing

4.f Results

- A world wide International map series covering every part of the ocean that depicted the natural seafloor in a credible, scientifically defendable manner

Part 5 The Fifth Edition's behest

- GEBCO is an on-going, constantly unfolding process. The Fifth Edition was a milestone on a journey that has never stopped.
- Succeeding milestones that built on the Fifth Edition were the creation of the GEBCO Digital Atlas and the production of a world-wide grid of depth values.
- Human and organizational elements. Producing the Fifth Edition was a clear demonstration that people from many nations and different branches of science can work willingly and freely together applying their specialized knowledge and skills towards a common goal. We have continued to do so since the Fifth Edition was completed.
- The Fifth Edition is testimony to what men and women of good will can achieve.