Exhibits 43-45

Sea Ice. The annual freezing and melting of Antarctic sea ice is one of the Earth's major climatic events. In its winter maximum, the sea ice is typically two- to three-feet thick, and covers nearly eight million square miles, an area greater than the continent itself. In summer it is reduced to 1.5 million square miles in a narrow fringe around the continent. It has profound effects on the physics, chemistry, and biology of the southern ocean.

In autumn when the ice cover is expanding, the ice acts as a distillation system, separating sea water into low salinity ice and high salinity brine, which sinks and increases the density of Antarctic Bottom Water, a globally distributed water mass. In winter, during its maximum extent, the ice shuts down the exchange of heat between the ocean and the atmosphere, lowering the surface air temperature by as much as 30°F and increasing the reflectivity (albedo) of the surface. In spring, melting releases microbes and plankton that had been growing in the ice and seeds of phytoplankton bloom. In summer it provides a breeding place for seals. For most of the year the transition zone from ice to open water is one of enhanced biological activity, where birds, seals, and whales congregate to feed. The schematic (© Scientific American 1988, after Gordon and Comiso, 1988) illustrates these actions.

The extent of the Antarctic sea ice has been closely tracked since 1973 from satellite-based sensors that measure the microwave energy emitted by the surface. Open water and sea ice appear very different in the microwave band, and therefore the ice edge can be established very precisely. There has been a slight decrease in the maximum extent of sea ice during the period of record, consistent with a slight climatic warming over the past 25 years. These microwave observations are our only source of information about the Weddell polynya, a large (over 100,000 square miles) area of open water surrounded by sea ice that maintained itself from 1974 to 1976 within the Weddell Sea. It has not been observed since, although evidence has been accumulated about the conditions that probably produced the polynya. Exhibits 44 and 45, prepared by NASA's Goddard Space Flight Center, show the annual minimum and maximum extent of the sea ice in February and September 1974.

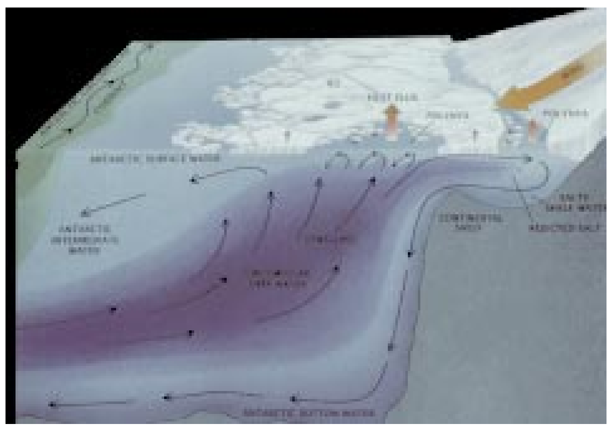

Exhibit 43

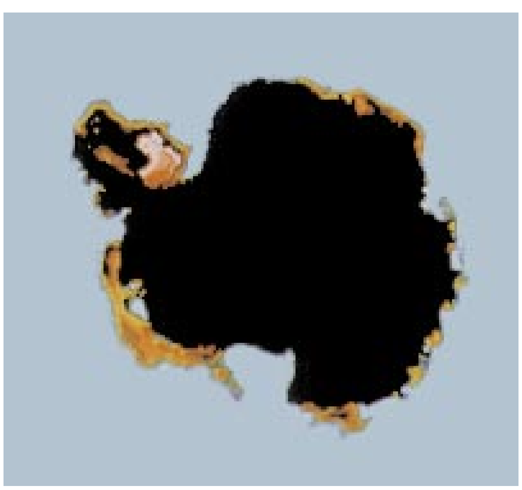

Exhibit 44

February (Summer) 1974

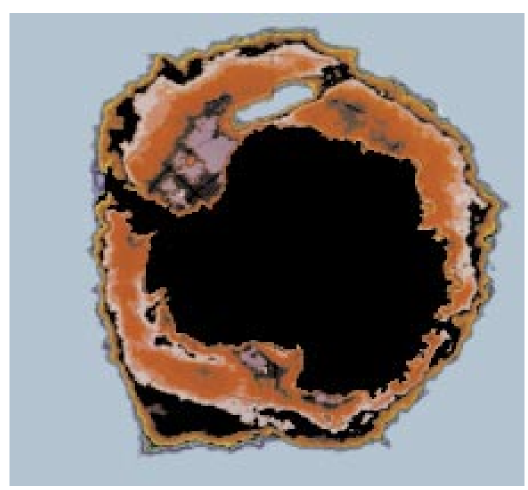

Exhibit 45

September (Winter) 1974

Exhibit 46

Satellite image of ocean color showing phytoplankton blooms, likely sites of biologically mediated flux of carbon dioxide between the atmosphere and the ocean. Carbon dioxide is the most important human-produced greenhouse gas contributing to global warming. To understand or predict global change, the amounts and the rates of carbon dioxide entering and leaving the atmosphere must be determined. The ocean is one of two major sinks, or removers, of atmospheric carbon dioxide (the terrestrial biosphere is the other one). Most oceanic carbon dioxide uptake occurs between 30°S latitude and Antarctica — the southern ocean. But the magnitude of this downward flux, or flow, is difficult to quantify with present knowledge.

