A LOOK TO THE FUTURE; OCEAN MAPPING IN THE TWENTY FIRST CENTURY

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Executive Summary

This paper attempts to position the GEBCO organization in time, that is, in the flow of events impacting the partnering organizations and the changes in technology that will influence GEBCO in the next few years. Against this backdrop, the paper explores the concept of producing a new edition of GEBCO and concludes that there will not be a "sixth edition" with the same meaning that earlier editions had. Rather, sounding data from navigational hydrography, contours from the IOCs regional bathymetric maps, multibeam data from the deep ocean, and altimetry –derived bathymetric information will be contributed to a digital data base from which all marine science can draw seafloor morphologic information.

Part 1. Introduction

When reading about the future, the reader usually wants to know just when in the future the events described are going to happen. However, when writing about the future, the writer knows that the hardest part of the paper is the timing of when the predictions will come true! It is in the writer's interest to not be too specific about dates, yet give enough to satisfy the readers' curiosity. That is what I must attempt to do here.

Since this is a centenary, it might be expected that I would speculate about the entire next century. That would be highly amusing and fun to do, with part of the pleasure coming from imagining the laughter when portions of the paper were read to the attendees GEBCO's *bi*-centenary. Obviously no one can seriously predict the events of a century. At the other end of the temporal scale, what should be said about what GEBCO is going to do the week after this conference is over? This is much more pressing and important and occupies the bulk of this paper.

We still need a time scale. Let us say that for this paper, the expression "short term" will be used when referring to events that should take place between the present and the production of the sixth "edition" (although as explained late, what constitutes a sixth edition is by no means clear). "Long term" will then apply to events after the sixth edition, but presumably within the next hundred years.

1.1 Caveat

It is difficult in many ways to write a "futures" paper prior to this conference. Many of the papers presented will be about components of the future: written by experts, they may well be the latest word on that topic. I am not expert on all the elements that will impact GEBCO's future and I really need to hear the opinions and forecasts of those who are. One of GEBCO's strengths, of course, has been its ability to attract a variety of such specialists into the fold, an action that greatly benefits other members. I suspect that the written version of this paper will need an update by the end of the conference and I know that the PowerPoint version will be updated the night before it is presented.

1.2 The world in 1903

It may be instructive to look at the world that the founders of GEBCO looked at and try to imagine the future they saw for GEBCO. They lived in a world that was very much still being explored, a world that existed to some extent only in imagination or dreams since no one had seen parts of it, yet a world that was being expanded. It was not known if there was land in the Arctic Ocean. Amundsen made the first voyage through the North West Passage the year that GEBCO was launched; Peary was not to reach the North Pole until 1909. One year previous to GEBCO's birth, the first trans-Pacific cable had been completed, while a year after it, work began on the Panama Canal. Another dimension was added to this drive towards expansion in 1903, in a hitherto unknown place called Kittyhawk, when the first powered flight took place.

What did the founders of GEBCO think about the world they lived in? More important for a futures paper, what did they dream about the world they were constructing? It is impossible to know what they dreamed from reading the official records of their works, but it is safe to speculate that they dreamed of mapping the entire world ocean, even though parts of it had not then been seen. If this was their dream, then it certainly came true.

1.3 The world in 2003

And us in 2003? We live in a world that is still very much being explored, a world that exists to some extent only in imagination or dreams since no one had seen parts of it, and a world that is being expanded. In the last twenty years we have seen the discovery of gas hydrates, of pharmaceuticals from the sea, of black smokers, of cobalt crusts, and of chemosynthetic life at ocean ridges, of world wide gridded data sets being made easily available. We are beginning to see a new order of sea-floor morphology revealed by detailed MBES surveys. Yet an examination of the latest track charts shows that there are still vast areas that have never been visited by a recorded research vessel. (Sharman, this volume). We do not agree on how much of the ocean remains un-explored, but estimates as high as 95% are not uncommon. With the end of the Cold War, military operations at sea have changed from fighting a global war in the deep ocean to fighting local wars in shallow water, and some of the deep ocean data has been declassified. And we await the launching into space of further Ocean Mapping instruments, such as ABYSS (Smith this volume)

What do we dream the future will bring? Many earth scientists share the <u>dream of having the entire surface of the earth, both subaerial and sub-aqueous, mapped seamlessly to a fine resolution.</u> (See for example, (Carron et al. 2001), (Vogt 2000)).

