Upheaval from the Abyss

Ocean Floor Mapping and the Earth Science Revolution

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 forbidding, unyielding to the call of science, adventurism and commerce.

Not that long ago, most scientists felt the ocean floor was a vast, featureless plain, an ancient repository of detritus 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. Few saw the ocean basins as worthy of anything but marginal scholarly interest.

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 would starve. These same currents help control the global climate; sudden changes in oceanic circulation may determine whether we live in a fairly tolerable climate, as now, or whether we 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 from which early life evolved.

This is the story of the herculean quest to map the world's ocean floor and how that endeavor, by inspiring the continental drift-plate tectonics revolutionaries of the 1950s and 1960s, helped overturn prevailing scientific notions of how the Earth's surface is created, rearranged and destroyed. The period covered, however, will span the last 150 years, 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. In addition to continental drift, this interval includes the development of the theory of evolution. The acceptance of the two theories rank as two of the greatest revolutions in scientific history. Both theories have benefitted from discoveries made during the mapping effort. History's two deadliest wars 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 era women were finally given the opportunity to contribute to scientific endeavors.

The 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 will ever see. 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 Endurance expedition 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. 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 were 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. This narrative will recreate what it is like to be on, under or over the ocean surface, 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 bulk of the narrative will be woven around the stories of Marie Tharp, Bruce Heezen and Maurice "Doc" 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 data that led to the map as well as data that clinched the scientific case for continental drift and plate tectonics. Another major character will be Alfred Wegener, the German meteorologist who trespassed upon geologists' ground by proposing the theory of continental drift.

Tharp, who worked for Heezen until his death in 1977, grew up all over the eastern United States, constantly on the move because of the demands of her father's job. William Edgar Tharp was a soil surveyor for the U.S. Department of Agriculture's Bureau of Chemistry and Soils. He went into the field and collected information that he and others later used to prepare the soil survey maps that the bureau began producing shortly after the turn of the century. William Tharp would work in the southern states during 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. The constant moving may have inspired Marie Tharp's individualism. Her father's work 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 that of 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 to Columbia's Schermerhorn Hall, where the department was based, to see if anything more interesting was available there.

There she met 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.

Heezen came from a well-to-do family in Iowa. While an undergraduate geology major at the University of Iowa, he attended a talk by 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 short-fused bundles of TNT over the stern of ships underway at full speed. Afterward, Heezen went 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 the two became involved in a bitter feud. As with many feuds the cause is a mystery, but once it developed each successive slight, real or imagined, led 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 fire Heezen. 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.

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 Institute (now Rice University) 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*, the *Vema* and the *Conrad*, 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. But he was also a dictator, a benevolent one perhaps, 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.

Wegener was a pioneer balloonist, decorated war hero, Greenland explorer and, above all, an insightful scientist. He became inspired and developed the theory of continental drift after noticing the similarity in the shape of the Atlantic coastlines of Africa and South America. His broad outlook enabled him to marshal evidence from a wide range of scientific disciplines. He first proposed continental drift in a paper in 1912. While convalescing from a severe wound received during World War I, he developed his ideas further. Finally, in 1915, he published a book, "On the Origin of Continents and Oceans," that presented the theory in detail.

Wegener's argument was simple: Until about 300 million years ago, all the continents were united to form the supercontinent Pangaea. Beginning at about 150 million years ago, the supercontinent began breaking up and the fragments began drifting apart. Wegener produced maps of how he thought the continents had been assembled or disassembled at various stages in time. He presented the geological, geographical, climatological and paleontological evidence in support of his theory, and he argued why other theories could not work.

Today, continental drift seems obvious, but from the time it was first proposed by Wegener in 1912 until the late 1960s the concept 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 a tenacious Wegener imbued the theory with a life that thrived long after his death until the skeptics were won over.

Other important characters include Harry Hess, the Princeton University professor and World War II Navy veteran who melded his wartime experience, geological expertise and inspiration from a talk by Heezen into the theory of sea-floor spreading which, when combined with Wegener's drift, laid the foundation for a more comprehensive plate tectonic theory; Frederick Vine, a Cambridge University graduate student whose analysis of magnetic anomalies on the ocean floor proved sea-floor spreading; and J. Tuzo Wilson, who recombined continental drift and sea-floor spreading into plate tectonics and who played a key role in converting the rest of the scientific community to what was once a much-ridiculed idea.

ORGANIZATION

This book will be divided into four parts: 1) Mountains under the Sea; 2) Wegener's Wraith; 3) Life and Death at Sea; and 4) Brave New Worlds. 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 "Mountains under the Sea," the major characters, Tharp, Heezen, Ewing and Wegener, 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 (all unpublished data were 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. The war served as a training ground for oceanic scientists and as a catalyst for the development of the technology and research infrastructure that had an incalculable impact on science after the war. Ewing, a pioneer in marine geology and seismology, and several of his students were involved in developing technologies for the U.S. Navy's war effort. Many of those technologies were applied to scientific research afterward. Hess commanded an attack transport for the Navy in the Pacific Theater and, as a result, became familiar with the topography of the Pacific Ocean floor. This familiarity helped lead to the insight that inspired the theory of sea-floor spreading.

