Scientific Ocean Drilling:

Contributing to the Nation's Ocean Research Priorities

U.S. Advisory Committee for Scientific Ocean Drilling
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White Paper in Response to:

Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy
National Science & Technology Council
Joint Subcommittee on Ocean Science and Technology

CONSORTIUM FOR Ocean Leadership
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The U.S. Advisory Committee for Scientific Ocean Drilling (USAC) is the national advisory committee for U.S. participation in the Integrated Ocean Drilling Program (IODP) and wider issues in scientific ocean drilling. USAC advises to the U.S. Science Support Program of the Consortium for Ocean Leadership.

EXECUTIVE SUMMARY

Deep beneath the ocean floor, scientists are sampling ancient sediments and volcanic rocks for clues about our planet's future. With the support of the National Science Foundation, the Integrated Ocean Drilling Program (IODP) continues to play an important role in advancing ocean, climate, and geologic research.

The United States has been a world leader in scientific ocean drilling for almost forty years and is poised to maintain its position with a newly refurbished and updated U.S. drilling vessel, the *JOIDES Resolution*. From early success in establishing evidence for plate tectonics, the program continues to illuminate the frontier of the earth sciences. Recent expeditions have sailed to the vastly unexplored Arctic Ocean where scientists recovered 50 million years of climate history from near the North Pole, and sailed to the Pacific Ocean off the U.S. coast where scientists began determining the nature and extent of methane hydrates.

In 2007, the federal government released the *Ocean Research Priorities Plan* to set science priorities and chart the course for ocean research over the next 10 years. Scientific ocean drilling has compiled a priceless database of materials and measurements from the world's oceans that has facilitated the study of the natural climatic, tectonic, and oceanic systems, as well as the natural phenomena that can affect these systems. By providing insights into the natural world, the continuing contributions of scientific ocean drilling, now accomplished by the Integrated Ocean Drilling Program, are a vital resource for accessing the data necessary to address the nation's ocean science priorities.

INTRODUCTION

The document *Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy*, published by the National Science & Technology Council's Joint Subcommittee on Ocean Science and Technology in January of 2007, presents the "national research priorities that focus on the most compelling issues in key areas of interaction between society and the ocean".

The research priorities presented in *Charting the Course* are grouped into six societal themes that focus primarily on the water column and coastal waterways. While the elements and priorities outlined are critical to our understanding of the ocean, the inclusion of themes related to observations made through scientific ocean drilling strengthen the document's impact because the study of the sub-seafloor underpins the other elements of the priorities plan.

The United States has been a world leader in scientific ocean drilling for almost forty years. The initial scientific drilling programs, the Deep Sea Drilling Program (DSDP) and the Ocean Drilling Program (ODP), both relied on US-supplied vessels collecting over 200,000 meters of samples from the sub-seafloor. Today, the research continues with the Integrated Ocean Drilling Program (IODP), an international collaboration sailing on three drilling platforms: the *JOIDES Resolution* (supplied by the United States), the *Chikyu* (supplied by Japan), and mission specific platforms (jack-up rigs, ice-breakers, etc., supplied by a European consortium).

Conventional methods of studying the ocean observe one point in time, possibly extending observations to decades. Observations made through scientific ocean drilling add up to 125 million years to our knowledge of the oceans and the global climate. Understanding the natural oceanic and climatic cycles over long time periods allows the magnitude of anthropogenic effects to be quantified. In addition, scientific ocean drilling has played an important role in determining the nature and extent of a new energy source – gas hydrates – as well as focusing on geologic hazards that continually threaten coastal regions or potentially cause global catastrophes.

Deep sampling of the seafloor unlocks a vibrant dimension in understanding the world's oceans as both an economic and a scientific resource, themes directly related to *Charting the Course*.

THEME 1: STEWARDSHIP OF NATURAL AND CULTURAL OCEAN RESOURCES

The ocean floor has an abundance of natural resources, from natural gas and petroleum to iron-manganese nodules and metal sulfide deposits to gas hydrates, a crystalline substance that looks like ice and forms when water and methane are combined at high pressure and low temperature.

Gas Hydrates: Gas hydrates store a significant fraction of the global carbon budget, having considerable implications for energy resources and climate. Climate, currents, and earthquake activity can destabilize these deposits, resulting in submarine landslides and massive methane release. These rapid changes in the seafloor and subseafloor environment can be understood through real-time monitoring by recent advances in technology.

