A Portfolio of Marine Science Education and Outreach Projects

by

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Research Report

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Chapter 1 - Introduction

Curiosity about how the world works plays a fundamental role as a driver of progress in science. In addition, the need to solve practical problems has motivated researchers and their supporters to seek further knowledge. As long as human beings have encountered the oceans, both factors have driven the ambition of understanding our water planet. The science of oceanography as we know it today was heralded by the round-the-world Challenger expedition (1872-1876) which was undertaken to make a wide variety of ocean observations (Deacon 2001). The need for further gathering of oceanographic information by countries around the world increased over the last century as political and economic agendas broadened. Specifically, control and thus knowledge of the seas became an imperative of military supremacy.

Accordingly, much of the oceanographic science in the United States during the 1900's was carried out to address the needs of the military. For example, improvements made to submarines in the early 1900's offered the promise of a powerful defense platform and pushed the development of ocean acoustics to the sonar we are familiar with today. Oceanographic science continued to be viewed as essential to fulfill military and economic needs throughout the Cold War and financial support tended to increase during this time frame. Once the Cold War abated, however, oceanography and science in general came under greater scrutiny in the competition for support.

In the United States of America, the government fiscal situation in the late 1990's led to pressure for greater accountability across many federal agencies. In the competition for resources, science funding agencies must now demonstrate the broader impacts of their science investments. The National Science Foundation (NSF) currently accounts for approximately 20% of the federal funding for research and education in science and engineering in the United States (NSF 2004) and is a major supporter of ocean science. Funds are distributed by NSF on a competitive basis with peer-review evaluation. To address the increasing accountability requirements, NSF instituted a new proposal review criterion on October 1, 2002. The first criterion remains the intellectual merit of the proposed activity while the new criterion explicitly requires that investigators detail the broader impacts of the proposed activity. Broader impacts include promoting teaching, training and learning; increasing the presence of underrepresented groups in science; enhancing research/education infrastructure; disseminating results broadly; and demonstrating how the proposed science benefits society.

As the need for accountability increases so does the need for experience in making research science accessible to the general public. In recognition of the growth of such a trend, the Marine Resource Management (MRM) Program in the College of Oceanic and Atmospheric Science (COAS) at Oregon State University (OSU) added a focus on Marine Education and Outreach as part of a recent reassessment of its academic areas of concentration. This master's thesis is one of the first aimed expressly at this focus.

The work described herein entailed three separate but related education/outreach activities aimed at distinct audiences. This portfolio required acquisition of a range of skills in order to effectively convey information in a fashion accessible to each target audience. The first project consists of contributions to a sample chapter of a book summarizing the present-day understanding of coastal Oregon oceanography for the general public. The second project is the development and teaching of two "suitcase" lessons in oceanography on icebergs and sea-ice aimed at a third grade level. The third project entailed public relations in support of the permitting process for oceanographic research in waters adjacent to northern Canada and Greenland. A chronicle of activities was written with the intention of benefiting other practitioners of science and native communities in the region. What follows is a summary of each of these three projects.

Chapter 2 - Oregon Ocean Book II

The objective of this project is to update the Oregon Ocean Book (Paramenter and Bailey 1985) which was published in 1985. The first Oregon Ocean Book is a discipline-organized overview of the Oregon coastal marine environment aimed at the general public. Several Oregon high school and community college teachers found the book to be a good source of locally relevant material for use in their classrooms. However, numerous discoveries in oceanography have been made since the inception of the Oregon Ocean Book rendering much of the original material out-of-date.

A brainstorming group was established in April 2002 with the task to delve into visions for an Oregon Ocean Book II (OOBII). The group consisted of scientists and authors who wrote the first Oregon Oceans Book, a local high school science teacher who currently uses the book as a teaching aid, and members from a wide range of programs at OSU and the National Oceanic and Atmospheric Administration (NOAA) facility in Newport, OR. The consensus goal from the brainstorming sessions was that the OOBII should serve as an image rich education and information resource. It should center on the new findings in oceanography in the past two decades. The target audience will continue to be the general public with the text at a high school reading level in order to be accessible. Material will be organized in thematic chapters as opposed to discipline based chapters, but it will not be cast as a text book as there are already numerous references on the market relating to general principals of ocean science. In keeping with its current worth as a teaching aid, the OOBII will fulfill the role as a locally relevant source of oceanographic material for use in a high school or community college setting.

With it's approximately 340 miles of coastline, Oregon is home to a well-established science community who study the unique coastal zone that it has to offer. Yet many of these scientists and what they study are known to the public on a very limited basis. There needs to be a more accessible source of new knowledge about the Oregon coast for the public, given the importance of the ocean in defining the State of Oregon. Not only will the OOBII present current Oregon-specific findings and new technologies in oceanography but it will highlight the people behind the research.

As one of the contributions to the revision of this book for this research report, in January 2003 a questionnaire was circulated to the science community in Oregon to gain insight into what topics are important to cover in the OOBII. The questionnaires were compiled and organized into a contact list and summary of important issues. The following thematic chapters with sample contents were born out of the responses that were received in addition to the brainstorming committee effort:

The Seafloor & Below
high resolution bathymetry, ridges and vents, seeps, hydrates, sediment records, earthquake history
The Ocean & Above
winds, circulation, seasonal regimes, key places, El Niño, nutrients, climate
Marine Community Tours
presentation of ecosystems from offshore toward land & along coast
Where Land & Ocean Meet
beaches, deposition, erosion, wave climate, engineering
Where People and Ocean Meet
hazards, pollution, management, resources, a look forward: stewardship, recreation

It is envisioned that a supplemental DVD will accompany the OOBII for inclusion of several educational activities, for example, a list of references for inquiry-based, hands-on activities that meet state and federal science objectives. The DVD will also likely include short videos and games relating to "Five Really Big Things to Know about the Ocean," currently in production by Oregon Sea Grant.

An implementation team was formed as of summer 2003 with the goals of seeking funding sources and communicating with OSU Press. It was decided that a sample chapter should be produced to have a tangible product to present to a range of possible funding sources. Virginia Gewin, an experienced freelance science writer was initially hired for this task. With guidance from OSU oceanographer Kelly Falkner and assistance from myself, Virginia interviewed numerous scientists throughout the state and compiled material for the writing of "The Seafloor and Below." My role was to compile the images for this chapter and develop the first draft of topical sidebars on coring and sonar which will be included in the chapter as insets. Other insets included member profiles of people in the Oregon science community and the Astoria Canyon. Virginia's edition was reworked by several members of the COAS publications support office and at present is still in draft form (Appendix 1).

From this point on the implementation plan consists of:

1. Obtain supplementary funds to existing NSF related science grants (NSF RFP 03-509 Communicating research results to public audiences) so that Principle Investigator's can synthesize primary materials to contribute to the OOBII and Sea Grant films and leverage their outreach to a much broader audience than typical (winter05).
2. Propose a program to the Education and Human Resources and/or the Ocean

Science divisions of NSF to employ marine resource management students interested in concentrating on outreach to create and produce all but the Sea Grant video aspects of the supplemental DVD (winter 05).

3. Obtain funding from Oregon based private foundations (such as the Fred Meyer Trust) to allow proactive distribution of the OOBII to libraries and schools (fall 05).
4. Produce the remaining chapters following an implementation strategy similar to that used to produce the sample chapter: i.e. K. Falkner to spearhead project; science editing by K. Falkner, P. Komar, J. Good, A. Trehu, J. Barth, and others (spring 05-summer 06).
5. OSU press reviews, edits, lays out and produces book (fall 06-spring 07)

Chapter 2.1 - Summary

The goal for this sample chapter was to end up with a product, which fulfilled the task of combining various aspects of the Oregon ocean and coastal environment into a text that was easily readable and visually stimulating for the general public. Along with the writing, my main contribution in piecing together this sample chapter was the gathering of images. This activity was undertaken somewhat independently of the main text writing by Virginia.

Meetings to discuss the content and text of the sample chapter included me, Kelly Falkner and Virginia. They took place approximately once a week from September through November, 2004. During the month of November I met with Virginia, independently, a few times to discuss what might work well for image content and layout. Her suggestions coupled with my thought on possible images led to the current iteration of the images in the draft (Appendix 1).

The first time the images were laid out with the text was just shy of a year after the chapter writing process began. The need for sending images and text through the publishing department at COAS for layout added much time to the project, to the point where the draft version of the images were not placed with the most current version of the text. A project like this would benefit from much more communication and collaboration between the text writers, image gatherers and layout personnel during the whole process. I would recommend that the layout be worked up early on, especially by the person who is responsible for gathering the images. This would give the layout creative control to someone who is more closely linked to the project.

When writing the text, Virginia struggled with this project as it differed substantially from the science journal articles she was used to writing. For a general public audience, science jargon must be avoided so that the material is accessible. Although much of her writing was adequate in this regard, the overall chapter lacked cohesion and so defeated the purpose of having it thematic based. After Virginia turned in her final draft and relocated to the Portland, OR area, the COAS Publishing office attempted to adapt the chapter into a more cohesive product. In the process, they decided to completely rework the organization of the material. Their revised version was problematic for some of the basic science included in the draft is not correct.

For the text the recommendation would be to have a scientist devote time to the writing of this sample chapter with the help of experienced editors. The hindrance, naturally, is funding to be able to do this. This project has probably floundered in part because it has not had the devoted attention it requires.

Chapter 3 - Suitcase Lessons in Oceanography

Suitcase Lessons in Oceanography were conceived of by Dr. Marta Torres of COAS. Marta is the principal investigator of an NSF funded program to develop elementary school level lessons covering four topical areas (Earth materials, Icebergs and Sea Ice, Air and Weather, and Mixtures and Solution) in marine science ("Developing suitcase lessons in Oceanography for K-6 students in concert with the FOSS-bases science curriculum currently in use by a tri-county educational district," GEO-0224566, period: 8/15/02 - 8/14/05). The lessons were integrated into preexisting Full Option Science System (FOSS) kits to act as an ocean science supplement.

FOSS kits came into being approximately 20 years ago at the Lawrence Hall of Science, University of California at Berkeley. FOSS kits are an inquiry-based science curriculum targeting students in grades K-8. These kits provide all materials needed for activities, experiments and lesson plans for 3-5 weeks of curriculum, in 2-3 plastic tubs. They were created to address the lack of science taught in the lower levels of education. Three overarching themes are incorporated in the FOSS approach: Scientific Literacy, Instructional Efficiency and Systemic Reform. Scientific Literacy refers to providing a foundation through age-appropriate learning that will open the door for more advanced scientific learning in the future. Instructional Efficiency incorporates the findings of current learning research (collaborative learning and student discourse) and stresses hands-on, inquiry-based, multi-sensory learning. This is proven to be more engaging than the traditional lecture formats. Systemic Reform refers to meeting national and state science standards along with stressing first hand experiences as opposed to passive exposure.

Suitcase Lessons in Oceanography relay ocean-related science concepts by adopting the successful design template employed in FOSS kits. Objectives of the suitcase lessons are to isolate and apply scientific concepts that will challenge the children and act as a foundation for higher levels of science learning. This fundamental science is reinforced at the K-6 level through the process of scientific research and the excitement of discovery.

The four suitcase lessons covered by the scope of the grant are based on the concept of earth as a system. Children learn how to simplify and apply concepts through the use of models in class activities. Activities focus on fundamental scientific concepts like cycles, density, temperature, mixtures, solutions, technologies, and changes through time. The design and testing of the four suitcase lessons took place in 2002-2004. Two suitcase lessons, Mixtures and Solutions (Figure 1) and Earth Materials were completed the first year. The first two suitcase lessons target 5^{th} graders and 2^{nd} -3^{rd} graders respectively. The second two lessons each targeted 3^{rd} graders.

The contribution of this research report was aimed to the latter age group and the topics concerned the Role of the Ocean in Weather and Icebergs and Sea Ice. My personal experiences with sea ice and icebergs during a month long scientific cruise in Nares Strait provided inspiration. Observation and assistance with teaching a previously created suitcase lesson (Figure 1) the spring prior to this project also helped to qualify me for lesson development.

Figure 1: Scott McAuliffe assisting a student with the Mixtures and solutions suitcase lesson, 2003.

Suitcase Lessons are available to local teachers for check out from COAS and teachers have the option of requesting that an oceanographer accompany the kit and teach the lesson. Each lesson is designed to take approximately 1 hour with 1-2 lessons per kit. Since they adhere to a FOSS-inspired all-inclusive design, Suitcase Lessons should be exportable to other school districts and are also applicable to settings beyond the classroom and targeted age-groups. Successful examples of the latter include use in public relations in Grise Fjord, Canada (spring 2003) and Qaanaaq, Greenland (summer 2004) (Figure 2, Figure 3). Members of the College of Oceanic & Atmospheric Science who are called upon by elementary schools to make presentations can benefit from ready access to these well-tested, age-appropriate materials. For the benefit of future development of Suitcase Lessons, a brief chronicle of the developmental stages of the icebergs and sea ice suitcase lessons is provided below.

Figure 2: Scott McAuliffe teaching the iceberg and sea ice suitcase lesson in Qaanaaq, Greenland, 2004.

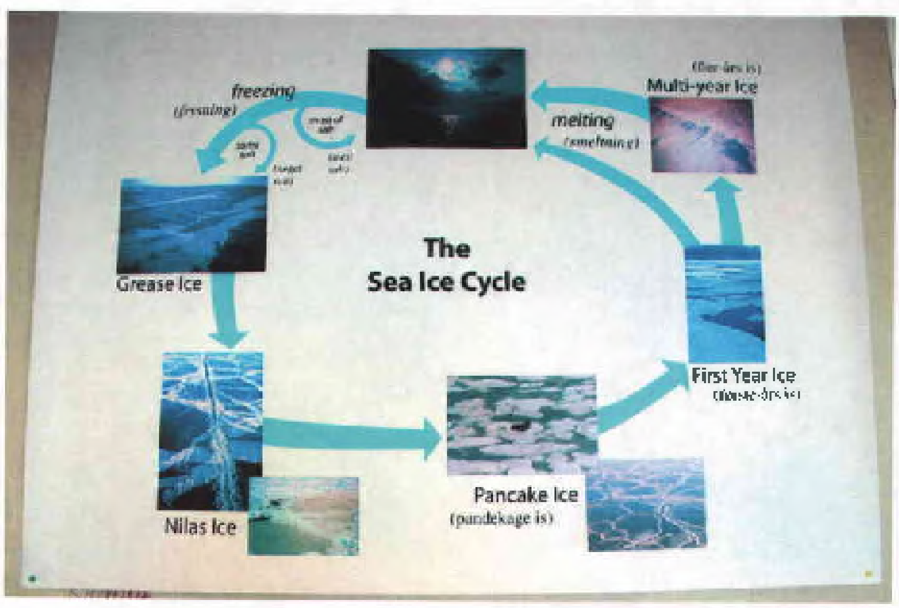

Figure 3: The sea ice cycle poster on the wall in a classroom in Qaanaaq, Greenland.

Chapter 3.1 - Chronicle of Suitcase Lesson Development

In September 2003, I began developing a suitcase lesson on icebergs and sea ice aimed at the third grade level. I conducted background research via the internet and located libraries with a variety of children's activity books (Simon 1988; VanCleave 1996; Project Wet 1995). From these sources I conducted an initial assessment of the level of information and activities that were appropriate to the age group. A thematic-based approach to lesson development was undertaken since children benefit from being able to link together objectives of lessons to one overarching topic (Ham 1992). Moreover, linkage of the theme to familiar personal circumstances is desirable in making a subject understood. I chose global warming as the theme for my lessons and conceived that iceberg/sea ice formation and melting would be taught in reference to the effect global warming has on them. My thought was to relate everyday life in Oregon (running automobiles releasing greenhouse gasses) to melting icebergs/sea ice and sea level rise.

The initial lesson plan consisted of delineating basic differences between the physical characteristics of icebergs and sea ice, describing the cycle of iceberg and sea ice formation, and conducting two experiments. The first experiment was supposed to demonstrate the effect of global warming on sea level rise while the second showed the fraction of an iceberg seen from the surface compared to that underwater. Experiment one involved filling two plastic cups halfway with water. The "iceberg" cup was marked at the water line then an ice cube was dropped into it. The "sea ice" cup had an ice cube placed into it before the water line was marked. Over the course of the lesson the ice melted and the objective was to observe the cups toward the end the lesson when the new water line on the iceberg cup would be higher the original marked water line. The water line on the sea ice cup would remain the same. The take home message is that icebergs are an input of water into the ocean and sea ice is formed from the existing ocean water. As global temperatures rise, melting icebergs will have a greater effect on sea level rise than melting sea ice. The second experiment involved an "iceberg" created in a freezer. The iceberg was placed into a clear bowl where it can be observed that most of an iceberg is underwater (Simon, 1988). The observations can be extrapolated into why icebergs are dangerous to ships.

I piloted the first draft of the lesson in mid December 2003 to a group of three second and third graders in my home. My approach was largely lecture based. It was quickly apparent that the lesson was neither hands-on enough nor conducive to an elementary school learning style. Global warming, as a theme, seemed overly complex for this age and much of the lesson was either not applicable to the theme or came off as rote recitation facts. Neither experiment was very effective in conveying the intended ideas. This experience highlighted to me the need to identify in very concrete terms what is intended to be relayed to this age group via experiments. Actually running through each experiment ahead of time could have sorted out the worthwhile from extraneous components and where there might be stumbling blocks.

Seeking experienced advice I spoke with Gail Gerdeman, presently teaching kindergarten but who also is in charge of maintaining and distributing the district FOSS kits. I also sought advice from Professor Dave Stemper, OSU Forestry Department, who specializes in environmental interpretation, and Gerhard Behrens, a local third grade teacher who is proactive in science education. Gail Gerdeman suggested that I replace the global warming concept with the basics of the formation cycles. She also suggested that I simplify some of the logistical aspects of my lesson. Instead of one long lesson packed with information, I elected to create two 45 minute lessons with fewer concepts but more reinforcement. The three concepts I chose to emphasize were the formation cycles of sea ice and icebergs, a physical description of sea ice and icebergs, and adaptation by animals and people to the polar environments. Dave Stemper pointed me toward "interpretive design" in which personification is often applied to an inanimate object (Ham 1992). In this case a water molecule was personified to bring the language to a level with which the students could relate. I coupled that with having kids imagine they were water molecules walking through the iceberg and sea ice cycles (Project Wet, 1995). Third grade teacher, Gerhard Behrens, had the further suggestion that I have the entire class move through each cycle together to ensure that everyone is engaged in the activity.

The lesson was piloted a second time in March, 2004, to a group of four children in an OSU campus setting. It was well received by the children and parents. Much of the lesson transcended age for it was new and informative to the parents as well as students. Although things went well, I retained some concern that the small group was easier to handle than would be a larger group in a formal classroom setting. I made relatively minor changes and delivered the lessons in three separate classrooms at a local elementary school. The two lessons were taught on consecutive days to each group and each two-day teaching period was approximately one week apart to allow me time to adapt the lesson according to feedback from outside observers present at each lesson. The most significant suggestion was that I cut the animal and human adaptations to polar climates due to time constraints and the lack of cohesion with the rest of the lessons. This advice helped to keep the lessons within the allotted 1-hour time-frames.

Dr. Kelly Falkner and Dr. Marta Torres met with me following my last lesson for a final debriefing. They raised an important issue regarding word choices. During my lessons, in an attempt to be empathetic, I noted that science could be "hard" or "tricky". This unfortunately could reinforce that science is inaccessible for children who do not consider themselves smart. Another key point to keep in mind when teaching children in elementary school is to limit the amount of lecture time, for children tune out almost immediately in a lecture situation. It is important to plan for smooth and quick transitions from activity to activity to retain the interest of the children. It appeared to be quite effective to stress movement, hands-on participation and personification for this age group. This is likely to be true with younger groups as well but not necessarily for older children for whom self-consciousness may inhibit participation.

