ANTARCTIC MARINE GEOLOGY AND GEOPHYSICS PLANNING WORKSHOP

FINAL REPORT
National Science Foundation Sponsored Workshop

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Planning the Future of Antarctic Marine Geology and Geophysics
United States Antarctic Program

Mission Statement

The primary goal of this workshop was to initiate discussion about future scientific objectives and technical needs of the Antarctic marine geology and geophysics community, in particular, how these needs relate to Antarctic research vessels. The need for this kind of workshop was twofold. First, it had been about a decade since the community last took a focused look at the long-range science goals and needs for Antarctic marine geology and geophysics, so a new perspective was needed. The need for such a dialogue was also based on the timing of the lease schedule for the current ship support to the US Antarctic Program. Although ship support for Antarctic science is contracted for several more years, the process of developing scientific requirements as planning input for ship support beyond this period takes a considerable amount of time, and it is critical that science users be involved throughout the process. Consequently, the primary goal of the meeting was to produce a document outlining the anticipated future scientific goals and objectives, in a broad fashion, and describing the specific technical needs for marine geologic and geophysical work in the Southern Ocean.

Rather than focus on the design of the current ships and ask the question of whether these ships will meet our future needs; the workshop was more forward looking, forcing Antarctic marine geologists and geophysicists to anticipate the course of scientific research over the next two decades and to address the technology required to meet those needs. Thus the questions guiding this meeting were:

1. As a community, where do we hope to be ten to twenty years from now?
2. What major scientific questions will we want to address?
3. How will we accomplish answering those questions?

In order to answer these questions best, participants were told to “think big” and to “think outside the box” for too often it is easier to work from an existing design than from a relatively blank slate. In the end, we took a combination of these two approaches; recognizing that the current vessel has many outstanding characteristics, but that existing capabilities may be enhanced, and new areas of research may demand changes in current technologies. This report is organized around the scientific framework of future research plans, in the broadest sense, with general scientific rationale outlined first. Based on this scientific framework, specific recommendations for ship design are then presented.

This report, produced from the March 23-24, 2002 workshop, will serve as a planning document and is available as a hard copy (email request to: aleventer@mail.colgate.edu) and on the Internet at the following address:
http://departments.colgate.edu/geology/faculty/AMGGPWReport.pdf

Future Science Directions and Recommendations

1. Continued oversight of vessel plans, design, construction and testing by research scientists.

First and foremost we emphasize the absolute necessity of continued oversight of all future planning for the next research vessel by research scientists with both scientific and technical expertise, in order to be certain that the marine geological and geophysical community is best served by our future research ship. This includes oversight of all planning prior to the development of a Request for Proposals by the Office of Polar Programs, to active participation in all phases of ship design and eventual construction, walk-throughs and testing of shipboard systems. This is the only way that we can be assured of maximizing this opportunity to develop an icebreaker that provides a superior logistical base from which we can conduct our research. We emphasize as well that continued oversight will most likely save money in the long run with far fewer costly changes necessary at later stages of construction and ship use. In order to achieve the degree of oversight we desire, we recommend continued consultation throughout the entire process, with a group of approximately four members of the Antarctic Marine Geology and Geophysical community. This core group is recommended in order to facilitate continued, well-organized, and informed involvement and feedback from our community. This group should be separate from the Antarctic Research Vessel and Oversight Committee (ARVOC), a committee with many additional responsibilities regarding ship use in Antarctica. We also suggest that small working groups may be necessary to address more specific issues such as newer technologies (for example, the use of remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs)).

2. Multidisciplinary science programs and their implications for increased space.

We foresee the development and application of more complex technical programs and multidisciplinary approaches to scientific questions; two examples are briefly described below in order to provide a scientific framework for our recommendation of increasing the total space available for a scientific party. Currently we are allocated space on the *NB Palmer* for 32 scientists and 7 technical support employees, for a total of 39 berths. We suggest increasing this to a total complement of fifty scientists and technical support crew. Consideration should also be given to the possibility of "expansion capability,' that is, the possibility of adding temporary extra bunks into spaces normally used for other purposes, such as storage, in the unusual circumstance that this extra berthing space would be required. However, we maintain that an upper limit of fifty scientists and technical support personnel is reasonable. As the number of berths increase, everything else must be scaled up to allow adequate work and living space for the additional participants, including increased laboratory space, galley space and common rooms. In addition, we suggest that more (~3) senior scientist cabins be considered, to accommodate lead scientists on multidisciplinary programs who would be better served with private working areas.

