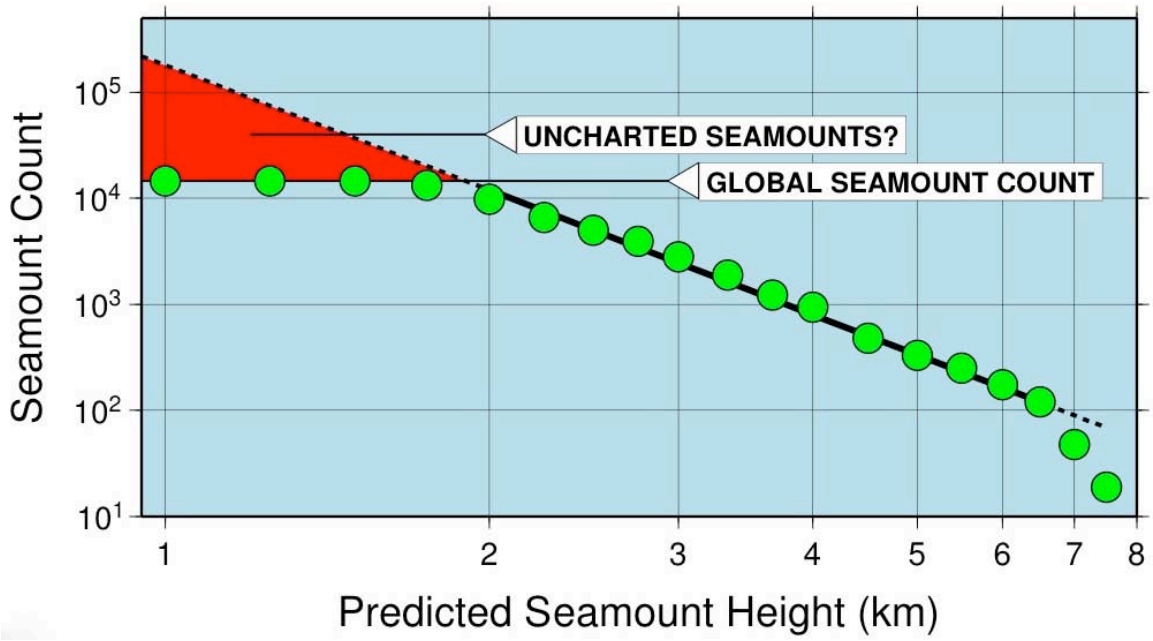
1. Seamount Exploration

Panel: Wessel, Sandwell, Bryan, Jordahl, Kilgour, Konter, Lee, Miller, Watts

Traditionally, seamounts are defined as underwater volcanic isolated constructs that reach at least 1,000 m height from base to summit. There are perhaps >100,000 seamounts taller than 1,000 m that have been inferred from satellite-based bathymetry. Research vessels have never visited the vast majority of them, arguably identifying them as the last major frontier in geographic, geological and ecological exploration on planet Earth. It is a daunting task to study such a large number and strategies have to be devised for their exploration. We explored several key aspects of the current status to guide future seamount exploration and identified several actions that we recommend be taken; these are detailed below.



Height-frequency distribution of seamounts based on satellite altimetry. There are approximately 100,000 seamounts taller than 1 km and 10,000 taller than 2 km. The summits of only a fraction of these 2-km tall seamounts have been surveyed with echo sounders (Wessel, 2001).

1.1. Mine Existing Data

Classified data. The US Navy has collected about 100 ship-years of depth sounding and other types of data as part of the Ocean Survey Program (Medea, 1995). These data primarily cover the portions of the northern oceans that were of strategic interest during the cold war. Unfortunately, these data remain classified for military purposes. Great Britain, France, and Australia have

collected similar classified or restricted data sets. Other countries such as Japan (see http://www.jamstec.go.jp/dataportal) have recently opened all their sounding data for free access by anyone. These new open contributions are becoming apparent as one now views the oceans in Google Earth. With the change in administration in Washington, the time is ripe to reconsider the declassification of the 100 ship-years of US data. So while there is a possibility that existing data could become openly available, there is still the major issue of the southern oceans, which are largely uncharted, yet hosts the majority of seamounts seen in the altimetry. In addition to the older proprietary data there is new data being collected as part of the "Red Dots" program. Following a recent submarine accident, efforts are under way to map seamounts having summit depths less that 300 m and these will appear on navigational charts. Is there a way that civilian research can benefit from these efforts? The results are summarized in the "Red Dots" report and the shallow-point soundings are being included on the US Defense Mapping Agency Navigation charts. We believe our best approach with regards to classified data is to enlist the help of the American Geophysical Union to write to the Oceanographer of the Navy and request that these data be unclassified, similar to the successful release of the Geosat data in the mid-1990s. We also suggest that other nations use a similar approach to seek the release of classified data from their own governments.

Proprietary data. Research ships of many nations crisscross the oceans on numerous expeditions, addressing a great variety of oceanographic goals and targets. Much of these data have been submitted to NGDC for archival purposes. However, recently these submissions have been reduced to a trickle. Preliminary investigations suggest this reflects several changes such as more nations preferring to distribute their data themselves (e.g., Japan, France) and less emphasis at NGDC to acquire foreign data. Many nations simply have not been asked to supply data but would be willing to do so. We suggest using our existing personal contacts in the foreign oceanographic community to determine if additional data could be released to the public, and make sure we acknowledge any nation that contributes data to the data centers. We also recommend that we take advantage of user meetings such as those held by SIMRAD and GEBCO to plead our case for the release of new and existing data.