By mid July, 2004, all written materials for the iceberg and sea ice lessons were posted on the COAS website (http://www.coas.oregonstate.edu/index.cfm?fuseaction=content.display&id=502). The suitcase lesson kit is available from COAS through its Publications and Outreach Office (Appendix 2).

Chapter 3.2 - Summary

The development of a Suitcase Lesson for third grade children was initially a struggle for me. Conveying scientific information to a younger audience differed greatly from communicating with my graduate school peers. The key is to deliver information in a concise and interesting manner that emphasizes the fun in science as opposed to learning the details. The following is a compilation of findings from my development experience:

- Avoid using complex conceptual jargon such as "global warming" when teaching elementary school kids.
- Avoid lecturing to this age-group.
- Encourage active participation from the class.
- Utilize a mix of teaching styles to cater to the various learning styles in the classroom such as:
    - Kinesthetic Learning techniques: This includes the formulation of experiments and activities that are hands-on and stimulating. Scientific concepts are better understood through "doing" as opposed to "hearing" or "seeing"
    - Multimedia: utilize various types of visual and audio stimulation to inform and excite the students
- Avoid stating that science is "hard" for that goes against what we, as teachers of science, want to convey to the children. Science is already fighting a preconceived notion that it is too complicated to learn so it is best not to reinforce that at an early age.

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Chapter 4 - Obtaining Science Permits in Nunavut, Canada and Northern Greenland: A Chronicle for the Nares Strait Freshwater Flux Project

The need for conducting science research in the Arctic continues to grow as its role in the global system becomes increasingly apparent. This environment has been subject to significant changes over recent decades (Serreze *et. al.*, 2000). Things such as the shrinking of the Arctic sea ice cover and warming of vast areas of permafrost signify important changes for global ocean circulation and climate, and challenges to human societies and infrastructure. In addition to environmental change, there have been dramatic social changes. With the establishment of a Home Rule government in Greenland in 1979 and the Province of Nunavut, Canada in 1999, Inuit people of Greenland and of Canada have acquired political control over their traditional homelands. (Note: In referring to Aboriginal peoples this text uses the designation *Inuit* for the Indigenous inhabitants of the Canadian territory of Nunavut and the indigenous people of Greenland. However, *Inughuit* are a subset of Inuit and refer specifically to the indigenous people of the Thule District, northern Greenland. This term is used herein when the Indigenous people of the Thule District are addressed specifically (Dick 2001)). For scientists who derive almost exclusively from non-Inuit cultures, these developments have ushered in a new era for research in the north. The situation for obtaining permission to conduct scientific research in the Arctic is evolving rapidly and varies by region and activity.

Historically, the explorations of Robert Peary, Knud Rasmussen and others have provided much knowledge about the geography, resources and peoples of the

Arctic. Some of their endeavors came about at the expense of Indigenous cultures while some benefited these cultures. Numerous anecdotes illustrate the potential for miscommunication and negative consequences in interactions between scientists and indigenous communities. A few examples of these are presented here. Current practice for scientific research licensing emphasizes compliance by outside communities with native community regulations and requests.

This document provides a chronicle of the communications and permitting process with native communities in Greenland and Nunavut in association with an NSF-sponsored, five-year Freshwater Flux Study being conducted in Nares Strait under the leadership of Dr. Kelly Falkner. It is the intention that this document serve to record a small piece of history in the making. While the observations herein are necessarily biased from a Western cultural perspective, an attempt is made to identify factors that affect our differing worldviews and so need to be recognized to avoid miscommunication. Hopefully this chronicle will aid Arctic researchers and indigenous communities by providing an example of an approach that was largely successful.

Chapter 4.1 - The Legacy of Early Exploration of the Arctic

Exploration of the Arctic region by Western civilization commenced with Pytheas, a Greek geographer around 325 B.C., who can be loosely considered the first Arctic explorer. His travels took him as far north as what is present day Iceland. With the rise of the Norsemen in the 9th century, exploratory voyages into the ice-filled waters of the North Atlantic increased. By the 15th century, the impetus for extensive Arctic exploration became economic. The goal was to find a faster way to the riches of the Far East by searching for a Northwest Passage. The search continued into the mid 19th century when Sir John Franklin and a crew of 129 officers and men set out on an expedition from Great Britain aboard the H.M.S *Terror* and H.M.S. *Erebus*. Their failure to return launched numerous efforts to determine their fate. Ultimately it was shown that the explorers of the Franklin expedition had succumbed to the harsh winter conditions. Not all was lost, though, as searching for the Franklin expedition expanded knowledge of the region and set the stage for the quest to be the first to achieve the North Pole (Ley 1962).

John Ross, in 1818, is credited with the first recorded western contact with the Inughuit of the far North. In 1886 Robert Peary (1856-1920) had his first encounter with Greenland by exploring the ice cap north of what is the present day village of Qaanaaq. This Arctic experience transferred into his determination to be the first to reach the North Pole and Peary consumed the next 23 years of his life in pursuit of this goal. After two failed attempts in 1893 and 1906, Peary, with the aid of local Inughuit assistants, claimed to be the first to reach the North Pole in 1909. Although there remains some doubt as to this claim, there is little doubt that Peary had a large and lasting impact on the Inughuit and wildlife resources of the far north. The northern Greenland village of Uummannaq was used by Peary as a staging area for his expeditions. He was instrumental in changing the Inughuit culture through the distribution of guns and metal implements even though the Inughuit had previous instances of rejecting western culture (Malaurie 2003).

In 1897, at the request of members of the Natural History Museum in New York, Peary managed to convince six Inughuit, including one named Minik, to accompany him from Thule to New York City. Four of the Inughuit including Minik's father died soon after arrival while one returned to Thule within the year leaving young Minik in New York. The famed anthropologist Franz Boas arranged a burial for Minik's father while in fact his bones were studied and placed on display in the Museum of Natural History (Harper 2001). The bones of the four Inughuit who died were housed in the museum, until recently, for further study.

The story of Minik and the displaced bones contributed to an accumulating sense of wrong doing in the eyes of the outside world. However, that sense did not necessarily hold true when viewed by the northern Greenland population as ancestors of Minik and present day villagers of Qaanaaq showed little interest in the return of Inughuit bones to the North (Carpenter 1997). The collection of Inughuit bones housed by the Museum of Natural History was ultimately returned to northern Greenland, village of Qaanaaq, in 1993.

Peary also brought to New York back the Cape York meteorites, which had historically been a significant iron source for the Inughuit. The meteorites are currently housed in the Museum of Natural History in New York City. To this day, members of the Qaanaaq community view the taking of the meteorites as thievery and desire to have them returned to northern Greenland. Although the meteorites are no longer a feasible source of iron, they are a symbol of cultural identity for the Inughuit and they exemplify looting of traditional resources by westerners under the name of "science".

Knud Rasmussen (1879-1933), who by birthright was half Greenlandic, became a favorite son of Greenland through his exploration prowess and his ability to connect with the local community of Uummannaq. He and partner Peter Freuchen are responsible for establishing a reliable year-round trading station in Uummannaq in 1910. This trading post facilitated access to and reliance upon Western goods in Northern Greenland. While in Greenland he completed several expeditions including the famous 5th Expedition during which he navigated the Northwest Passage by dogsled. The 5th Expedition allowed him to connect with and record the cultural practices of indigenous people along the way and he is now credited with preserving ethnographic information that would have long been lost otherwise (Malaurie 2003).

In the northwestern Canadian Archipelago, Albert Peter Low (1861-1942) carried out an exploratory expedition in 1903. A geologist by trade and an avid explorer, Low was given the opportunity to travel aboard the steamship *Neptune* for a geologic survey. The cruise was scientific in nature, with an additional mission to exert Canada's sovereignty over what is now the territory of Nunavut. The *Neptune* cruise is recognized as securing Ellesmere Island, amongst others, for Canada (Dick 2001; Alcock 2003). By the time Low arrived to the region, the Inuit had been exposed to the western world largely through conducting trade with whaling operators. Low observed the impact of these influences in his writings (Low, 1906):

"A few years ago a firm to which the HMS *Active* belongs established a station on the south side of Southampton Island, Canada and imported a number of the Big Island natives [Inuit]. These natives, being provided with modern rifles, soon killed off or frightened away the deer in the neighbourhood. The old inhabitants of the island (Sagdlingmuit) being armed only with bow and arrows and spears, were unable to compete with the better armed strangers, and as a result the entire tribe, who numbered 68 souls in 1900, died of starvation and disease during the winter of 1902."

An important period in the Thule district concerns the exchange of technologies between the Inuit of Baffin Island and those of northern Greenland. Oral tradition states that Qitlaq, a shaman of the Pond Inlet area of Canada, had a vision of Inuit much farther to the north. His premonitions were confirmed by European whalers who brought word to the Canadian Inuit of the coexistence of their counterparts in northern Greenland (Malaurie 1956; Dick 2001). Qitlaq then lead 38 men, women and children on a quest for these people of the far north. About half that number made the full journey, as others turned back towards Baffin Island. The smaller party reached the northern Greenland establishment of Etah and proceeded to coexist with the Inughuit.

Through this contact, knowledge that had been lost was transferred back to the Inughuit. This included a superior technique for snow house construction, reintroduction of kayak construction and techniques for hunting from these boats (Gilberg 1975) and bow and arrow construction allowing the Inughuit to exploit their caribou resource. In turn, the Baffin Island group adopted the Inughuit sledge and way of hitching dogs, splayed in fan, which allowed for greater mobility over the rough, high Arctic ice.

Chapter 4.2 - Influences on Indigenous Societies in Northwestern Canada and Northern Greenland

Chapter 4.2.1 - Religion

The extensive search for the Northwest Passage left the western world with improved maps of the Arctic region and tales of Inuit tribes and an abundance of marine mammals. Following these tales, legions of whalers and missionaries journeyed to the Arctic. These two groups have had some of the greatest lasting impacts on the current Indigenous population. While whalers brought tools and goods such as cloth and tea, they also brought along alcohol and disease which spread rapidly through the Arctic communities. Outbreaks such as those reported by Captain Sherard Osborn in the mid 19^{th} century (Dick 2001) were not uncommon:

"Every whaler who had visited the coast northward of Cape York during late years reports deserted villages and dead bodies, as if some sudden epidemic had cut down men and women suddenly in their prime."

Missionary work was carried out by the Lutheran church which is currently the major religion in Greenland (Greenland Tourism 2004). In Canada the missionaries were primarily Anglican and a majority of Nunavut remains Anglican today (Canadian Statistics 2001). However, at the heart of Inuit identity and spirituality is the connection with their land and hunting grounds. It can be said that there exists an "umbilical" link between the Inuit and their environment (Malaurie, 1956). Traditionally, Inuit practiced a shamanistic religion that was forced underground by the many Christian missionaries. Shamanism is intertwined with nature through rituals and stories passed on by the elders. For example, the Sea Spirit, Sedna controls the hunted animals of the sea and it is essential for the local *angakkuq*, or shaman (Malaurie 2003) to appease her when the animals are scarce (Willis 1993). Shamanistic practice still remains evident in the Arctic to this day. For example, the author witnessed a ritual in Qaanaaq in which captured fish are placed on the ice facing the hole from which they came to allow their spirit to return to the sea and replenish the fish stock.

Chapter 4.2.2 - Language

Inuit relied on an exclusively oral tradition to educate the younger generation of their history and culture. However, a written form of the Inuit language was born from the need for missionaries to communicate in a media in with which they were familiar. Poul Egede, son of famous Greenland missionary Hans Egede, pioneered the written form of Greenlandic through the use of Roman orthography. He proceeded to publish a book on the grammar of Greenlandic in 1760 and translated the New Testament in 1766. Samuel Kleinschmidt took over where Egede left off by standardizing the written form of the Greenlandic language throughout Greenland (Harper 1983).

The Eastern Canadian written version of Inuktitut, a spoken language similar to Greenlandic, took on a much different written form as the early versions of it were based on Cree syllabics. The syllabic form of writing Inuktitut did not flourish until a missionary named James Edmund Peck arrived in Hudson Bay in 1876 with the job of teaching reading and writing to the Inuit and translating biblical material into Inuktitut. From that point on written Inuktitut, in Easter Canada, flourished and became a common means of communication.

The Greenlandic language is a variety of Inuktitut known as East Inuit. Inuktitut can be divided into several dialects which are spoken from Alaska, through Canada and into Greenland. Currently there is only one recognized written language in Greenland, Western Greenlandic, although there are distinct Eastern Greenlandic and Inughuit dialects. Western Greenlandic is discernable to speakers of Inughuit and Eastern Greenlandic. However, there is enough of a difference between the dialects that speakers of Eastern Greenlandic are currently promoting the creation of a written language. Schooling in Qaanaaq is in Greenlandic with an additional emphasis on Danish. However, the system is anticipated to change over the next decade to engender more of an emphasis on learning Danish.

Inuktitut is the working language of the government of Nunavut though government services and documents are also offered in English and French (Wonders 2003). There is a language barrier for English speaking people desiring to interact with native communities in Arctic Canada. However, it is not of the same degree as in northern Greenland, for many of the Canadian Inuit are taught English at an early age in the school system.

Since Greenland was once a colony of Denmark and is still under the Danish constitution the outside observer should be aware that Danes living in Greenland at the time of home rule establishment are legally Greenland citizens. Most academics, administrators, health service professionals and professionals in other trades in

Greenland are still ethnic Danes (Petersen 2001). They generally have good salaries and tend to have a more formal education than Indigenous Greenlanders. However, few ethnic Danes understand, let alone speak, Greenlandic. It is fairly common for Greenlandic people to speak Danish as a lot of business is conducted in Danish. People who speak Danish also tend to speak at least some English. This is especially true in Southern Greenland where a majority of the population has been educated in Denmark and has exposure to English speakers. These people tend to occupy positions in local government, local schools and the tourist industry. An unjust sense of hierarchy relegated by ethnic background is what inspired the path to home rule in the first place though it is something that clearly remains in existence in the present (Petersen 2001).

Another common problem throughout the Arctic is something known as "brain drain". Education of the next generation is considered essential by the local Arctic communities but once residents are educated they rarely return to the North to live. Jobs appropriate to advanced education remain sparse. Denmark tends to be where one goes from Greenland to become educated in a secondary institution. In order to do this a student must be able to speak Danish, which at this moment in time is not mandatory in the Qaanaaq school system. While there is a need to preserve Greenlandic by teaching it in schools, this may be limiting to students who wish to further their education in Denmark.

One last note on language of which researchers should be aware is that Danish and English place names have and will likely continue to be reverted back to their Greenlandic and Inuktitut designations. A prominent example is the village of Thule which is now known as Qaanaaq. The former is a Danish name given to the northern village by Knud Rasmussen. The installment known as the United States Thule Air Base in Northern Greenland is referred to by Inughuit as Pituffik. The capital city of Greenland named by missionary Hans Egede as Godthaab now goes by Nuuk. The capitol city of Nunavut is known as Iqaluit but was formerly Frobisher Bay. There are also geographic designations in Canada which have not officially been changed but are known nonetheless among the people by their Inuk names. For example, Grise Fiord is also Ausuittuq.

Chapter 4.2.3 - Technology

The introduction of Western technology to the Arctic has significantly impacted northern society and continues to do so today. Dogsled travel was eclipsed exclusively by snowmobile travel in Grise Fiord in the 1960's. One reason this occurred was the shift to a wage economy that this community underwent (Dick 2001). Suddenly, residents were working eight hours a day yet still needed time to hunt for their family. The fastest available mode of transportation to the hunting grounds was adopted to save time. This need coupled with a steady salary allowed them to afford snowmobiles which have become a way of life in the Canadian Arctic. Natives still employ dogs as hunters. They are also another set of ears, eyes and sensitive noses which can test ice stability and find the way home in the fog.

Greenland has outwardly shunned the use of snowmobiles and deferred to traditional dog teams and kayaks for transportation and hunting bear, seal, walrus and whale. Approximately five percent of Greenland's total population hunts for a living.

In the Thule region this proportion rises to fifty percent as Inughuit rely heavily on subsistence hunting (Dragsdahl, 2001).

The introduction and establishment of the television and satellite dish in the Arctic may arguably have had a greater impact on the loss of traditional knowledge and ways than motorized vehicles. These once isolated communities are now electronically connected to the outside world and during the long, dark winters there is much time to watch television and videos. Emulation of world pop culture amongst the present day youth is more common than not. While television introduces other languages and exposure to diverse cultures, it is a passive medium. Television robs time from other cultural traditions and brings with it the trade-offs known so well within southern cultures.

Chapter 4.2.4 - Political Developments in Greenland and Canada

July 9th, 1951, the United States initiated Operation Blue Jay, the building of the Thule Air Force Base, by sending 120 ships with 12,000 men to Northern Greenland. The base was completed in a short Arctic summer and is thus considered one of the most massive engineering feats of its time. In 1953, the 150 Inughuit of Thule, Greenland were forcibly moved by the government of Denmark to a location 150 km north. The sudden decision for relocation, on the part of Denmark, had to do with this installation of the United States Military Air Force Base (Fogelson 1987). Famed French explorer and ethnographer Jean Malaurie spent time in Thule during Operation Blue Jay writing that that "Inouk, the man with the harpoon, was doomed" (Malaurie 1953). More resilient than Malaurie gave credit for, in 1980 the Inughuit pressured the Danish government into investigating the reasons behind the relocation. A 1994 Danish-Greenlandic investigative report stated that the relocation of the Thule Tribe was not forced by the Danish government. Unwilling to accept this proclamation, Uussaqqak Quijaukitsoq, who was 4 years old at the time of the relocation, formed the group Hingitaq 53 or "1953 exiles" for the purpose of galvanizing the Inughuit fight against the Danish government. This group turned a small indigenous band of people into a political force and it paid off in 1999 when the case concerning the relocation of the Thule Tribe went to the Danish District Court. The District Court ruled in favor of the Thule Tribe finding their removal to have been "an unlawful violation done to the population of Uummannaq" (Dragsdahl, 2001). The Tribe was awarded a monetary sum and requested an apology from the Prime Minister of Denmark. September 2nd, 1999, the prime minister of Denmark, Poul Nyrup-Rasmussen, apologized in a written statement:

"On behalf of the Danish state I apologize to the Inughuit, the population of Thule, and to the whole population of Greenland for the way the decision about the move was taken and carried out… utatserqatserpunga." (George, 1999)

Aqqaluk Lynge, the President of the Inuit Circumpolar Conference (ICC), said "for the first time, we have a prime minister of Denmark who is apologizing in our Greenlandic language. It is very important to us" (George, 1999) for this is a sign of acknowledgement of and respect for the Inughuit.

Further compensation for the relocation is being sought. The most recent case was ruled on in the Danish Supreme Court this past November, 2003 (Danish Supreme Court 2003). Since the Supreme Court did not rule in favor of the Inughuit, they are now working on bringing their case to the international court on the basis of human rights violations. Common thought amongst the community is that it will take at least another five years before the international court considers their case.

On the Canadian side, in 1953, 17 families were removed from Pond Inlet and Inukjuak and relocated to Grise Fiord and Resolute. On the surface this relocation was promoted of as a way to allow Inuit to return to their "native" state. The truth of the matter was that the Canadians were worried that a lack of permanent high arctic residents would bring their claim to sovereignty over the Canadian Archipelago into question. This was especially important in the 1950's at the height of the Cold War where superpower nations were jockeying for control of the Arctic. In the mid 1990's a settlement delivered compensation to the current survivors of the relocation though there was no formal apology from the Canadian Government.

