THE NATIONAL ACADEMIES
REPORT IN BRIEF

Exploration of Antarctic Subglacial Aquatic Environments: Environmental and Scientific Stewardship

Radar measurements have revealed a vast network of lakes, rivers, and streams beneath the Antarctic ice sheet. The next stage of exploration requires direct sampling of these aquatic systems. However, if sampling is not done cautiously, the environmental integrity and scientific value of these environments could be compromised. Carefully managed research should proceed, guided by internationally agreed upon research protocols.

Antarctica is renowned for its extreme cold; yet surprisingly, there is liquid water at the base of the Antarctic ice sheet several kilometers beneath the surface. Using both airborne and surface radar measurements, researchers have now identified more than 145 subglacial lakes (see Figure 1) the largest of which is Lake Vostok with a surface area similar to that of Lake Ontario.

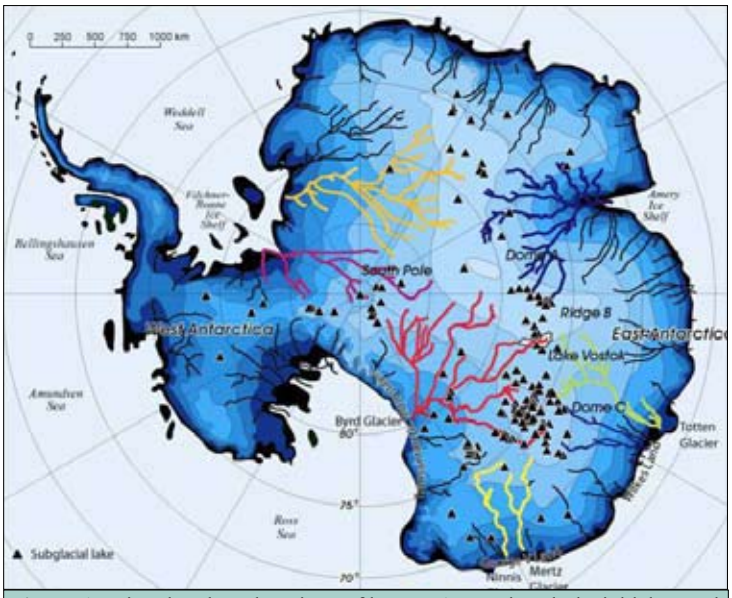

Figure 1. Triangles show locations of known Antarctic subglacial lakes and predicted major drainage routings. Currently, Lake Vostok is the only lake about which we have any depth of information. Source: Siegert et al. 2007.

These lakes are among the last unexplored places on Earth. Sealed from Earth's atmosphere for millions of years, they may provide vital information about microbial evolution, the past climate of the Antarctic, and the formation of ice sheets, among other things. Although much can be learned from remote sensing and ice core data, many key questions require that samples of water, microbial communities, sediments, and underlying rock be obtained.

As of early 2007, no one has yet drilled into a lake but entry within the next one or two years is likely. Thus, the challenge is to determine the best way of drilling into, extensively sampling, and monitoring these environments. Currently, no clear protocols or standards for minimizing contamination have been established, although general guidelines are provided in the Antarctic Treaty.

The Scientific Committee on Antarctic Research (SCAR) is an international body that guides scientific research in the Antarctic. In response to growing scientific and public interest in subglacial lakes, SCAR established the Subglacial Antarctic Lake Exploration (SALE) group. The group recommended developing an integrated science plan for the exploration of subglacial lakes but has not yet addressed environmental and scientific stewardship issues in depth.

At the request of the National Science Foundation (NSF), the National Research Council convened a committee to develop a set of environmental and scientific protection standards needed to

responsibly explore the subglacial lake environments in Antarctica. Specifically, the committee was asked to: 1) define levels of "cleanliness" for equipment or devices entering subglacial aquatic environments; 2) develop a sound scientific basis for contamination standards, and 3) recommend the next steps needed to define an overall exploration strategy. The committee included U.S. and international scientists and gathered information from the global scientific community.

SETTING REALISTIC GOALS FOR MINIMIZING CONTAMINATION

One of the fundamental questions to be answered is whether life exists in these environments. There is some controversy in the peer-reviewed literature, mainly because no samples of lake water have yet been taken. The only available data are from studies of Lake Vostok using chemical and microbiological analyses of lake water that has frozen to the bottom of the Antarctic ice sheet (accretion ice). Many types of microbes, including bacteria, yeasts, and fungal spores, are found in low abundances within the ice sheet above the lakes, and some of these microbes may still be viable as they enter the subglacial lakes through natural processes.

Until there are definitive data concerning the absence of microbial populations, it should be assumed that microbial life exists. The need for responsible environmental stewardship is heightened by recent evidence that shows these lakes are connected by rivers and streams that flow beneath the ice sheet. Any alteration to a single lake or other subglacial environment might also alter others in the system. A clear understanding of the subglacial hydrologic system is also needed before initial sampling is done.

