THE GLOBAL OCEAN MAPPING PROJECT (GOMAP) AND UNCLOS: OPTIMIZING ARTICLE 76 SURVEYS FOR RE-USE IN PORTRAYING GLOBAL BATHYMETRY.

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ABSTRACT

The international, long-term Global Ocean Mapping Project (GOMaP) has been proposed and endorsed by bathymetric specialists as justifiable and technologically feasible. As envisaged, the Project would take roughly 225 ship-years to map the roughly 90% of the world ocean that is deeper than 500 m. The primary objective would be to blanket the world ocean floor with sidescan sonar observations and multibeam bathymetry at an approximate deep-ocean spatial resolution of 100 m (assuming the use of current technology); however a variety of compatible underway observations could be added to the operation as well.

Given the size of the existing deep-sea mapping fleet and the competing requirements for such vessels, it might reasonably take 20 to 30 years to complete the task. Total cost is estimated to

be in the range of $8 to $16 billion (US). To put that figure in perspective, it represents only a fraction of the money spent so far on space exploration.

In the meantime, comparable surveys are likely to be undertaken over the next few years in the deep waters off many continental margins of the world, as several dozen coastal states initiate projects to define the outer limits of their juridical continental shelves, according to the provisions of UNCLOS Article 76. For the most part, these mapping programs cannot be deferred indefinitely, on account of the ten-year deadline imposed by UNCLOS for the implementation of Article 76.

If the ocean mapping community agreed from the beginning to promote compatibility and complementarity between proposed GOMaP and Article 76 surveys (i.e. specifications, coverages, modi operandi, data policies, etc.), the future consolidation of their respective data sets, and the construction of a seamless global seabed description, would be much facilitated. This presentation will provide an overview of the potential scope of seabed surveys that could take place over the next few decades, and will discuss the technical, scientific, and economic benefits of coordinating these operations.

INTRODUCTION

The end of the 20^{th} century was a period of exciting mapping projects in our solar system. Unfortunately, the century closed with Earth being one of the most poorly mapped objects in the solar system. As demonstrated by Figure 1, much of the world's seafloor has not yet been properly surveyed. In a series of presentations and discussions over the past two years, the concept of a long-term (20-30 year) international, systematic effort to map the entire world seafloor from beach to trench has been reviewed and found to be technically feasible with current technology and existing vessels (P. Vogt, W-Y. Jung, and D. Nagel, Eos, AGU, v. 81, p.254, 258; Meetings Report, Eos, v. 81, p.498, 2000). There have also been efforts to define the GOMaP, to set standards, to establish a loose organizational structure for information and data sharing, and to discuss the issues involved in estimating the effort required to undertake and accomplish such a large task.

The strategic goal of GOMaP is to systematically map the world ocean floor with at least 100 percent coverage of sidescan imagery and swath bathymetry and to perform whatever other data collection that can be carried out simultaneously. Minimum standards for data accuracy, pixel navigation, and resolution will need to be established before GOMaP is launched.

In the meantime, several coastal states have initiated, or are planning to initiate, survey programs in the deep waters off their continental margins for purposes of defining the outer limits of their juridical continental shelves in accordance with the provisions of UNCLOS Article 76. For modest incremental outlays of cost and effort, some if not many of these surveys could contribute to the overall GOMaP effort; this would require the adoption of compatible standards and procedures, and a harmonization of survey plans.

WHY A GOMAP?

It should be self-evident that detailed maps of the Earth's topography are at least as important to those who inhabit the Earth as are maps of extraterrestrial bodies. Many direct benefits could be realized from a precise knowledge of seafloor topography, e.g. improved assessments of geologic resources; finfish and shellfish habitat mapping; geologic risk assessments (for example, submarine landslides, earthquake fault activity, tsunamis, and submarine volcanism); navigation hazards; and bottom boundary conditions for dynamic oceanographic and meteorological models that are used in the prediction of long-term global change.

WHAT ARE THE TECHNICAL ISSUES?