1.4 Predicting the world in which GEBCO must function.

The twenty years straddling the production of the Fifth Edition witnessed a change from hand-drawn relief to computer-generated relief, positioning by satellites was made public, seafloor mapping evolved from single beam echo sounders to side scan sonar to multibeam and satellite altimetry, the Deep Sea Drilling Project launched, the cooperative union of two independent and very different International organizations in a common cause, the United Nations Convention on the Law of the Sea conceived, developed and signed, and the major paradigm in earth science make the transition from untested theory to dogma. The twenty years since then produced GIS as a common and widespread tool, the Internet evolved as the major communication and information tool, GPS de-restricted and improved to the point where positioning at sea is no longer an issue, data that had been collected for military purposes released to the public domain, computer power and storage increase by leaps and bounds, the GEBCO Digital Atlas released and updated, grids derived from the GEBCO contours, satellite altimetry data combined with echo soundings…and more. Will the next twenty years be as exciting?

While science and technology strongly impact GEBCO's future, they are only part of the equation; there have been enormous changes in society, Government, organization structures and business that play as important a role in the future. This paper attempts to capture the essence of these changes as trends and predict how they might impact the future of this organization we call GEBCO.

Part 2 The Present situation and special strengths of GEBCO

The strength that built the Fifth Edition came from the successful blending of hydrography and oceanography at, it must be emphasized, both the individual and organization level. Organizationally, IHO and IOC combined forces, while at the individual level, hydrographers and marine geologists and geophysicists worked side by side contributing their different skills. (Oceanography as used here means geologic and geophysical oceanography, sometimes called marine geology and marine geophysics.)

2.1 Hydrography at the Organizational Level

Although hydrography is commonly known for its role in producing navigation charts for mariners, there are many other elements to the discipline. Off-shore hydrography is concerned with the provision of hydrographic data as an extension of the coastal zone normally encompassing the continental shelf, the development of mineral deposits, including hydrocarbons, and provision of data for fisheries management while oceanic hydrography is concerned with the acquisition of hydrographic data in the deep ocean areas for the depiction of sea-floor geomorphology.(United Nations Economic and Social Council 1978)

The operational definition of hydrography has most recently been refined by Hecht [2001] to read:

> Hydrography is the total set of spatial data and information, and the applied science of its acquisition, maintaining and processing, necessary to describe the topographical, physical and dynamical nature of the hydrosphere and its borders to the solid earth, and the associated facilities and structures.

The IHO constantly seeks to stay abreast of the changes in the world and its Strategic Planning Working Group has produced the following draft of it's objectives**:**

1. To improve global coverage, availability, quality and access to hydrographic data (*and its related oceanographic*) information, products and services (*especially nautical charts and publications*)
2. To improve global hydrographic capability, capacity, science and techniques.
3. To establish international standards for the quality and formats of hydrographic data, information, products, services and techniques and to achieve the greatest possible uniformity in the use of these standards.
4. To give authoritative (*and timely)* guidance and advice on all hydrographic matters to governments and international organizations
5. To facilitate coordination of hydrographic activities among Member States.
6. To enhance cooperation amongst States on a regional basis
7. (To manage central or joint services for the National Hydrographic Offices of the Member States).
8. To raise global awareness of the importance of Hydrography.

Clearly continued support for GEBCO meets all these objectives.

2.2 Oceanography at the Organizational Level

The great questions that the public will expect oceanography to address over the next twenty years will include global warming and climate change, food from the ocean, protection of the marine environment and resource recovery from the seabed. Bathymetry contributes strongly to the latter.

These are not the only questions that ocean science sees itself focussing on. A summary of those issues are contained in a report of a workshop the IOC held in Potsdam in 1999 (Field et al. 2002). The Potsdam meeting reported that accuracy of bathymetric remains a limitation of some other branches of oceanography. It sees the need for bathymetric surveys: for laying fiber optic cables, for mapping the seafloor around oil recovery structures in areas where slope stability might be impacted by turbidity currents, that backscatter must be interpreted to yield environmental information, that bathymetric data must be collected into a GIS, that improved bathymetric maps will improve tide prediction and models of circulation, need better altimetry and a better geoid model.

How this bathymetric data is to be collected and the organization required to support these requirements is not dealt with. Perhaps it was assumed that GEBCO and the ibcs will continue to fulfill this function.

