LENGTH: 4500 Words

Abyssal Plains

The Endeavor to Map the World's Ocean Floor

The deep oceans are the last great frontier remaining on Earth. Trains, automobiles, airplanes and helicopters have conquered the vast wilderness on the terrestrial surface, from the searing deserts and dark forests of the tropics to the icy wastes of the polar regions. Today anyone with the drive and an appropriate budget can travel upriver to the heart of the Borneo jungle, climb Mount Everest or spend the night at the South Pole. But the deep oceans beyond the continental shelves remain aloof, forbidding, unyielding to the call of adventurism and commerce.

Not that long ago, most scientists felt the ocean floor was a vast, featureless plain, a dumping ground slowly filled by sediments eroded from the surface of a fixed, undynamic Earth. Light from the sun, the primary energy source for life on Earth, never reaches the ocean floor and therefore many scientists believed the depths were largely lifeless.

On these counts the scientists were wrong.

The ocean floor is a vast repository of minerals, from metals to petroleum, upon which our industrial society depends. Deep ocean currents affect the world's fisheries, without which millions of people around the world would starve. These same

currents help control the global climate; sudden changes in oceanic circulation may determine whether or not we live in a fairly tolerable climate, as now, or whether we have to endure another Ice Age. The floor of the deep contains many secrets to the history of both the Earth and life, and deep-sea vents may prove to be the womb in which early life evolved.

This book will tell the story of the mapping of the ocean floor, beginning with the first attempts to map the depths in the Age of Sailing Ships to the rise, so to speak, of submersibles and satellites as scientific tools during the Space Age. This period, spanning approximately the last 150 years, encompasses two of the greatest scientific revolutions, evolution and continental drift. The two deadliest wars in history were fought during this time and a Cold War was waged for the hearts and minds of the people of the world; this strife made its mark on scientific progress by motivating governments to fund scientific research at unprecedented levels and by spurring the development of new techniques and technologies that would make the task of mapping the ocean floor possible. During this interval women were finally given the opportunity to contribute to scientific endeavors.

This focus will be on the 30-year-long effort to produce the first map of the world’s ocean floor, published in 1977 by Bruce Heezen and Marie Tharp of Lamont-Doherty Geological Observatory. The map in itself is a work of art; by now several generations of

map enthusiasts have stared awestruck at the colors, lines and details of a world few humans have ever seen. Like the blank spaces on the continent of Antarctica that inspired the deadly race to the South Pole by Robert F. Scott and Roald Amundsen and the epic expeditions of Ernest Shackleton, the World Ocean Floor map tantalizes the imagination. It casts a spell over the soul of the unwary, seducing the landlocked and challenging the adventurous to grow more intimate with the ocean, to care about what is on it, in it and under it. It drives the romantic wild with the desire to see beneath the veil of the water's surface.

The sensual appeal is but a part of the importance of the map. Through the effort to survey the ocean floor, scientists resurrected the moribund theory of continental drift, whereby vast forces reshuffle the locations of land masses over time. Drift had been suspected by some for decades, but as a result of the mapping effort its existence was confirmed. Confirmation of continental drift led to the development of the more inclusive theory of plate tectonics, which explains virtually all of the volcanic and earthquake activity in the world today. The lens of plate tectonics has helped geologists identify promising areas for mineral exploration both on land and below the sea. And this exploration in and around deep-sea vents has led to discoveries that have revolutionized our understanding of the origin and organization of life on earth. This knowledge influences our search for life on other planets, too.

Most scientific histories of this era are linear accounts of how X discovery led to Y paper, giving Z scientist an insight that produced the next cycle of discovery, paper, insight. The narratives unfold as if the process was conducted by faceless, sexless automatons in isolation from the secular world.

All too often, nothing is said of what the scientists experienced while collecting or analyzing the data. In this book, I intend to recreate what it is like to be on, under or over the ocean, or to analyze data collected from the ocean. How does it feel to walk on the rolling deck of a schooner dwarfed by the waves, with the wind howling and rain stinging the face? How can one sleep below deck in the oppressive heat and humidity of the tropics? How does a submariner maintain his composure as the hull creaks and groans in response to the crushing pressure of the depths? What are the dynamics of groups restricted to confined spaces for long periods of time? How does it feel to spend years of one's life bent over a drafting table, hour after hour meticulously plotting measurements on charts by hand, in the hope that someday, somehow, the work will lead to a worthwhile discovery?