Data obtained through scientific drilling in the last decade have been critical in improving our understanding of the processes that control gas hydrate formation. Scientists can now quantify the amount of gas hydrate marine sediments, link local methane generation and transport through the sediments, and quantify fluid and gas advection rates. Within the sediments and at the seafloor, complex and complementary microbial relationships that produce and consume methane have been discovered. A current area of research includes the response of gas hydrates to warming of the Arctic shelf, which results in methane release. A robust assessment of potential methane release from destabilization of permafrost-associated gas hydrate requires surveying the size and distribution of the reservoir and the processes responsible for gas hydrate dynamics in this sensitive region.

Mineral Resources: Scientific ocean drilling has revolutionized the understanding of the formation of Fe-Cu-Zn massive sulfide ore deposits at sediment covered spreading ridges. Expeditions have identified two different modes of massive sulfide formation, and subsequent research on them provided important information regarding the ore-forming processes. The discovery of an unexpected high-grade copper replacement mineralization below vein-controlled feeder zone mineralization caused international resource companies to review their exploration strategies-annual impact of roughly $500 million.

THEME 2: INCREASING RESILIENCE TO NATURAL HAZARDS

The 2004 Sumatra earthquake and associated tsunami off the coast of Indonesia vividly demonstrated the potential magnitude of oceanic natural hazards. Scientific ocean drilling allows scientists to access otherwise unrecoverable data, allowing for the study of the mechanisms, consequences, and periodicity of natural hazards such as tsunamis, but also earthquakes, landslides, volcanic eruptions, and meteoroid impacts.

Earthquakes: The Integrated Ocean Drilling Program has launched an ambitious five-year drilling project off the coast of Japan to drill into the earthquake-generating zone of the Nankai Trough. The expedition will, for the first time, directly observe earthquake mechanisms in a subduction zone. Scientists are collecting samples from the fault zone to study the frictional properties of the rocks and will install sensors to record earthquakes at the source. The collected data will yield insights into the processes responsible for earthquakes and associated tsunamis, including how water and rock interact in subduction zones to influence earthquake occurrence and related tsunami generation.

Landslides: Submarine landslides have produced huge tsunamis, with future collapses threatening the coastal United States. The Nuuanu Landslide, 300 km northeast of Honolulu, resulted from the catastrophic removal of over 3,000 km^3 of rock from the Koolau Volcano. This massive landslide was drilled in 2001-2002 revealing that it correlated with two eruptions of Koolau – each an order of magnitude larger than the 1980 Mt. St. Helens eruption – approximately 2 million year ago, which probably instigated the landslide event. An expedition to the Gulf of Mexico successfully recorded, for the first time, the conditions that facilitated past slope failures in this region. The measurements recorded will improve our accuracy in modeling fluid flow and the role of fluid over pressurization in slope failure.

Volcanic Eruptions: Mt. St. Helens is a small volcano compared to those that rise from the ocean floor. Volcanoes that produce massive eruptions (large igneous provinces) in the ocean have resulted in plateaus and mountains that have significantly altered the seafloor's topography and potentially ocean circulation and ocean chemistry. While they have not occurred within the short human written record, large-scale eruptions have often occurred throughout the history of the planet, resulting in massive tidal waves and dramatically altering the planet's climate. Investigations performed through scientific ocean drilling have shown that the resulting plateaus and mountains formed quickly over relatively short periods of geologic time. Some of the eruptions have also been linked with global ocean anoxic events, suggesting that they may have been the cause for the extinction of some species.

Meteoroid Impact: The most famous meteoroid impact, blamed for the extinction of the dinosaurs, occurred at Chicxulub close to the Yucatan Peninsula 65 million years ago. This impact, however, has subsequently been buried by oceanic sediments and remains hidden from view. Investigations exploring this and other craters are now underway though surveys that use seismic waves to image the site and scientific ocean drilling to collect physical samples. Ash and sediments from the Chicxulub impact, for example, have been recovered around the world, clearly demonstrating the global consequences of such impacts.

THEME 4: THE OCEAN'S ROLE IN CLIMATE

The importance of scientific ocean drilling's revelations about the Earth's past climate cannot be understated. Past climatic variations provide a key framework for quantifying the human effect on the global climate. Humans, by emitting greenhouse gases, are causing the global climate to change in a way that has not occurred in the recent past. These human impacts are superimposed on natural climate variations -- variations that cannot be investigated using historical climate observations. Sediments recovered through scientific ocean drilling, however, contain millions of years of records on past climates. These records are contained within the rocks' sedimentary structures, biology, and geochemistry.