2.3 Oceanography and hydrography at the individual Level

The fifth edition's main contribution will probably be summarized by history as being one of taking a data set of variable density, sparse coverage and questionable uncertainty, and blending and interpreting it so that it formed a cohesive whole. A huge amount of interpretation was required because the data set was so inadequate and because so little was known about many parts of the ocean. The science to guide the interpretation was worked out in parallel with the interpretation. For example, in constructing sheet 5.12, Heezen and Tharpe postulated a pole of opening for the South Atlantic, then drew arcs representing paths that fracture zones about that pole would follow, then examined the sparse data for evidence of such FZ. When some was found, this both helped interpret the map area and confirm one element of what is now called sea-floor spreading.

Who was it that performed this role? Very early, the guiding committee recognized the clear need for interpretation and created the position of scientific coordinator, one or more for each map sheet. Coordinators were a mixture of university and Government scientists.

Coordinators began by assembling the data covering their map sheet. Beginning with the 1:1M plotting sheets, they had to be aware of the research cruises that had taken place in the area, determine if the data collected had been submitted to IHO for inclusion on the 1:1M plotting sheets, for those that had not contacting the chief scientist of each cruise and soliciting the data, combining the new data with the old… a lot of painstaking labor before interpretation could begin.

Interpretation was part art, part science, part intuition, part rule-following. It required a highly developed sense of scale: original echograms recorded horizontal features at a fairly short wavelength, plotted soundings usually lengthened that wavelength to at least twice sounding spacing, while cross-track wavelengths could be ten or a hundred times greater. Producing an isotropic surface from such a range of wavelengths was not trivial. Schenke (this volume) describes the process in detail.

One of the fundamental strengths of science is the peer review process, ensuring that published material meets the standards of the moment. Once a scientific coordinator had finished preparing the contours for a sheet, it was passed to reviewers well versed in the physiography of the map area. This step helped assure users of the maps that they represented the best possible interpretation of the data available, an assurance reinforced through showing the tracks in the body of the maps.

Without this solid infusion of scientific knowledge and effort, GEBCO would have withered and died since it would not have been accepted by the International scientific community.

When looking to the future, we have to ask what role interpretation by scientific coordinators will have. Changes since the production of the Fifth Edition include greater amounts of data, a unifying theory of how oceans are created, acceptance of computer contouring as a tool, altimetry world wide (except poles), and multibeam surveys which do not need interpretation (within footprint). These probably combine to require a different level of interpretation than in the past, one requiring skills not employed in previous editions.

2.4 The sum is greater than the parts

GEBCO is a voluntary organization and is collegiate like a university. It is a loose grouping of experts and specialists. GEBCO is neither a business nor a military organization. GEBCO is multinational. The cultures from which the individuals involved in GEBCO come are very different. Some members represent national and international organizations. The fact that the voluntary members of GEBCO often wear different hats, because they may represent their employers, their sponsors or even themselves, means that conflicts may arise. Resolving them adds to the strength of the organization

Part 3. Likely impacts from science and technology over the next twenty years

3.1 Data Collection

Data will continue to be collected from surface ships, and surface ships will still move at limited, though perhaps increased, speeds. Even with the advantage of swath widths afforded by MBES, (Carron et al. 2001) estimate that it will take some 800 ship-years to cover the entire seafloor from the 25 m contour out to the deepest ocean. Submarines move two or three times more rapidly, and are excellent data collection platforms, as the SCICEX program demonstrated (see, for example (Jakobsson et al. 2000)). Their availability is not good and their costs are high. Both will most likely be used for multi-disciplinary cruises, and bathymetry will seldom be the high priority: indeed, there are cruises in which the only sounder operated is the ship's navigation sounder. It will be up to all of us to try to ensure that bathymetric data are collected on every possible occasion. Some are predicting a shift from the "expeditionary" style of at-sea data collection, which collects data over an area in a few weeks, to repetitive measurements of the same point or small yet critical are to collect time series; the later will not produce much new bathymetry. (McNutt 2002) Nor will the trend seen in some branches of oceanography to using *in situ* sensors to collect time series data at a single point.

Some data collected by military vessels during the Cold War has been released to the public domain. There is always hope that this will continue, but increasing tensions in the world militate against this.