1.2. Enhance Existing Cruise Planning

Better use of transit legs. All oceanographic research involves transit legs from ports to areas of interest and back. Given the spatial distribution of seamounts, there will in all likelihood be seamount targets along or near a transit section. We should encourage the creation of an international resource (perhaps based on the Seamount Catalog) that identifies unstudied seamounts and encourages oceanographic vessels with bathymetric mapping equipment to detour slightly from cruise tracks so they can map out unknown seamounts. We propose to develop tools that make such planning easy for anybody to do. One approach

already available is to provide overlays in Google Earth that show predicted depth as well the locations of existing bathymetry coverage (see box Seamount Discovery Tool). This software combined with a simple hand-held GPS would provide the information needed for anyone to visit uncharted seamounts. In addition, a more sophisticated track-planning tool should be developed that would help cruise planners (e.g., UNOLS) by automatically producing an alternative track that optimizes coverage of seafloor and target seamounts not previously visited, while minimizing additional survey time.

Collect seamount-related data. We need to convince other scientists and funding agencies of the importance of collecting data that are not central to the mission of a particular cruise. A list containing desirable data for seamount research (e.g., multibeam, gravity, magnetics, 3.5 kHz, CTDs, etc) should be made available to all PIs for consideration. As many ships have empty berths, it should be possible to provide student opportunities to go on cruises and assist in the collection of such data, at little or no extra cost. We need to convince funding agencies that they should insist on all cruises collecting as much and diverse data as possible for cross-disciplinary end-users.

Establish piggyback proposals. Given the expense of oceanographic expeditions we suggest funding agencies strongly consider adding a mechanism whereby scientists could routinely propose short (e.g., a few days) piggyback projects that could be added to accepted regular seagoing proposals. Knowing the planned track of upcoming expeditions would allow us to determine high-interest seamount targets that could be surveyed providing additional survey time could be financed. Such add-on projects would optimize the use of ship-time and tax dollars. An example of this is the Australian Marine National Facility (http://www.marine.csiro.au/nationalfacility/) where ancillary 'piggy-back' projects can be integrated into the voyage-determining projects. Perhaps some aspects of the US Navy's Red Dot program could be considered for such add-on tasks?

1.3. Take Advantage of Ships of Opportunity

There are all sorts of commercial traffic, from shipping to cruise liners to fishing fleets and more recently eco-tourism vessels that also traverse the oceans, as do many private yachts. Most of these have at least single-beam echo sounders while others may have multibeam systems; all are likely to have good GPS navigation. We need to investigate how we can liaise with such groups to encourage their participation in seamount exploration. As an example, participation might be encouraged with the prospect of advertised discovery (e.g., blogs or Google Earth), and the right to *propose* a name. Preliminary analyses suggest that many of these potential commercial partners would find good public relations to be in their best interest, and to provide data already collected may not add much, if any, cost to their operations. For instance, the air sampling project that Lufthansa contributed to is an example of commercial operator good

will and public benefit (see http://www.caribic-atmospheric.com/2005/gen_inf.htm). Furthermore, Regional Fisheries Management Organizations (RFMOs) may be a source of data collection through commercial fishing operations in remote areas e.g., Indian and southern Pacific oceans where data and voyages are particularly scarce. We also suggest capitalizing on the new NOAA Okeanos Explorer whose mission is to explore unexplored seafloor areas. An obvious priority here is to propose to NOAA a list of seamount targets they could use in their cruise planning (as well as the planning tools discussed earlier).

1.4. Encourage Altimeter Missions

The European Space Agency will launch CRYOSAT-2, the next generation of non-repeat orbit satellite altimeter in November 2009. While CRYOSAT-2 is focused on polar science, it will also be operated continuously over the oceans for gravity field recovery. If the satellite operates for at least 4 years it will lower the errors in the satellite gravity field by about a factor of 2. This will enable the detection of additional smaller seamounts currently below the threshold of detection in the older Geosat/ERS-1 data. The US Navy is also planning GFO-2 (Geosat Follow-on 2) but is currently considering it to travel in a repeat orbit. Our community may be able to influence these decisions by writing a letter in support of their missions and outline how better satellite altimetry coverage of the ocean surface can benefit international seamount research.

1.5. Maintain and Expand Seamount Infrastructure

While several databases and online resources have been established (in particular, the Seamount Catalog and Seamounts Online), there remain difficulties with using these to their fullest potential for seamount research. Several attributes of seamounts need to be included to allow richer and more interdisciplinary search capabilities, in particular geologic (tectonic setting, active, dormant, erupted compositions and substrates, hydrothermal activity, manganese crust, etc.), physical (location, height, slope, base depth, etc.), and biological attributes (trawled, fish sightings, reference to detailed studies, etc.). These databases are logical choices for maintaining the lists of seamount targets discussed earlier. Funding is needed to maintain these databases as well as to expand them further. These resources are vital for us to coordinate seamount research in the future.

References

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Wessel, P., Global distribution of seamounts inferred from gridded Geosat/ERS-1

altimetry, J. Geophys. Res., v. 106, no. B9, 19431-19441, 2001.