The geologic history of the Earth includes dramatic climate events that can be studied to answer pressing questions regarding future climate change. For example, expeditions have focused on understanding how fast ice sheets melt as climate changes, how sensitive the Earth's temperature is to natural greenhouse gas increases and decreases in the past, how ecosystems adapt to gradual versus catastrophic climate change, how changes in ocean circulation lead to abrupt climate change, and other questions relevant to current and future climate change. A few examples of past scientific ocean drilling accomplishments are described below.

Pliocene Warm Period and Permanent El Niño: Scientific ocean drilling of the Pacific Ocean has revealed the role of that ocean basin on global climate change. Sediments collected from beneath the seafloor show that prior to the onset of the ice ages, about three million years ago in the early Pliocene, carbon dioxide levels were similar to today. Surprisingly, the Earth was warmer than today by about 3˚C, indicating that the climate has been extremely sensitive to changes in atmospheric carbon dioxide concentrations. Ocean conditions during this time period resembled that of a permanent El Niño, which strongly influences the North American climate. Paleoclimatologists, armed with data from beneath the seafloor, are working with climate dynamicists to further refine climate models and understand what the Pliocene warm period can tell us about our future climate.

Global Warming and Arctic Climate: The Arctic is thought to be an early indicator of global climate change, as evidenced by dramatic increases in temperature and decreases in sea ice extent over the last century. To judge whether climate change is affecting the Arctic regimes, scientists must first quantify the natural variability of its climate. Only then can they determine the region's sensitivity to changes in greenhouse gases quantities. In 2005, the first scientific drilling expedition to explore the Artic Ocean recovered sediment from the Lomonosov Ridge at a point only 250 km from the North Pole. The results from these investigations show that the Arctic had a tropical climate and ecosystem 55 million years ago, which was the last time the atmosphere contained extremely high quantities of carbon dioxide. The cold climate and sea ice which we are familiar with appeared only when carbon dioxide levels dropped to about pre-industrial values around 15 million years ago.

Climate Cycles and Episodes of Drought: Through scientific drilling in ocean basins off the California and Venezuela coasts, scientists have recovered sedimentary sequences with such high rates of accumulation that they can resolve rapid climate changes. At these locations, the natural variability of ocean and climate conditions can be studied on decadal or centennial time periods. For example, scientists can track the climate during the rise of the Mayan civilization and after it's fall. Detailed environmental records show that there was a major climate shift, resulting in multi-year droughts, at the time the Mayan culture collapsed between 750 and 950 A.D. Through scientific ocean drilling, natural climate variations that can potentially impact water resources and habitability can be studied.

Sea-Level Change: Climate change often results in sea-level change as global temperature changes can produce or melt continental glaciers, thereby adding or removing water from the oceans. As the last ice age ended, sea level rose as continental ice melted, submerging land that was once dry, especially off the eastern United States. Scientific ocean drilling has focused on three areas where sea-level change can be studied in detail – the New Jersey margin, the Antarctic, and Tahiti. Together, these expeditions have defined the history of sea level rise and fall over the past 60 million years. Scientists have also investigated how sediment transport and coral growth are affected by sea level changes.

THEMES 3, 5, AND 6

Scientists use the sediments cored by scientific ocean drilling to determine the natural state of and the variability within the environment at a given location. This crucial information places the anthropogenic effects on the environment into context. Are humans having a large or small effect on their environment? Are the changes we see in climate patters or ice patters part of the Earth's natural variability? How much change is normal in any given ecosystem?

Monitoring of ecosystems, currents, and oceanic conditions only stretches back to a maximum of 100 years; data collected from beneath the seafloor extends these records back 100 million years. Deep-sea samples and observations offer unprecedented opportunities to study past climate change, effects of natural hazard, and sub-seafloor microbial activity. As geoscientists analyze and interpret past climate and tectonic regimes, they provide the parameters that are used to build and define models that predict future changes. These data will lead to the better understanding of ocean and climate conditions, enabling marine operations, improving ecosystem health, and enhancing human health.

SUMMARY

As scientists determine the extent of human impact on global climate and the world's oceans, they must quantify the natural system and, more importantly, variations therein. Since 1968, scientific ocean drilling has compiled a priceless database of material and measurements from the world's oceans that has facilitated the study of the natural climate and oceanic systems over the last 100 million years, as well as the natural phenomena that can affect these systems. Scientific ocean drilling has also provided vital insights into the natural hazards that could affect the way of life at the local, regional, and even global levels, and into vast sub-seafloor ecosystems that are controlled by contrasting hydrothermal circulation, water-rock reactions, and a diverse microbiosphere. This significant contribution demonstrates that scientific ocean drilling is an essential underpinning component of the nation's ocean research program, and should be fully backed by the scientific community and policymakers.