The use of drifters and floats is increasing, and they can be equipped with an echo sounder and positioned by GPS. It is unlikely that they will be deployed to collect only bathymetry and other parameters will be the focus of the deployment.

Robots, tethered and autonomous, are already being used for detailed surveys. It has been suggested that larger autonomous vehicles could be built and deployed over larger areas.

Satellites are dealt with under Remote Sensing.

3.2 Positioning.

For the first five editions of GEBCO, positioning of vessels at sea was a major difficulty, one that not only absorbed energy but set an upper limit on map publication scale. General cartographic practice used to be to not publish maps at a scale where the uncertainty in positioning data would show as an area rather than a point on the map. The introduction of GPS ends all that; positioning of the research vessel on the face of the earth is no longer an issue. Inexpensive, globally-referenced, consistent, accurate positions are easily accessible. There will be a transition period, hopefully short lived, where mapping areas of the ocean where the bulk of the data available is from the pre-GPS era and new maps are to be made from a combination of pre- and post-GPS positioned data.

Current positioning research is focussed on positioning the ends of the acoustic beams of a multibeam system on the seafloor.

3.3 Data base / data centre

At present, this important function is provided by the National Geophysical Data Center in Boulder, Colorado, USA, which operates a worldwide digital data bank of oceanic soundings on behalf of the Member Countries of the IHO. In the data bank, oceanic soundings with depths greater than 100 meters are inventoried, quality controlled and updated. Data sets are provided free of charge to the IHO for use by its Member States in various exchange formats. Member States and other organizations submit bathymetric data thereby creating a valuable pool of soundings available to the marine hydrographic and scientific community. (Sharman, this volume).

In the future, it may no longer be necessary to submit data to a central data center. Instead, bathymetric information may be locally managed and made available on servers maintained by those who "own" the data, if concepts like "Spatial Fusion" come to fruition. If it does, there will be an even greater need for quality control and standards, a role that NGDC currently performs on its data holdings.

The much bigger question is that of how this data is interpreted and transformed into information.

3.4 Digital products.

The GEBCO Digital Atlas (GDA) is described by Jones (the volume). The digital revolution is progressing so rapidly that the GDA no longer can be considered leading edge. Since the publication of the Fifth Edition, all of what used to be called surveying, mapping, charting, and cartography have undergone a revolution that has combined them into Geomatics, which applies Information Technology to produce a Geographic Information System (GIS). GIS is rapidly evolving from a field that required specialised training into a general type of software that professionals in fields ranging from aquaculture to coastal zone management are able to use easily, and they will want bathymetry as one of the GIS layers.

"It is proposed that GEBCO and IOC consider adopting digital methodologies for the production, distribution, and advanced visualization of bathymetric information in user-friendly form. One way to do this would be to package global bathymetric information and related facts in a series of information layers: locations of data points, bathymetric grids at varying resolutions, depth contours at standard intervals, the IHO Gazeteer, IHO Limits of Seas and Oceans, national maritime boundaries, etc. The package would include easy-to-use GIS software that allowed users to combine and visualize selected layers within defined geographic limits, and to manipulate this information to produce special effects e.g. shaded relief maps, custom depth contours, oblique views, fly-throughs, etc. The option for producing printed output would be available, of course, as would be the capacity to export selected data to external GIS environments for specialized manipulation and for combination with other types of information." (Macnab and Jakobsson 2002) see digital bathymetric chart section

3.5 The Internet

As a major driving force in mapping, the Internet is just coming into its own.(Monahan et al. 2001). Sitting anywhere on land, one can readily and easily download thousands of maps, data sets and images. The internet, or something like it will go to sea: already being developed and deployed on a limited basis, it will not be long before data can be moved from instruments aboard ships to shore-based labs, and vice versa, quickly and easily.(Berger and Orcutt 2002) GEBCO will not have a future if it is not part of the internet. Our web site is a good beginning, but users are already expecting more from web sites than the passive display of information. They want interactivity!

3.6 Seabed information.

New approaches introduced in the last few years, particularly multibeam sonar systems, permit close to 100% coverage in mapping the seabed. These systems can produce (near) complete pictures of seabed topography, providing products similar to land maps based on aerial photography. Within the area ensonified, they collect so much data that only computer analyses can handle it, no human interp is needed or practicably applicable. Where MBES is used to mow the lawn, overlapping coverage, then areal coverage of consistent quality is produced. Of course, like all sounding data, the speed of the vessel is a major limitation and it has been estimated that hundreds of ship years will be needed to cover the world ocean. (Carron et al. 2001). One consequence is that for some time both single beam and MBES ata will co-exist and methods of combining them will have to be developed or perfected.