The story of ocean-floor exploration contains most of the classic conflicts of great fiction -- man against nature, man against man and man against himself. It is also a love story, about love of the sea, of science, of competition with one's colleagues and of one another. This book will take advantage of

this rich material to rescue the tale from the orderly, sterile environment of academic history and give it the vigorous, combative, lusty humanity it deserves.

MAJOR CHARACTERS

The narrative will be woven around the stories of Marie Tharp, Bruce Heezen and Maurice Ewing, three scientists at what is now known as Lamont-Doherty Earth Observatory of Columbia University. Tharp and Heezen spent 30 years mapping the ocean floor before producing the first world ocean floor map in 1977. Ewing founded Lamont and was largely the driving force behind the collection of the data that led to the map.

Marie Tharp, who worked for Heezen until his death in 1977, grew up all over the southern, eastern and midwestern United States, constantly on the move due to the demands of her father’s job. William Edgar Tharp was a soil surveyor for the U.S. Department of Agriculture, Bureau of Chemistry and Soils. He went into the field and collected data that he and others later used as the basis of the soil survey maps that the bureau began producing shortly after the turn of the century. William Tharp would work in the southern states curing the winter and in the northern tier in the summer. Since there was always a new county or parish to work on, the Tharps rarely returned to any particular location. This may have inspired Marie Tharp’s individualism. It almost certainly had an impact on her love of maps.

Marie Tharp was an indifferent student, a young woman with few prospects for an interesting career in 1941. December 7 of that year changed her life as it did for millions of Americans. While many men were off fighting the Axis, a few graduate departments in the sciences opened their doors to women. As a result, Tharp was rescued from a life as an English teacher, becoming a geologist instead.

After the war, Tharp became bored with her career as a low-level geologist for a Tulsa, Oklahoma, oil company and went to New York to look for something more exciting. She decided against working at the American Museum of Natural History after a paleontologist told her of taking two years to extract a fossil from the surrounding rock. Tharp knew of Columbia University's geology department, so she went up to Columbia's Schermerhorn Hall, where the department was based, and see if they had anything more interesting available.

There she met Maurice Ewing, the man who was soon to found Lamont Geological Observatory. Ewing, flustered by her resume -- including undergraduate degrees in English and math and a Master's degree in geology -- could only ask if she could do any drafting. She said she could, was hired, and spent the next 40 years of her life preparing maps of the world's ocean floor.

Bruce Heezen came from a well-to-do family in Iowa. While an undergraduate geology major at University of Iowa, he attended a talk by Maurice "Doc" Ewing on echo sounding of the Atlantic

Ocean floor. Ewing, finally taking his position on the geology faculty at Columbia after being appointed in 1944, had a lot of research to do but little money with which to do it. So he went on a Sigma Xi -- a scientific honor society -- lecture tour in search of bright graduate students who could serve as research technicians, accepting oceanic adventure instead of pay.

Ewing was a pioneer in the use of explosives as a tool in mapping the geologic strata of the ocean floor. He tantalized his audience with tales of undersea mountains and descriptions of heaving bundles of TNT with short fuses over the stern of ships underway at full speed. Afterwards Heezen went up to meet Ewing, who asked, “Young man, would you like to go on an expedition to the Mid-Atlantic Ridge? There are some mountains out there and we don’t know which way they run.” Heezen, like a fisherman summoned to become a disciple of the Messiah, heeded the call.

Early on Heezen was Ewing’s star pupil, but later he became involved in a bitter feud with Ewing. As with many feuds the cause is a mystery, but once it developed each successive slight, real or imagined, let to escalation of a conflict that became an all-out war. Such strife could have destroyed Heezen’s career as Ewing, the director of Lamont-Doherty Geological Observatory, had the power and, thus, the advantage. Ewing tried to deny Heezen funding, sea time and access to data and at one point attempted to get Heezen fired from Lamont. But Heezen persisted, overcoming the obstacles Ewing put up and developing new research

interests.

Heezen was an early pioneer of researching the ocean floor in submersibles. He died of a heart attack on board one, the U.S. Navy's NR-1, in 1977, just three weeks after the final data for the World Ocean Floor map was submitted to the printer.