Two examples of the types of multidisciplinary projects anticipated are described below; we emphasize that many other possible programs could be designed:

Many marine sediment-coring programs have been carried out in the Antarctic Peninsula region; these programs have made a tremendous contribution to our understanding of the glacial history of the region and the response of the Peninsula to climate change over several different time scales. However, far fewer ice cores have been drilled, limiting our ability to develop a more coordinated understanding of the complexities of climate change in a region that is clearly experiencing rapid change today. Clearly, climate change records from two different and "independent" sources may provide more insight into the relationship between atmosphere, cryosphere, and ocean conditions during climatic fluctuations. Coordinated marine sediment and ice coring projects in the Antarctic Peninsula region with deployment of ice coring programs via helicopters would bring us forward in this endeavor. We recognize the current logistical constraints of placing ice-coring programs in areas that may be difficult to access by travel over the ice itself or by more traditional forms of Antarctic air support (C-130 for example). However, informal conversations with members of the ice-coring community indicate that helicopter support of an ice-coring program in the Peninsula would be logistically successful. While helicopters are used extensively to support projects in the McMurdo region, they have been used only once from the NB Palmer. The details of how such a program would be coordinated remain to be determined, with logistics ranging from deployment of an ice-coring project completely independent of ship support once deployed, to a program where routine ice-core processing could take place on board ship, in concert with a marine program (see section 5 for comments on clean room capabilities).

Many researchers have already completed projects that integrated multiple disciplinary field techniques on a single cruise, for example, where the project goals ranged from ecosystem monitoring and characterization to evaluation of how water column processes impacted the marine sediment regime. In this case, biological and geological field parties worked together toward a common objective. For example, the ROAVERRS (Research on Ocean Atmosphere Variability and Ecosystem Response in the Ross Sea) had coordinated biological and marine geological objectives. A consequence of the broad scientific objectives of these types of programs is that the number of scientific participants can be quite high. In the past, berthing space has been less than desired and has pushed research groups to prioritize objectives forcing important projects to be cut. In addition, with more berthing space for the scientific party, more researchers would be comfortable adding smaller but related projects on to their cruise. The increased return scientifically, could be great; especially when the ship visits poorly studied regions of Antarctica. With the recognition that even on a cruise with purely marine geological and geophysical objectives, additional physical, chemical and biological data will be of great value in the long run, we recommend increasing berthing space on the ship.

3. Comprehensive programs that cross geographical transitions and correlation between environments -continental to deep sea.

In terms of developing a more integrated view of geological processes in Antarctica, we anticipate larger scale research efforts that are focused on transects of study, potentially reaching from the continent (aeromagnetic work?, ice coring programs?) → shelf processes/deposits → deep sea. The rationale for this kind of work is based on the connections between these subenvironments, with geologic features and processes linked across these boundaries. In the long-term, our science may benefit from focused attention on specific regions of Antarctica and the Southern Ocean (though not at the expense of individual programs). For example, we foresee the possibility of a series of transects from continent to offshore that might coordinate the efforts of programs like ANDRILL (at the edge of the ice shelf or fast ice), SHALDRIL (on the continental shelf) and future ODP-style efforts (primarily though not exclusively open ocean), with an objective of combining results from each program.

Similar to recommendation #2, this type of program may place extra demands upon the research vessel in terms of an increased number of berths and consideration of the logistics for transporting scientists, equipment and samples (such as cores), to and from areas on the continent and/or ice shelves. The use of helicopters and landing craft will most likely be necessary, with implications for ship design and space. This is discussed in more detail below. We emphasize that in the programs described, the ship would not be used solely as a support vessel (not a cost-effective use of a vessel outfitted for research), but as a multi-functional platform. We note that longer-range helicopter support may facilitate shore-based work in restricted areas.