"Wegener's Wraith" will tell how data from the ocean floor proved instrumental in proving Wegener's idea of continental drift in one of the most dramatic revolutions in the history of 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, known as the mantle, which lay below the surface. 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 Himalaya 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 Nevada 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.

Wegener was inspired to develop the theory by maps that showed a striking similarity in the shapes of coastlines 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 interested other people, such as 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 – with the maps prepared by Heezen and Tharp, the data collected primarily by Ewing and Lamont-Doherty but also by Woods Hole, Scripps Institute of Oceanography and others, the brilliant analyses by Vine and the theoretical advances by Hess and Tuzo-Wilson – 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 will be described in the section "Life and Death at Sea." Heezen, for one, tired of estimating 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 craft enabled Heezen and Tharp to fill gaps in their data and have enabled Heezen and other scientists to see tectonic processes in action. Submersibles also made possible the discovery of new, unusual organisms living on a 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.)

While the debate about continental drift was raging, Heezen and Tharp continued with their mapping efforts. With the support of the National Geographic Society and the help of Heinrich Berann, an Austrian artist, Heezen and Tharp produced dynamic, color versions of their earlier black-and-white maps of individual ocean basins. When the National Geographic series was completed, the U.S. Navy gave them the funding to take on the world, which resulted in the publication of their jewel, the World Ocean Floor Panorama, in 1977. Heezen never had a chance to appreciate the achievement, however. Three weeks after the Panorama proofs were approved and sent to the printer, he died of a heart attack on board the U.S. Navy's nuclear-powered research submarine, NR-1.

The concluding (and shortest) section of the book, "Brave New Worlds," will summarize progress in ocean-floor mapping since Heezen and Tharp published the World Ocean Floor Panorama. While scientists still go down to the sea in ships to study the oceans, satellites have become increasingly important tools in the study of the sea. The book will describe how space-based satellites can see what lay below the surface, why people have turned to using satellites, and tell the stories of pioneers of satellite oceanography like William Haxby. In the end, the focus of the book will turn from the depths to the heavens and discuss how discoveries of life in the deep-sea vents has influenced our search for life on other worlds.

Here is a tentative Table of Contents:

Part 4: Brave New Worlds

13. View from above – Satellites replace soundings for ocean-floor mapping
14. Where no man has gone before, No. 1 – undersea explorations inspired by mapping effort
15. Where no man has gone before, No. 2 – how ocean-floor discoveries influence the search for life on other planets
16. Epilogue

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 Heezen's and her records in order to make sure I get the story right. Recently I ghost wrote a chapter for Marie that will be included in an upcoming volume commemorating Lamont's 50th anniversary.

Almost all of Tharp's and Heezen's map collection is housed at the Geography and Map Division of the Library of Congress. Most of Heezen's papers are at the Smithsonian Institution; the remainder are 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 or the Library of Congress.

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 many of the Navy's historical documents are housed.

Few 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, it is unfortunately the type of dry, linear account I criticized earlier in the proposal. Sullivan's book also devotes little space to the ocean floor mapping effort. John Noble Wilford, in *The Mapmakers*, tells the story of the discovery 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 published in 1997, 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. Recently Robert Kunzig published *The Restless Sea*. Several chapters deal with Tharp's mapping efforts, but the passages are, unfortunately, marred by mistakes, misinterpretation of some of the facts and repeated statements disparaging Tharp's work. The record should be corrected. Other recent books about the sea, although not directly related to undersea exploration, include *Longitude*, by Dava Sobel, *The Perfect Storm*, by Sebastian Junger, and *Ship of Gold in the Deep Blue Sea*, by Gary Kinder. Their sales prove that stories of the sea still have a powerful hold over the human imagination. (Ironically, Columbia University was one of the plaintiffs suing Columbus-America – featured in *Ship of Gold* – for a portion of gold recovered from the wreck of the *SS Central America*. The University initially argued that the salvors used Lamont data to locate the wreck, but it eventually dropped the lawsuit after several years of litigation.)

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 ghost 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.

Several years after earning my biology degree I obtained a job at The Map Store in Washington, D.C. The Map Store was heaven for a map-lover like myself. Maps of all types, from all parts of the world, from all kinds of makers surrounded me. Aeronautical charts, nautical charts, globes, street maps, black-and-white outline business maps, raised-relief maps and much, much more distracted me from my efforts to server customers and organize stock. One map I frequently admired was Heezen and Tharp's World Ocean Floor Panorama. I did not know its story at the time.

In 1995 I began working at Lamont-Doherty Earth Observatory. Slowly I realized 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 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! This was the home of the people who had mapped the ocean floor! I heard stories of Ewing, Heezen and Tharp, 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.

SUMMARY OF MY QUALIFICATIONS

For nearly 20 years I have walked a sinuous line between science and journalism.

Currently a Ph.D. candidate in the environmental sciences from the University of Virginia, I hold two relevant master's degrees, one in geography from George Mason University, the other in journalism from Columbia University. (My classes at Columbia included Samuel G. Freedman's book writing seminar.) I have worked as a research assistant at several universities and related institutions – including Lamont – and consulting firms and have served in various editorial and correspondent capacities at the Daily Press and Digital City Hampton Roads in Newport News, Va., the Daily Record in Parsippany, N.J., the Daily Progress in Charlottesville, Va., and The Times in Shreveport, La.