Chapter 4.3 - Modern Science Permitting Procedures

With the Danish and Canadian governments transferring greater authority to Indigenous populations, an extra dimension is added to obtaining clearances for Arctic research. The intent in the clearance process is to require that researchers inform, involve and obtain permissions at the local level. The Indigenous population has a vested interest in reviewing requests to determine whether proposed activities might interfere with or adversely affect their communities. The science activities and findings may also be of benefit to the communities. Historical lack of communication between Indigenous communities and researchers is evident in the following anecdotes that stress both sides of the issue and highlight that suitable solutions can often be worked out with direct contact.

During Arctic oil exploration activities in the 1970's & 1980's, certain poorly timed detonations of seismic explosives in coastal regions resulted in losses of precious fish. The timing of the explosions was not key to the science. Had the Indigenous population been consulted and their advice regarding the timing of the fish runs heeded, the loss of this local resource might have been avoided.

The Canadian-led North Water Polynya project obtained clearances from Denmark and Greenland to enter coastal waters of northern Greenland in early spring 1998. Upon arrival in the region, local inhabitants informed the Canadian icebreaker captain that the ship did not have their permission to work in their waters. An appeal was made to the governments of Denmark and Greenland who informed the vessel that the authority lie with the local people and negotiations would have to proceed directly with them. Local people were concerned that a number of their hunters who are out on the sea ice at that time of year would be cut off from safe return by the ice-breaker's path. A party from the vessel was flown ashore and eventually reached an agreement to modify their cruise track. The scientists were frustrated by the unexpected loss of time and the missed opportunity to capture the fuller spatial extent of the spring bloom that they were hoping to observe.

In contrast to these negative experiences, a classic example of scientists and Indigenous populations working together is that of the co-management scheme for the

Indigenous Bowhead Whale fishery in Alaska. Whaling regulations were established using a combination of Western scientific data provided by scientists and Traditional Ecological Knowledge provided by the tribes who had a vested interest in the whale fishery (Freeman 1989).

In 2001 a Canadian chief scientist of a geological ship-based mission in Nares Strait successfully obtained research permits from the local Inuit despite inherent sensitivities to seismic work. Face-to-face communication consisted of approximately one week in Grise Fiord, Canada, talking with the mayor, Hunters and Trappers Association, school personnel, and local government. She distributed a number of gifts with her home institution logo to the community members as tokens of good will. This included a vest for the mayor and pins, hats and yo-yo's for others. Berths were opened in the project for local participation in the research cruise. An essay competition among high school students was arranged for 2 berths. In consultation with the principal, she selected 2 boys ages 16 and 17 to participate as Nunavut observers. The boys, working with a scientist, contributed to an excellent cruise report. Loneliness and reliability, issues that could be expected of teenagers anywhere, had to be contended with over the course of this cruise (Jackson 2001).

Chapter 4.4 - Nares Strait Project Chronicle

Chapter 4.4.1 - Project Overview

In 1992, Dr. Kelly Falkner of Oregon State University and Dr. Andreas Münchow of the University of Delaware were funded to carry out a 5-year project entitled "*Variability and Forcing of Fluxes through Nares Strait and Jones Sounds: A Freshwater Emphasis*" under an NSF Arctic Freshwater Initiative. This project has come to be known as the Canadian Archipelago Throughflow Study or CATS: http://newark.cms.udel.edu/~cats/. The main objective of the research is to determine the amount and variability of seawater and ice flow south through Nares Strait and its relationship to possible forcings. Initial field work was carried out during a July 21-August 16, 2003 cruise (HLY-0301) aboard the United States Coast Guard Cutter Healy in Northern Baffin Bay and Nares Strait. The subsequent field plans entail aircraft based operations in the ice during the spring of 2005 and 2007. This work is to be conducted from a base camp and will involve retrieval of the moorings (Figure 4)) and in 2005 refurbishing and redeploying them. At this point the project is ongoing, so what follows is a chronicle of the permitting related actions taken thus far.

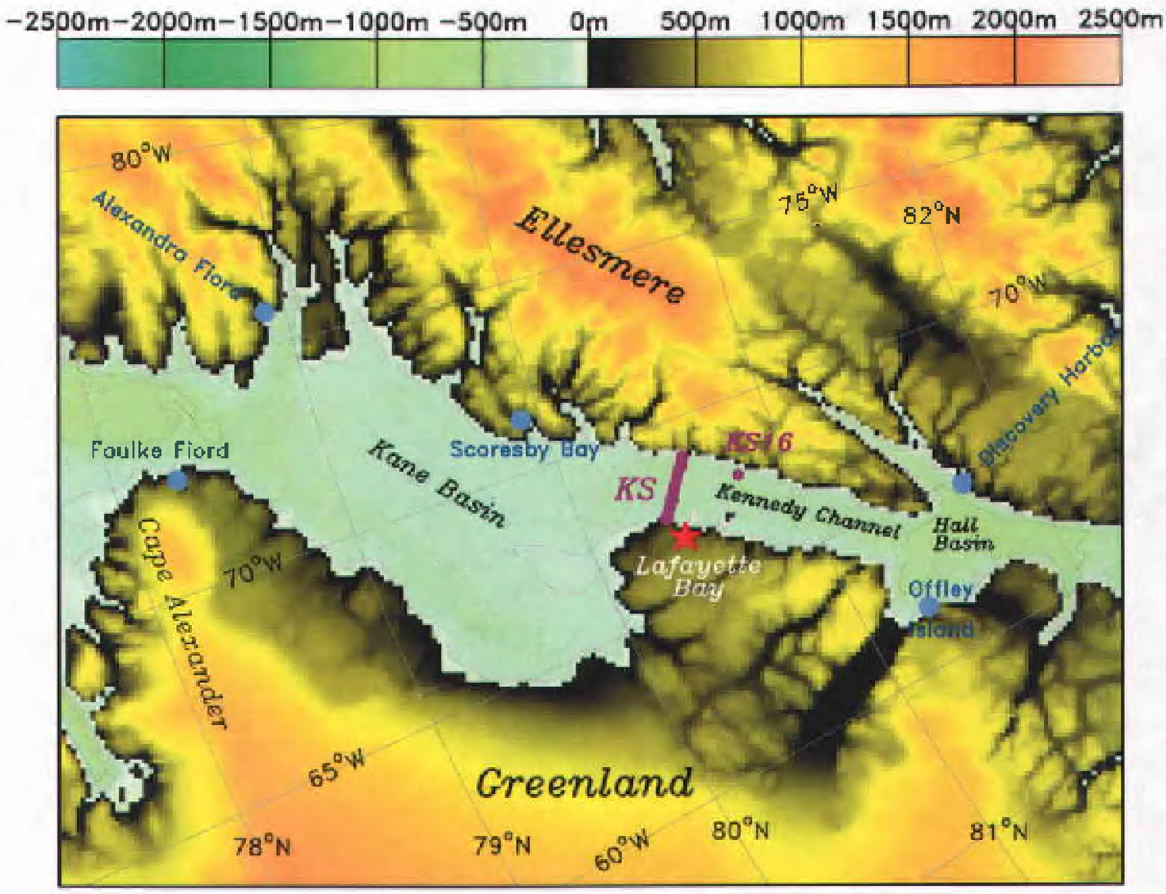


Figure 4: Mooring locations for Nares St. flux program. Red star marks targeted site for 2005 base camp for aircraft operations. Pressure sensing moorings in blue. Main array moorings in pink.

APPENDICES

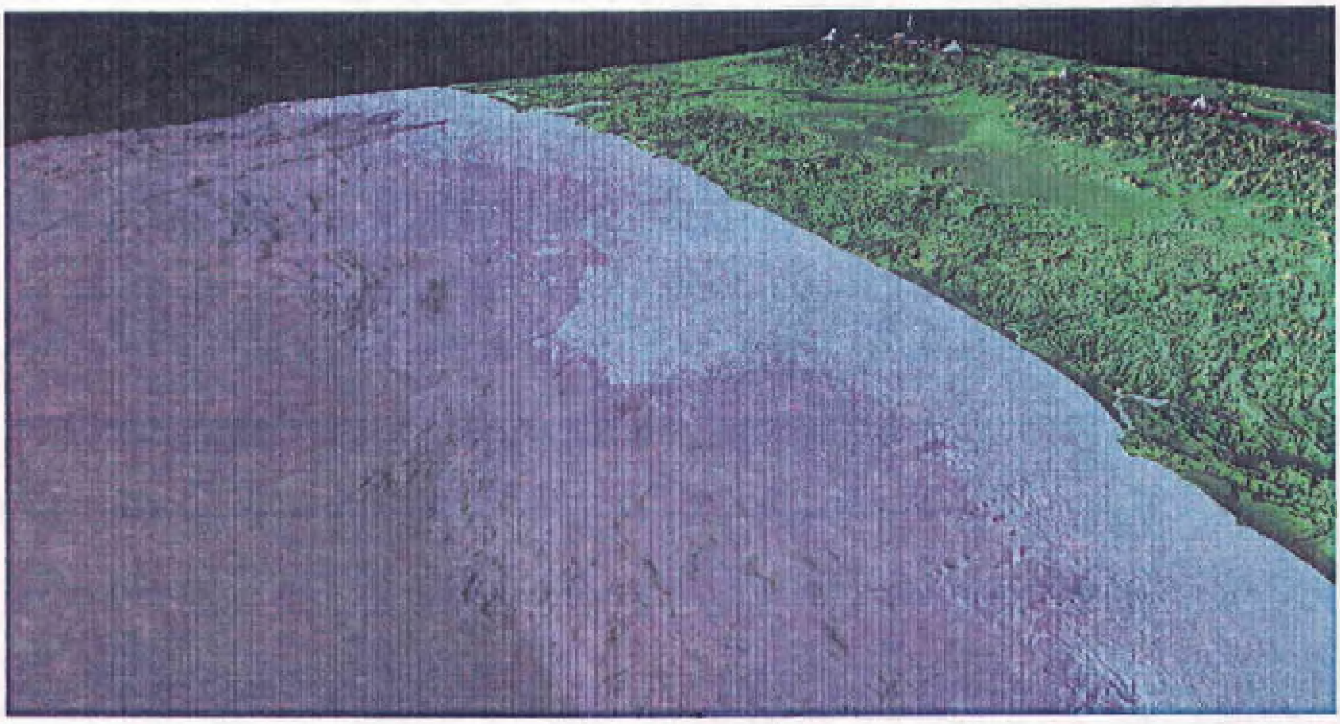
APPENDIX 1

CHAPTER 1

The Seafloor and Below

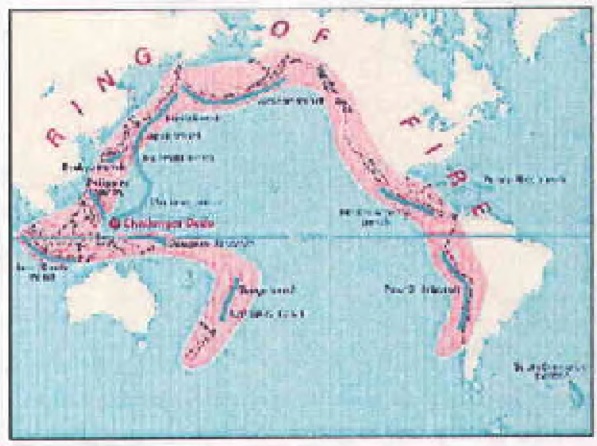
Oregon's climate and geography are greatly influenced by the geological forces that shape the rich and diverse topography of the Oregon landscape, and the lesser known but equally compelling active seafloor landscape. Oregon's 440 miles of coastline are part of a much larger and active geological area that borders the edges of the Pacific Ocean and contains more than 550 volcanoes. This area is known as the "Ring of Fire." Along the continental rim of the Pacific Ocean, convection currents fueled by radioactivity in the Earth's inner core cause ocean plates to diverge, converge, and slide past one another, regenerating as they move, spread, and sink. During this process, energy is released through hydrothermal vents, volcanic eruptions, and cold seeps.

Discoveries of hydrothermal vents, cold seeps, and undersea volcanoes have been possible in the past 30 years from exploration of deep-sea sediments using improved technologies. These discoveries have expanded our knowledge of unique living organisms that inhabit extreme seafloor environments, identified possible energy sources, exposed potential hazards such as



Bathymetry of the continental shelf on the Oregon coast earthquakes and tsunamis, and helped us understand ancient climates and the factors that contributed to major and minor historic climatic events. New techniques to determine water depth, capture sonar images with sidescan equipment, characterize sediment and rock types and active fault zones, and observe and take measurements from submersible vehicles have led to the creation of large datasets that characterize segments of the seafloor.

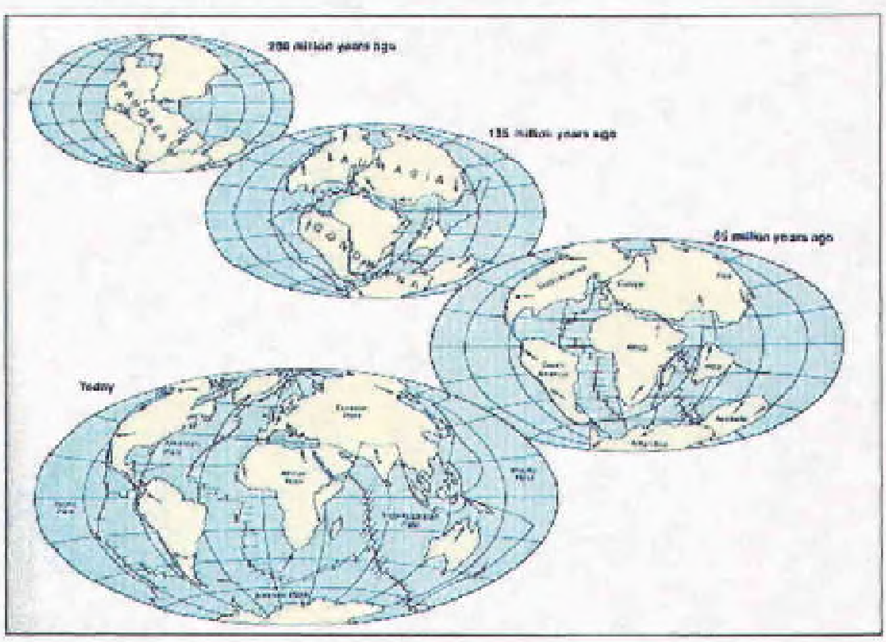
One of the greatest challenges facing scientists today is combining different datasets to more fully and accurately describe Oregon's seafloor and its associated biological habitats. Technology such as Geographical Information Systems (GIS) includes computer software, hardware, and data to analyze and visually present information based on location of geographic features. GIS techniques allow scientists to characterize, classify, and predict the distribution of geological features off Oregon's coast. Scientists use the visual information generated from GIS to better understand the processes that create and transform the seafloor—processes which ultimately affect the fisheries, climate, economy, and people of the Pacific Northwest and Oregon.



Pacific "Ring of Fire."

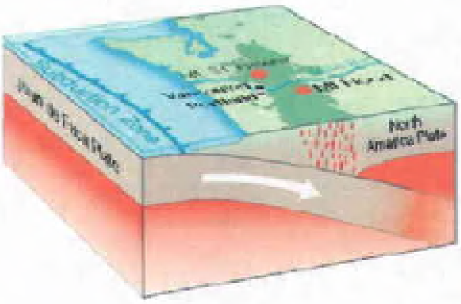
New technology that uses fiber optics and other instrumentation will allow geologists to monitor ocean floor processes in real-time, enhancing our understanding of geological activity of the seafloor and our ability to predict seismic events. The future of marine geology will include portable geophysical arrays and broadband seismometers, high-precision acoustic mapping instruments that can function in all water depths, sophisticated autonomous underwater vehicles, and advanced ocean drilling capabilities, to name a few.

This chapter of Oregon Ocean Book II explores Oregon's underwater landscape and the geological forces that shape the seafloor. It discusses the latest technologies used to create visual images of the geography of the seafloor and how this imagery is used to better understand the Earth as a system. It explores plate tectonics and physical features created by the release of energy from beneath the



Continental drift.

seafloor. It describes some of the newest findings in marine geology including methane hydrates, a source of energy that could potentially replace some reliance on fossil fuels. And it outlines some of the challenges geologists face today as they try to map the ocean floor to accurately define its features.



Cascadia subduction zone where the Juan de Fuca plate subducts under the North America continental plate.

More importantly, this chapter describes marine geology as an interdisciplinary approach. The factors that contribute to the creation of seafloor features such as hydrothermal vents and cold seeps do not act in isolation—rather, they act in combination with geological, physical, chemical, and biological forces. Only through monitoring and viewing Oregon's ocean floor through a multi-discipline eyeglass will scientists be able to piece together the habitats that are continually being created and destroyed as a result of active geological processes.

Plate Tectonics

A Pacific Northwest Event

In May of 1980, the landscape of the Pacific Northwest was transformed when an earthquake that measured 5.1 on the Richter scale caused Mount St. Helens, a 9,677-foot composite volcano in southwestern Washington State, to erupt. The event, coined one of the most important events in the 20th century in the United States, leveled 230 square miles of surrounding forest habitat, forced a plume of ash thousands of feet into the atmosphere that ultimately deposited a 60-foot thick layer of ash in some locations, reduced Mount St. Helens to 8,364 feet, and caused pyroclastic flow—a mixture of gas, pumice and ash—to move down the mountain at speeds of 100 miles per hour, leaving a path of destruction in its wake. The entire eruption lasted nine hours, but the landscape changes from this event can be seen decades later.

The eruption of Mount St. Helens left an indelible impression in the minds of Pacific Northwesterners because of the explosive and violent force of the eruption, the speed at which changes to the surrounding landscape occurred, and the proximity of the volcano to a large human population in and around Seattle, Washington and Portland, Oregon. Visitor centers, hiking trails, presentations by naturalists and park rangers, and a revived local tourist economy are constant reminders of the event and the potential for similar events because of the presence of other nearby active composite volcanoes. Composite volcanoes, also called stratovolcanoes, are steep-sided symmetrical volcanoes with a crater

Mt. St. Helens eruption.

and vent or series of vents in which magma moves from the Earth's crust through the vents. Mt. Ranier in Washington State and Mt. Hood in Oregon are examples of active composite volcanoes above sea level.

Unbeknownst to many people, the geologic forces that ultimately contributed to the eruption of Mount St. Helens are also at work throughout the Pacific Northwest beneath the surface of the ocean where the Earth's plates converge and spread. The resulting geologic features from this subducting process include hydrothermal vents, cold seeps, canyons, banks, seamounts, and clathrate formations—similar to many geologic features we see on land.

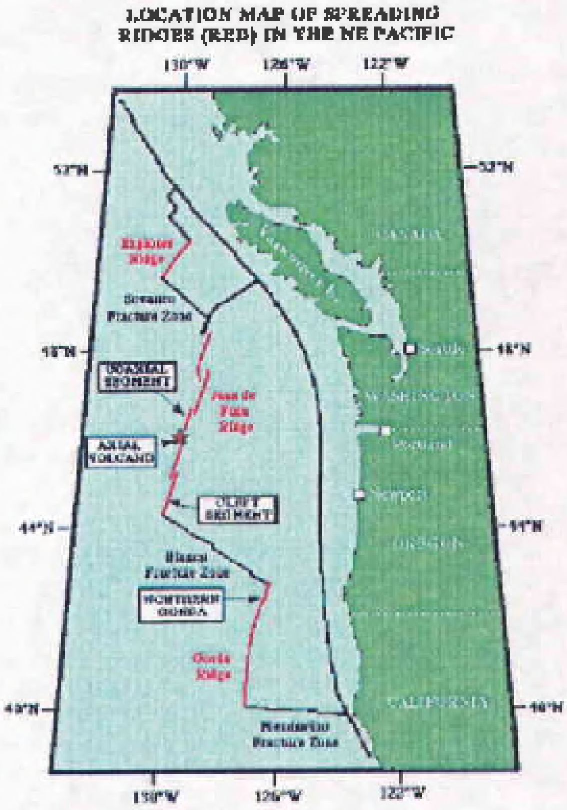
Moving Earth's Plates

The first attempts to describe the network of rigid but mobile plates that cover the Earth's surface were met with skepticism. Alfred Wegener proposed "continental drift" in 1915,theorigzing that one supercontinent called Pangea, created over 250 million years ago, had been slowly torn apart—sending continental landmasses around the globe. The idea remained unaccepted by mainstream scientists until echo sounders revealed a vast mid-ocean ridge system over the next 30 years.

