The ANTOSTRAT Legacy: Science Collaboration and International Transparency in Potential Marine Mineral Resource Exploitation of Antarctica

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ABSTRACT. The Antarctic Offshore Stratigraphy project (ANTOSTRAT; 1989–2002) was an extremely successful collaboration in international marine geological science that also lifted the perceived "veil of secrecy" from studies of potential exploitation of Antarctic marine mineral resources. The project laid the groundwork for circum-Antarctic seismic, drilling, and rock coring programs designed to decipher Antarctica's tectonic, stratigraphic, and climate histories. In 2002, ANTOSTRAT evolved into the equally successful and currently active Antarctic Climate Evolution research program. The need for, and evolution of, ANTOSTRAT was based on two simple tenets within SCAR and the Antarctic Treaty: international science collaboration and open access to data. The ANTOSTRAT project may be a helpful analog for other regions of strong international science and geopolitical interests, such as the Arctic. This is the ANTOSTRAT story.

ANTARCTIC OFFSHORE STRATIGRAPHY PROJECT: THE EARLY YEARS

In 1986, the science community established the Scientific Committee on Antarctic Research (SCAR) Group of Specialists on Cenozoic Paleoenvironments in Southern High Latitudes to study and assess geologic sample and core data as well as geophysical remote sensing data to better comprehend Antarctica's geologic history and its impact on global sea level and climate change (Figure 1). Recognizing that Antarctica is 98% ice covered, the Antarctic

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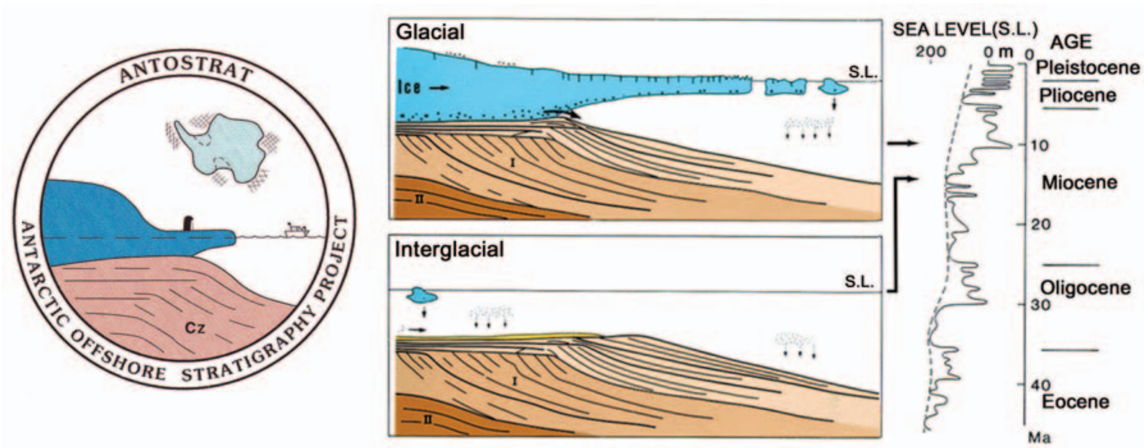

FIGURE 1. The ANTOSTRAT logo and an early 1990s ANTOSTRAT model linking global sea levels to Antarctic ice sheet history (modified from Cooper and Webb, 1992).

Offshore Stratigraphy project (ANTOSTRAT) was established under the aegis of the Group of Specialists to focus geoscience investigations on Antarctica's offshore regions (Cooper and Webb, 1992). The stated objective of ANTOSTRAT was to bring together all research groups responsible for collecting offshore geological and geophysical data, to collaborate in field and laboratory studies directed toward understanding Cenozoic paleoenvironments, to plan future offshore geologic studies, and to promote scientific deep drilling.

Prelude to Potential Marine Minerals

Data relevant to ANTOSTRAT had been collected in Antarctica since the early 1970s, but these were commonly unavailable to anyone except the data collectors (or to collaborators via private data exchange agreements). The geologic and geophysical data collected during the pre-ANTOSTRAT years were also being used for assessments of offshore mineral resources by national, academic, and corporate research groups. Because many of the offshore geologic and geophysical data, especially the seismic reflection data, were not openly accessible, there was a perceived "veil of secrecy" on the eventual uses of ongoing geoscientific studies. Many beyond the Antarctic community were asking whether these studies were for research purposes or for mineral exploration.