Just what does it mean to completely map the world's ocean floor? A good example of 100 percent swath coverage can be shown by the data collected during a Naval Research Laboratory survey in part of the extinct Aegir Ridge rift valley (Norwegian Sea) and its adjacent rift mountain summits (Figure 2A). These data, resolving features with wavelengths of approximately 200 m, and the corresponding side-scan sonar image (Figure 2B), resolving wavelengths on the order of 10-20 m, capture the topography and sediment characteristics of the debris flows and turbidites that have spilled into the rift valley.

The GEOSAT and ERS-1 microwave altimetric mapping programs allowed us to estimate the bathymetry from the gravity field (Figure 2C) on a global scale at full wavelengths of 20,000-30,000 m (Sandwell and Smith, 1997). To illustrate the magnitude of the proposed GOMaP effort, the region illustrated in Figure 2A-C is less than 1/3000 percent of the total ocean floor. Figure 2D is the CLEMENTINE solar-illuminated image of part of the Schroedinger lunar crater, with an area of the same dimensions as in images A-C. The central swath (20-40 m pixel resolution) is comparable in resolution to a 12-kHz ocean-floor sidescan image at a 500-1000 m depth range, while outer areas of the image have spatial resolution comparable to that of 12-kHz sonar in the deep (~7 km) ocean.

The spatial resolution for swath bathymetry is somewhat less than for sidescan. Bathymetry and sidescan resolutions improve sharply with decreasing water depths, particularly for the 10 percent of the world ocean less than 500 m deep. Taking into account the decrease of swath width with water depth, it has been estimated that over 600 ship years are required to map waters 25-500 m deep, compared to approximately 200-250 ship years for the deep ocean (500 m and greater). Better pixel navigation accuracy suggests hull-mounted systems (9-16 kHz for deep water, and 30 kHz or higher for shelf waters) may be superior to towed systems but they require dedicated ships, while towed systems may be operated from a variety of vessels. Seafloor mapping with air-deployed hyperspectral and laser bathymetric scanning may be required to replace or supplement shipborne and hydrographic survey launch mapping in clear waters less than 50 m deep.

Spatial resolutions for GOMaP multibeam sonar bathymetry and imagery would everywhere be 100 m or better in most locations except in the very deep sea, where it would approach 200 m. This is comparable to what has been achieved by the Shuttle Imaging Radar over the terrestrial earth, the MAGELLAN radar mapping of Venus, the MARS GLOBAL SURVEYOR and other probes on Mars, and the GALILEO mission to the moons of Jupiter. Presently co-registered multibeam (swath) bathymetric and sidescan data exist for only a small portion of the ocean bottom.

The following table lists recommended cell sizes for geographic grids of bathymetry and sidescan imagery, over a range of depths that extend from the nearshore to the deep ocean. To yield reliable geostatistics during the gridding process, these cells need to be populated by an adequate number of observations, which could most effectively be achieved through co-registered observations of bathymetry and sidescan imagery collected at a sufficient horizontal spatial resolution.

	Grid Cell Size	
Depth Range	Bathymetry	Imagery
0-200 m	20 m	1 m
200-4000 m	100 m	2-5 m
4000-11,000 m	200 m	5-10 m

Depth accuracy of individual soundings must be less than 0.2 percent of the sonar's altitude above the bottom. All depths must be reported as true depths, which implies correction for tides, harmonic mean sound speed, and ship's dynamic draught or sonar dynamic depth. In deep water, 2D RMS horizontal positioning accuracy must be at least 10 m. 3D measurements using GPS should have 1 m elevation accuracy. In shallow water, low-end Real Time Kinematic 3D position accuracy standards of 10 cm in x, y, and z should be met. These would be similar to an International Hydrographic Organization Order 1 survey, defined in IHO Special Publication 44.

Data processing and cleaning standards have yet to be defined for the GOMaP, but ongoing discussions are being held. In particular, the minimum number of soundings per grid node and gridding techniques must be specified. All sonar systems must meet the accuracy standards described above and verify their compliance by running a patch test at the beginning and end of each survey.