The ocean ridges are locations where plates move apart. Molten basalt escapes and hot magma rises to the ridge as the ocean floor spreads and gives birth to new seafloor, creating ridges as it cools. Rising an average of about 14,763 feet, these deep-sea mountains have elevations comparable to or higher than many mountain chains on land.

New ocean crust is produced at spreading centers every year. The ocean crust has an average thickness of 3.7 miles and the global mid-ocean ridge system is about 31,000 miles long, with an average spreading rate of about 2 inches per year. As the seafloor spreads, old seafloor is pushed away, eventually converging with other plates. In the 1940s, scientists were mystified by the paucity of sediment in the middle of ocean basins. If oceans had been in existence for 4 billion years, they believed there should have been a sizable sediment layer. Today we know that the seafloor is always changing, as older seafloor makes way for new during the converging process.

Technological advances improved understanding of seafloor creation and plate tectonics. Magnetometer readings revealed that rocks on the ocean floor were magnetized in a pattern of symmetrical stripes about a spreading center. Magnetic patterns could be used to trace past seafloor spreading events, as each event



Velocity map.

locked in the magnetic signature in sediments at the time the magnetic minerals cooled. The Earth's heated mantle is responsible for the creation of new seafloor and ultimately the control of rigid plate movement. Together, seven major and 20 smaller plates comprise the global terrain. The most geologically active regions in the world are locations where plates move towards, away from, or slide past each other.

As an oceanic plate moves towards a continent such as North America, the denser oceanic plate dives or subducts beneath the more buoyant continental plate. Offshore of Oregon, features created from this movement are known as the deformation front; those features slowly migrate away from the continent as more sediments are accreted. The faults, peaks, and valleys lie in an active seismic region and are subject to folding and shearing. As features are sheared off the top of the subducting plate, they slowly become part of the continental landscape, often called the forearc by geologists. The forearc in Oregon, for example, is that region between the deformation front and the High Cascades.

Accretion forces new land material onto the continental plate that may be uplifted as it is squeezed toward the land by the next accretionary event. In geological terms, the Coast Range is a relatively recent addition to Oregon's landscape. Oregon's landscape has a unique hodgepodge of rock, sediments, and terrain found throughout the state, evidence of its dramatic geologic past. It is estimated that two-thirds to three-fourths of the state's rock originated from elsewhere in the Pacific basin, a result of multiple collisions with smaller continental plates.

Additional evidence of tectonic plate movements includes the more than 550 active volcanoes that circle the Pacific Rim. The volcanoes along the Cascades are part of this group. The Cascades arc of volcanoes lies inland because they are the product of the subduction zone below the surface of the continent. Subducted ocean floor can reach deep into the Earth's mantle where water is pulled down with sediment and crust and the melting point is lowered. As the former crust melts, it returns to the surface.

Fracture zones also offer evidence of the tectonic mayhem. The seafloor off Oregon's coast is riddled with cracks and chasms, etched relief signifying the centuries of stress delivered to the plate. The 500 km-long submarine mountain chain, the Juan de Fuca Ridge, is the largest of three remnants of an ancient plate. The Farallon plate, a large plate that began to subduct over 30 million years ago, gave rise to the Cascade Mountain Range. Two other plates, Gorda and Explorer, together with Juan de Fuca, comprise the Cascadian Subduction Zone (CSZ) which extends from British Columbia to northern California. The jagged Blanco fracture zone connects the rival plates. The plates average about 50 miles thick and are constantly moving, particularly in active geologic areas such as ridges and spreading centers.

In the 1960s, researchers began exploring the fractured faults, rising ridges and spreading centers around the world. In the early 1970s, Oregon State University oceanographers, along with University of Washington colleagues, questioned the possible existence of other subsurface features such as hot springs and unique mineral deposits at mid-ocean ridges. The existence of hot springs might help detail the mineral composition of oceanic waters as well as the seafloor, possibly leading to commercial recovery.

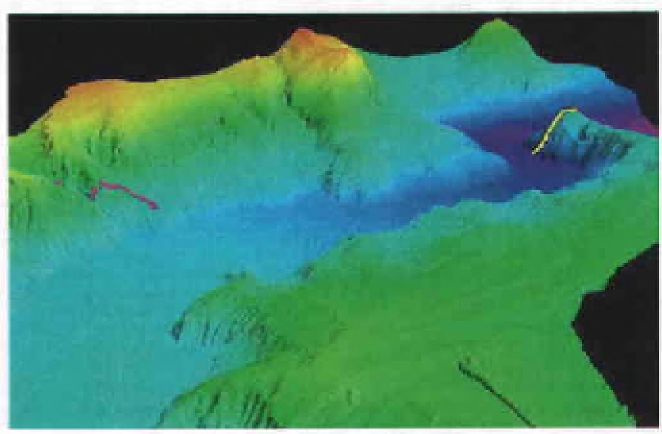
Many factors influence the size, shape, and activity of formations on Oregon's seafloor. Geologic activity below the seafloor, features such as the Columbia River, and the movement of ocean and continental plates are all at work, shaping and reshaping the landscape below the surface of Oregon's ocean. Heading north to south along Oregon's coast, we'll view some satellite images and vertical cross sections of Oregon's seafloor to explore in greater detail some of the formations scientists have been able to identify. Oceanographers are just beginning to monitor and explore these and other features to better understand the physics, chemistry, biology, and physiology of life forms that live in these unique environments.

Astoria Canyon

A Submarine Canyon

Our journey begins in the northwest corner of Oregon, near Astoria. Astoria was the site of the first fur trading post and American settlement west of the Rocky Mountains. Salmon canneries, timber harvesting, and shipping made Astoria a vibrant coastal port town from the mid-1800s through the early decades of the 1900s. Fishing, logging, and tourism now support the local population of 10,000.

One of the most prominent underwater features

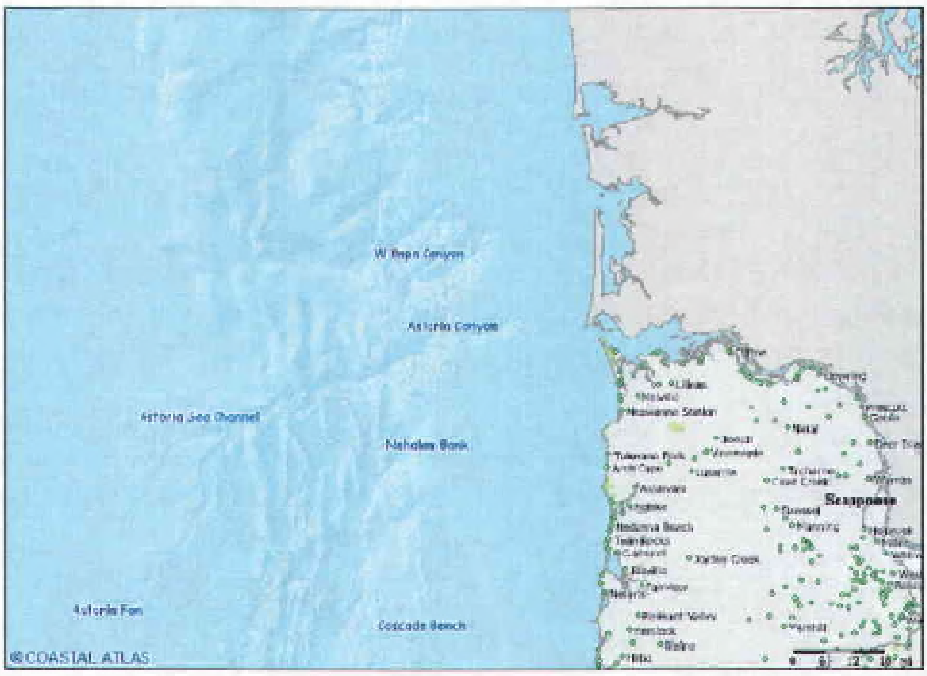


Velocity map.

off Oregon's coast, Astoria Canyon, is a submarine canyon 10 miles west of Astoria and the mouth of the Columbia River. The canyon is 25 nautical miles long and perpendicular to the continental shelf, sloping westward toward the depths of the Cascadia Basin. At the deep end of the canyon, sediment from the Columbia River spreads out over an abyssal plain—a broad, relatively flat expanse of seafloor several miles below sea level covered in a thick layer of sediment with rugged low hills and high sea mounts—called the Astoria Fan.

Astoria Canyon is deeper than Arizona's Grand Canyon, which has rim elevations from 1,200 to 7,000 feet. Compared to the Grand Canyon which formed over millions of years, Astoria Canyon formed quickly, and was carved by a series of dramatic Ice Age floods 15,000 to 17,000 years ago.

During the last Ice Age, the Cordilleran ice sheet crept southward into Idaho where a half-mile high dam of ice blocked the Clark Fork River. Waters rose behind this ice dam, flooding western Montana and creating Glacial Lake Missoula. The lake stretched eastward some 200 miles, creating an inland sea of more than 500 cubic miles of water—more than the water in Lake Ontario and Lake Erie combined. Periodically, the ice dam would fail, draining Glacial Lake Missoula in as little as 48 hours and creating cataclysmic floods. The force of the flood waters is estimated at 10 times the combined flow of all the rivers of the world traveling at speeds approaching 65 miles per hour. The repeating floods carved out the Columbia River gorge and the deep bends and twists of the Astoria Canyon, carrying sediment to sea.



Astoria Canyon.

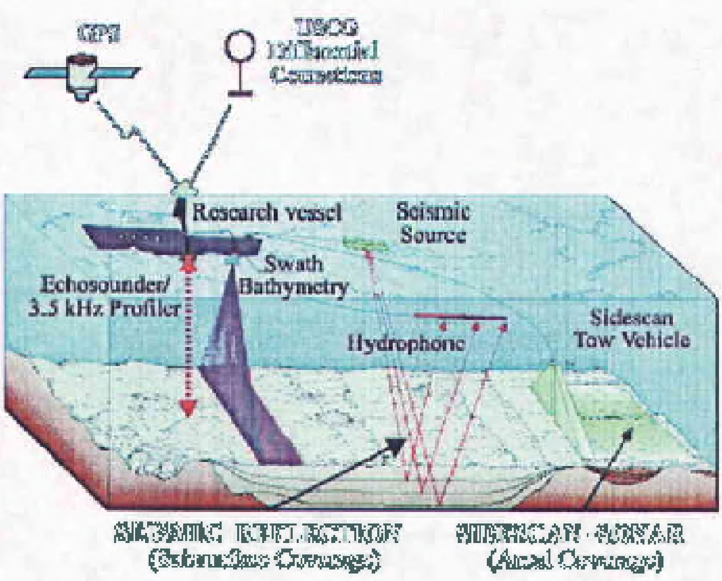
Submarine canyons such as Astoria Canyon are usually formed by strong, sediment-laden, turbidity currents that carve as they flow downhill. Downcutting continues slowly, followed by a flood, then a great deal of cutting. The creation of a submarine canyon is interrupted and accelerated by catastrophic events. Submarine canyons are rare along the U.S. west coast because tectonic plate movements tend to disrupt their course, preventing the formation of long,

Sonar

The use of sound to determine how far an object is away from where you are is not a new concept. It has been used in the animal world for thousands of years by bats and dolphins, for example, to detect obstacles, predators, and prey. Early oceanographers mimicked nature by experimenting with sound traveling underwater. Once the discovery was made that sound traveled well underwater the search for knowledge lead to releasing a loud, acoustic signal underwater, and receiving the reflected sound waves that bounced off of underwater objects through a hydrophone, or underwater microphone. Timing the difference between the release of the acoustic signal and the reception of it back at the ship, along with knowledge of the speed of sound through water and some simple math, the location of these underwater objects could be determined. We call this technology Sound Navigation and Ranging, or SONAR. With the great military need for identifying objects underwater, such as submarines, during the first and second world wars the SONAR technology grew to the point of having the practical and scientific application of determining depth of the bottom of the ocean while on a ship. Through the years oceanographers have found that accurate readings from SONAR can be greatly affected by environmental factors such as ambient pressure (or depth), temperature, and salinity.

Echo sounders, beginning in 1922, were the first use of SONAR for determining water depth. Ships harbored a transducer on the bottom of the hull that transmits and receives sound waves. A 'ping' sound wave was released from the transducer and would fan out in a conical shape as it headed for the bottom. That sound wave would be reflected off of the bottom and then received by the transducer, again, using the time the sound took to travel through the ocean then back to calculate the water depth.

Side Scan Sonar works by pulling a transducer, or towfish, in the water behind the ship thus allowing the transducer to be closer to the bottom, reducing the amount of random "noise" the towfish would pick up. The sonic waves are emitted perpendicular to the ship and are reflected back to the towfish. An image is generated revealing contours and objects on the bottom of the ocean.

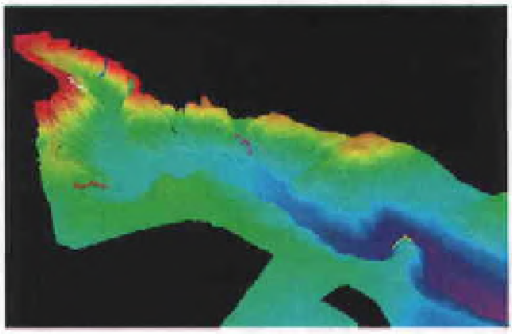


Velocity map.

Multibeam Swath Bathymetry (MSB) is one of the more popular methods of determining bottom geography of the ocean. Like the lone echo sounder of old, a MSB system sends sonic waves from transducers mounted on the hull of a ship. However, instead of one transducer there is an array of them, as many as 120. They are able to send out a band of sound that is equal to approximately two times the water depth. As all of the sonic reflections are collected by the array of transducers that information is processed by on board computers and turned into a bathymetric map, just like the many images Chris Goldfinger creates, with an accuracy of about 10 meters.

Institute for Marine Acoustics – Sonar Primer Inventors website... good info about sidescan sonar: http://inventors.about.com/gi/dynamic/offsite.htm?site=http://www.marine%2Dgroup.com/

continuous features. However, in the Columbia River basin, the powerful currents tend to keep pace with tectonic activity. Astoria Canyon is atop the Cascadia Subduction Zone, where the Juan de Fuca tectonic plate is being pushed under the North American plate. A total of 79 earthquakes were monitored with



Astoria Canyon, looking toward the southeast.

hydrophones from 1991 to 2001, evidence of the type of activity and processes taking place along plate boundaries.

Columbia River's Flow Seaward

Today, water from the Columbia River continues to pour into Astoria Canyon and sweep it clean. The Columbia is second only to the Missouri-Mississippi River system in annual run-off, and its steep gradient is unique. The lower-salinity water in Columbia River's plume is carried south and west by the California Current and is traceable 400 miles south to Cape Mendocino in California.

The continental shelf buffers the canyon from input of sediment from the Columbia River. OSU's Chris Goldfinger studies the earthquake potential and structural history of the Cascadia Subduction Zone. His research suggests that in winter storm months when most sediment transport occurs, the plume from the Columbia River is driven northward by the Davidson current where it enters the ocean. Thus, most Columbia River sediments do not reach the head of Astoria Canyon. Instead, the sediments are widely distributed on the Washington shelf.

Mapping the Deep Canyon

The first limited scientific studies of Astoria Canyon were conducted in the 1960s and 1970s. Only in the past several years have scientists been able to learn details about the sediments, water movements, and biology.

In 2001, a team of oceanographers, geologists, and biologists explored the submarine abyss during the Lewis & Clark Expedition. The three-phase project used advanced mapping techniques and a remotely operated vehicle (ROV) called ROPOS that resulted in the first modern maps and records of the geology and marine life of Astoria Canyon. Other tools included hydrophones for bio-acoustic sampling, mid-water trawls, CTD (conductivity-temperature-depth) casts, and high-resolution video. Sediment cores revealed gray clay from glacial times and layers from slumping induced by earthquakes.

During the first phase of the project, scientists used deep-towed sidescan sonar and a high-

Black coral. Photo courtesy of Ingvar Eliasson.

resolution multi-beam sonar system to identify the best places for ROV transects. During phase II, a team of geologists, ichthyologists, invertebrate zoologists, physical oceanographers, and fisheries biologists conducted a series of dives using ROPOS to study geological forces and ecological relationships. Phase III concluded with a comparison of the relatively pristine environment of Astoria Canyon with heavily fished Heceta Bank. Geologists surveyed Heceta Bank with an acoustic remote sensing system, Imagenex, mounted on ROPOS. Imagenex is a "pencil-beam" scanning sonar device, which makes sonar sweeps from side to side as the ROV travels, resulting in a high-resolution zig-zag pattern of depth soundings. The high-resolution imagery helped classify the bottom topography of Heceta Bank to allow for comparisons between different underwater landscapes.

An Unexplored Biological Haven

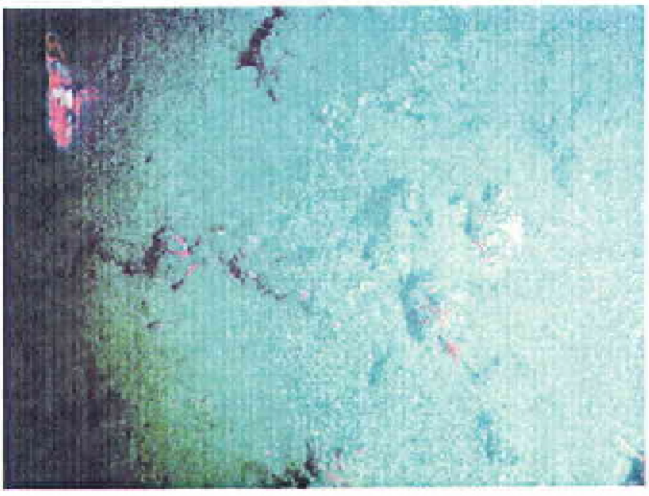
Although Astoria Canyon is not heavily fished by commercial fishers, the canyon plays a key role in the distribution of fish stocks off the Oregon coast. The micronutrient-rich Columbia River (high in iron and silicium) mixes with the macronutrient-rich coastal upwelling system of the Eastern Pacific to produce a highly productive river plume. Astoria Canyon is also a localized upwelling center. Canyons cutting the continental shelf enhance wind-driven upwelling, which brings phytoplankton to the surface. Zooplankton feed on phytoplankton; in turn, fish, and other animals feed on zooplankton.

Although Astoria Canyon is well-mapped, its biology remains largely unexplored. Invertebrates such as sponges, corals, seastars, snails, and worms comprise more than 90 percent of the astounding variety of animals in Astoria Canyon. In one of many discoveries during the 2001 expedition, researchers found a 1,312 ft wall rising from the canyon floor with a diverse community of deep-water invertebrates, including numerous species of gorgonian and black corals. Researchers photographed organisms and archived samples at the Natural History Museum of Los Angeles County. Museum invertebrate experts and students hope to understand the distribution of the corals, and, more generally, how the structure of the canyon and the currents interact to influence the distribution and abundance of biological life that includes several whale species. NOAA hydrophone monitoring from 1991–2001 recorded nearly continuous whale calls in Astoria Canyon. The canyon lies within the migratory corridor for species such as blue and fin whales.