In the decade preceding the establishment of ANTOSTRAT, interest in Antarctica's potential mineral resources was increasing (e.g., Behrendt, 1983; Splettstoesser and Dreschhoff, 1990), with the escalating price and demand for such resources. The most important of these resources were hydrocarbons.

Collaboration in Science

With the implementation of ANTOSTRAT in 1989 and the first ANTOSTRAT symposium in April 1990 (Cooper and Webb, 1990), at which the emphasis was on offshore geoscience data, the level of interest in the science and geopolitics of the offshore areas blossomed. At the 1990 symposium, the groundwork for collaboration in studying the offshore data was laid down with the formation of working groups for the five principal marine regions around the Antarctic continent accessible by surface vessels (i.e., Ross Sea, Wilkes Land, Prydz Bay, Weddell Sea, and Antarctic Peninsula). The working groups were tasked to collate, analyze, and publish collaborative research papers on the geoscience data from each region. The first tenet of ANTOSTRAT (i.e., collaboration in science) was now in place, and the interest in, and support for, ANTOSTRAT gained momentum among all countries engaged in conducting marine surveys of the Antarctic margin.

THE ANTARCTIC SEISMIC DATA LIBRARY SYSTEM FOR COOPERATIVE RESEARCH: OPEN ACCESS TO DATA—A LINK TO THE ANTARCTIC TREATY

There was, however, still no mechanism in place for open access to the most valuable of all Earth science data

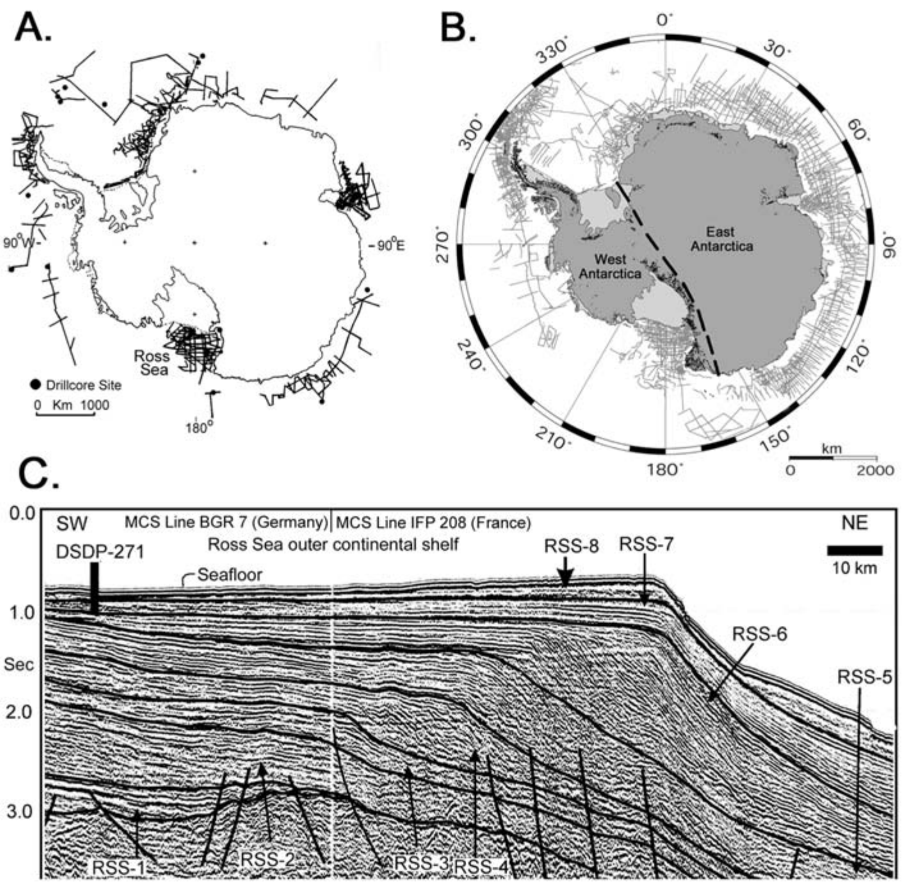

FIGURE 2. Multichannel seismic reflection (MCS) data. Maps showing track lines of data: (A) collected before 1988 (modified from Behrendt, 1990) and (B) collected as of late 2009 (about 350,000 km). (C) Example MCS profile across the Ross Sea with seismic stratigraphic units (RSS) and Deep Sea Drilling Project site noted (modified from Cooper et al. 2009). About 275,000 km of MCS data are now in the SDLS.