Maurice Ewing was indeed a Messiah for many scientists, promising salvation from ignorance about the Earth. He had grown up on the harsh, dry Staked Plains of Texas where his parents struggled to make a living as farmers. Regardless, they sent six of their seven children to college. Ewing attended Rice in Houston, supporting himself with scholarships and summer work in grain elevators and prospecting for oil. While a young professor at Lehigh University in Pennsylvania, he began seismological studies of the ocean floor. Eventually he moved on to Woods Hole Oceanographic Institution, where his seemingly tireless pace didn't fit in with the more gentlemanly atmosphere. During World War II he worked with the U.S. Navy developing anti-submarine warfare equipment and methods that contributed to victory in the Battle of the Atlantic. In 1947 he took a position in the Geology Department at Columbia and founded Lamont Geological Observatory in 1949.

On land and at sea, Ewing maintained a brutal pace, working almost round-the-clock for decades, collecting and analyzing data, writing up results for publication, consulting with colleagues and students and seeking funding. He kept ships, like

the *Atlantis* and the *Vema*, busy gathering as much data as possible with as many instruments as were available. The data collected as a result of his efforts largely fueled the Earth science revolution in the 1950s and 1960s. As a result, our perception of the Earth's surface as a fixed, relatively unchanging terrain was destroyed and replaced with the knowledge that the surface is composed of plates that move over time, grinding against, colliding into and overriding neighbors, unleashing the terrible powers of earthquakes and vulcanism, creating the beautiful montane vistas of the Himalayas, Alps or Sierra Nevada and the idyllic island arcs of Indonesia or the Antilles.

Ewing was a charismatic leader, easily drawing bright, dedicated students like Heezen into his fold. Many stayed with him for their entire careers, following him from Lehigh to Woods Hole, from Woods Hole to Lamont, and from Lamont to Texas after Ewing was forced to retire from Columbia University.

Ewing was also a dictator, a benevolent one maybe, but a dictator nonetheless. When followers like Heezen tried to be more independent, bitter rifts of the human kind rather than the geological kind often opened. These differences were not limited to former students or employees. A number of scientists who made their scientific reputations using data Ewing collected have failed to give him proper credit for his contributions.

ORGANIZATION

This book will be divided into four parts: 1) Pearl Harbor Was Good to Me; 2) Wegener's Wraith; 3) Death at Sea; and 4) No More Explorers. Throughout, the impact of the historical events on the mapping of the ocean floor will be acknowledged. The influence of the effort to map the ocean floor on history will likewise be noted.

In "Pearl Harbor was Good to Me," the major characters, Tharp, Heezen and Ewing, will be introduced. Wrapped within the stories of their early lives will be a description the history of ocean-floor mapping from the early 1800s until just after World War II. Among the early events to be discussed are the production of the first map of the North Atlantic Ocean floor by the "Pathfinder of the Sea," Matthew Fontaine Maury, in 1854; the epic *H.M.S. Challenger* expedition, lasting from 1872 to 1876, in which this Royal Navy ship sailed around the world, logged 68,000 miles, gathered enough data to fill 50 volumes and yielded original scientific publications well into this century; and the German *Meteor* expedition of 1925 to 1927, in which tens of thousands of depth measurements were obtained for the South Atlantic.

World War II interrupted the analysis of the *Meteor* expedition data (and all unpublished data was destroyed by Allied bombing of Potsdam, Germany, during the war), yet proved a

watershed for oceanographic research. Naval forces needed to know more about oceanic topography for navigational and tactical purposes. Vicious submarine battles were being waged in nearly all of the world's oceans. Therefore a tremendous amount of work was directed toward rapid sounding of the ocean's depths, learning more about the characteristics of sea water and ocean currents, and finding better ways either to reveal or conceal the locations of submarines. In addition to serving as a training ground for oceanic scientists, the technology and research infrastructure developed had an incalculable impact on scientific endeavors after the war.

"Wegener's Wraith" will tell how data from the ocean floor proved instrumental in proving Alfred Wegener's Theory of Continental Drift in one of the most dramatic revolutions in the history of Earth science. In short, the theory (along with the more comprehensive Theory of Plate Tectonics) states that the surface of the Earth is composed of plates floating on a liquefied layer below the surface known as the mantle. Forces within this layer act upon the plates, causing them to drift over time. The plates split apart in rift zones, grind past one another along faults, slam into one another to produce mighty mountain ranges like the Himalayas or Alps, or ride up over one another, creating the great island arcs such as the Indonesian Archipelago or the Antilles, deep trenches such as those off the Mariana Islands or Puerto Rico, or great mountain ranges like the

Sierra Nevadas or Andes. Many of the topographic features of both the land surface and ocean floor can be explained within the framework of Continental Drift/Plate Tectonics.

