

Water as the Medium of Measurement

Mapping Global Oceans in the Nineteenth and Twentieth Centuries

Penelope K. Hardy

While humans have always interacted with the sea, the ways in which they have imagined and thus defined it have changed significantly over the course of history. Beginning in the nineteenth century and continuing into the twentieth, scientific investigations of the ocean increasingly attempted to understand and map the ocean in three dimensions. While in the West this effort started earlier, with late-eighteenth- and early-nineteenth-century British investigation of global tidal patterns, or even with seventeenth-century efforts to map undercurrents in the Mediterranean, it reached its full flower by the mid-nineteenth century, as scientific investigators from Europe and the United States began to explore the ocean environment from aboard ships.¹ These in situ studies accessed the otherwise inaccessible ocean bottom using an expanding series of sounding technologies, and they resulted in a series of new attempts to represent the ocean in its many physical and biological dimensions in various maps, charts, and diagrams. The ocean bottom thus became a necessarily technologically mediated space that scientists and their partners defined as available for enlistment towards their commercial, disciplinary, and nationalistic goals. To accomplish this, the water that filled the ocean's basins became a tool for knowing and interpreting these invisible contours.

Reimagining the ocean as not just a highway or fishing ground but as a territory with physical features and knowable topography required invention and repurposing of technology, but it also meant a shift in understanding of both the ocean space and the water itself.² The ocean had certainly always had a third dimension in the human imagination, as people understood the risk of ships grounding on hidden shoals or foundering in open water, but this third dimension was unknown, and to a large degree considered unknowable. Early modern thinkers occasionally considered the ocean bottom, as Athanasius Kircher did in his 1664

Mundus Subterraneus, where he imagined the various seas linked through some network of subterranean passages through which water might move, thus explaining the tides. But measuring the ocean in order to establish its bounds in the wake of the Western scientific revolution, especially in its third dimension, involved the use of new tools, including ships that could manage the distances and depths involved, implements that could extend the human grasp miles beyond the sight of their wielders, engines that could handle the immense lengths of line necessary to reach the bottom, and eventually new technologies such as echo-sounding, which repurposed the water itself into a medium of measurement rather than just the substance filling the space to be measured.

As the ocean's bounds became delimited by numbers and details, as its topography became more clearly settled, its investigators imagined it as more and more land-like, and they began both to portray it in land-like ways and to enlist it for the uses they imagined for land. As the ocean gained mountains and plateaus, those plateaus could be imagined holding telegraph cables. As the ocean gained geological detail, those details could be enlisted for scientific arguments about terrestrial geology. As the ocean bottom was redefined as land, that land could be imagined as territory—useful, knowable, and even possessable. At the beginning of Western cartographic history, as I discuss below, understanding of the ocean shifted slowly from discrete bodies of water that divided the land to a global ocean which was navigable and thus connected the globe. The new, scientific reimagining of the nineteenth and twentieth centuries thus echoed the earlier shift; as the ocean bottom became known and land-like, it could connect continents telegraphically, be enlisted in global geological arguments, and extend terrestrial territorial claims. At the same time, however, the ocean bottom remained—and remains—unknown in significant ways. This fluid identity did not inhibit its enlistment for human purposes; indeed, the degree to which the human image of the reimagined ocean bottom retained fuzzy boundaries enhanced rather than degraded its usefulness, its suitability for repurposing. A little knowledge allowed investigators to make claims that appeared scientific, while retaining enough unknowns to engage the imagination.³

EMPTYING THE 2D SEA AS A SPACE FOR SCIENCE

As geographer Martin W. Lewis has argued, “The current taken-for-granted system of maritime spatial classification did not, in fact, emerge in broad outlines until the 1800s and did not assume its full-blown form until the twentieth century” (1999, 189). Earlier traditions imagined the ocean first as a world-encircling river, and later as a series of seas, usually understood and named by location and adjacency to terrestrial territories. Maps changed to reflect this shifting conception, though they often reflected the coastal nature of travel, even to distant ports,

and maps intended for navigation highlighted the coastal landmarks encountered en route and reflected the commercial nature of these ventures, whether those involved exploitation of ocean resources such as fish or simply travel to distant markets where spices or other commodities could be purchased. Neither these nor the terrestrial world maps created by cartographers to depict the expanding known world portrayed the ocean's depths. Cartographers populated the vast, empty ocean basins with symbols of both the danger and mystery of the unknown: sea serpents and depictions of other marine beasts, half-described or imagined.