for research and hydrocarbon exploration: multichannel seismic reflection (MCS) data (Figure 2). The MCS data are used to image the structure of the Earth, from the seafloor down to 10 km or more below the sea floor. Such information is needed to decipher how continents and their margins formed. They also help to identify where hydrocarbons may be present. The MCS data are therefore both a powerful research tool and a basic and widely used tool in the exploration for petroleum. A key criterion for establishing their intended use is the level of access to the data. MCS data used for research purposes will be openly accessible to others (via publication and later release), but data collected for commercial exploration purposes will rarely be made accessible.

In late 1990, with the level of debate on Antarctica's mineral resources increasing, it was clear to members of the ANTOSTRAT steering committee that the second tenet of ANTOSTRAT (i.e., open access to data in accord with Article III of the Antarctic Treaty) needed to be addressed promptly to clearly demonstrate that ANTOSTRAT was truly a science project and not mineral exploration of Antarctica undertaken under another name. In April 1991, ANTOSTRAT convened a special workshop in Oslo, Norway, to develop and agree to a system by which the highly valued MCS data would be made openly accessible. This would help ANTOSTRAT move forward faster with its collaborative science agenda of making circum-Antarctic maps needed for understanding Antarctica's geologic and climate history.

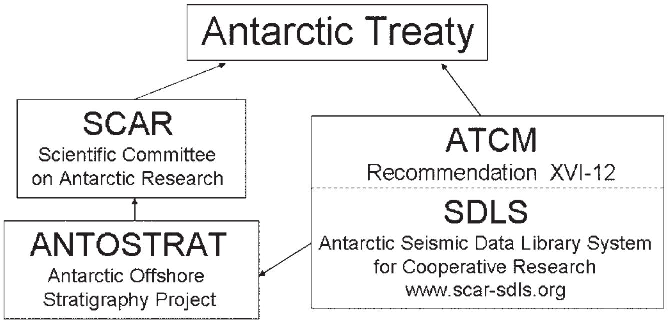

FIGURE 3. Generalized organizational diagram showing the former relationships of SCAR, ANTOSTRAT (now ACE), SDLS, and the Antarctic Treaty. The SDLS is now under ACE.

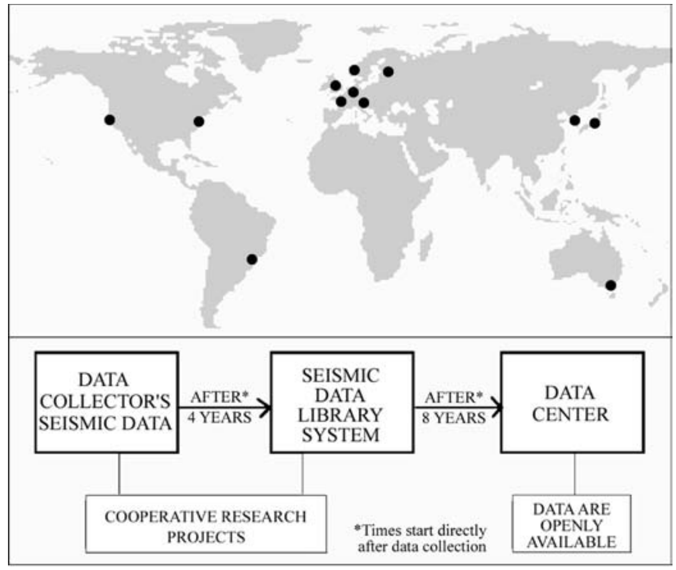

FIGURE 4. (top) Locations of SDLS branches and(bottom) concepts of the SDLS (modified from Cooper and the ANTOSTRAT Steering Committee, 1991, and SDLS, http://www.scar-sdls.org, accessed January 2010). The SDLS provides open access worldwide to Antarctic seismic reflection data for use in cooperative research projects.

The Oslo workshop included lead scientists from groups in the 11 countries that had collected MCS data (Cooper and the ANTOSTRAT Steering Committee, 1991; Figure 2A,C).[1] The participants developed a plan for a new science data library. All participants agreed to the plan and forwarded an outline of it to the XVI Antarctic Treaty Consultative Meeting (October 1991). There the outline statement was discussed and adopted as Recommendation XVI-12, thereby formalizing the SCAR Antarctic Seismic Data Library System for Cooperative Research (SDLS) as part of the Antarctic Treaty System (Figure 3). The second tenet of ANTOSTRAT (i.e., open access to data) was now in place.