The GOMaP "organization" should, working with appropriate international bodies (International Hydrographic Organization, for example), establish standard protocols for survey design in addition to specifications for instrument calibration, data processing, and quality control. It should also work closely with states that are embarking upon UNCLOS surveys, to coordinate the planning and execution of operations, to standardize procedures for data handling, processing, and management, and to facilitate the future merging of their observations.

BENEFITS OF COORDINATING GOMAP AND UNCLOS SURVEY OPERATIONS

Data re-use represents one of the most promising advantages of coordinating GOMaP and UNCLOS operations. As outlined above, marine mapping operations tend to be expensive and time-consuming - significant economies can be realized by collecting data sets in ways that make them useful for more than one purpose. GOMaP operations are not likely to be mobilized soon, however with UNCLOS surveys already underway in many parts of the world, the latter could provide some early and much-needed momentum for a global mapping program - provided, of course, their respective procedures and operations are well matched. With proper planning and coordination, UNCLOS surveys could also facilitate the overall GOMaP implementation program by dividing survey operations into regional components that are more manageable, and by eliminating the need for securing permission to carry out survey operations within EEZs. By the same token, the costs of many UNCLOS surveys are being underwritten by coastal states, thereby permitting GOMaP to focus its financial resources in areas that lie beyond zones of national interest - assuming that acceptable arrangements can be achieved for the transfer and onward distribution of national survey results.

Another important benefit of coordinating these operations is that it would increase the pool of stakeholders in a global ocean mapping program by extending to many coastal states an incentive to upgrade their survey coverage and to enhance their technical skills and facilities while contributing to a major international program. The resulting partnerships would no doubt prove to be a fertile ground for international cooperation and exchange aimed at improving our understanding of the world ocean.

IS THIS WORTH DOING, CONSIDERING THE MAGNITUDE OF THE TASK?

GOMaP will take roughly 225 ship years to complete the portion of the world ocean deeper than 500 m (~90 percent) at a cost of between $8-16 billion, assuming US survey ship rates. There will be political hurdles concerning Economic Exclusion Zones and territorial seas (about one-third of the ocean area). Given the size of the seafloor mapping fleet and competing requirements for these resources, it may take between 20-30 years to just complete the deep-water portion, if fully funded. Mapping the shallowest 10 percent of the world ocean probably offers the greatest practical benefits to mankind, but presents special technical and political problems. We estimate that between 500-600 ship/survey launch years will be needed to complete this task.

Internationally, hundreds of billions of dollars have been spent on extraterrestrial exploration, while it is estimated that an order of magnitude less has been spent on ocean exploration. While extraterrestrial exploration may be important for the long-term survival of mankind, recent events ranging from major earthquakes to threat of global climate change should make our understanding and ability to accurately model our planet our highest priority in Earth and planetary science.

Many who are now concerned with ocean mapping will not be here to see the seabed mapped to the accuracy that we now have achieved for most of the other bodies in our solar system. The present generation needs to engage in planning, to influence policy and funding organizations, and to implement a program for systematically mapping, understanding, and modeling the major systems of the earth. The GOMaP proposal is a response to that need.

HOW DO WE START?

The response so far from specialists who have participated in GOMaP planning discussions has been encouraging, and there are informal indications of interest from institutions that might consider contributing to the undertaking in a supporting or operating capacity. It has been recommended that the GOMaP undertake initially a pilot project as a proof of concept in one of the following areas: 1) the Gulf of Mexico [good opportunities to utilize existing Gulf Coast assets, and to demonstrate international cooperation]; 2) the Juan de Fuca plate [a nearly complete "ocean floor in miniature," a chance for international cooperation, and support for the NEPTUNE project]; 3) an area in the Southern Ocean with exceptional scientific interest but with very sparse data coverage; 4) the EEZ of a small, amenable coastal state; and 5) the Black Sea [a good opportunity for international cooperation in an area of geological and archaeological significance].