In addition to mapping shape, it is often also possible to map acoustic backscatter data. Backscatter is related to bottom composition and texture, and maps of backscatter are providing information on these elements. "Automatic" seabed classification is being introduced.

3.7 Remote sensing.

Satellite imaging technologies have impacted many forms of ocean mapping. Altimetry maps changes as small as a few centimetres in sea surface height, data which can be used as an indicator of undersea topography. Smith, (this volume) describes the development of this approach and shows the path towards the resolution of shorter horizontal wavelength features. Not only can altimetry be used to produce seafloor maps from only its own data, it can be used to unify and interpret acoustic data where it is widely dispersed and randomly oriented. Altimetry will undoubtedly have a significant role in the future of world scale-bathymetric mapping since it is the only cohesive, single instrument source of data for the deep oceans.

Experts within the GEBCO Working Group on the Integration of Geoscience Data have been investigating through data compilations and studies, the seafloor topography signal that has been recovered or may be recoverable from current or future satellite altimeter data. These studies are carried out to better understand the signal and noise characteristics in the mapping of seafloor structures by altimetry and will be used to improve altimetry data processing algorithms and demonstrate the possibility of higher-resolution mapping using new altimeter technology. See (Marks 2002)

Part 4. Likely Conceptual changes

4.1 Map scale.

In the past, GEBCO has been thought of as a map series at world scale. To see entire oceans or indeed the entire earth, one used GEBCO. To see more detail, one used a larger scale chart (where one existed, and with caution since it may have been made from the same data set). The entire concept of scale is changing with the introduction of GIS and electronic charts. In them, to see more detail, one simply “zooms in” on an area of the same map. The area is enlarged and more detail is shown. Users assume, sometimes incorrectly, that the underlying data will support the displayed scale of information. These users are becoming accustomed to looking at maps through one window, and easily adjusting the detail in what they see in the window. Under this scenario, the scale of the map is whatever the user wants it to be. GEBCO will have to adapt to this new concept of scale.

4.2 Edition

A future for GEBCO paper could talk about how the Sixth Edition is to be produced. After all, we have seen five editions produced over the last hundred years, making it seem natural that a sixth edition would be the next step. Although making that assumption is easy, not examining it would be folly. We live in a time when a couple of clicks of a button will produce an animated weather map on a screen, one that is updated every half hour: Do these maps have “editions”? The concept of edition that was developed for the age of paper printing is changing and we must ask whether there will ever be a complete paper Sixth Edition or whether some other form of constantly updated map will evolve. At GEBCO’s two hundredth birthday the attendees might marvel that the twentieth century was so constrained by the printing press and try to imagine what it would have been like to live with such confining limitations.

Achieving a “constantly updated map” will not be trivial. It will require energy and tallent applied over time. But there are no serious technological barriers, and such a treatment of updating already exists in some disciplines, including the Electronic Chart. Of course, there will be issues to resolve like how to apply the principal of peer review to a constantly updated product.

4.3 Increased Focus on Continental Slope and Rise

Containing the deeper parts of the Slope, the elusive Foot of the Slope and the area around the 2500 meter contour, the zone of interest to UNCLOS Article 76 has not been as well studied as other areas in the ocean. Generally, continental shelves and oceanic ridges received the most attention. This will change as Coastal States collect the data needed to establish the outer limit to their juridical Continental Shelves under Article 76. New data collection is already underway in a number of countries (see, for example, (LeVisage et al. 1998; Symonds and et al 1998). These data may or may no not enter the public domain until the outer limit is established, but they do represent a major new source of data in the next ten years. New, often smaller, geomorphologic features are being discovered and we must ensure that GEBCO scale, both horizontal and vertical, is appropriate to show them.

A second reason to expect greater interest in the Slope area is the presence of methane hydrates (sometimes called clathrates) in the sediments of the rise over wide areas of the ocean. Although exploitation of them is still a long way into the future, the areas of their occurrence are coming under increased attention.

During the next few years, GEBCO will have to focus on this area.