Methods and protocols to minimize contamination have been developed for other unique environments. For example, space exploration has developed methods for storing cleaned vehicles and instruments in a completely sterile environment until they are launched into space. The harsh Antarctic environment and the logistical constraints of keeping 4 km of drilling equipment sterile pose many challenges.

The report concludes that drilling in conjunction with sampling procedures will inevitably introduce chemical contaminants into subglacial aquatic environments and that steps should be taken to ensure that these activities have only a minor and/or transitory impact on the environment. Microbes will also inevitably be introduced into lakes and streams and may change the existing communities. However, the likelihood that the lake environments will be significantly altered by those microbes is very low. Microbes from drilling activities that do not naturally occur in the ice sheet would most likely not be able to survive in the subglacial lake environments.

In addtion, the report recommends protocols that outline the steps and technologies (e.g., hot water drilling, sterile drilling fluids) needed to minimize the number of microbes introduced as well as the number of lakes and streams that might become contaminated by drilling and sampling.

RESEARCH SHOULD GO FORWARD, GUIDED BY AGREED UPON PROTOCOLS

It is time for scientific research on subglacial lakes to begin, but only through a carefully managed, conservative approach that preserves the environmental integrity and scientific value of the environments. The report provides a set of recommendations and a decision tree to be used as a framework for the environmental management decisions that need to be made at both the international and the national levels in accordance with the Antarctic Treaty (see Figure 2). Working through SCAR, it will be important to develop criteria and research specifications that may be incorporated into management plans.

The committee sought to develop the scientific rationale for setting standards that addresses the wide range of interests of many stakeholders and interested parties, including the international community.

Recommended First Steps

Develop a consensus-based international plan for exploration. The National Science Foundation should work in conjunction with the United States representatives to the Scientific Committee on Antarctic Research and to the Committee on Environmental Protection to involve all Antarctic Treaty nations in developing a consensus-based management plan for the exploration of subglacial aquatic environments. This plan should seek to develop scientific understanding and ensure that the environmental management of subglacial aquatic environments is held to the highest standards. Multinational projects should be encouraged in the study of subglacial aquatic environments, and all projects aiming to penetrate into a lake or stream should be required to undertake a Comprehensive Environmental Evaluation. (Recommendations 5 and 6)

Characterize subglacial lakes with remote sensing. The United States, together with other interested parties, should begin immediately to obtain remote sensing data to characterize a wide range of subglacial aquatic environments. Data and samples should

be obtained from subglacial aquatic environments as soon as practicable to guide future environmental stewardship, scientific investigations and technological developments. (Recommendation 11)

Establish protected areas. As soon as adequate survey data have been gathered, subglacial aquatic environments intended for research should be designated as Antarctic Specially Protected Areas to ensure that all scientific activities are managed within an agreed international plan and are fully documented. Certain exemplar pristine subglacial environments should remain untouched for long-term conservation purposes. (Recommendation 3 and 4)

Recommended Protocols and Standards

Initial exploration protocol. Characterization of subglacial lakes by remote sensing is underway but far from complete. The following steps should be taken to guide decisions about which subglacial aquatic environments should be studied:

- Continent-scale radio-echo sounding data should be assembled and subglacial aquatic environments identified;
- All regions where the basal melt-rate is likely high should be identified;
- Detailed radio-echo sounding of known lakes should be done;
- A hydrologic map of the subglacial drainage system for each catchment should be constructed;
- Potential target environments should be identified based on the subglacial drainage system.

Once potential research sites are identified, the likelihood of attaining scientific goals should be evaluated based on the representativeness for other lakes and settings, for accessibility, and for the constraints of logistics and cost.

Acceptable levels of biological contamination. Drilling in conjunction with sampling procedures will