Proposals could be submitted to various funding agencies during 2001 or 2002.

WHO SHOULD BE PLAYERS?

The next step in the political process is to engage international organizations that have a vested interest in the long-term success of a project with GOMaP goals. These include but are not limited to the International Hydrographic Organization (IHO), the UNESCO Intergovernmental Oceanographic Commission (IOC), the Joint Commission on Oceanography and Marine Meteorology, and especially, the IHO/IOC General Bathymetric Chart of the Ocean (GEBCO). These organizations can promote the concept among their members and in so doing facilitate international coordination and funding.

Wide-margin coastal states represent another constituency of marine interests that could help achieve the aims and objectives of GOMaP by mobilizing mapping expeditions that meet national needs, but which can also produce observations for enhancing international data bases. In this light, it is suggested that the concept of a pilot project could be extended to comprise an

Article 76 survey off a coastal state that features a representative wide continental margin. Such an operation would provide a practical opportunity to develop a working interface between GOMaP and UNCLOS surveys through the design and trial of organizational and operational procedures. The work could be carried out on a voluntary basis by a self-supporting coastal state, or alternatively, it could be sponsored and executed by an international team operating on behalf of a developing state. While operational experiences could be freely shared, public distribution of the collected observations could be temporarily restricted pending completion of the coastal state's Article 76 submission.

This project will not succeed just because it needs to be done; it will only happen with the dedicated involvement of those individuals and institutions that have expertise and experience with oceanic surveys. It is hoped that members of the Article 76 community will appreciate the value of GOMAP's aims and objectives, that that they will contribute to its realization.

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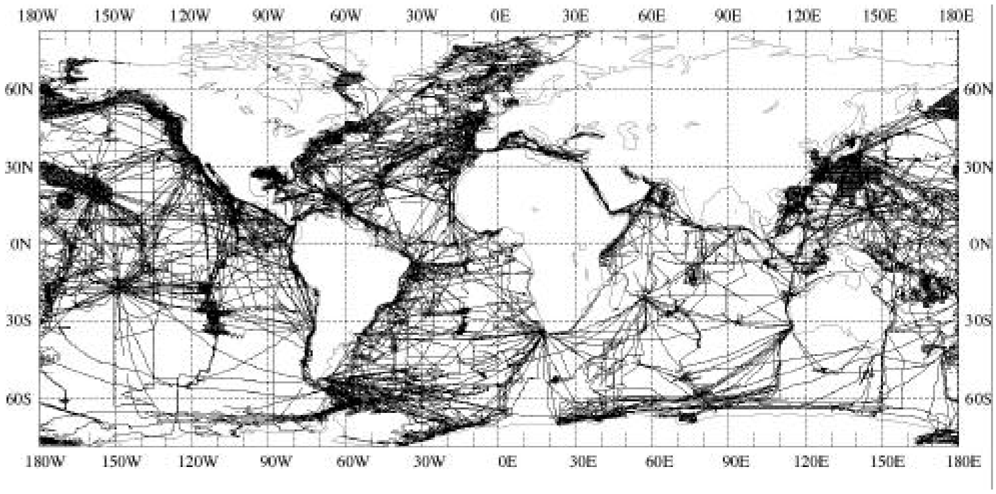

Figure 1. Inhomogeneous world seafloor database: ship tracks for 1980-1999 period, courtesy of the US National Geophysical Data Center. Tracks for surveys using sidescan sonar and/or swath bathymetry are a small subset of tracks shown here. Note: actual width of tracks is much smaller than shown in this figure.