4.4 The changing role of interpretation

In the past, data valuable to GEBCO was usually be collected at little direct cost since research ships would normally operate an echo sounder as part of their regular program. Single beam echo sounders required little in the way of operator or servicing at sea. While this is still true, MBES is a different story since it has not yet evolved to the point of requiring no operator intervention. Data processing for MBES is similarly resource intensive. Nevertheless, indepednt traks of multibeam can be sent to NGDC where it is archived reviewed for quality, and inventoried for ready access, retrieval, and redistribution. Since processing multibeam data requires sophisticated software and equipment, it is made available as entire data sets or reduced data sets.

Within the area of seafloor ensonified during a multibeam survey, there is no need to interpret the shape of the seafloor and express it in contours as there was during the single beam, widely spaced track days. There is so much data that it creates the contours itself. Within the ensonified area, interpretation can focus on what the contours mean. Between multibeam passes, there will still be a need to interpret the seafloor from single beam tracks, and ways may be devised to use, in the areas between tracks, the extra information provided by the multibeam.

At the opposite end of the scale, altimetry provides long wavelength information (Smith, this volume). While combining altimetry and single beam has been made operational (Smith and Sandwell. 1994), interpreting the three data types together awaits development.

Part 5 Likely impacts from Organisational developments

5.1 IHO /IHB and volunteering hydrographic offices

The IHO supports both GEBCO and the IOC IBCs. IHO sees the data involved as a resource that will be exchanged freely. The IHB sees the IBCs as forming a bridge between navigation charts and GEBCO charts. Because of pressure on resourses, it makes little sense to keep separate the bathymetry collected by the three parties. The future participation of VHOs is very dependent on the future relationship between GEBCO and the IBCs. This relationship must be structured in a way that it is seen as possitive to the VHOs and one that uses limited resourses for maximum return.

5.2 IOC and its regional mapping projects

Through seven Editorial Boards and a Coordinating Committee on Ocean Mapping (CGOM), IOC publishes regional bathymetric maps of specialized areas. Starting with the Mediterranean IBC (IBCM), there were now seven IBCs, the latest covering the Arctic Ocean (IBCAO) and Southeast Pacific (IBCSEP). Some IBCs such as the IBCAO were already integrated into GEBCO, and but not all of the seven Editorial Boards agree to this strategy as yet. The IBCs use the output of SCUFN. IOC wants to collect all data into a single data centre available to anyone so that charts may be produced at any scale. NGDC is working with the IBC Editorial Boards, which increases the global marine geology and geophysics holdings in national and international data centres. Some Hydrographic Offices supply data to the IBCs.

(Macnab and Jakobsson 2002), two of the architects of the IBCAO and scientific advisors to GEBCO, argue that the time when cartographic production considerations of paper charts which fully justified the creation of two series of bathymetric charts, has been overtaken by advances in digital technology. They point out that data in digital form lends itself to a much wider range of processing and interpretative options than the traditional printed chart, with far less effort and time required to achieve results that would have been unimaginable just a few years ago. In this environment, the production of printed charts is almost a secondary process.

In addition to this technological argument, it may make economic sense to have a combined series. VHOs would supply data once, the areas covered by the ICMs would be mapped once, GEBCO would include the most detailed maps of small regions within its large ocean wide coverage.

There would appear to be clear advantages in GEBCO and the IBCs working more closely together.

5.3 UN Atlas of the Oceans

The FAO Fisheries Department, together with a number of other UN and national bodies has launched a web site entitled the United Nations Atlas of the Oceans. This is not designed to produce a bound book type “atlas” but is instead

> “an Internet portal providing information relevant to the sustainable development of the oceans…Collaborators include the Russian Head Department of Navigation and Oceanography (HDNO), and the US National Oceanic and Atmospheric Administration (NOAA), which, in addition to a wealth of information, seconded a senior manager to serve as Project Manager and provided him support staff and funding. The Census on Marine Life (CoML) and the National Geographic Society have also agreed to join the Atlas partnership. Cinegram Media Inc., a private publisher, will be producing CD-ROMs and other media in order to reach a wider audience, particularly among the public and educators.”

A visit to the website in March 7, 2003 reveals that it has, as downloadable images, the cover of the GDA and a portion of one of the 1:10,000,000 sheets. Maps Russia’s HDNO are also included. Clearly there are some links to build here.