Cascadia Subduction Zone

Cold Seeps and Earthquakes

The eastward-moving Juan de Fuca tectonic plate meets the westward moving North American plate at the Cascadia Subduction Zone off the west coast of Canada and the United States. Cold seeps are found in this geologically rich and active area where water is forced out of crushed sediments by tectonic pressures. Seeps can also occur in the presence of other processes such as undersea aquifers, pressurized salt rising through shale carrying hydrocarbons, or microbial activity under the seafloor. Where energy-rich fluids are vented from the seafloor, communities based on chemosynthetic bacteria thrive.
Cold seeps discharge fluids that are about the same temperature as the surrounding water (depending on depth, this temperature could be 36–40°F or even higher), in contrast to hydrothermal vents which discharge extremely hot fluids. Cold seeps are relatively stable, while hydrothermal vents are volatile,



Heceta Bank.

becoming covered by discharge and appearing at new locations. Early research demonstrated that cold seep emissions were slow and steady.

Discovery of Seeps

In the 1980s, Oregon State University professors Vern Kulm and Erwin Suess discovered the first cold seep communities in the sediments of the Cascadia

Subduction Zone. Juan de Fuca sediments are scraped off and squeezed onto the North American plate, causing loss of water in the composition of rocks as they are forced onto the slope. To learn more about these rocks, Kulm viewed the area in a submersible. Giant white clams, thousands of tube worms, and patchy, white bacterial mats covered an area of 20–30 square feet where abundant methane and other hydrocarbons flowed up from deep sediments. Researchers also observed 2–3 foot-high limestone chimneys. After the expedition, Kulm found an Oregon fisherman with dozens of carbonate chimneys in his yard as decoration, some used as flower pots.

The discovery of cold seeps was in tandem with similar discoveries of cold water seeps offshore Japan and Peru. Cold seeps have since been found in Monterey Submarine Canyon at a depth of 10,500 feet and subsequently in shallower water in Monterey Bay, in the Florida Escarpment, and several other locations along continental margins.

Chemical Deposits

The hydrocarbon-rich environment of cold seeps includes hydrogen sulfide, methane, and other chemicals such as iron, manganese, and silicon. The chemical composition and concentration of minerals in the fluid varies by location, reflecting mineral content of sediments and factors that force the fluid from the sediment. For example, in Monterey Bay, NOAA reports fluids from tectonic sediment compression at a Clam Flat seep have 100 times more sulfide and very high methane concentration compared to nearby seeps suspected to result from an artesian flow of rainwater entering a sandstone aquifer. Chemicals in fluids can be used to study water circulation and to infer changes that have occurred in the Earth's climate.

Minerals deposited around cold seeps have potential economic value. Oregon State University researcher Marta Torres has studied deposits of barite off the shore of Peru and in 2004 investigated cold seep deposits in the San Clemente Basin off southern California. Barite deposits can accrete in columns as high as 33 feet tall. The deposits forming today on the seafloor are analogous to ancient barite formations currently being mined in Nevada, Arkansas, and China for a range of industrial and manufacturing uses.

Fauna at Cold Seeps

Bacteria process sulfides and methane at cold seeps, converting it to chemical energy. The types of bacteria and biological communities vary, depending on the chemicals found in the cold-seep fluid. Larger fauna at the seeps, including clams and tubeworms, ingest the bacteria and become symbiotic hosts. Bacteria benefit from sheltering inside the host's body; the hosts (which do not have mouths or stomachs) benefit

Chemosynthetic community living around a hydrothermal vent.

from the food produced by the bacteria. Foragers such as crabs, sea urchins, and brittle stars also feed within seep sites.

Chemosynthetic communities can be lush, and bacteria may appear in mats. A community discovered near natural petroleum seeps in the Gulf of Mexico was known as "Bush Hill" for its "bushes" of tubeworms. It is estimated that tubeworms at cold seeps can live as long as 170 to 250 years. Fossil records left by these stable chemosynthetic communities can offer insights into the present-day biodiversity at cold seeps.

Using Instruments to Study the Ocean Floor

Remotely operated vehicles (ROVs) allow us to send our brain and hands to the seafloor to collect seawater and analyze it for chemical compounds. Once sediment cores have been brought to the surface by the ROV, scientists process the cores for chemical and

Calyptogena kilmeri in the Monterey Bay.

microbiological analyses by first cutting the core into sections inside a no-oxygen atmosphere "glove box." Scientists study bacteria using a variety of advanced microscopic techniques including fluorescence microscopy and scanning electron microscopy to produce high-resolution, three-dimensional images of specimens.

New science is constantly being reported from the methane-rich environments of hydrothermal vents and cold seeps. New species—and sometimes new Phyla—are discovered. The "rules" for life are constantly being rewritten. In May 2004, researchers announced the discovery of asphalt volcanism in the Gulf of Mexico, where undersea vents erupt asphalt instead of lava. The asphalt supports colonies of chemical-eating organisms. Eruptions of hot asphalt destabilize gas hydrate deposits and contribute to faulting and slope failures.

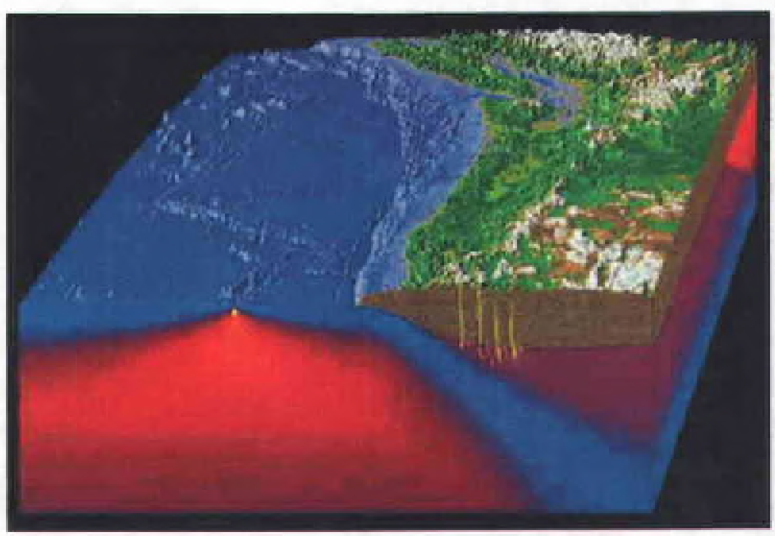
Undoubtedly, discoveries to come will define new features and ecosystems. The study of seeps and vents helps us gain knowledge about marine ecosystems, climate change, seafloor stability, and coastal hazards.

Earthquakes, Volcanoes, and Tsunamis

On the evening of January 26, 1700, off the coast of Oregon and Washington, 600–1,000 km of the coast suddenly dropped 1–2 m below sea level. Based on historical and paleoseismic data, investigators now believe this upheaval was caused by a large earthquake along the Cascadia Subduction Zone. The event also generated a tsunami, estimated to hit land at 10–12 m high. The tsunami was noted in Japanese historical records and is remembered in Native American oral histories.

Offshore of the Pacific Northwest, an ocean ridge is formed by mantle material under the crust that is welling up through the surface of the seafloor. This process is creating new ocean floor and is pushing the older ocean floor of the Juan de Fuca plate toward and beneath the North American continental plate. Where these plates are diverging is called the Cascadia Subduction Zone. Within a continental plate subduction zone, three potential sources of earthquakes occur: the continental crust, the oceanic plate that's being pushed beneath the crust, and the thrust fault that marks the plate boundary.

Until recently, the Cascadia Subduction Zone was considered to be dormant compared to the earthquakes and volcanic eruptions that typify other continental margins. However, significant earthquakes



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Continental margin on the Oregon coast.

with magnitudes greater than 8 have occurred along this 1,500-km fault margin that extends from the middle of Vancouver Island, BC, through Washington and Oregon to Northern California. Based on recent geologic evidence, investigators found that large subduction earthquakes have been occurring every 300 to 650 years along the southern two-thirds of the Cascadia margin.

The subducted ocean floor warms and becomes somewhat more elastic as it is pushed deeper beneath the continental crust. In the offshore thrust zone where the hard rock from the oceanic plate meets the opposing rock of the continental shelf, mechanical stress builds. This "locked" zone stores energy that is ultimately released as an earthquake. The strain from the plates locking extends hundreds of kilometers inland from the coast. The molten "transition" zone is also under strain and most likely ruptures. Investigators believe the warm temperatures within the Juan de Fuca plate and its gentle dip as it goes under the North American plate has resulted in long time periods, perhaps hundreds of years, between earthquakes.

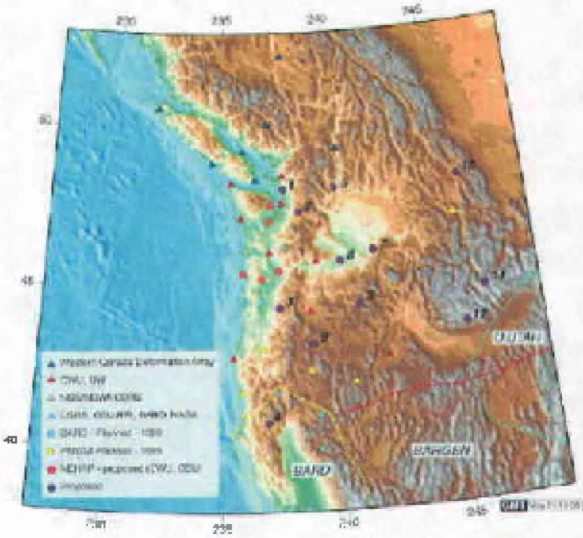
The subduction zone is wider to the north off the Olympic Peninsula and narrower from the central Oregon coast to Northern California, lessening the amount of ground shaking during a substantial subduction earthquake that could potentially affect cities 60–125 miles inland. The narrow width of the subduction zone in this area also limits the earthquake size, depending on the length of the rupture along the margin.

When the stress reaches its breaking point, the resulting earthquake could cause damage to population centers anywhere along the Pacific Northwest coast, as well as Seattle, Portland, and down the Willamette Valley. Although geologists are relatively certain that this will occur, the location of the earthquake center and its timing cannot be predicted. Based on new GPS geologic mapping in and around the area, magnetic studies, and argon dating, investigators are fairly certain that some or all of the faults in the Portland basin are potentially active.

Advances in Technology and Data Analysis

In the past few years, advances in Global Positioning System (GPS) technology, increased coverage, and improved data analysis have made it possible for investigators to measure crustal strain accumulation at plate boundaries in real time with a high degree of certainty. Although this research tool has improved the study of regional geotectonics and estimates of seismic hazard, the measurements represent only a small moment in time. Investigators currently don't have enough data on the long-term behavior of faults, size of events, average rates of occurrence, and times between events to be able to make reliable predictions. The models of earthquake cycles used today for stress accumulation and release at a particular fault or fault segments assume that stress buildup is proportional to the time since the last earthquake. This assumption is the basis for probable forecasts of seismic activity.

Investigators are able to use a combination of tools and methods to study fault systems. The results from short-term geodesy and seismology data and longer-term geological data complement paleoseismology, the study of earthquake history from the record of submarine



Updated [illegible] Pacific Northwest Geodetic Array (PANGA). Continuous operating GPS sites and proposed augmentation of the [illegible] array.

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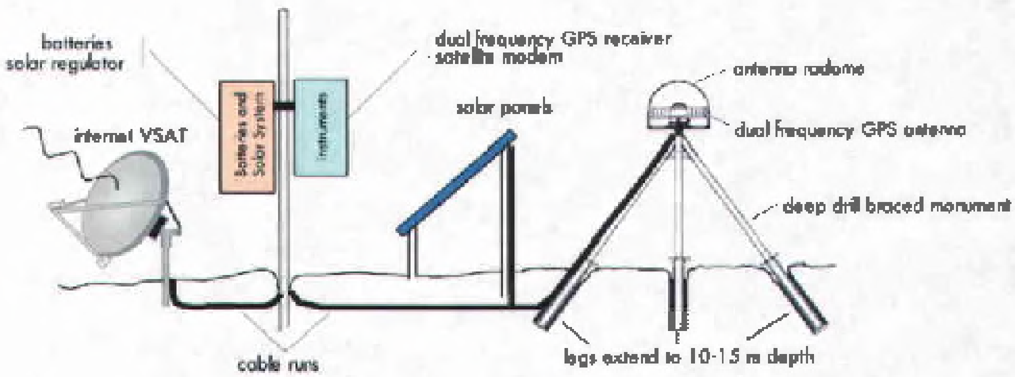

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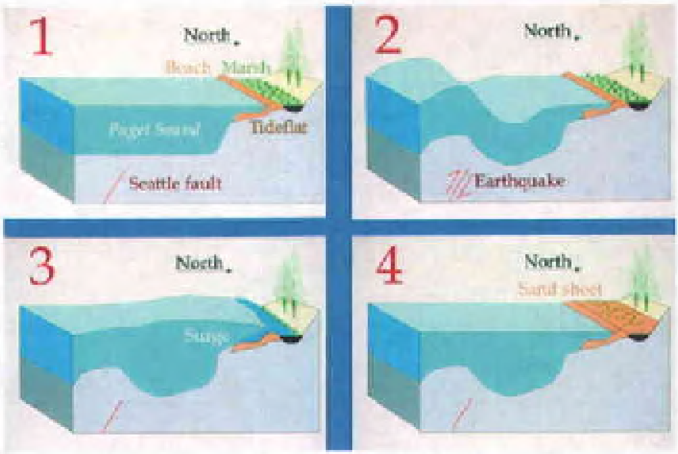

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landslides, to present a more-detailed picture of seismic activity.

Recently, Chris Goldfinger and Joel Johnson from COAS and C. Hans Nelson from Texas A&M University found preliminary evidence that indicated within the past 10,000 years, 18 earthquakes have ruptured the entire length of the Cascadia margin from Vancouver Island to Northern California. These events repeated about every 600 years—the most recent was about 300 years ago. Their preliminary results also suggest that prior to the January 1700 earthquake, one event occurred in the mid-1600s and another in 1300 AD.

Based on the paleoseismic record and tsunami evidence, investigators have been able to determine specific locations for past earthquakes along the Oregon coast. They discovered a 7,300-year record in Bradley Lake in Coos County and a 5,500-year record in Sixes River estuary near Port Orford. Seventeen tsunami events were identified at Bradley Lake; these events have occurred at least 100 years apart, but one has occurred at least every 900 years. The time between events at Sixes River in Southern Oregon also varied widely, as

Caption goes here.

far apart as 900 years or as close together as 70 years, with an average recurrence of 529 years. Researchers estimate the average recurrence for the past 3,500–4,000 years to be about 490–550 years.

Most people are conscious of eruptions and earthquakes that affect population centers. But the regularly occurring small swarms of earthquakes, sliding, and scraping of the Earth's crust underneath the land and sea of the Pacific Northwest often go unnoticed except by siesmologists and geologists.

Deployment of dense GPS arrays around the world in the 1990s has resulted in investigators recognizing transient slow faulting as a widespread and fundamental mode of strain release in subduction zones. Slow, deep earthquakes that last from two to four weeks occur every 14.5 months in the Cascadia Subduction Zone along the deeper reaches of the plate interface below the thrust zone, which breaks every few hundred years to produce great earthquakes. This cyclical steady movement means that strain is being released even when people don't notice it above ground. These events are called "silent slip" events. Investigators suspect that a large earthquake closer to the surface might start with a silent slip event. Researchers may be able to define a relationship between silent slips and large earthquakes at the thrust zone.

Continuous monitoring of changes in the position of GPS stations has been used to track land changes associated with tectonic events. Investigators analyzed GPS results from the Pacific Northwest Geodetic Array (PANGA) and determined that eight slow earthquakes occurred since 1992. They were observed to start in the northern region of the subduction zone in the Puget Sound area. The first identification of a deep slow earthquake happened in 1999 when a sudden shift in the movement of the crust in the area between the continental plate boundary offshore and the Cascade volcanoes switched from its characteristic contraction to a momentary extension. Another was identified in 2002. Models suggest that the continental plate interface creeps a few centimeters during these events at depths of 18–31 miles. The observed deep slow earthquakes are estimated to be about magnitude 6.7.

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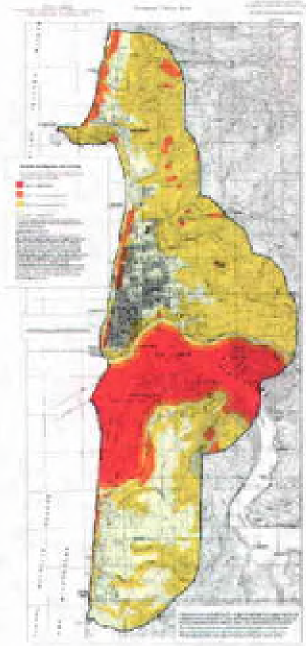
Earthquakes and Public Risk

What is the human risk of undersea earthquakes? More than 50% of the U.S. population lives in coastal areas. The last time a magnitude 9 earthquake occurred along a U.S. coast was on January 26,



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the seismometer to an antenna on its buoy transmits the quake signal to the tsunami-warning centers via satellite.

Axial Seamount

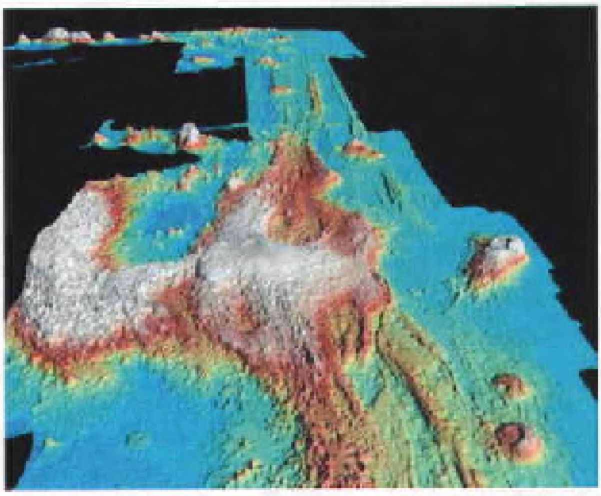
An Underwater Mountain

Cannon Beach, Oregon is a small community known for its nine miles of beaches and Haystack Rock, a 235-foot high coastal monolith—the third largest in the world. Three hundred miles west of Cannon Beach on the ocean floor is the Juan de Fuca Ridge where a chain of seamounts 900 miles long exists. Axial Seamount, a prominent feature on the Juan de Fuca Ridge, is an active volcano covering 216 square miles. It has a summit caldera, an indication that it erupted from a shallow magma chamber, then collapsed. The seamount also has two rift zones, where two plates move away from each other, and magma rises to make new crust in the ocean.

The presence of a caldera on Axial Seamount suggests eruption from a shallow magma chamber and subsequent collapse. This cross-section of the volcano has pillow lavas (black ovals) older than 50,000 years. Sheet flows that range in age from 9,000-5,000 years drape the flanks of the volcano. Sheet flows less than 5,000 years old fill the floor of the caldera.

1700; earthquakes have been occurring regularly for the past few thousand years. The continental slope along the coast bears evidence of massive underwater land slides that may have been triggered by earthquakes. These events can trigger tsunamis and destroy offshore facilities, and the resulting ground shake could release large volumes of methane into the ocean.

