Questions for David M. Lawrence

Why did you decide to write this book?

Probably to atone for all the times I fell asleep in the undergraduate biogeography class where I first learned of continental drift and plate tectonics.

Why will the average reader find the history of ocean mapping and plate tectonics interesting?

We are always fascinated by stories of people overcoming overwhelming obstacles to achieve some sort of victory – whether that victory be in sports, war, art or science. The natural (and sometimes self-imposed) difficulties faced by the scientists were incredible, yet, by brilliant inspiration, unflagging persistence and in some cases grim determination, these researchers managed to shatter the false edifice of accepted wisdom about the Earth and erect in its place a vision that is virtually unassailable, that explains many phenomena which beforehand were poorly understood.

You write, "I believe it is as important to remember the day-to-day human experience as it is to remember ideas, data, and debate. . . . I hope my effort succeeds in rescuing this tale from the orderly, sterile environment of academic history and giving it the vigorous, combative, lusty humanity it deserves." Why do you feel this is important and how did you shape your book to achieve this?

It seems to me that too many people envision scientists as geeks in white lab coats who have never experienced passion, sex, death or defeat. But I know scientists are as human as anyone else, with all the foibles and strengths of the rest of the species. I think it helps people relate to science and scientists if the storytellers convey the humanity of the researchers.

For my book, I focused as much as possible on the personal experience of people like Felix Andries Vening Meinesz, who endured months at sea on submarines designed for men much smaller than he was; or on people like Marie Tharp, who had to convey probably millions of numbers on sheets of paper into a vision of the characteristics on the ocean floor.

What was the most interesting story you came across in your research for this book?

You're asking the wrong person to single out one "most" interesting story. I admit, however, that there are few stories that amaze me more than that of Vening Meinesz during World War II. While the Nazis occupied most of his house to use as officers' quarters, he held meetings of the Dutch resistance in his basement. Most of the obituaries and memorials I have seen justifiably dwell at length on his scientific career, but none of the ones I read mentioned how he spent the war – which just as important in understanding the man and the type of steel nerves it took for him to keep going to sea in submarines despite the great discomfort and even greater risk.

Who are some of the key characters in the history of ocean mapping and plate tectonics and what is their significance?

The bulk of the narrative is woven around the stories of Maurice "Doc" Ewing, Marie Tharp and Bruce Heezen, three scientists at what is now known as Lamont-Doherty Earth Observatory. 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.

Tharp, who worked for Heezen for 30 years 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. She was an indifferent student, a young woman with few prospects for an interesting career in 1941 – until December 7 of that year. 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, and become a geologist instead. After the war she moved to New York to look for something more interesting than working for an oil company. She met Ewing, who was soon to found Lamont Geological Observatory. Ewing hired her because of her drafting skills – and she spent the next 40 years of her life preparing maps of the world's ocean floor.

Heezen came from a well-to-do family of turkey farmers 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, who had a lot of research to do but little money with which to do it, was seeking bright graduate students who could serve as research technicians, accepting oceanic adventure instead of pay. After the talk, Ewing asked Heezen, "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. While Heezen did become embroiled in a bitter feud with Ewing in later years, he never abandoned his quest to unveil the face of the deep.

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. On land and at sea, he 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 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.

Alfred 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. The theory was highly controversial, and was held in contempt by many scientists at the time Wegener died trekking across the Greenland Ice Cap in the winter of 1930. But his tenacity 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 John Tuzo Wilson, who recombined continental drift and sea-floor spreading into what we now know as plate tectonics and who played a key role in converting the rest of the scientific community to what was once a much-ridiculed idea.

How do continental drift, plate tectonics, and ocean floor mapping relate to each other? What was the theory of continental drift and why was it initially rejected? What led the scientific community to eventually change its mind?

Continental drift is basically the theory that the continents as we know them were not always arranged the way they are now – they move independently of one another, crashing together in some places and tearing apart in others. Many people claim that plate tectonics is a completely different theory – which it is in the same way that a child or grandchild is different from an ancestor. Wegener's theory of continental drift is the ancestor of plate tectonics. Plate tectonics differs from continental drift in that the basic unit is a crustal plate – which often is a mix of continental and oceanic crust – rather than just individual continents; also the mechanics of plate tectonics are better understood.

One of Wegener's biggest problems was that he could never come up with a plausible mechanism to explain continental drift. Some of the things he proposed – such as suggesting the continents were like icebergs floating in an ocean of oceanic crust – seemed ludicrous to the scientific community, and rightly so. But the staunch resistance he met does not make sense. Many of his critics did not seem to realize that the question, "Does this phenomenon occur?" is separate from "Why does this phenomenon occur." For example, a railroad safety investigator does not need to know why a train derailed before coming to the conclusion that the train in fact derailed. The wreckage is generally regarded as sufficient evidence that something unfortunate happened. Wegener had marshaled quite a bit of evidence that the continents had move, but most of his critics ignored him.

As you will find in the book, the crucial evidence lay on the ocean floor – which is why ocean-floor mapping played such an important role. People saw relatively detailed depictions of the ocean-floor topography for the first time. They also saw the geographic patterns of other structures and phenomena, such as sediment layers and magnetic anomalies in the rock lining the ocean floor.

You cite the mapping of the ocean floor as one of history's greatest scientific accomplishments. Why?

Tharp, who did most of the mapping, may have had millions of data points to work with, but those millions of data points covered a small percentage of the ocean floor. She and Heezen were working in the days before satellites gave scientists a way to envision the appearance of the ocean floor though gravitational effects on the height of the ocean surface. They had to do a lot of educated guessing to determine what the ocean floor looked like, and they did virtually all of their

plotting by hand. When one compares their ocean floor maps – especially the World Ocean Floor map – to maps generated from satellite data, it is hard to be anything other than amazed at how much they got right.

You refer to Alfred Wegener, who came up with the theory of continental drift, as a hero. Why do you feel this way?

Wegener was not fearless, but he was physically and mentally courageous. He did not avoid what Sir Ernest Shackleton called the "red warfare" on the Western Front in World War I – he bore the wounds to prove it. He did not avoid Shackleton's "white warfare" in the Arctic – he gave his life at an age when most explorers would leave the work to younger men. And Wegener never shied away from the intellectual warfare in defense of his ideas – even though he reaped a harvest of ridicule as a result. Many ideas in science, even good ones, die in obscurity. But Wegener refused to abandon continental drift, constantly working to improve the theory and to bolster it with new evidence, and left it theory in good position to survive his death. Even though the theory of continental drift was often derided, it was still discussed and on the minds of scientists when the flood of new data from the ocean floors began to arrive following World War II.

Why is it important for us to know what lies so far beneath the sea? What are some of the more recent discoveries of interest? What is left to learn about the ocean floor?

I think humans have a deep need to explore, kind of like a John F. Kennedy-esque "We do these things because they are hard," thing. Our spirit withers and slowly dies when we lose the urge to probe the unknown. In the past 20 years we have discovered this vast ecosystem – completely disconnected from the sun that gives the gift of life to most of us – growing along thermal vents in the mid-ocean rift valleys. A Woods Hole expedition recently discovered extensions of this ecosystem in the Indian Ocean. Many scientists believe that life itself may have begun in a system similar to one of these vents, and some astronomers believe that extraterrestrial life may likewise be found deep in the oceans of other worlds.

I do not know what else there is to learn about the ocean floor – but that is precisely the reason why it is important to keep exploring.