5.4 CLCS and UNCLOS Continental Shelf submissions

One document that may have more impact on the short term future of Ocean Mapping is the Guidelines produced by the Commission on the Limits of the Continental Shelf (CLCS) (United Nations 1999). This document describes the types and quantities of data the CLCS considers necessary to support delineation of a Continental Shelf under Article 76. It will serve to guide data collection over extensive areas of the ocean for the next ten years or so.

A possible link between GEBCO and the CLCS lies in the Convention itself. Paragraph 3.2 of Annex II, which establishes the CLCS, states

> “The Commission may cooperate, to the extent considered necessary and useful, with the Intergovernmental Oceanographic Commission of UNESCO, the International Hydrographic Organization and other competent international organizations with a view to exchanging scientific and technical information which might be of assistance in discharging the Commission's responsibilities.”

GEBCO has included members of the CLCS among its scientific advisors in the past and should investigate building stronger links in the future.

5.5 International Seabed Authority

Under UNCLOS, the International Seabed Authority (ISA) is the organization through which States Parties to the Convention shall organize and control activities in “the Area”. The Area comprises the seabed and ocean floor beyond the limits of national jurisdiction, ie beyond juridical Continental Shelves. The Authority came into existence on 16 November 1994, upon the entry into force of the 1982 Convention and became fully operational as an autonomous international organization in June 1996. All States Parties to UNCLOS are members of ISA.

The ISA has issued 15-year contracts to various groups (some of which are Government agencies) to explore certain patches of the seafloor with a view to recovering manganese nodules. The “pioneer” areas for manganese nodule recovery lie between the Clarion and Clipperton Fracture Zones (stretching west from Mexico to south of Hawaii). The contractors have done varying amounts of work in their areas, and collected different types of data. Data confidentiality has been an issue: as is normal in the mining and petroleum industries, the contractors want their data to be confidential.

There are opportunities for GEBCO to increase its presence with ISA. The Legal and Technical Committee includes members fully knowledgeable of the role of bathymetry in marine science and should be approached.

5.6 Universities

Universities were a major player in Fifth Edition with fourteen of the scientific coordinators coming from universities in four countries. A future GEBCO will hopefully include them, and new arrangements will have to be worked out to satisfy their need and those of their funding agencies.

5.7 GOMaP (Global Ocean Mapping Program)

The vision of GOMaP is to systematically map the ocean floors with at least 100 percent coverage sidescan and swath bathymetry and perform whatever other data collection could be carried out simultaneously (e.g., subbottom profiling, magnetics, gravity, physical oceanography and meteorology). (Carron et al. 2001). GoMAP exists as a well-thought out project which is still at the proposal stage. Its future depends on funding, and the chances of obtaining funding are unclear in the current climate. There are some regional mapping initiatives that could be considered test areas or pilots for GOMap. Clearly it would be mutually beneficial for GEBCO and GOMaP to be interlinked.

5.8 ODP – Ocean Drilling Program /Integrated Ocean Drilling Program (IODP)

The Ocean Drilling Program (ODP), (to be replaced by Integrated Ocean Drilling Program (IODP)) is an international partnership of scientists and research institutions organized to explore the evolution and structure of Earth. Although it is primarily interested in what lies beneath the seafloor, this program often produced bathymetry maps of areas it was considering drilling, based on an analysis of a small scale bathymetric map, and did some detailed bathymetric work around its drill sites. The depth data collected were usually sent to NGDC. ODP is actively developing partnerships and it may be fruitful to examine a possible role with GEBCO.

5.9 Land mappers

The dream of having the entire surface of the earth means that there will have to be programs developed with land mapping agencies.

Part 6 Likely impacts from societal changes

6.1 UNCLOS-

Even though the United Nations Convention on the Law of the Sea was conceived, developed and signed during the production of the Fifth Edition, its impact is only now becoming apparent. It will impact GEBCO and the entire field of Ocean Mapping for the next twenty years and GEBCO's future must respond to, and help influence, its unfolding. UNCLOS divides the World Ocean into zones; except for the Continental Shelf, their delineation is relatively straightforward and need only be declared by a Coastal State. However, delineating the juridical Continental Shelf under the definition in Article 76 requires a large amount of sea floor mapping and interaction with the body empowered to scrutinize them, the Commission on the Limits of the Continental Shelf (CLCS).