4. Rapid response science and its effect on ship capabilities.

Under many circumstances critical scientific programs may develop in response to an event that even if anticipated in the general sense, may occur at an unanticipated time. Although it is difficult to prepare for the unexpected, an attempt should be made to adapt the ship and the ship-using community to these possibilities. The first may be simpler to accomplish than the second, and we will not attempt to address potential scheduling difficulties and the repercussions of the implementation of rapid response science projects on programs already in progress. However, we will try to address the ways in which ship design can be modified to be the most flexible in accommodating study of events for which we may not get a second chance to sample. In particular, we emphasize the need to get to specific sites relatively quickly and to have a wide range of sampling options available. We use the example of the recent breakup of the Larsen B Ice Shelf as an event that comes under this category. In this case, helicopters and drones would have been critical to support the logistics of a study examining the breakup event. In many cases, these rapid response science projects would be interdisciplinary.

With this single example in mind, two things to consider are first, how easy it would be to get the ship and equipment to the right location in the necessary time period, and second, how to transport scientists to and from the ship. In the first case, we recommend addressing the ship's maximum speed coupled to its icebreaking capabilities so that a greater portion of the Antarctic margin is accessible. This issue is not limited to rapid response science (see #5 below). In general, access to a greater range of sites along the Antarctic margin is desired, which may necessitate increasing the class of icebreaker from what is currently available to the US Antarctic Program. As well, we note the need to ferry scientists to and from specific sites and the need for both continued dedicated helicopter space in the form a deck and hangar, and for more "sea-worthy" and "landing-worthy" small boats.

5. Sampling needs in currently inaccessible areas of the seafloor, ocean and continent.

Several different types of science and technologies fall into this category. However, specific issues are of paramount importance to all. First, we reiterate addressing the ship's maximum speed coupled to its icebreaking capabilities so that a greater portion of the Antarctic margin is accessible. In general, access to a greater range of sites along the Antarctic margin is desired (areas with heavier sea ice concentrations, for example), which, as stated previously, may necessitate increasing the class of icebreaker from that which is currently available to the US Antarctic Program. Continued dedicated helicopter space (deck and hangar) will facilitate access to currently inaccessible sites, as will expansion of our capabilities with more "sea-worthy" and "landing-worthy" small boats. These will increase our abilities to work in areas that are currently less accessible, such as fjords and locations close to ice margins. The design and deployment of such a small boat would have implications for overall ship design. We understand that the ARVOC also has been considering adding a "smaller" boat to the currently available Antarctic fleet, but there has been debate about its size and capabilities. The Antarctic Marine Geology and Geophysics working group, like ARVOC, needs to consider the size and capabilities of a small vessel in more detail before making a specific recommendation.

We highlight two categories of research efforts that are limited by our inability to conduct the field research necessary to complete particular scientific objectives.

Sub-Ice Shelf / Sub-Sea-Ice Processes. Currently we have very few (if any) ways to address questions regarding sub-ice shelf and sub-sea-ice processes, except along the immediate ice edges. We anticipate an interest in looking "up" (i.e. biologists – example of under sea ice krill study in Weddell Sea, by Brierley et al. 2002, *Science*, 295, 1890-1892, using autonomous underwater vehicle *Autosub*-2; see http://www.soc.soton.ac.uk/autosub/ for a complete description of the instrument) and looking "down" (sediment cores and terrain visualization of areas underneath ice shelves for example). While we addressed the interests of the marine geological and geophysical community specifically, we expect that these types of projects will be of interest to biologists, glaciologists, and chemical and physical oceanographers as well.

Technologically, these types of projects can be approached with a variety of remotely operated vehicles (ROVs) (potentially some with coring capabilities) and autonomous underwater vehicles (AUVs) (with geophysics capabilities). Our brief survey of the literature reinforces that development of these technologies is being pursued actively (for example, http://www.spawar.navy.mil/robots/pubs/oceans2000.pdf, AUV Commercialization – Who's Leading the Pack?, R.L. Wernli). We note that the British Antarctic Survey is using the AUV *Autosub-2* and that the *Healy* recently tested the use of the MBARI-designed ALTEX AUV (see http://www.aslenv.com/reports/OIA%202001%20MBARI%20Tervalon%20Paper.pdf for a brief description). In considering these new technologies that already exist and are being used, and those that certainly will evolve over the next two decades, we must take into account a ship design amenable to the deployment, recovery, and safe on-board storage of these devices. The two main considerations are deck space for storage and deployment devices. We recommend that a large scale "garage-type" space be considered for the ship, similar to the current NB Palmer helo-hanger, but perhaps with some overhead rail systems for easier movement of large and heavy, but delicate equipment. We also recommend that serious consideration be given to how these devices might best be deployed, in terms of both the weight limits and physical placement of A-frames and cranes on the main deck.