The tsunami threat is so critical that Hwy 101, Oregon's scenic coastal highway, is dotted with tsunami evacuation signs. Concerns about the threat of tsunamis have increased over the past decade because of mounting evidence that Pacific Northwest coastal earthquakes could cause more damage than first believed. NOAA scientists installed an array of seismometers in deep Pacific waters to sense major oceanic quakes that then transmit warnings by satellite to the West Coast. A wire from



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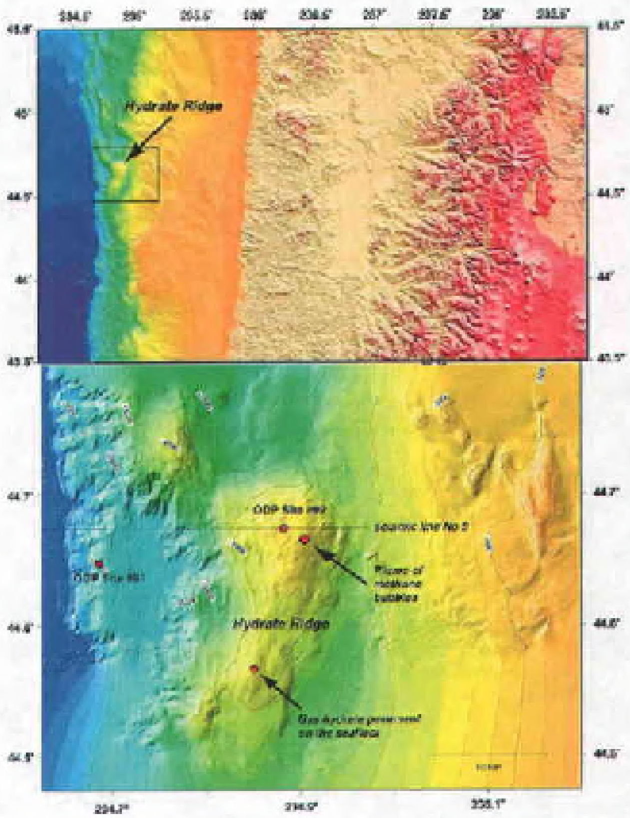
Hydrate Ridge



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About 54 miles west of Corvallis, Oregon, is the town of Newport, Oregon. Established in 1882, Newport is an eclectic mix of fishing vessels, art galleries, restaurants, and tourist spots. The local population of 9,000 is proud of its lighthouses, Historic Nye Beach, marine Hatfield Science Aquarium, and natural resources.

About 3.7 miles seaward of Newport is a seafloor formation called Hydrate Ridge. Hydrate Ridge was formed along a convergent margin from the collision of the Juan de Fuca oceanic crustal plate and the North American continental plate. It is the second frontal ridge of the accretionary wedge that formed from folded and thrust sediments initially deposited on the subducting Juan de Fuca plate. Gas hydrates, also called clathrates, have been found in abundance in concentrated areas on Hydrate Ridge through direct observation of hydrates, gas seeps and pock marks during Alvin dives, bright side-scan reflections from the seafloor, and the recovery from sediment cores near fault zones.

Gas hydrates may form when low temperature, high pressure, a hydrate former such as methane, and water are present in the right combination. Gas hydrates are crystalline solids with gas molecules, usually methane, trapped in a ring of water molecules. They are also called clathrates, the term for any crystalline solid where small molecules are enclosed by a structure of larger molecules. The word clathrate is based on a Latin word meaning "to enclose with bars."

Methane is the most common gas found in marine gas hydrates. The lattice of a methane hydrate holds each methane molecule close together. A large quantity of gas is packed into a small volume—the methane in a cubic foot of hydrate will expand to about 164 cubic feet at the Earth's surface. Methane is stable at low temperature and high pressure; unlike water it can exist as a solid on the seafloor and in sediments near the seafloor. The crystalline substance looks like ice and is sometimes called "burning ice" or "flammable ice."

Conditions for gas hydrates exist in the permafrost layer of polar regions and on the seafloor. On the continental margins of the seafloor, there is a rapid accumulation of both sediment and organic detritus from dead plants and animals. Anaerobic bacteria in the low-oxygen sediment generate methane from the organic matter.

Although not yet fully understood, gas hydrates interest geoscientists, petroleum engineers, climatologists, biologists interested in the unique ecosystems, and others seeking to extract clues about Earth's past and future.

Bob Collier holds a burning gas hydrate.

Stability and Role in the Climate Model

Gas hydrates are destabilized by heating or loss of pressure. Earthquakes, fluctuations in ocean temperature, sea level changes, and other natural phenomena—as well as human activity such as drilling—may destabilize gas hydrate deposits, releasing possibly large amounts of methane into the atmosphere. Methane is a powerful greenhouse gas, with 20 times the warming capability of carbon dioxide. Several studies have suggested that methane released from gas hydrates has affected global climate in the past, such as the runaway greenhouse climate of 55 million years ago.

Researchers are working to identify the geological processes that most likely affect the stability of hydrates in sediments and to account for the effects of hydrates in climate models—whether moderating or accelerating change. For example, hydrates may contribute to warming during an ice age. As sea levels fall when more water is bound in ice at the polar caps, there is less water above hydrate beds; the drop in pressure can cause instability of hydrates and a release of methane into the atmosphere. Hydrates may also accelerate global warming. As sea temperatures rise, hydrates could again become less stable and release methane. Increased methane release from hydrate deposits in the warming permafrost at high latitudes has been measured in recent years.

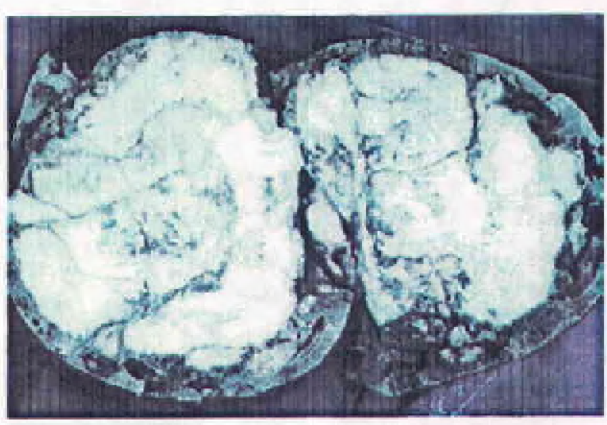
Energy Potential

There is marked interest in gas hydrates because of their potential as a source of fuel for the future. More methane may be stored in gas hydrates than in all other conventional fossil fuel reservoirs. But it is challenging to accurately assess the amount of methane trapped in gas hydrates around the globe because gas hydrates quickly decompose into water and gas when marine sediments containing hydrates are recovered. Recent data show that gas hydrate distribution is patchy. Nevertheless, high concentrations of hydrates occur in distinct deposits that can be mapped with advanced remote sensing data.

Before gas hydrates can be used as an energy source, the risks associated with mining gas hydrates must be better understood. The United States Department of Energy's ambitious research plan begun under The Methane Hydrate Research and Development Act of 1999 includes research on what production methods could safely harvest the methane and whether release of methane could cause collapse of seafloor foundations for oil and gas drilling rigs or raise greenhouse gas levels.

Quantifying Methane Hydrates Using New Technologies

Research on gas hydrates is aimed at answering questions about the depth of gas hydrates beneath ocean floor, the size of the known fields or veins of hydrate, and potential locations of other fields. The acoustic signature of methane hydrate can help researchers locate and study it. Sound waves accelerate when a methane reservoir is encountered. Gas hydrates—whether in layers, veins, nodules, or smaller amounts in sediment pores—bind together the sedimentary layer and make it stiffer. When the stiffer sediment of a hydrate fields overlays a fluid



Gas hydrate.

reservoir of free gas, the interface of those two layers reflects back seismic waves in patterns called bottom simulating reflectors or BSRs.

Scientists are studying core samples and digital data to better calibrate scientific instruments used to image gas hydrate deposits, understand the processes that form gas hydrates, interpret the geological record of past gas hydrate occurrence, and learn about the microbial processes that supply and consume methane in this environment.

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Ocean Drilling Program (ODP) Leg 204 expedition to Hydrate Ridge in 2002 studied the distribution, concentration, and environmental effects of gas hydrates. Scientists drilled 45 holes at 9 sites and recovered more than 11,811 feet of sediment in a suite of 33-foot long cores. One of the most surprising results of Leg 204 was the discovery of the coexistence of massive gas hydrate, free gas, and highly saline pore water in the upper 6 to 12 feet of sediment near the summit of Hydrate Ridge. When hydrates form, salt is excluded and is slowly diffused from the hydrate over time. If the hydrate forms quickly, however, salts don't have time to diffuse, and the water in the sediment pore space becomes saltier than seawater.

The discovery of highly saline fluids proves that gas hydrate is forming rapidly. This also explains why plumes of bubbles emerge from the seafloor and rise through the water column above several topographic highs on the Oregon margin. Scientists speculate that the geology of the area, which includes active faults and margins, creates a dynamic environment for free gas and methane hydrate to occur simultaneously. Scientists were able to quantify gas hydrate abundance during Leg 204 using new technologies. These include the first use of the hyacinth system, which recovered and preserved gas hydrates under the pressure at which they were formed, and a digital infrared imaging camera (developed by FLIR Corporation of Portland, Oregon) that helped to detect and quantify icy gas hydrates in the cores. These technologies, combined with traditional approaches, advanced understanding of how much gas hydrate is present in marine sediments and the processes that control its distribution.

Researchers working in this field propose a long-term observatory on and beneath the seafloor off the Oregon coast to understand the dynamics of gas hydrate systems. Engineers are developing new technologies to mine gas hydrates and researchers will continue to study hydrates to understand this fascinating seafloor environment and potential energy source.

Gorda Ridge

Hydrothermal Vents

Known as the "Gateway to America's Wild River Coast," Port Orford is located 70 miles north of the California border. Rich in history and natural resources, this small coastal town with its rugged beaches, cranberry bogs, and historic architecture points westward to an equally diverse and unique underwater landscape.

Due west of Port Orford lies Gorda Ridge, an undersea mountain range that runs in a north-south direction off the coast of southern Oregon and northern California. This area of the Cascadia undersea subduction zone was thought to be dormant until a few years ago. On the ocean bottom, magma underlies the ridges where new ocean crust is being formed. The underlying molten magma is at least 2200 °F, while water deep in the sea is cold, approaching 32 °F. This large temperature differential cracks the rocks which separate the two layers, creating fissures and faults. The temperature differential also causes ocean water to circulate through the cracks in the volcanic basalt. Cold seawater is pulled down into the fissures; it becomes heated, dissolving metals and other minerals from the rocks it passes. Heating causes the metal-rich solution to become lighter and more buoyant and push through the fissures.

At the seafloor, the rising solution forms a hot geyser into the cold seawater. The solution has a different chemical composition from that of seawater: it contains much higher percentages of metals such as iron, hydrogen sulfide, manganese, and zinc. Dissolved materials carried in the solution precipitate out in the water column. Some precipitate creates "chimneys" of a half-meter to several kilometers tall. The buoyant fluid rises up through the chimneys and then spreads out in plumes, like the heated smoke coming out of a factory smokestack. These plumes of solution look like smoke; thus some vents are called "black smokers."

Exploring the Vents

Vents were first explored at the Galapagos Spreading Center in February 1977. OSU oceanographer Jack

Caption goes here.

Corliss, chief scientist for the expedition, was the first observer who ventured into the deep-sea research vessel Alvin, the three-person submersible that descended 8,200 feet to the ocean bottom. Corliss and his colleagues found multitudes of unknown organisms swarming around warm fluids seeping from cracks in the hardened lava, a virtual oasis in the middle of an otherwise barren landscape. Alvin scientists successfully gathered samples of these remarkable organisms, as well as fluids streaming out of the vent, and brought them to the surface for further examination.

Scientists with NOAA's Vents Program had been using undersea instruments to track seismic activity on the volcanic Gorda Ridge. In 2001, a modified version of the U.S. Navy's once top-secret array of submarine-tracking hydrophones detected a volcano erupting on the ocean floor 130 miles off the southern Oregon coast. Like the Juan de Fuca Ridge off the northern Oregon and Washington coasts, molten lava oozes from the ridge to the seafloor. When the magma is injected into the ridge and the rocks crack, seismic activity occurs. Corresponding earthquakes were strong enough to be detected by land-based seismographs, the largest measuring 4.5 magnitude.

Robert W. Embley, a marine geologist with NOAA's Vents Program, and Christopher Fox, a geophysicist with the Vents Program at the Hatfield Marine Science Center, were the first to witness this live seafloor eruption after the detection system was installed in 1993. In 1996, Fox just missed an eruption because of bad weather and inadequate equipment. Until that time, technology and scientific knowledge was limited; most research was restricted to land volcanoes and seismic events and little was known of the deep-sea landscape.

However, long cables, underwater cameras on ships and submersibles, and multi-beam swath bathymetry allow for exploration of the deep sea. The earliest maps of the seafloor were based on lowering primitive sounding lines that characterized only a small fraction of subsurface features, leaving the impression there was little relief to the seafloor. Single beams of sound were replaced by multi-beam systems (see sonar sidebar) in 1979, followed by multi-beam swath bathymetry, a system that measures water depth and emits multiple sonic waves to map a wide swath of the seafloor. Scientists are now able to map the seafloor with an accuracy of about 33 feet. Researchers now know that eruptions and earthquakes can have dramatic effects on the ecosystems of the upper ocean as well as the seafloor, sending up huge plumes of warm water that can be several miles wide, rising 5,000 feet above the seafloor and halfway to the ocean's surface.

Vents Off the Oregon Coast

Since their discovery, hydrothermal vents have been found on several ocean ridge systems, including the Juan de Fuca-Gorda Ridge system off the coast of Oregon and wholly within the Exclusive Economic Zone (EEZ) of the United States. The Gorda Ridge is an undersea mountain range that runs in a north-south direction off the coast of southern Oregon and northern California.

In 1993, scientists were able to install a monitoring system of underwater microphones near the Axial volcano on the Juan de Fuca Ridge, where a megaplume of high-temperature hydrothermal fluids had been observed several years earlier. Within a week, scientists heard the first volcanic eruption. The crew on a research vessel at sea located the 12-mile plume and measured its temperature and height. Within another week scientists lowered a remotely-operated vehicle to study the immediate after-effects of such a plume. NOAA began fine-scale reconnaissance of the area. The volcano's caldera (crater) was 2 miles wide and 4 miles long. Three vent fields covered much of the caldera.

The Gorda Ridge Hydrothermal System contains massive copper-, zinc-, and gold-rich sulfide deposits. Active research is underway at Gorda Ridge to study clues about the Earth's core, survey mineral deposits, and learn about hydrothermal ecosystems.

Caption goes here.

Prospecting for Vents

When the very first vent was discovered at the Galapagos Spreading Center, oceanographers searched targets for signs of new volcanic activity and venting at depths of 21,300 to 37,730 feet beneath the ocean surface. COAS geochemist Gary Klinkhammer tested water samples taken on that expedition and published the first decisive work on hydrothermal manganese, an element highly enriched in vent systems which has become one of the most applied tools in vent "prospecting."

Scientists can use what they have learned about the chemical composition of the effluent of hydrothermal vents to search for traces in the sea water and track the effluent to its source. A CTD instruments can measure seawater salinity, temperature, and anomalies created by hydrothermal vents at various depths. Because hydrothermal particles cause the surrounding ocean water to become cloudy, scientists also use a transmissometer to measure the transparency of water and help them find new vents.

Hydrothermal vents are not fixed geological features. A 2002 expedition returned to the Rose Garden site at the Galapagos Rift, discovered in 1979 and studied throughout the 1980s. Instead of a fissure in the ocean floor supporting a vibrant animal community, the scientists found that Rose Garden had been covered by a lava eruption. But only 650 feet away, new hydrothermal vents named Rosebud have appeared, supporting yet another vibrant community of mollusks, tubeworms, and anemones. Someday, these new vents may also be buried.

Unique Lifeforms

The diverse lifeforms found at Rose Garden in the Galapagos exploded the myth of the deep ocean as a featureless abyss with little life. The organisms clustered around the hydrothermal vent were new species, often new Families or Orders, and one new Phylum.

Life requires water, carbon, minerals/nutrients, temperature range, space, and an energy source. On Earth's surface, oxygen is used to burn organic carbon as fuel. Colonies of plants and animals can convert chemicals to energy at seawater depths where photosynthesis is not possible. Organisms in the deep ocean can take oxygen directly from sea water to burn iron, manganese, or some other compound found in rock.

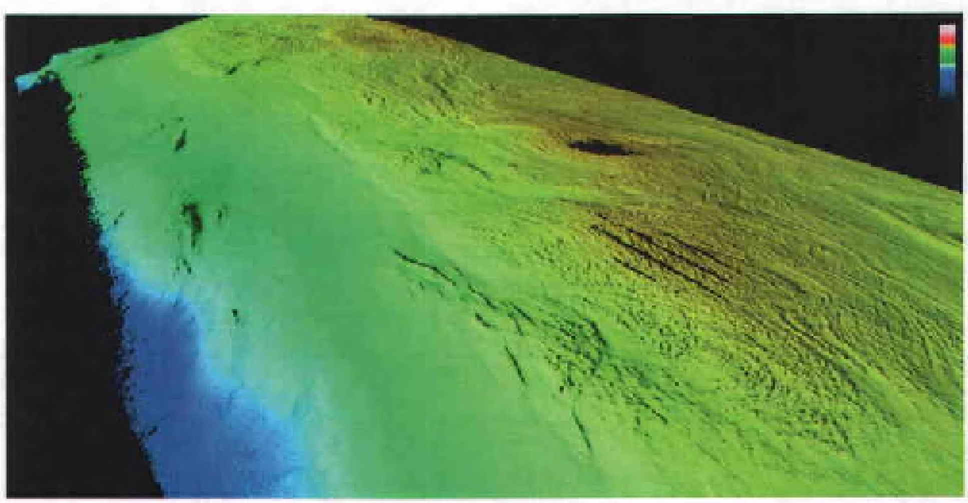
Observations from the ocean-bottom colonies continue to expand what we think of as the habitable area of Earth. For example, microorganisms found at the Mothra vent field on the Iuan de Fuca Ridge in 2003 were growing in a 250 °F environment. Water at that depth is under great pressure and does not boil. It was previously thought no life could exist at this temperature, the same temperature used in autoclaves to sterilize instruments. Yet, microbes living in volcanic basalt have been found near hydrothermal vents. Microbiologists and marine geologists continue to look for new ecological niches that can be exploited by microbes.

The small size and isolation of these short-lived hydrothermal environments raise questions about how lifeforms find their way there. In addition to discovering new species and environmental niches, researchers aim to understand chemosynthetic communities, how larva is dispersed, survival techniques, and how life thrives in extreme heat and amid toxic metals.

Heceta Bank Blanco Fracture Zone

A Seismically Active Transform Fault

The Blanco Fracture Zone is a seismically active transform fault off the coast of Oregon. Earthquakes are common along the Blanco Fracture Zone, but the plates slide past one another and do not change the shape of the ocean floor. Thus, tsunamis are not created, and the earthquakes are rarely felt.Continental margins are the location of recently discovered features: hydrothermal vents, cold seeps, and gas hydrates. Their discovery was made possible by advances in technology, such as the deep-sea submersible Alvin and pressurized coring tools, which make possible exploration of the deep seafloor. Researchers are beginning to map the extent of these features and to understand how these seafloor features impact climate models, future fuel needs, and our understanding of Earth as one integrated system.



Caption goes here.

APPENDIX 2

Icebergs and Sea Ice Lessons

These two lessons are part of the "Suitcase Lessons in Oceanography" for K-6 students developed by S. McAuliffe as part of a NSF GeoEducation grant. (GEO-0224566). Complete portable modules ("Suitcase Lessons") will allow any member of our faculty, and other institutes to introduce science concepts included in state and federal science standards, within the context of oceanographic science. The lessons are inquiry dominated, and are designed to complement the FOSS (Full Option Science System) science curriculum currently in use in the Linn-Benton-Lincoln Educational Service District. They are based on fundamental science principles, the process of scientific research and the excitement of discovery.

The lessons were generated with input from four teachers from Adams Elementary school and Oregon State University oceanographers Kelly Falkner and Marta Torres, whose input was pivotal to the success of this effort. The teachers met individually with the scientist to brainstorm ideas for the lessons and to give feedback about possible lessons. They arranged for the scientist to teach the "suitcase" lesson to their class, and gave a pre- and post- knowledge assessment survey. After the lessons were presented, the teachers provided evaluations on the lessons' effectiveness and offered suggestions for improvement.