From the late fifteenth century, though, Europeans began to venture beyond their coast-hugging routes and braved the open ocean. To account for this new mode of travel, navigational charts needed to extend beyond coastal features and display the oceans as basins that connected destination ports. The lines between them and their cartographic cousins thus blurred as more of the world became navigable. By the time Magellan's ships circumnavigated the world in the second decade of the sixteenth century, routes between all known places could be charted (Rozwadowski 2018, 77). The resulting map, however, showed the ocean in two-dimensional outline, like a cut paper silhouette, perhaps recognizable by its distinctive profile, yet lacking in detail and emptied of the earlier imagined creatures.

As historian Helen Rozwadowski has argued, this "emptying" of the ocean left it open to scientific investigation of various kinds (2018, 85–86). Instruments to measure the elevation of the sun and stars allowed the calculation of latitude by the early sixteenth century, but the accurate measure of longitude remained elusive and the source of much scientific (and governmental) interest until the development of accurate and robust chronometers towards the end of the eighteenth century (Andrewes 1996). Aside from accounting for the ship's position, extended voyages meant a growing incidence of scurvy, and while the curative effects of citrus, for instance, were already known, this was little help on an extended voyage and still did not explain the etiology of the disease, so captains and their sponsoring governments continued to experiment through the eighteenth century (Rozwadowski 2018, 97). Finally, the ocean's effects reached even into major ports like London in the form of tides, and a growing global system of transportation and communication allowed an integrated effort to understand, chart, and predict them by the early nineteenth century (see Reidy 2008).

The involvement of governments in these efforts was neither incidental nor inconsequential. The opening of extensive global ocean travel both enabled and enacted the beginning of what is now recognized as global imperialism. Whether for commerce, for domination, or—usually—some combination thereof, government-sponsored voyages meant government interest in the safety of ships and their crews, thus the need to solve the problems of scurvy, longitude, and tides. The interest of these same governments in the natural history of their destinations is unsurprising; in addition to the safety and security of their new possessions or trade partners, this knowledge let them know what was exploitable

and how (Portuondo 2009). By the nineteenth century, government patronage of commercial sea interests was well established in the West, even as sea voyaging itself, and the purposes for it, were changing as the Industrial Revolution transformed transportation and communications. These phenomena led to a popular “discovery” of the ocean in the nineteenth century, as a larger proportion of the population not only voyaged by sea, but had greater access to the seaside as terrestrial destination and site for recreation as well as social and intellectual pursuit (Rozwadowski 2005). The same combination of phenomena drew natural historians to the shore as well. Eventually, they went beyond it, using ever-larger vessels to investigate—and map—the conditions and inhabitants of the sea bottom further and further from shore.

MAPPING THE DYNAMIC OCEAN

One of the first efforts to collect such information synoptically came—appropriately enough—from a naval officer motivated by a nationalistic desire to see his country compete in the realms of both science and global commerce. Commerce had long proven a primary motivator for science, and in particular ocean science, as demonstrated by projects ranging from early modern developments in astronomy to the British effort to understand magnetism and the tides. As superintendent of the U.S. Navy’s Depot of Charts and Instruments beginning in 1842, Matthew Fontaine Maury was responsible for the storage, calibration, and maintenance of the navy’s navigational instruments and chronometers, as well as procurement of its charts.⁴ His office was also responsible for the storage of ships’ deck logs, in which the captain and officers recorded incidents of the ship’s voyage, but also observations of the winds, weather, and sea conditions, which were tied to the specific latitudes and longitudes at which they were encountered. These were legal records, and so had to be retained, but in general the navy had no further use for them, so they did little but mold and take up space. Maury, however, quickly realized that the data contained within them collectively described climatic conditions across broad swaths of the planet’s surface and through each season of the year (for more detail, see Hardy 2016).

Maury’s staff harvested this data, which he soon supplemented by soliciting the assistance of deploying naval captains and later merchant mariners, giving them standardized forms on which to record specific kinds of data while underway (Burnett 2009, 194). Maury sold his project to the navy hierarchy as a domestication of chart-making—after all, was American reliance for charts upon Britain, with whom the country had been at war a mere generation earlier, not a national security issue?⁵ Maury imagined representing the accumulated information graphically, envisioning a chart on which “the experiences of a thousand navigators” would guide the neophyte “as though he himself had already been that way a thousand times before” (Maury 1856, vii). With the wealth of data his agents were

now gathering, Maury did create new charts, beginning with the Atlantic Ocean, but beyond the traditional navigational chart he envisioned a much broader series of representations of what he recognized as a global ocean-atmosphere system.