Coring capabilities. Coring technologies continue to evolve; we would like the US program to exist at the forefront of these technologies. Three main issues are addressed here: 1) the ability to core/drill sediment lithologies, such as sands and tills that traditionally have been technically problematic, 2) the ability to acquire longer cores, and finally, 3) the ability to acquire cores from ice-covered areas of the continental margin.

SHALDRIL – The rationale for SHALDRIL has been spelled out in great detail in previous documents (http://www.arf.fsu.edu/arfhtml/download/shaldril_hi.pdf), so will not be repeated here. Simply put, "conventional piston and gravity cores cannot penetrate the over-compacted, ~10-m-thick glacial diamicton layer on the continental shelves and upper slopes." The SHALDRIL initiative is centered on the implementation of a drilling technology that will permit recovery of the records that lie within and beneath the glacial diamictons, in order to develop a better understanding of climate and the history of fluctuations of the Antarctic ice sheet. Shipboard requirements for the SHALDRIL initiative include the presence of a moonpool (76" diameter) through which coring will take place and dynamic positioning abilities for the research vessel.

Long piston corer (i.e. 80 meters?) – With the current design for deployment of the Jumbo Piston Corer, our recovery is limited to piston cores of 25 meters in length. Given the potential goldmine of long, ultra-high (annual to decadal scale) resolution sediment records (drift deposits and basinal systems), the ability to acquire longer sediment cores within biosiliceous sediment units is critical. We have had great success with maximizing our recovery using the current system (25 meters), and anticipate that longer cores could be acquired successfully, with some modifications to deployment design. We base our recommendation for jumbo piston cores reaching an 80-meter length on the capability of the French research vessel *Marion Dufresne* to recover cores of this length. We note that although it is possible to recover 80-meter cores, 50-60 meter cores are more commonly acquired by the *Marion Dufresne* in marine pelagic sections. The *Marion Dufresne*, however, does not have the ice-breaking capability to perform in ice-covered seas, so cannot be used to fill this need. The French system (Calypso corer) was designed by Yvon Balut; we recommend discussions be initiated with Balut concerning Calypso core design, as well as discussions with Bill Curry at WHOI, concerning their current plans for a long piston corer on the *Knorr*.

Requirements to be considered here include whether to position the coring horizontally (side rail system as on *Marion Dufresne*) or to rig the core vertically and deploy the coring system through a moonpool. In addition, we must consider how design will affect ship length and main deck layout, the A-frame location, core barrel storage, winch wire storage (thicker wire therefore more storage space, stronger winch, etc.). Many of these considerations have been discussed in a previous report (Domack, E., 1995, A long core facility on the R/V Nathaniel B.

Palmer: Scientific justification and feasibility, A report submitted to the Office of Polar Programs, National Science Foundation by the Polar Earth Science Working Group).

We note as well, that discussion and consideration of other coring devices should remain open. For example, the DOSECC AHC800 drilling rig was recently used on the New Jersey shelf with the *Knorr*. This is a rotary system equipped with active heave compensation, deployed through the *Knorr*'s moonpool. This system achieved sub-seafloor penetration of ~13 meters in interbedded sands and muds. Another example of the successful use of an alternate technology, is the BAS use of vibro-coring technology to core into soft and hard till in the Marguerite Trough.

Additional impacts on ship design for both SHALDRIL and the long coring system include the need for a climate controlled storage space. Even with the shorter 25-meter cores, acquisition of even a relatively small number of long cores necessitates addition of a refrigerated van to the NB Palmer. We recommend as well, the strong consideration of "logical" pathways for movement of core sections around on deck and in and out of labs and storage (i.e. no sharp corners or stairs between deck, laboratory and storage facilities).