Each kit includes: Introductory materials that outline science concepts, detailed descriptions on how to use the materials, alignments to benchmarks (generated by Melissa Feldberg), handouts and a complete set of materials needed to present the lesson to a class of ~30 students.

Evaluations include:

- Pre-class test of the students' knowledge of a specific topic given the day before the lesson is taught.
- Post-class test given the day after the lesson is taught (test is the same as pre-test)
- Evaluation sheet completed by the presenter based on students response, personal observations and any input from the teachers.

The science/math concepts covered include:

- Review the concept of density which was presented in the FOSS water kit.
- Review the water cycle and concepts of evaporation and precipitation.
- Discuss formation of icebergs through the "iceberg cycle" while emphasizing the idea of compression of snow to form glaciers and calving of glaciers to form icebergs.
- Discuss formation of sea ice through the "sea ice cycle" and how that differs from iceberg formation.
- Briefly discuss the way that sea ice affects animals and people living in these cold environments and the importance of sea ice and iceberg knowledge for navigation of seafaring vessels.
- Estimating/fractions – Icebergs are ~7/8ths below the sea surface.

- Reinforce the concept of cycles in nature.

Hands-on activities include:

- Students physically move through the iceberg cycle and sea ice cycle as a water molecule with a developed set of hand signals.
- Observing physical differences and similarities between Icebergs and Sea Ice images.
- Creating a Venn diagram depicting the differences and similarities between icebergs and sea ice.

GLOSSARY for Icebergs and Sea Ice Lesson

adapt (a-'dapt) to make fit (as for a specific or new use or situation) often by modification.

calving ('kav-ing) *of an ice mass*: to separate or break so that a part becomes detached, and falls into the ocean, creating icebergs.

compress (kom-'pres) to reduce in size or volume as if by squeezing.

crystallization ("kris-ta-li-'zA-shun) to form crystals; in our case ice crystals and snow flakes from water molecules.

evaporation (e-vap'-o-ra'-tion). The physical process of transforming a liquid into a gas by heating or warming the liquid (Ex/ the sun warming the ocean).

glacier ('glA-sher). a large body of ice moving slowly down a slope or valley or spreading outward on a land surface.

iceberg ('Is-"berg). A large piece of floating ice that has broken off of a glacier. The greater part of its mass is below sea level.

oceanographer (oc-ean-o'-gra-pher). A scientist who studies the ocean.

Cool Facts about Icebergs and Sea Ice

1. When iceberg ice is dropped into water it makes cracking and popping sounds. This is due to the highly pressurized gasses in the ice being released.

2. The largest iceberg on record was found in the Antarctic. It was 280 miles long and 60 miles wide!

3. The largest iceberg found in the Arctic was 8 miles long and 4 miles wide. If melted down it had enough freshwater for each person in this world to have 4 liters each of water to drink.

4. The name "Iceberg" comes from the Danish word "*iisbierg*" and Swedish word "*isberg*" which both mean "mountain of ice"

Notes for Suitcase Oceanography Icebergs and Sea Ice
Lesson 1
Where do Icebergs come from?

1. **In Advance**
    a. One day in advance of you arriving have the teacher give the kids the pre-evaluation test.
    b. Ask the teacher if they could have the students make and wear name tags.
    c. Print up enough copies of the "iceberg cycle" worksheet for the kids in the class to each have their own copy. The Venn diagram map should be copied on the back side of the "iceberg cycle" worksheet and will be used during day two.
    d. Students will need a pencil to fill out the "iceberg cycle" worksheet when the time comes.

2. **Introduction**
    a. Hang wall chart of iceberg cycle upon arrival and distribute handouts (laminated sheets and worksheet).
    b. Give your name (s) and say you are from COAS-OSU (explain the acronym).
        i. Tell kids that you are an oceanographer
        ii. Ask the kids for a definition of "oceanographer."
        iii. Tell the kids what "oceanographers" study and that you are here to specifically talk about Icebergs and Sea Ice over the next two days.
        iv. Tell the kids to raise their hands to be called on for answering questions
    c. Put the world map up on the overhead (the kids will also have a handout of it with Greenland on the backside).
        i. ASK: "Where in the world do you think you would find Icebergs and Sea Ice?"
            1. ANS: Arctic, Antarctic, Alaska, Greenland (most icebergs in the Arctic come from Greenland… see "Greenland Glaciers" handout)
        ii. ASK: "How do you travel to these places in the world?"
            1. ANS: plane, ship
    d. Put up the two overheads of the ship going through sea ice.
        i. "Here is a ship going through sea ice, which we will talk about tomorrow."
        ii. The next overhead shows sea ice turning over after is has been broken by the ship. The sea ice in the overhead is about 2-3 meters thick. Make sure the kids know what a meter is.

(these two overheads are a quick introduction to the lesson tomorrow)

e. Overhead of chipping ice off of icebergs
    i. Iceberg ice is under so much pressure that it makes cracking and popping sounds when placed into water. This is the sound of pressurized gas releasing from the iceberg ice. Small pieces of icebergs can be used as ice in drinks, much like the ice from your freezer at home, which is what these people on the overhead are doing when they chip off pieces of the iceberg.

3. **Vocabulary**
    a. Before we go any further we'll need to go over a few vocabulary terms you'll need to know for the lesson
        i. Put up the "vocabulary" overhead with a piece of paper covering the answers.
        ii. Go through each word and ask the kids if they know what it is then reveal the answer after the class gets a shot at defining the words.
        iii. For calving ask "do you know what a calf is? Well, when talking about glaciers, calving is just the "birthing" of an iceberg from a glacier. You can think of the iceberg as the calf.
        iv. Try to reinforce the vocabulary words as the two day lesson progresses.

4. **Water Cycle discussion** (This is for review purposes. The kids should know what the water cycle is). Put up the overhead of the Water Cycle.
    a. "How many people know what the water cycle is?"
        i. Call on one kid to help you through the water cycle.
    b. "That brings us to something very much like the water cycle… it's called the iceberg cycle! But first we'll nee to do a quick demonstration… Can I have 4 volunteers?"

5. **Iceberg Cycle Discussion/Activity:**
    a. Demonstration of snow compression with 4 kids
        i. Bring 4 volunteers up to the front of the classroom by calling on them.
        ii. Tell them they are going to be water molecules (since it is fun to personify a molecule ask the kids to name the water molecules. Take three suggestions from the kids then choose which one you think will be best or have the kids choose by voting for which one they like best: ex/ our water molecules will be named "Splash")
        iii. "We have 4 "Splashes" up here."
        iv. "What happens when we are in the liquid state?"

1. "Splashes" move around with their hands down but they all have to be touching one another (direct the kids so that they do it correctly)

v. "What happens when water freezes in the atmosphere?" (it crystallizes and forms snow)

1. All 4 "Splashes" should form a pinwheel. All 4 should form a circle and place their left arm in the middle. Each kid should grab the left forearm of the kid in front of them with their left hand. (The kids will have to be walked through this section of the demonstration). Now we are frozen and we've formed a snow crystal. "Are we more or less dense than water?"
    a. ANS: less dense… should know that from FOSS kit
2. Do water molecules take up more volume when they freeze? (yes… kids should know this from FOSS kit)
3. How do we know this? (ice floats on water)

vi. Now we will <u>*compress*</u> the snow

1. Have the kids all squeeze in toward the middle while you simulate a force coming from all sides of them pushing the kids together.

vii. "this is exactly what happens to the snow that forms a glacier, layers of snow fall over the years compressing the lower layers of snow and turning them into glacier ice"

b. Iceberg cycle (in the classroom)

i. "Let's follow "splash" through the iceberg cycle. First the water crystallizes into snow…(continue through the cycle)" Ask kids to help you out along the way which shouldn't be too hard since the poster will be right in front of them.

ii. Snow → falling → mountains → no melting/compression → glacier → calving → iceberg → melting → water → evaporation → clouds → cooling → snow

1. As you go through the cycle give the kids hand signals to do for all of the actions
    a. ***Falling*** - both hands above your head slowly falling down toward your waist. Flutter your fingers to simulate snow.
    b. ***No melting/compression*** – press both palms together simulating the squeezing of an object.
    c. ***Calving*** – hold one hand straight out, palm down. Hold your second hand on top of and perpendicular to your first hand. Run your second hand off the front edge of your first hand simulating a piece of ice breaking off of a glacier.

d. ***Melting*** – both hands above your head making wave motions as they come down towards your waist. Simulates heat waves and ice turning back into water.
e. ***Evaporation*** – do the opposite of falling. Hands start by your waist and rise over your head with fingers fluttering to simulate water vapor rising into the air.

iii. "What big part of this cycle am I missing?"
1. ANS: the sun! ... The sun was left out so that the kids could look at the iceberg cycle critically and apply their water cycle knowledge to the iceberg cycle.

iv. "Are there any glaciers in Oregon? Do these glaciers calve? Why/why not?" (There are glaciers on Mt. Hood. These glaciers do not calve since calving is when a piece of glacier breaks off and falls into the ocean).

c. ***Iceberg Cycle Activity*** (outside or in an indoor open space if the weather outside is bad. See "Iceberg Cycle Activity Layout").

i. You'll need the pieces of rope included in the kit or use the existing playground markings (basketball court, foursquare court) to designate the different areas of the iceberg cycle on the ground. There is also sidewalk chalk included in the kit which can be used as a third option for marking areas for the activity. There are three areas you need to mark off:
1. **Atmosphere** – a designated area where kids can move around as water vapor. *Use the rope that has been tied to form a circle.*
2. **Mountains** – a flat line with two sides drawn on it to designate the extent of the mountain range. *Use the shorter length of rope which is included. TIP*: Make sure that the kids start layering on top of each other. This forces the kids not to line up, which, at this age, goes against the ingrained skill of forming lines.
   a. Make sure that the mountain line leads into an area that can act as the ocean. This will be where the glaciers calve off into.
3. **Water** – the surface of the ocean needs to be drawn on the ground so that the kids know their boundaries when they are in the "water" as "icebergs." *Use the longer length of rope to designate the surface of the ocean.*
   a. When the kids form icebergs they should remain on the surface because ice floats!

ii. Have the kids gather in one confined area (usually the "atmosphere") so that you can set up the activity. Talk to them while you are drawing your chalk lines or laying down the rope… that way you can emphasize that they need to pay attention to you.

iii. Atmosphere – the kids are gathered in this one confined area and they are now all "splashes" floating as water vapor in the atmosphere. Tell them to move around since water molecules in the vapor form do this in the atmosphere.

iv. The air is now cooling so what do the water molecules do? They crystallize and form snow. This snow falls into the mountains (remind the kids to do the hand signals for the iceberg cycle actions). Remember the activity we just did indoors where we formed the pinwheel crystal. Now, outside, each kid represents many crystals of snow.

v. As more snow falls on us in the mountains what do we do? ***Compress***

vi. Now we move slowly toward the ocean as a … ***Glacier*** and we… ***Calve*** off into the ocean (have the kids in groups of threes when they are in their initial "iceberg") Tell the kids to "stop moving" or "freeze" and try to identify the "icebergs".

vii. "The sun comes out so the icebergs start ***melting***." Tell the kids to "stop moving" or "freeze" so that you can make sure the icebergs are getting smaller.

viii. "Now the sun is warming up all of you so what happens? You… ***evaporate*** and go back into the atmosphere."

ix. That brings you to the end of the Iceberg cycle. Run through it again to drive home the cycle. Make sure that the kids show you the hand signals for each action in the Iceberg cycle.

x. When done, bring the kids back inside and tell them to get out their Iceberg cycle handout.

d. Fill out Iceberg Cycle handout

i. Put up an overhead of the terms that will fit in the Iceberg Cycle so that the kids can copy and spell the words right.

ii. Give them a minute to fill out the handout then go back over it so that every kid will have the correct answers. Cover up or take down the Iceberg Cycle poster so that the kids can't just copy the poster.

6. Description of icebergs

a. Mention what descriptive terms are and what the kids should focus on (e.g. color, shape, size)

b. Have an iceberg handout for each kid in the class and give them all a minute to look over the iceberg pictures and think of descriptive terms for them.

c. Describe the different relative sizes of icebergs (See "Iceberg and Sea Ice Size" handout):

i. Growler – the size of a car.

ii. Bergy Bit – Roughly the size of a 32 foot boat.

iii. Small berg – Roughly the size of a 200 foot ship
iv. Medium berg – the size of an oil platform
v. Large berg – size of an oil tanker

d. How do you know the size of icebergs? This will connect with the idea of scale (boat and plane next to icebergs).
   i. Put up the first iceberg overhead up and ask for the kids to give you descriptive terms (they will also have a handout with the iceberg). TIP: the kids will probably say "large" or "big" ask them how they know that.
   ii. Show another picture this time with the plane in it. "How do you know the size of this iceberg?" This will bring in the idea of scale.
   iii. Show a third picture without the ship and ask for a few more descriptive terms. Ask again how big the iceberg is then put up the overhead that shows a boat next to that identical iceberg.
e. Why might it be important to describe icebergs?
   i. Common language between ships navigating iceberg infested water. (e.g. "Look out for the blocky shaped small berg in front of you.")
f. As you talk about the different sizes of icebergs ask the kids if they might be dangerous to ships.
g. Ask the kids "How much of an iceberg do you think is underwater?" (about $7/8^{ths}$ of an iceberg is underwater)... Make sure the kids know what $7/8^{ths}$ means and explain fractions. Most of the kids will be familiar with fractions so a good way to explain a concept is to have one or two of the kids who understand it, explain the concept to the rest of the class.
h. Show the overhead with the iceberg underwater. Tell the kids that one reason icebergs are dangerous to ships is that you can't see a majority of the iceberg because it is underwater.
i. Icebergs are very dangerous because they are unstable and can flip over easily.
j. Put up the overhead of Jerome Baker towing the iceberg and tell the kids that some people have jobs where they move icebergs so that they don't damage oil platforms (see included article).

7. **Recap:**
   a. Ask students to share one thing they learned today that they did not know before (this will act as a self led summary of your iceberg lesson).

Where Do Icebergs Come From?
ALIGNMENTS TO BENCHMARKS (NSES K-4)

Inquiry (A)

Abilities Necessary To Do Scientific Inquiry
- Ask a question about objects, organisms, and events in the environment
- Communicate investigations and explanations

Understandings about Scientific Inquiry
- Asking and answering questions and comparing the answer with what scientists know about the world
- Types of investigations include describing objects, events, and organisms; classifying them; and experimenting
- Scientists develop explanations using observations and what they know about the world
- Scientists make the results of their investigations public and review and ask questions about other scientists' work.

Physical Science (B)

Properties of Objects and Materials
- Materials can exist in different states – solid, liquid, and gas. Some common materials, such as water, can be changed from one state to another by heating or cooling.

Earth and Space Science (D)

Properties of Earth Materials
- Earth materials are solid rocks and soils, water, and the gasses of the atmosphere.

Changes in the Earth and Sky
- The surface of the earth changes.

Science and Technology (E)

Understanding about science and technology
- People have always had questions about their world. Science is one way of answering questions and explaining the natural world.
- Women and men of all ages, backgrounds, and groups engage in a variety of scientific and technological work.
- Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

History and Nature of Science (G)

Science as a human endeavor

- Many people choose science as a career and devote their entire lives to studying it. Many people derive great pleasure from doing science.

Thinking Processes (from FOSS)
Relating
Organizing
Comparing
Communicating
Observing

Where Do Icebergs Come From?

ALIGNMENTS TO OCSS (Benchmark 1 – Grade 3)

Matter

- Describe objects according to their physical properties
- Describe changes that occur in matter

Earth and Space Science

- Recognize physical differences in Earth materials.

Scientific Inquiry

- Make observations. Ask questions or form hypotheses based on those observations, which can be explored through simple investigations.

WHERE DO ICEBERGS COME FROM? - LESSON 1

Checklist

Name: ____________________ School/Agency: ____________________
Address: ____________________ Telephone: ____________________
City: ____________________ County: ____________________ Zip: __________
Check Out Date: __________ Check In Date: ____________________

Item (Circle any items that are missing)	Check In	Chec k Out
LESSON MANUAL		
FOSS TEACHER'S GUIDE		
THE ICEBERG CYCLE - POSTER		
ROPE FOR ICEBERG CYCLE ACTIVITY		
LAMINATED HANDOUTS - (ICEBERGS, WORLD MAP)		

I acknowledge that I have physically reviewed the trunk items and that all items are included and are in satisfactory condition. I further acknowledge that the items are my responsibility for the time I have the trunk and that the loss of any items is my responsibility to replace.

____________________ ____________________

Checked Out By: Checked In By:

Notes for Suitcase Oceanography Icebergs and Sea Ice
Lesson 2
Why is sea ice formation important?

8. **In Advance**
   a. Hang up the Sea Ice Cycle poster along with the Iceberg Cycle poster
   b. Make sure that the kids have their Venn Diagrams which are printed on the backside of the Iceberg cycle handout.
   c. Students will need a pencil to fill out the Venn Diagram handout when the time comes
9. **Review the day before**
   a. Review some of the things that the kids learned yesterday (have a kid lead you through the Iceberg cycle chart…; Ask them questions about sizes of icebergs and names of those different sizes; recap why icebergs can be dangerous to humans.)
   b. Discuss with the kids that you will be talking about sea ice today as opposed to icebergs.
10. **Sea Ice cycle Discussion/Activity**
    a. Go over the sea ice cycle with the kids in the class emphasizing the different stages of ice formation and the fact that sea ice has a little bit of salt left in it.
       i. Name the salt molecules by asking the kids what they think it should be named. Take three suggestions then have the class vote on it by raising their hands. When you do the exercise outside you can have water molecules that you named the day before ("splash") and salt molecules that the class just named (e.g. "Fred")
       ii. Demonstrate inside with 5 kids this time (see day one demonstration). This time only two kids will form an ice crystal by facing each other and holding each others hands. When that crystal is formed have the remaining kid put on a colored penny and be a "Fred." That "Fred" will get locked in between (stand in between) the two ice crystals.
       iii. This is what happens to some of the salt in Sea Ice… it gets trapped between ice crystals.
11. **Sea Ice Cycle Activity**
    a. Lead the kids outside. Today you will only need to designate where the ocean is. If possible, try to use the space that was designated as the ocean for the iceberg cycle as the ocean for this lesson also.
    b. The kids swirl around in the ocean as "Splashes." When the water starts to get cooler the "Splashes" form two person ice crystals and rise up to the surface. Ask the kids what is missing… the salt (Freds)! (If there is an odd number of kids then handout an odd number of salt pennies, for an even number of kids handout an even number of pennies)

c. "Now there are "Splashes" and "Freds" floating around in the water because it is… sea water which is salty."
d. "We're all mixing around and now the water is cooling off so form your crystals and since we are… less dense than water we rise to the surface."
e. "What happens to the "Freds"?" Most of them go back into the water but some of them get stuck in between the ice crystals.