In the same year, 1991, the Madrid Protocol on Antarctic Environmental Protection to the Antarctic Treaty (Antarctic Treaty System, 1991) was signed establishing a 50-year moratorium on resource exploration and exploitation. The MCS data can be used for both exploration and basic research, yet the adoption of the SDLS into the treaty opened access to these data and removed the perceived veil of secrecy about how they were being used. Because MCS data are critical for understanding Earth history and paleoclimates, they continue to be collected and made openly available for research purposes.

A Unique Approach

The SDLS is unique in its approach to resolving the difficult issue of open access to highly valued data. The SDLS is a research library system under SCAR and the treaty and not an international data bank linked to national or other agencies. The focus is on promoting collaboration and data sharing for research purposes, while respecting and preserving intellectual property rights. The World Data Center (http://www.ngdc.noaa.gov/wdc/) has primary responsibility for archival of data.

The SDLS operates under clearly defined guidelines in SCAR Report 9 (Cooper et al., 1991; Childs et al., 1994). These guidelines apply to all MCS data collected in Antarctic regions.

A key guideline of the SDLS is that the restrictions on use and access to MCS data decrease with time after the data are collected (Figure 4):

- For an initial period (zero to four years after collection), data collectors retain full intellectual property rights to their data.
- For the succeeding period (four to eight years), MCS data go into the SDLS, where they can only be used for collaborative research purposes with the data collector. The data collector cannot deny the collaborative efforts unless another research group is already working on the same proposed project.
- In the final period (after eight years), the MCS data then become openly accessible to anyone, with the only restriction being that persons who use the data cite the data collector. The open access is via the

World Data Center, other unrestricted data centers, and/or the SDLS Web site (http://www.scar-sdls.org).

A key hurdle in organizing the SDLS was how it was to be funded. Summarizing from SCAR Report 9 (Cooper et al., 1991), SCAR provides no funds for the SDLS. Funding for library branches is the responsibility of the host organization. Data are currently sent to branches on CD-ROM and DVD-ROM; hence, a room and computer system that is supervised by a senior Antarctic researcher (to ensure SDLS guidelines are followed) is sufficient. Funds for the data standardization and preparation of the CDs and DVDs containing the MCS data are the responsibility of the data collector, via National Antarctic Programs and/or institutional funds. The funds are submitted to the group producing the CDs and DVDs when the MCS data are submitted. Currently, the CDs and DVDs are produced by the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS) in Trieste, Italy. Oversight and management of the SDLS is done by a three-member executive committee, currently with two members at the U.S. Geological Survey and one member at OGS.

Achievements in Transparency and Collaboration

The implementation of the SDLS under ANTOSTRAT purview has provided an acceptable and rational mechanism for graduated open access to seismic data (Figure 4) and has removed the secrecy of data collection for mineral exploration. The eventual use of MCS data is not guided by SDLS guidelines. Yet the SDLS has, since 1991 (i.e., for 19 years as of the time of this report), facilitated and promoted a culture of geoscience collaboration on large-scale (i.e., more than 10 countries) international projects in Antarctica's offshore regions, projects that would not otherwise be possible.

The SDLS has further helped encourage a greater willingness to cooperate in sharing of expensive and difficult-to-collect MCS data. The reality is, however, that each organization's practice in their data submissions to the SDLS is influenced by many factors, including funds available to submit data, national agency policies, protecting students and others undertaking research projects, and incomplete data processing. Hence, data submissions are frequently behind the SDLS schedule and vary between countries. Patience and persistence has been required to achieve the SDLS-stipulated and Antarctic Treaty Consultative Meeting (ATCM)-approved data submissions. Nevertheless, over the years, the SDLS, initially under ANTOSTRAT and more recently under the Antarctic Climate Evolution program (ACE), has gradually incorporated about 275,000 km of MCS data, which is 85% of the MCS data due at the SDLS and 79% of all data collected (Figure 2B). A majority of those data are older than 8 years and are therefore openly accessible (Cooper et al., 2009).