Under ice coring – Although addressed briefly previously, we reinforce our interest in acquiring sediment samples (including cores) from underneath ice shelves or impenetrable sea ice. We anticipate that in the future, ROVs and/or AUVs with coring capabilities will exist. We must consider how these instruments will be deployed, recovered and how they will be stored on board ship (i.e. garage-type structure). As stated earlier, it is difficult to plan for the unknown; but maximum flexibility in the organization of deck space will be a critical factor.

In the case of all the systems described, decisions must be made regarding on board processing capabilities, especially since in some cases the immediate examination of cores may be instrumental in making decisions with regard to the cruise track. Whether or not cores should be split on board ship must be considered, as should be the appropriateness of specific measurements (ephemeral property measurements, for example). Our recommendation is that this capability be present. With regard to ship design, these considerations will determine the types and size of laboratory space needed, with an emphasis, again, on space design being extremely flexible. We point out the ODP model of on board core processing, which allows relatively complete core characterization and sample allocation prior to the end of a cruise. Of course, this would necessitate an increase in lab and living space and larger scientific parties. A larger ship with more flexibility in terms of modular lab space would facilitate this capability. Finally, we address the issue of clean space on board the vessel. The decision to bring ice cores on board would require the presence of a clean (and cold) room for packaging of cores without cross-contamination. Special precautions would have to be made with regard to air handling systems and clean access to a clean room.

6. Geophysical needs and implications for ship design.

We recognize the absolute necessity of acquiring high quality geophysical data, from both hull-mounted and towed systems. Consideration of how to accomplish this is critical to the success of our program. These issues are not unique to the design of our ship; we urge consultation with marine architects and others with the technical expertise and experience to provide the best advice. In particular, for any hull-mounted systems, such as a multibeam and chirp sonar, consideration of hull design and shape, and how they impact the generation of bubbles and funneling of ice needs to be considered. *We cannot emphasize the importance of hull design enough*. For towed systems, considerations with regard to ship design are centered on several issues including the need for keeping the stern area as clear of ice as possible, over the greatest distance, as well as a deck configuration with the flexibility to allow longer and multiple MCS streamers and larger air compressors. With regard to the air compressors, appropriate below-deck compressor capability must be built into ship design from the outset. For both hull-mounted and towed systems, we need to consider interference by frequencies generated by the ship's engines as well as the compressors.

In addition, we note that the USAP is falling behind other national Antarctic programs in terms of sea floor mapping capabilities. In particular we point out the use of the ultra-high-resolution seismic TOPAS parametric echosound system by the British Antarctic Survey (BAS), the Germans (Polarstern) and the Spanish Antarctic Program, which provide superior sub-bottom data and the new Simrad swath mapping systems used by BAS and both the Spanish and Italian Antarctic Programs. We do note the recent installation and testing of the *NB Palmer*'s new SIMRAD system, which is a strong step in the right direction, though early reports suggest more work is necessary to bring the system's capabilities in line with our expectations.

Another way to approach the acquisition of geophysical data is through the use of AUVs, which have been briefly discussed already. Two immediate advantages are obvious. First, this would this allow us access to areas that are ice-covered, by either heavy pack ice (as in the Weddell Sea) or ice shelves. Mapping of bottom structures, under the ice, would allow us to observe, for the first time, details of many under ice processes, an important step in understanding processes occurring in this transitional region between the continent and deep sea. Second, if an AUV could be sent off on a mission while the ship is "anchored" on station while performing tasks, such as coring, we could effectively double the amount of science accomplished over that time period. In many cases the AUV would acquire data that would permit short-range planning and site selection during a cruise.

The issues discussed above pertain specifically to the acquisition of the best data sets possible. Several additional issues related to geophysical data sets are also important to consider. For example, we emphasize the need for separation of permanent computing facilities on the vessel, for easy maintenance and longer life of this equipment (i.e. humidity, clean air, climate control, vibration control). In addition, the volumes of data that are being collected force us to consider long-term data archiving, such that our data sets reach their maximum potential scientific value. Much like core material or rocks collected from the continent, swath mapping and other geophysical data sets must be archived permanently through a well-coordinated plan that allows for merging of data to create spatially comprehensive maps. A program dedicated to archiving geophysical data sets clearly is a critical step to be taken as quickly as possible. We note the OPP has just funded a research group to archive multibeam data from the Antarctic.