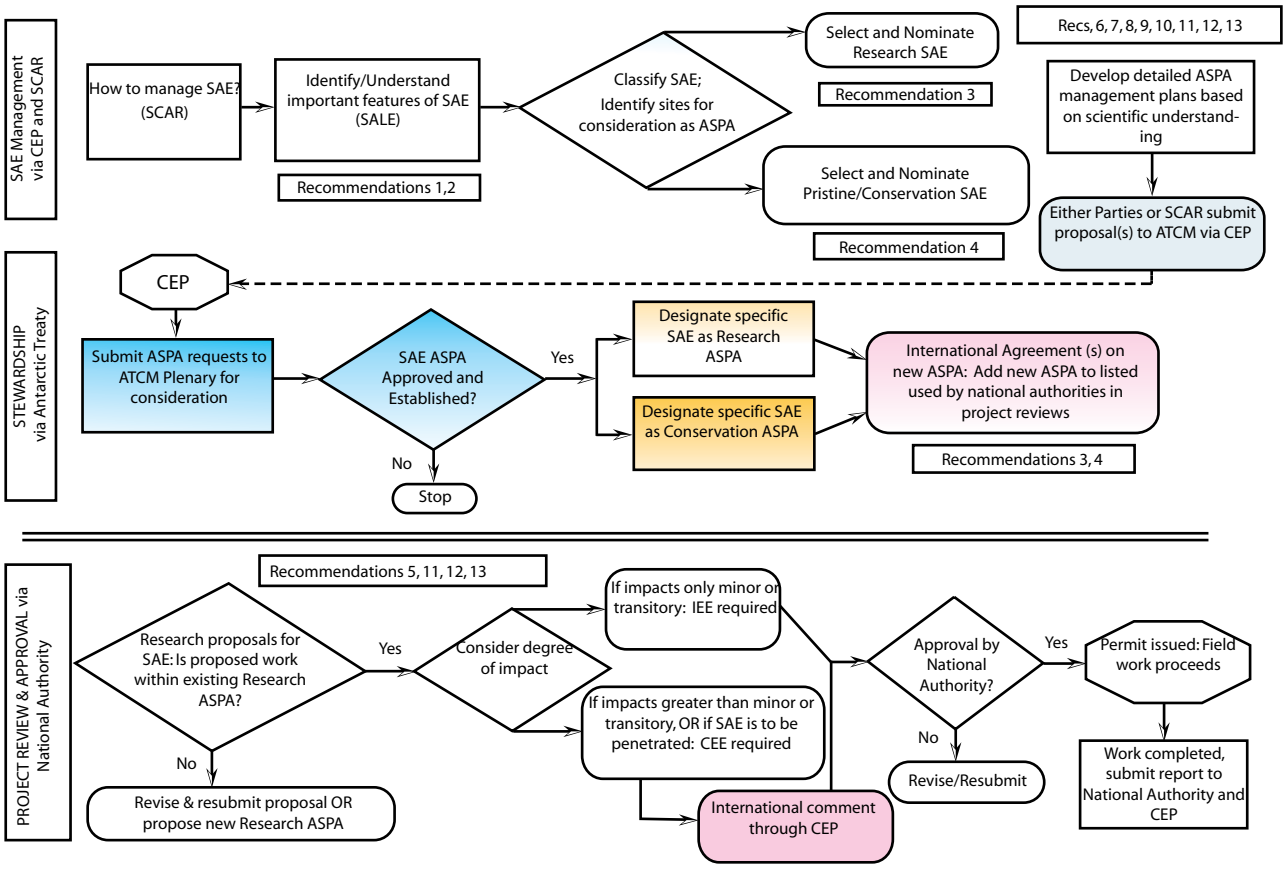

Figure 2. This diagram provides an overview of the committee's recommendations and a suggested framework to address the key areas of importance for subglacial lakes—stewardship, management, and project review. It is deliberately consistent with the guidelines of the Antarctic Treaty, as well as national and international programs or authorities involved in the treaty process. It has the necessary flexibility to update information and evolve over time as new findings accumulate about drilling, biological and geological information, and exploration methods.

inevitably introduce microorganisms into subglacial aquatic environments. The numbers of microbial cells contained in the volume of any material added to these environments or on instruments placed there should not exceed the minimum concentration of microbes in the basal glacial ice being passed through. (Recommendation 7) As sampling of Lake Vostok and Lake Ellsworth proceeds, the data should be used to evaluate recommended biological contamination levels.

Acceptable levels of chemical and other types of contamination. Toxic and biodegradable materials should be avoided, as should the introduction of nonmiscible substances. At a minimum, the concentrations of chemical contaminants should be documented and the total amount added to these aquatic environments should not be expected to change the measurable chemical properties of the environment. Every effort should be made to preserve the integrity of the lakes' chemical and physical structure during exploration and sampling of water and sediments, but exceptions should be made for certain objects and materials placed for scientific purposes, for example, for monitoring equipment. (Recommendations 8, 9, and 10)

Recommended Research

Research and development should be conducted on methods to reduce microbial contamination throughout the drilling, sampling, and monitoring processes, on methods to determine the background levels of microbes in glacial ice and lake water, and on development of miniaturized sampling and monitoring instruments to fit through the drilling hole. (Recommendation 13)

CONCLUSION

The exploration of subglacial aquatic environments is in its initial stages. Many fundamental questions about these environments can only be answered by entering and sampling the water. Accordingly, the management of subglacial aquatic environments requires responsible environmental stewardship while allowing field research. All aspects of management, stewardship, and project review and approval will continue to involve absolute requirements mandated by the Antarctic Treaty, government standards specific to particular parties, and scientific standards such as those recommended by SCAR.

As the science and exploration of subglacial environments grows beyond its infancy, the initial methodologies and protocols recommended in this report will need further development and regular revision. Although this study is being produced by a U.S. scientific advisory body at the request of the National Science Foundation, the committee hopes that its multinational makeup will be recognized and that the recommendations in this report will serve as a basis for broad international discussion about environmental stewardship for the exploration of subglacial aquatic environments.

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This brief was prepared by the National Research Council based on the committee's report. For more information, contact the Polar Research Board at (202) 334-3479 or visit http://nationalacademies.org/prb. Copies of the report are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.

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