The southern ocean is the fourth regional experiment of a U.S. contribution to an international program — the Joint Global Ocean Flux Study (JGOFS) — that is tracing the flow of carbon through the ocean's intertwined chemical, biological, and geological pathways. This work follows other regional experiments in the North Atlantic, the equatorial Pacific, and the Arabian Sea. While each region was chosen for its distinctive oceanic and climatic setting, the southern ocean is unique because its very cold surface allows very high values of dissolved carbon dioxide and because it facilitates vertical convection to the ocean bottom. Climate change models not only show that most of the global oceanic uptake of carbon dioxide occurs in the southern ocean; they also show that the southern ocean flux has the greatest sensitivity to biological variations.

The U.S. Antarctic Program research icebreaker Nathaniel B. Palmer is supporting the southern ocean research. By the end of March 1998, Palmer will have made seven cruises in less than 2 years in support of the Antarctic Environment and Southern Ocean Process Study (AESOPS), a major JGOFS experiment. More than 40 principal investigators will have studied processes including the exchange of gaseous carbon dioxide between the atmosphere and the ocean, the uptake of carbon by phytoplankton blooms, the sinking of organic and inorganic carbon-based matter to the ocean bottom, and the sequestering of carbon within the bottom sediment. Image © Science 1993 after C.W. Sullivan et al.

blue ice in the Allan Hills. After several years of research, planetary scientists recognized that this meteorite had originated on the planet Mars and been ejected to the Earth during a Martian collision with some other object. The presence in this meteorite of carbonate minerals, often associated with fluids, offers clues to past environmental conditions on Mars. Recently, an interdisciplinary team of scientists suggested that the presence of these carbonate minerals, along with complex hydrocarbon molecules also found in the meteorite, may be evidence of life on Mars some 3.6 billion years ago, although other researchers indicate that the carbonates formed at 1150°F in the absence of water, conditions not amenable to life as we know it.

Biological studies in the Antarctic also show how living things adapt to one of the harshest climates on Earth. Understanding the genetic and physical basis for the great adaptations of Antarctic life is revealing fundamental insights to biological processes, and is likely to prove useful to humans (Exhibits 47, 48, and 49).

A very exciting opportunity that can be developed is an application of molecular biology techniques to determine the biological history of the Earth, at the microbiological level, that is embedded in ice and sediment cores. With the ability to extract any nucleic acids that may be present, followed by sequencing, fingerprinting, etc., it should be possible to learn how life has changed with the Antarctic environment.

In an entirely different area of research, biomedical studies in Antarctica, and especially at the South Pole, usually in collaboration with NASA, have helped understand the physiology and psychology of living in the isolated environment of the Antarctic.

Antarctica has not always been glaciated. Indeed, 80 million years ago the coastal regions of Antarctica supported lush, temperate forests that were inhabited by a wide diversity of animals. At that time the continent was situated at a latitude similar to that of southern South America today. As the continent drifted toward the south away from the other Gondwana continents, insolation diminished and Antarctica's climate cooled. The evolutionary changes of plants and animals living on the continent and trying to adapt to these more harsh conditions are among the most spectacular and poorly understood paleontological events in Earth's recorded history. There is still much to learn about the evolution of the Antarctic continent, the ice sheet, and the organisms that have lived or continue to live there.

With the rich history of the discoveries emanating from Antarctic research over the past 50 years, as well as their frequent relevance to human well-being on Earth through improved understanding of weather, climate, ocean circulation, etc., Antarctica truly affords a unique laboratory for the conduct of science.

Exhibits 47-49

Life in the Extreme. Knowledge about extreme and unusual environments that are home to microbial life has expanded rapidly in the last decade. These environments, ranging from icy polar seas and dry polar deserts to hot deep-sea hydrothermal vents, may be analogs to ancient environments on Earth and on other planets. Only a fraction of these systems has been studied; knowledge of them will help us understand the diversity of microbial life, its biochemical adaptations enabling survival, and the range of physical and chemical conditions in which life can survive and even flourish.

The Antarctic offers unique opportunities for study of life in environments that are at the limits of the planet's cold, darkness, and dryness. In them, the energy available to support life is among the lowest levels on Earth. Here are three examples, chosen from many:

Exhibit 48

The perennially ice-covered lakes of the McMurdo Dry Valleys harbor communities of cyanobacteria that appear to thrive in stratified, saline water well below 32°F and sometimes in brine pockets in the ice cover.