7. Long-term monitoring of the oceanic environment.

We anticipate the potential of a variety of long term monitoring projects including, but not limited to those that may keep track of earthquakes (ocean floor seismometers), sedimentation (sediment traps) and currents (moored arrays of current meters). Deployment and recovery of instruments is relatively routine. Note that we did not discuss this in depth but recognize that additional conversation may be necessary, particularly in terms of how these programs might affect ship design, as, for example the potential need for a “Baltic type” room on both sides of the ship.

Specific Recommendations

1. Continued oversight of vessel plans, design, construction and testing by research scientists with appropriate technical expertise.
2. Size of ship to accommodate 50 scientists (includes technical support staff).
3. Increase icebreaking abilities (extends workable season and percentage of margin accessible).
4. Continued space for helicopter support (helicopter deck and hangar) – alternate use possible if flexibly designed.
5. Addition of more “sea-worthy” and “landing-worthy” small boat(s).
6. Addition of AUV/ROV support to the ship, with consequent implications for flexible garage-style storage space with overhead track, and consideration of deployment – A frame and crane capacities and placement, along with staff considerations.
7. Presence of a moonpool for coring and potentially deployment of instruments.
8. Increased jumbo piston coring capacity – either horizontal or vertical arrangement.
9. Increased refrigerated storage and core processing capabilities.
10. Consideration of “logical” pathways for routine movement of awkward and heavy pieces of equipment and samples (such as cores).
11. Increased flexibility and overall size of lab space – modular space.
12. Acoustic characteristics of the ship that produces the least interference.
13. Maximum ability of ship to create stern ice-free zone for towed equipment.
14. Separation of permanent computing facilities for easy maintenance and longer life of equipment (i.e. humidity, clean air, climate control, vibration control).
15. Plan for long-term archiving of swath mapping data.

Appendix I
Workshop Program

GENERAL AGENDA

Saturday 3/23/02

8:00 – 9:00	**Continental style breakfast at AGU facilities**
9:00 – 9:15	Welcome and Introduction (Amy Leventer)
9:15 – 9:30	Brief comments by Dr. Scott Borg, NSF-OPP
9:30 – 9:35	Introduction to sediment coring issues (Amy Leventer)
9:35 – 10:05	Shaldril (John Anderson)
10:05 – 10:20	ROV with coring capabilities (Kathy Licht)
10:20 – 10:45	**Break**
10:45 – 11:15	Long coring via the JPC (Amy Leventer, Gene Domack)
11:15 – 11:45	Core processing and storing on board ship (S. Brachfeld, E. Domack, S. Ishman, T. Janacek, R. Murray) Core splitting, Geotek track, Geochemical measurements
11:45 – 12:00	Shore-based support: the ARF and satellite core storage (Tom Janacek and Gene Domack)
11:45 – 12:00	
12:00-12:30	OPEN FORUM
12:30 – 1:30	**Lunch Break (lunch provided for group)**
1:30 – 1:35	Introduction to Geophysical issues (Amy Leventer)
1:35 – 2:00	Seismic issues: high resolution/shallow penetration; deep penetration (Gail Christeson, Steve Cande)
2:00 – 2:30	Multibeam issues – ship-based operations (any volunteers to initiate discussion?)
2:30 – 3:00	Multibeam issues - shore-based support: swath map archive/data distribution center (Eugene Domack)
3:00 – 3:30	Autonomous vehicles and submarines (Bruce Luyendyk)
3:30 - 3:45	**Break**
3:45 – 4:15	Brief agenda items – Site survey requirements for ODP (Gail Christeson) Update on IODP (Frank Rack) Lessons from the Healy (Larry Lawver) Links to other disciplines Links to other initiatives Use of helicopters Rapid response projects
4:15 – 4:45	OPEN FORUM
4:45 - 5:00	Summary (Amy Leventer)

Sunday 3/24/02

8:00 – 9:00	**Continental style breakfast at AGU facilities**
9:00 - 9:30	Review and any new agenda items
9:30 - 10:30	Small group discussion and writing of recommendations
10:30 - 10:45	**Break**
10:45 - 12:30	Presentation of recommendations
12:30 - 1:30	**Lunch Break (lunch provided for group)**
1:30	Adjourn

Appendix I
Participant List

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