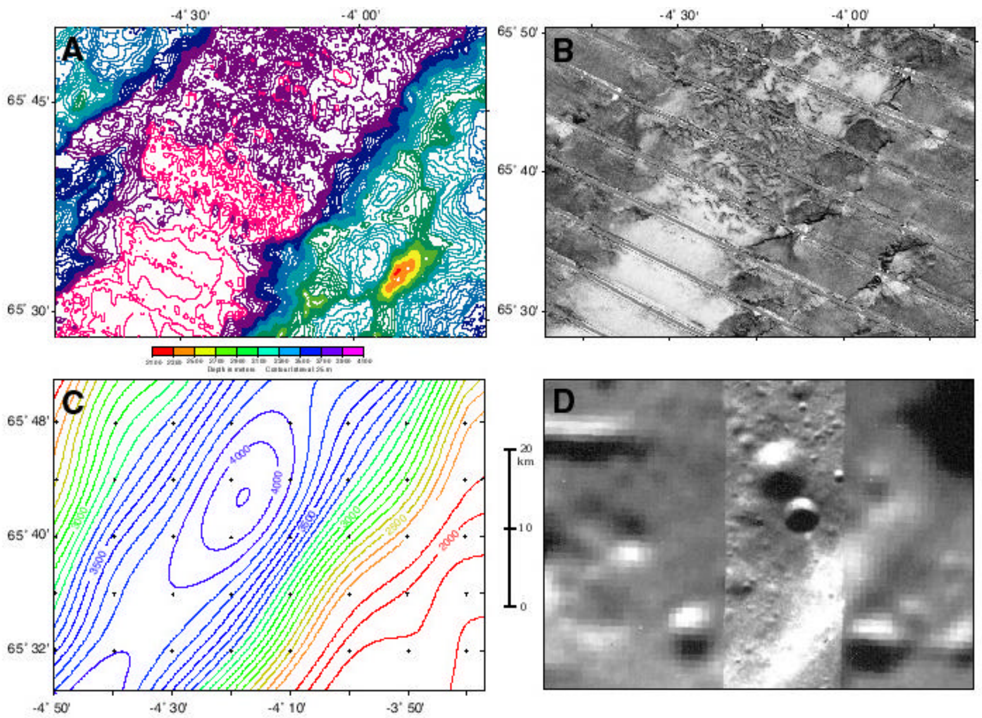

Figure 2. A) 16-KHz multibeam (HYDROSWEEP) bathymetry for part of the extinct Aegir Ridge rift valley, Norway Basin (NRL data). B)11-12 kHz SeaMARC II sidescan sonar image of same area. Darker shades indicate stronger returns (NRL data). C) ERS-1/GEOSAT-derived predicted bathymetry for same area (Sandwell and Smith, 1997). D) *Clementine* solar-illuminated image of part of Schroedinger lunar crater, with area of same dimensions as in images A-C. The central swath (20-40 m pixel resolution) is comparable in resolution to a 12-kHz ocean-floor sidescan image at 500-1000 m depth range, while outer areas of the image have spatial resolution comparable to that of 12-kHz sonar in the deep (~7 km) ocean. (P. Vogt, W-Y. Jung, and D. Nagel, Eos, AGU, v. 81, p. 258)

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Peter Vogt received his BS (geophysics major) at the California Institute of Technology in 1961. After spending a year at the University of Innsbruck, Austria as a Fulbright Fellow, Vogt did his graduate work at the University of Wisconsin, Madison (MA in Oceanography, 1965; PhD in Oceanography, 1968). The MA research dealt with seafloor basalt magnetization and magnetic anomalies, and the PhD work comprised a geophysical reconnaissance of the Arctic Basin and Norwegian-Barents Sea. Vogt was employed at the US Naval Oceanographic Office (1968-1975), and since then has worked as a marine geophysicist (plate tectonics, ocean crustal magnetization, seafloor sediment dynamics, and other topics) at the Naval Research Laboratory. With his coworkers, he has researched marine geology and geophysics in nearly all the oceans, and has spent over tree years total on a great variety of research vessels, acting as co-Chief Scientist for example on the Glomar Challenger and on the Keldysh (MIR submersibles). Vogt has authored or coauthored about 150 technical publications, with over 4000 literature citations. He was awarded an Honorary Doctorate from the Univerity of Bergen (Norway) and made a Fellow of the Norwegian Academy of Science in 2000. Vogt is fluent in German and Norwegian, with a fair knowledge of Russian and Spanish.

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