Article 76 includes the need for an accurately located 2500m contour and the requirement to map the Foot of the Slope. The latter may lead to refinement of the ability to discriminate small features at great depths and to the development and application of statistical /mathematical models of the seafloor. Isolated elevations adjacent to continental margins will have to be examined to determine whether they are continental or oceanic in origin, and in some cases, the nature of ridges will require further investigation. There will be a need to maintain a supporting data base and supporting infrastructure that could be examined by the CLCS when they consider a submission.

In deeper waters, UNCLOS establishes the International Seabed Authority as discussed above.

6.2 The Declaration Of Special Or Protected Areas

As part of the movement towards environmental protection, many states are declaring special marine areas in which human activity will be limited. Establishment of these areas, and the research that will be undertaken within them, will lead to detailed mapping of localized areas. GEBCO must assure that this information is incorporated.

Part 7 The Future Role for GEBCO

GEBCO will serve the world's marine community through mapping the world ocean floors in their entirety to higher resolutions through fruitful partnerships with International organizations and individuals.

Working from the shoreline outwards, and from traditional large scale to small scale, in a process which incorporates the larger-scale data into the next successive seaward zone:

- Coastal hydrography will continue to collect data for the safety of navigation, primarily through national Hydrographic Offices.
- As Coastal Zone Management gathers momentum, the coastal zone will be mapped to greater intensity by various agencies.
- Broad margin states will map the limits to their continental shelves.
- In some regions, these will be combined into the IOC Regional Maps.
- GEBCO will assemble these data and maps into ocean-wide maps which combine the latest surface and satellite measurements into a cohesive and coherent data set.
- Outputs will include the data itself for use by the users own software, gridded or otherwise homogenized versions of the data set, interpreted contours, digital and paper maps, and layers for marine GIS.
- Data sets will be continuously updated.

Organizations at all levels can contribute to this process, and their contributions will be felt at all levels. IHO member states will see their data multiplied in value since it will be used several times. IOC 's Regional Map projects will likewise achieve greater return on its investment though being used as part of a greater whole. GEBCO will concentrate on deeper oceans, on combining and managing data and on ocean –wide mapping.

Individuals will be able to participate at one or more levels. An individual scientist might, for example, work on producing an IOC Regional Map and then work on integrating it into GEBCO.

Part 8 A Model for the Sixth "Edition'

"It is proposed that GEBCO and IOC consider adopting digital methodologies for the production, distribution, and advanced visualization of bathymetric information in user-friendly form. One way to do this would be to package global bathymetric information and related facts in a series of information layers: locations of data points, bathymetric grids at varying resolutions, depth contours at standard intervals, the IHO Gazeteer, IHO Limits of Seas and Oceans, national maritime boundaries, etc. The package would include easy-to-use GIS software that allowed users to combine and visualize selected layers within defined geographic limits, and to manipulate this information to produce special effects e.g. shaded relief maps, custom depth contours, oblique views, fly-throughs, etc. The option for producing printed output would be available, of course, as would be the capacity to export selected data to external GIS environments for specialized manipulation and for combination with other types of information." (Macnab and Jakobsson 2002)

Conclusion A Vision of what GEBCO Could Become: Digital and Virtual

Most bathymetrists dream of mapping the entire ocean floor at a fine resolution, and many of them spend time and energy obtaining funding and operating programs that collect data to be used towards that dream. Data will be collected, but that is not the immediate goal that should be sought by GEBCO since GEBCO does not send ships to sea. rather GEBCO is the vehicle that converts that data into useable information and disseminates it to the world. The GEBCO that does so will ---

- Will be a creature of the digital world and making digital products from digital data. (It will be able to produce a paper product if needed.)
- Produce a diversity of products based on depth, bottom characteristics, and other geologic and geophysical data
- Understand scale, and produce information appropriate to many scales of investigation – its spatial data after all
- Evaluate the quality of data on which the products are based, and provide uncertainty indicators for each product
- Continue to thrive on partnerships and expand its range of partners
- GEBCO will provide bathymetric and other layers to users of marine GISs who will assemble and integrate other layers of information from a variety of data holdings, by themselves, in real time, using simple Internet tools.
- Be led by a Guiding Committee whose roles will include: establishing standards for data quality, data quality assurance, and data access; maintaining a network of experts in bathymetric data collection and interpretation; encouraging broad participation with other data suppliers in a common data warehouse framework; and establishing new access channels between data holdings and end users.
- Provide a forum for facilitating and for creating linkages.

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