12. Description of sea ice

a. Have a sea ice handout, which has grease, nilas, and pancake ice on one side and first-year and multi-year ice on the back side, for each kid in the class and give them all a minute to look over the sea ice pictures and think of descriptive terms for it.
b. Remind them that descriptive terms are used to describe the color, shape and size of the sea ice
c. Now that we have formed sea ice, what are the different stages of this formation?
    i. Water → grease ice → nilas ice → pancake ice → first-year ice → multi-year ice → water
d. Place the sea ice overheads up in the order that they are formed and ask the kids for descriptive terms:
    i. **Grease ice** is like slush
    ii. **Nilas ice** is like the thin brittle ice that forms over puddles that kids like to break through and smash.
    iii. **Pancake Ice** is a bit thicker but has rounded edges from smashing into other pieces of ice.
        1. Some kids (in Newfoundland) will play a game called "copying" where they hop from piece to piece of pancake ice. This is a very dangerous game.
        2. On the "Icebergs and Sea Ice size" pancake ice is similar to the size of a bergy bit.
    iv. **First year ice** is about 2-3 meters thick and forms during the first year. All floes on the "Icebergs and Sea Ice size" handout refer to first year and multi-year ice.
    v. **Multi-year ice** is a bit thicker, 3-5 meters, and forms over multiple years. This is the ice that researchers land planes on.
e. How do you know the size of the sea ice? This will reconnect with the idea of scale (seal on pancake ice, penguin on first-year ice).
f. As you talk about the different sizes of sea ice ask the kids if they might be dangerous to ships.
g. Yves Sievret is one person who makes a living by being on ships describing sea ice and telling ship captains what ice they can break through and what ice they should avoid (see included article).
h. Because sea ice has salt in it, it is more flexible so in order to land planes on it you must seek out sea ice that is thick enough to support the weight of the plane. Thickness of sea ice depends on the temperature. If the temperature is warmer (-5 degrees C) then the ice

must be thicker to handle a plane landing. However, colder temps mean that the ice would be harder therefore thinner ice will be able to handle the landing of a plane.

i. Remember that sea ice floats which means that it is less dense than water but most of it is also under water. How much is underwater? (about 7/8$^{\text{ths}}$)

13. Venn Diagram

a. Have each kid flip over the iceberg cycle handout and on the back will be a Venn diagram.
b. The categories are Icebergs, Sea Ice, and Same.
c. Give the kids a few minutes to start filling out the chart according to what they think are unique traits to sea ice and icebergs and then what they think the both have in common. Try to emphasize descriptive terms such as color, size, and shape. TIP: use "Thickness" to compare sea ice and icebergs since they both can get big but icebergs are usually much thicker than sea ice.

14. Movie Clip

a. The Blue Planet, Frozen Seas DVD
    i. Show chapters 5, 8 and 10.
b. Chapter 5
    i. Highlight the polar bears hunting on the sea ice... "What do the bears use the sea ice for?" Remind the kids that the bears are probably walking on multi-year ice.
c. Chapter 8
    i. Penguins adapting to the cold by huddling together. Weddell seal dealing with the sea ice freezing over where it lives by scraping a hole open with it's teeth.
        1. What do mammals need to live?... need to breathe air.
        2. Do you think it might be a problem for a seal if sea ice freezes over where it lives all winter? So, how does it adapt to these conditions?

Why is Sea Ice Formation Important?
ALIGNMENTS TO BENCHMARKS (NSES K-4)

Inquiry (A)

Abilities Necessary To Do Scientific Inquiry

- Ask a question about objects, organisms, and events in the environment
- Communicate investigations and explanations

Understandings about Scientific Inquiry

- Asking and answering questions and comparing the answer with what scientists know about the world
- Types of investigations include describing objects, events, and organisms; classifying them; and experimenting
- Scientists develop explanations using observations and what they know about the world
- Scientists make the results of their investigations public and review and ask questions about other scientists' work.

Physical Science (B)

Properties of Objects and Materials

- Materials can exist in different states – solid, liquid, and gas. Some common materials, such as water, can be changed from one state to another by heating or cooling.

Life Science (C)

Organisms and Their Environments

- Organism's patterns of behavior are related to the nature of their environment

Earth and Space Science (D)

Properties of Earth Materials

- Earth materials are solid rocks and soils, water, and the gasses of the atmosphere.

Changes in the Earth and Sky

- The surface of the earth changes.

Science and Technology (E)

Understanding about science and technology

- People have always had questions about their world. Science is one way of answering questions and explaining the natural world.
- Women and men of all ages, backgrounds, and groups engage in a variety of scientific and technological work.

- Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

History and Nature of Science (G)

Science as a human endeavor

- Many people choose science as a career and devote their entire lives to studying it. Many people derive great pleasure from doing science.

Thinking Processes (from FOSS)

Relating
Organizing
Comparing
Communicating
Observing

Why is Sea Ice Formation Important?

ALIGNMENTS TO OCSS (Benchmark 1, Grade 3)

Matter

- Describe objects according to their physical properties
- Describe changes that occur in matter

Life Science

- Describe a habitat and the animals that live there

Earth and Space Science

- Recognize physical differences in Earth materials.

Scientific Inquiry

- Make observations. Ask questions or form hypotheses based on those observations, which can be explored through simple investigations.

WHY IS SEA ICE FORMATION IMPORTANT? - LESSON 2

Checklist

Name: ____________________School/Agency: ____________________
Address: ____________________Telephone: ____________________
City: ____________________County: ____________________Zip:__________

Item (Circle any items that are missing)	Check In	Check Out
LESSON MANUAL		
FOSS TEACHER'S GUIDE		
THE SEA ICE CYCLE - POSTER		
ROPE FOR SEA ICE CYCLE ACTIVITY		
"SALT" PENNYS FOR SEA ICE CYCLE ACTIVITY		
VIDEO – THE BLUE PLANET: FROZEN SEAS		
LAMINATED HANDOUTS – (SEA ICE, SEA ICE CYCLE)		

Check Out Date: __________Check In Date: ____________________

I acknowledge that I have physically reviewed the trunk items and that all items are included and are in satisfactory condition. I further acknowledge that the items are my responsibility for the time I have the trunk and that the loss of any items is my responsibility to replace.

____________________ ____________________
Checked Out By: Checked In By:

Evaluation

Designed by Adams Elementary School 3rd grade teacher Gerhard Behrens and Oregon State University Marine Resource Management Masters Student Scott McAuliffe.

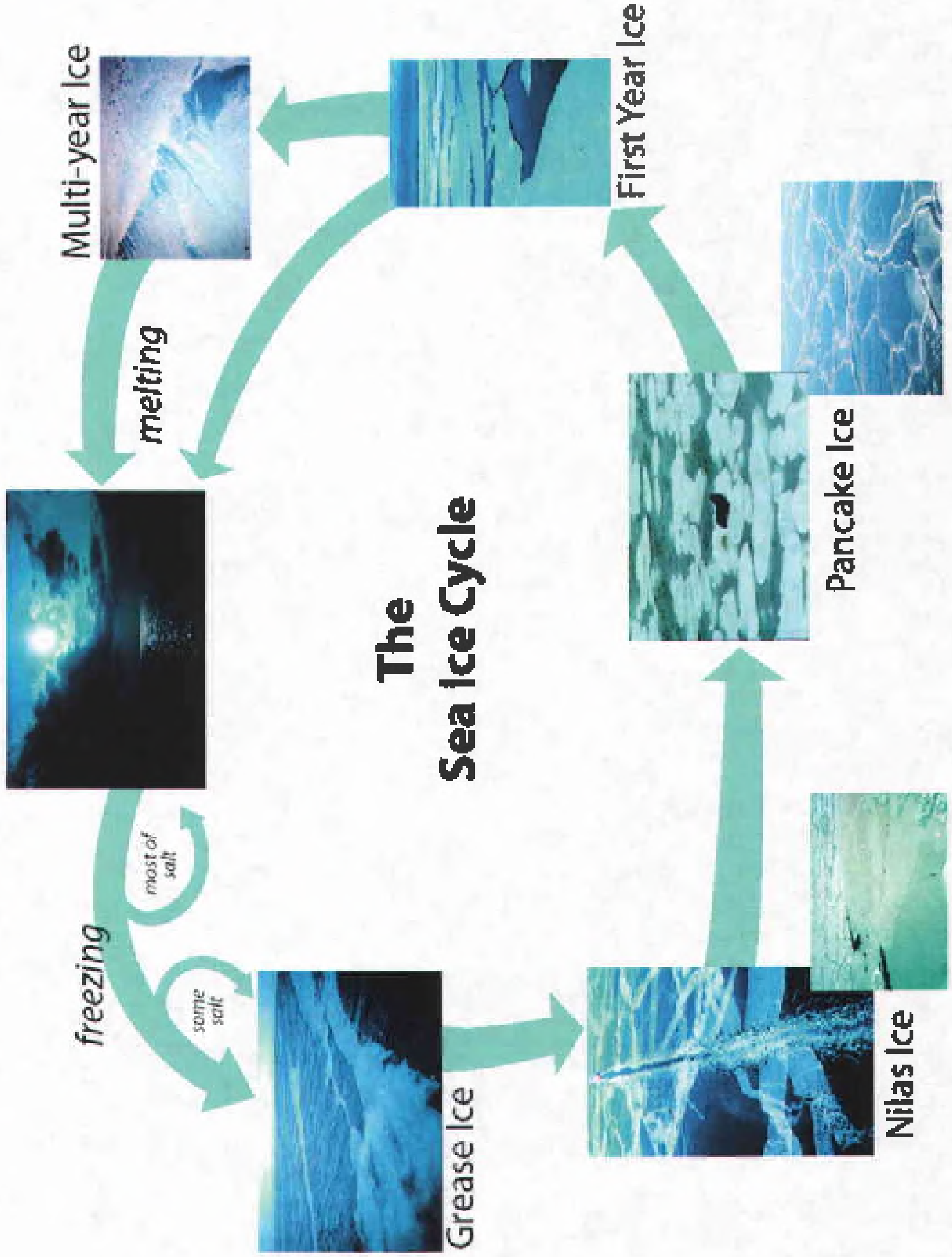
Directions:
The pre-test should be given the day before the first lesson is taught and the post-test should be given the day after the second lesson is taught. Make arrangements with the class teacher to preferably have them give the pre and post test. Approximate time to complete the test should be 5 minutes.

1. The template shown below should be written on the board.
2. Hand out a blank piece of paper for the students to write on. Have them fold the paper in half creating two columns. Label the columns with "Icebergs" and "Sea Ice" (see below)
3. The students are directed to answer the following questions with the help of sentence starters to copy onto their paper (see below).
   a. Tell me three things you know about icebergs and sea ice.
   b. Draw a picture of each of them and show where the water line is.

ICEBERGS	SEA ICE
I know……. **I know……….** **I know……..**	**I know…….** **I know……….** **I know……..**
A picture…….	**A picture…….**

The Iceberg Cycle Poster: 3' x 4' in dimension

The Sea Ice Cycle Poster: 3' x 4' in dimension



Handouts for Iceberg and Sea Ice Lessons

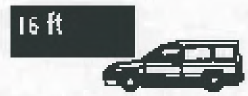
GREENLAND GLACIERS


The
Iceberg Cycle

ICEBERG & SEA ICE SIZE

Growler: less than 5 m (16 ft)

Pancake: 30 cm - 3 m (1 - 10 ft)

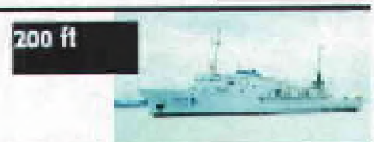


Bergy Bit: 5 - 15 m (17 - 50 ft)

Ice Cake: 3 - 20 m (6 - 65 ft) across

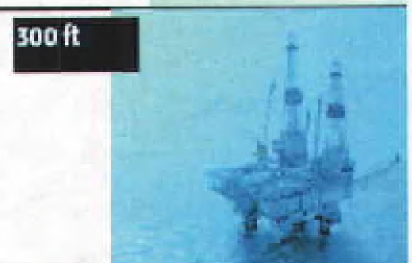
Small Berg: 15 - 60 m (50 - 200 ft)

Small Floe: 20 - 100 m (65 - 328 ft)



Medium Berg: 61 - 122 m (201 - 400 ft)

Large Berg: 123 - 213 m (401 - 670 ft)



Medium Floe:

100 - 500 m (328 - 1640 ft)

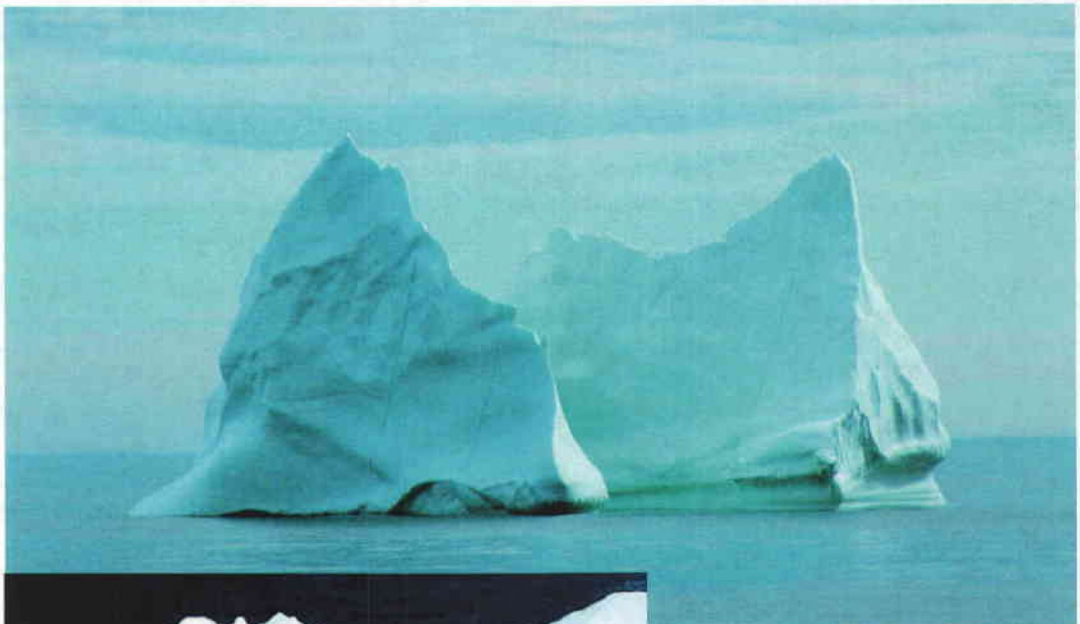
Very Large Berg:

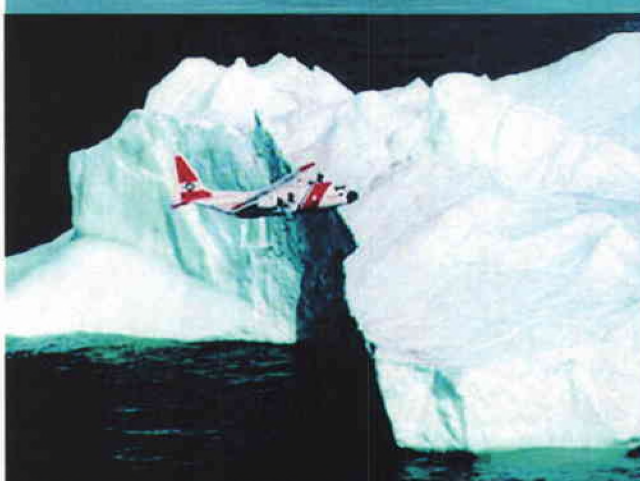
greater than 213 m (670 ft)

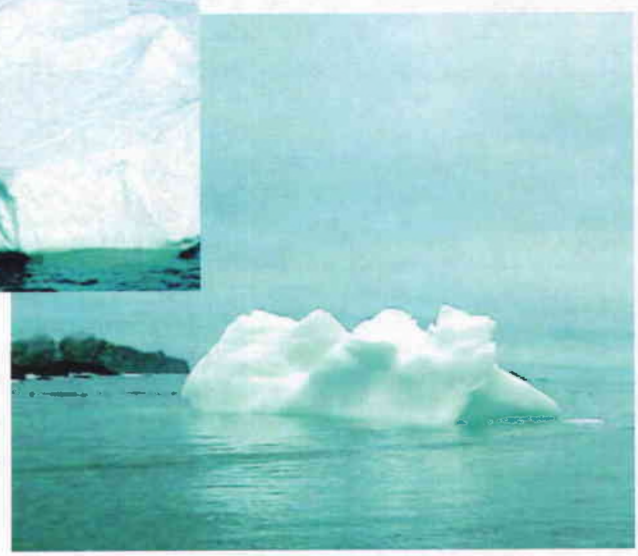
Big Floe:

500 m - 2 km (1/3 - 1 mi)

ICEBERGS







SEA ICE

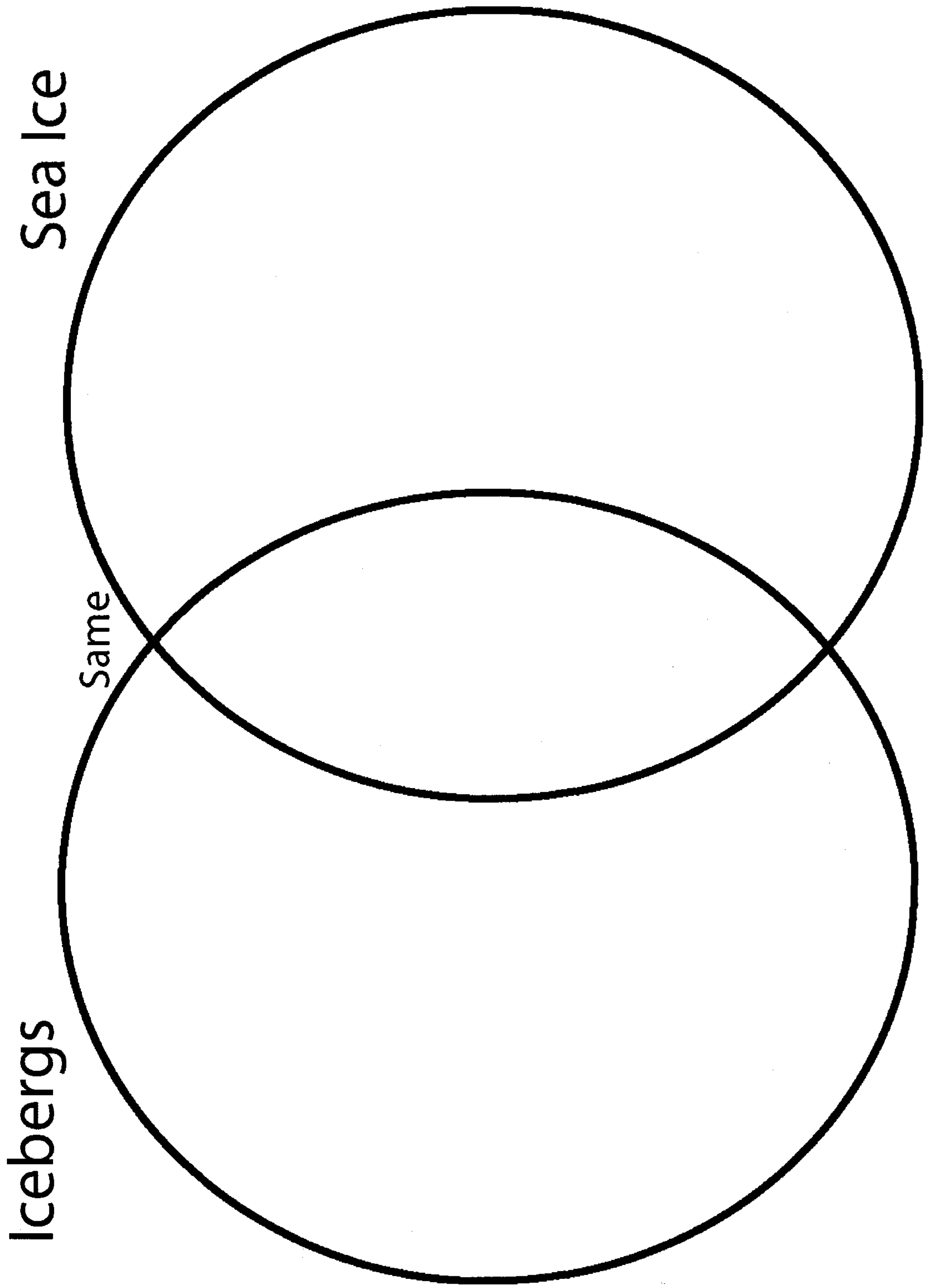
Nilas Ice

Grease Ice

Pancake Ice

First Year Ice

Multi-year Ice


Sea Ice
Same
Icebergs