The SDLS, like the Antarctic Treaty, is a dynamic body that requires constant attention and participation of the science community for its success, and to achieve this, the SDLS holds yearly to biyearly workshops. The SDLS now has 13 branches in 11 countries (http://www.scar-sdls.org).

ANTOSTRAT: LATER YEARS AND SUCCESSES

The history of ANTOSTRAT and its principal research findings (see Cooper et al., 2008) would not be complete without listing some of the successes achieved under its two principal tenets of science collaboration and open access to data. The ANTOSTRAT project has spawned and helped a generation of young researchers to learn how science is accomplished in Antarctica, under SCAR and the Antarctic Treaty, and to promote their science and the greater collaborative interests within the science community. It has also inspired and promoted a generation of major offshore Antarctic drilling projects and currently, under ACE, a project to create circum-Antarctic stratigraphic and paleobathymetry maps for climate history. Scientists working under ANTOSTRAT collaborations have

- published hundreds of individual research papers (see the 54-page bibliography in Cooper et al. [2008]);
- held numerous international ANTOSTRAT symposia and workshops to disseminate research results and SDLS workshops to assess SDLS operations and plans;
- compiled and published several geoscience map atlases of offshore regions based on multinational data sets from areas around Antarctica;
- promoted, designed, and conducted many offshore drilling operations for climate history (e.g., Ocean Drilling Project Legs 178, 188, and 318 (2010), Cape Roberts Project drilling [http://www.victoria.ac.nz/geo/croberts/], and others);
- submitted to the SDLS about 275,000 km of MCS data estimated at more than $300 million to collect and process; and
- carried the valued tenets of ANTOSTRAT into the next generation as significant elements in the ACE program (Florindo and Siegert, 2008; ACE, 2010).

ANTOSTRAT was one of many successful long-term international science projects under the leadership of SCAR. Unlike all other geoscience projects, ANTOSTRAT was directly linked to the Antarctic Treaty System, a link that has continued, now under ACE, for 19 years, via the SDLS and ATCM Recommendation XVI-12. In a small way, ANTOSTRAT and the SDLS helped carry the treaty through one of its most challenging periods during the search for a solution to the Antarctic minerals exploration problem.

As with all dynamic institutions, the continuing success of the SDLS relies on the proactive determinations of its constituents, the scientists and their national Antarctic programs, to keep it vibrant with their creative ideas, active science participation, and funding for data submissions. We see long-term value for these endeavors and urge continued support of the SDLS.

ANTOSTRAT: FUTURE ANALOGS

Can ANTOSTRAT, with its successes in facilitating international collaboration and open access to valuable data for marine geologic studies of the Antarctic continental margin, be adopted as a template for studies of other continental margins with potential mineral resources and inherent scientific value in paleoenvironment and climate histories? As an example, could the ANTOSTRAT template be applied in the other polar region, the Arctic?

The Arctic Ocean and its continental margin is an area of great international and economic interest, but there is yet no established guiding treaty for the region as there is for Antarctica. With regard to mineral resources and geoscience research (i.e., ANTOSTRAT analog), the Arctic region is now governed by laws of the encircling nations and further subject to the tenets of the United Nations Convention on the Law of the Sea. Yet these laws and guidelines do not promote or achieve the greater goal of open access to data to facilitate scientific studies of benefit to all. Although large geoscience data sets, including a growing amount of seismic reflection data (e.g., Kristofferson and Mikkelsen, 2004), already exist for the Arctic Ocean region and many of these have been published, there are still many such data sets that are not yet openly accessible to the international science community. Furthermore, there is currently no internationally adopted mechanism by which future data sets would be made openly accessible.

In the Arctic example, as in other regions of international interest, adopting the straightforward tenets of ANTOSTRAT (and the SDLS) could facilitate greater geopolitical harmony by promoting scientific research over national and commercial interests. Such research is needed to answer fundamental questions about Earth processes that are key to our survival.

ACKNOWLEDGMENTS

We thank the editors for the invitation to relate the ANTOSTRAT success story, one in which the real “heroes” to be thanked are the hundreds of geoscience investigators and managers from research institutions in more than 20 countries, people whose dedicated collaborations within SCAR and under treaty guidelines provide a role model for Antarctic science endeavors. We thank Jerry Mullins and Ginger Barth for their helpful reviews.

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NOTE

1. The People's Republic of China was not represented at the workshop because no one was aware that they had collected MCS data in 1990–1991 until they reported this fact at ATCM XVI.

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