Today, Continental Drift seems obvious, but from the time it was first proposed by Wegener in 1915 until the late 1960s was highly controversial. Indeed, at the time Wegener died trekking across the Greenland Ice Cap in the winter of 1929, his theory was held in contempt by many scientists. But Wegener, a tenacious man, imbued the theory with a life that thrived long after his death until the skeptics were won over.

Wegener was inspired to develop the theory by maps that showed a striking similarity in the shapes of the continents on either side of the Atlantic Ocean. Heezen's and Tharp's map of the Atlantic Ocean floor and a globe they produced showing the locations of the 40,000-mile-long Mid-Ocean Rift stirred other people's interest, such as that of Princeton's Harry Hess, in continental drift. After Heezen gave a talk on the Mid-Ocean Rift at Princeton, Hess told him, "Young man, you have shaken the foundations of geology." The scales had begun to fall from the eyes of the skeptics and, using the maps prepared by Heezen and Tharp and the data collected primarily by Ewing and Lamont-Doherty but also by Woods Hole, Scripps Institute of Oceanography and others, the converts came and worked and by 1968 proved that the continents did indeed drift across the face of the earth.

Undersea exploration using submarines and submersibles --

to the extent that it related to efforts to map the ocean floor -- will be described in the section “Death at Sea.” Heezen, for one, tired of estimating the what the ocean floor looked like from measurements collected on the surface. He wanted to see it up close, and got his opportunity to do so as a pioneer in submersible use. The deep-diving boats enabled Heezen and Tharp to fill the gaps in their data and have enabled Heezen and other scientists to see tectonic processes in action and discover new, unusual organisms living on food chain completely disconnected from the sun, which provides the energy for most life on this planet. (Recent research indicates that life may have originated in deep-sea vents.) Heezen loved to photograph bottom-dwelling animals and deep topography. He and his students discovered evidence of powerful currents that stirred the depths thousands of feet below the surface. In one instance Heezen discovered the deep ocean equivalent of a flash flood after telephone cables were ripped apart off of Newfoundland. This section will primarily cover the period from 1968-1977, spanning the time from the ultimate acceptance of continental drift/plate tectonics to Heezen’s death at sea.

The concluding (and shortest) section of the book, “No More Explorers,” will summarize progress in ocean-floor mapping since Heezen’s death. While scientists still go down to the sea in ships to study the oceans, satellites have become increasingly important tools to map the oceans. The book will describe how

space-based satellites can see below the surface, why people have turned to using satellites, and tell the stories of pioneers of satellite oceanography like William Haxby. The book will end with a poignant scene; Marie Tharp looking over the first satellite-based map of the world's ocean floor and comparing it to the work by herself and Heezen.

PRACTICAL MATTERS

Marie Tharp lives in South Nyack, New York. She is supportive of the book idea and has given me access to herself, her home and hers and Heezen's records in order to make sure I get the story right. Almost all of their map collection is housed in the Library of Congress Geography and Map Division. Most of Heezen's papers are at the Smithsonian Institution; the remainder is at Woods Hole. Ewing's papers are archived at the University of Texas in Austin.

Many historical materials relating to Lamont-Doherty Earth Observatory (as it is called now) are available at Lamont or at Columbia University's main campus in Manhattan. The endeavors of Lamont scientists received fairly intense coverage by New York City newspapers. These can be researched at the New York City Public Library.

Records relating to the other great oceanographic research institutions, such as Woods Hole and Scripps, are available at their headquarters. Records pertaining to research funded by the U.S. Navy or on U.S. Navy ships can be found through the

Department of the Navy or at the National Archives, where much of the Navy's historical documents are housed.

Few of the early pioneers of the ocean floor mapping effort are alive today. Tharp is one. Maurice Ewing's brother and collaborator, John Ewing, is another. Ewing lives in Woods Hole, Massachusetts. Joe Worzel, Maurice Ewing's technical wizard who either modified existing instruments or invented new ones to get the data Doc Ewing wanted, lives in Wilmington, North Carolina. Both men have already assisted me in researching this proposal, and are willing to continue doing so. A number of scientists who began their careers in the late 1950s or early 1960s are still active in research at Lamont-Doherty Earth Observatory, Woods Hole Oceanographic Institute, Scripps Institute of Oceanography, Cornell University and Dartmouth University and are available for interviews.