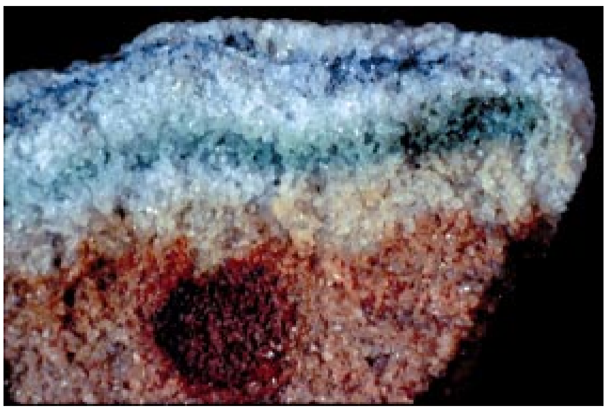

Exhibit 47

The outer few sixteenths of an inch of some rocks in the cold desert of the McMurdo Dry Valleys creates microclimates with just enough above-freezing days per year and just enough moisture that minute spaces between grains are home to organisms. These organisms are active enough to contribute to weathering of the rock surface, but they appear to be on the limit of their capability and are dormant most of the year. Here, an opened section of Beacon Sandstone from Linnaeus Terrace (Dry Valleys) shows layers of algae, fungi, and bacteria (photo courtesy of E. Imre Friedman, Florida State University).

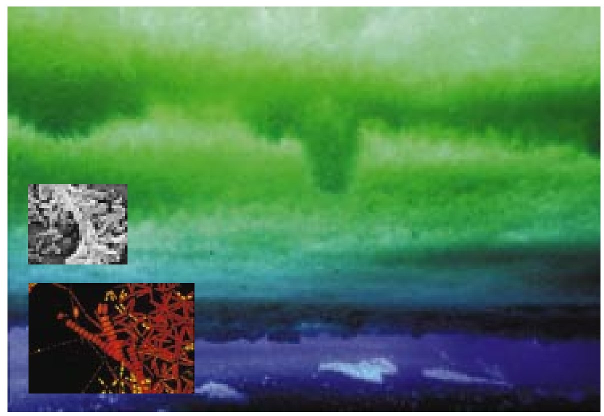

Exhibit 49

The undersurface of sea ice has rich algal blooms. The color inset is a photomicrograph of chains of sea ice algae with fluorescent stain to reveal protein (red) and lipid (yellow) content of living cells. The other inset shows bacteria from sea ice at greater magnification in a scanning electron microscope image (photos courtesy of C. W. Sullivan, National Science Foundation).

5.4 Environmental Considerations

Human activity in the Antarctic began as a quest for exploration, for economic gain, and for scientific knowledge. These goals were reflected in the early Antarctic exploration in the 19th century and the entry into force of the Antarctic Treaty in 1961. Interest in Antarctica now also reflects humankind's expanding influence upon and awareness of the environment.

Antarctica is one of the few remaining nearly pristine sites in the world, and is certainly by far the largest such site. Antarctica is particularly vulnerable to some types of environmental change, notably those that would require biological activity for reversal or amelioration. Pollutants that would be readily biodegradable elsewhere can have very long lifetimes in the Antarctic environment, increasing the possibility of long-term alteration through human activities.

Two treaties have already been put in place to extend the original Antarctic Treaty to include preservation concerns. The Convention for the Conservation of Antarctic Seals took effect in 1978, and the Convention on the Conservation of Antarctic Marine Living Resources took effect in 1982. The Antarctic Treaty together with the recommendations and measures adopted under it and the Seals and Marine Living Resources Conventions have collectively become known as the Antarctic Treaty System.

To enhance protection of the Antarctic environment, the Antarctic Treaty parties in 1991 adopted the Protocol on Environmental Protection to the Antarctic Treaty, designating Antarctica as a natural reserve and setting forth environmental protection principles to be applied to all human activities in Antarctica, including the conduct of science, tourism, and fishing. The Protocol has been signed by all of the 26 Consultative Party nations to the Antarctic Treaty, and will enter into force after the 26 nations have deposited their instruments of ratification, acceptance, approval, or accession.

The U. S. has taken a number of steps to implement the Protocol. Aggressive environmental measures have been introduced into the USAP under the Safety, Environment, and Health Initiative, including removal of all solid wastes and institution of an extensive recycling program at U. S. stations. The USAP has taken a science-based approach to environmental assessment in which careful measurements of environmental parameters are used to monitor changes and evaluate the need for additional protection measures. Thus, U. S. policy currently reflects not only geopolitical and scientific concerns, but also a position of leadership in the international stewardship of the Antarctic environment.