OTHER BOOKS

Several books have come out over the years that touch on aspects of this story, but none have given the tale the attention it deserves. The late Walter Sullivan details the history of the development of the theory of continental drift/plate tectonics in the book *Continents in Motion*. While detailed and authoritative, is unfortunately the type of dry, linear account I criticized earlier in the proposal. Sullivan' book also devotes little space to the ocean floor mapping effort. John Noble Wilford, in

The Mapmakers, tells the story of the mapping of the Mid-Oceanic Ridge in a chapter called, “Mountains of the Sea.” In *Mapping the Next Millennium*, Stephen S. Hall briefly relates the history of satellite mapping of the ocean floor in a chapter entitled “The Hidden Crucible.” The first part of Richard Ellis’ book *Deep Atlantic* describes the exploration of the depths of the Atlantic Ocean. Ocean-floor mapping makes up a small part of the section, but most of the narrative is devoted to life in the depths. The book most closely resembling what I propose to write is *The Universe Below*, by William J. Broad. Broad’s book, which was just published, is entirely devoted to deep-sea exploration and is well seasoned with narratives of his own experiences in the abyss. It is well-written and engaging, but largely ignores the mapping story.

I believe there is more than enough room for the proposed book on the market. While the primary readership would be people interested in science, the adventure and humanity of the story as I propose to tell it should attract the attention of a broader audience.

WHY DO I WANT TO WRITE THIS BOOK?

As a boy I frequently fantasized about the sea. I read every book I could get my hands on, whether it be fiction or not (although I admit a predilection for pirates, shipwrecks and ghosts ships!) and dreamed of becoming an oceanographer. My

career goals were sidetracked in college when I discovered plant geography, but in the process of earning a Bachelor's degree in biology I took a course in biogeography that focused primarily on the development of the theory of continental drift/plate tectonics and the implications of the theory on our understanding of the distribution and evolution of plants and animals. To this day that class, early as it was in the morning, has remained one of my favorite and most unforgettable.

After graduation I went to the University of Oklahoma to get a Master's in geography -- well, I tried, but didn't finish. In particular, I studied physical geography (focused on climate, landforms, plants and animals). As a physical geographer I could never escape the call of the landscape for my attention, nor the desire to understand how it came to be. As a just a plain geographer, I felt a spell cast whenever I was in the presence of maps. I took advantage of the keys entrusted to me by the university to explore storerooms, map cases and filing cabinets to study and admire the maps I found.

Several years and many misadventures later, I found myself looking for work in Washington, D.C. As a washed-up ex-geography graduate student, I naturally headed to the National Geographic Society, but was intimidated by their personnel procedures. I walked out the front door, turned south on 17th Street and headed for the Farragut West Metro Station. As I neared the entrance I noticed a small shop called The Map Store. I decided to see if

they had a job.

I really stood out when I walked in, a sucker in a power-gray monkey suit and a dazed look on my face. I figured there was no way they would hire me, but I talked to the manager at the time, Tom Rohrer, and in less than 15 minutes I was employed.

The Map Store is heaven for a map-lover. Maps of all types, from all parts of the world, from all kinds of makers surrounded me. I could get aeronautical charts, nautical charts, globes, street maps, black-and-white outline business maps, raised-relief maps and much, much more. I got as much as I could. One map I didn't get, although I frequently admired it, was Heezen and Tharp's World Ocean Floor map. I did not know its story.

After about one year, I returned to graduate school, this time at George Mason University. This time, I earned a Master's degree in Geography. Afterward, I began a Ph.D. program in Environmental Sciences at the University of Virginia, and spent as much time as possible doing field work in the Appalachian Mountains -- themselves a result of an ancient tectonic collision between North America and what is now Europe and Africa. Periodically I felt the draw of the sea and traveled to the Atlantic coast, where I would ponder my smallness in comparison with the vast, expanding ocean at my feet.

After exercising my uncanny knack for alienating academic advisors, I found myself out of funding at Virginia in 1994. Desperate for work, I heard of a job at Lamont-Doherty Earth

Observatory, applied for it and was hired. I began working there in 1995, slowly realizing the significance of the institution as I walked through its buildings, haunted its library, and gazed at its collection of sediment cores taken from the depths of all the world's oceans. This was the place that had acquired much of the data that won the argument in favor of continental drift and plate tectonics! Here worked the people that had mapped the ocean floor!

As I worked at Lamont I heard stories of Ewing and Heezen, of cruises aboard the various ships, of storms and seasickness, of competition with people from other institutions, of the struggle to survive in a hostile scientific world. I now realize there is an exciting story to tell, and I want to be the one to tell it.