Collecting the information he wished to portray was not as easy as he had hoped, however. The old logs were soon mined out, and his fellow naval officers proved less than universally enthusiastic and conscientious about collecting new data, no doubt something they saw as simply an additional administrative task. Maury began communicating with captains directly, begging them to collect as much data as they could at every point on their routes, including by sounding in deep water.⁶

Sounding by line was an ancient technique for measuring depth whose technologies had changed little over the years. The basic premise involved a weight tied to a line and then thrown overboard. When the weight hit bottom, which an experienced navigator could feel through the line, the amount of line payed out revealed the water's depth. Traditionally, however, sailors had only bothered to do these measurements near the coast, or in other situations in which potential shallow water meant a threat of running aground. While a few deep-water measurements had been attempted—and recently even managed—they were not routine; the procedure required stopping a ship mid-ocean and holding it as steady as possible for the length of the measurement, an effort in which the average sailor saw little utility in a location where the bottom posed no risk to the ship.⁷ Maury, however, wanted these measurements not for safety, but to further his understanding of the ocean in all its dimensions.

He also asked captains to report any errors found on published charts, especially vigias—shoals charted on slender evidence—many of which he believed did not actually exist. While initially he asked his fellow officers to gather data as “a great favor,” that approach ensured neither the quantity nor the consistent quality of data he wanted.⁸ To standardize the data, Maury devised an “abstract log,” a blank form that would prompt the observer to record specific kinds of data at specific times. This log, which evolved into a set of forms in slightly different formats for different users, was itself a technology of data collection and standardization. Logs had long been kept as official records of a ship's voyage; Maury's efforts at standardization co-opted that tradition to record and gather specific kinds of data on a scale impossible for him to otherwise access.

By October 1843, he had convinced his immediate superior of his project's value, and he wrote up a few pages of “Suggestions for the Attention for the Home Squadron.” These instructions detailed for ships' officers not only what data he wanted, but also which instruments already on board their vessels could be used to gather it, where and how best to set them up, and how often to take observations. Maury's allies in the scientific community petitioned the secretary of the navy to instruct U.S. naval vessels operating worldwide to participate.⁹ His lieutenants got to work compiling a chart of the Atlantic from the materials on hand which Maury

hoped to publish by the end of 1845, but compliance among naval captains was spotty at best and covered only those routes frequented by naval vessels.¹⁰ While the data thus provided some new insights, they were not as extensive as Maury had hoped, they provided little ability to check information between ships, and they left large swaths of the oceans unmeasured.

Following up on earlier suggestions by Representative Stephen Mallory, chair of the House Naval Affairs Committee, that American merchants and whalemen might constitute a storehouse of information about the ocean, Maury began recruiting among these captains, and soon asked the hydrographic bureau chief to make an official request. In return, Maury imagined the better understanding of the winds and currents thus attained could allow captains to choose more efficient routes for their travels, saving them time and money while decreasing risk. His plan then was to furnish merchants with his blank forms; those who returned them filled with data at the end of their voyage would be furnished with a copy of his wind and current chart.¹¹ In July 1847 he was distributing copies of the first sheet of his wind and current chart. By November the other seven sheets of the Atlantic were in press.¹²

Maury's charts differed from previous ones because instead of simply displaying the ocean's surface and the land—the backdrop of a voyage—they displayed as well the voyages of each ship that had contributed to the project, color coded by month and season of travel. Maury was attempting to map not just the ocean's contours, but its dynamic physicality as experienced at sea. In fact, Maury argued explicitly that this amounted to charting the accumulated experience of those who had traveled that path before, as he had previously hoped to do, thus making it accessible to both neophyte and veteran navigators.¹³ Small, comet-shaped graphics indicated the direction and force of winds encountered, as well as their consistency. Currents were marked with a number indicating velocity in knots alongside an arrow indicating direction. With the charts, Maury published a volume of explanations and sailing directions—initially a slim pamphlet, but of greater heft with each new edition over the following years. These both explained how to read the charts and, later, analyzed specific example tracks sent in by Maury's corresponding observers.

When the *W.H.D.C. Wright*, a bark out of Baltimore, followed Maury's directions and reached Rio de Janeiro from the Virginia Capes in just thirty-eight days, then returned in thirty-seven, a seventeen-day improvement over the previous average in each direction, other captains took notice. Many soon proved willing to participate in Maury's data-gathering scheme, receiving blank logs before their voyages, filling them out while underway, and receiving copies of the new charts and sailing directions upon their return, allowing Maury to begin work on similar charts of the rest of the Pacific and Indian Oceans as well.¹⁴

In addition to this greater geographic coverage, Maury began to plan charts displaying more kinds of information. The original set of charts with their collected

tracks—the Track Charts—would be known as Series A. They were followed by Trade Wind Charts (Series B); Pilot Charts, which showed prevailing winds in various seasons (Series C); Thermal Charts (Series D); Storm and Rain Charts (Series E); and Whale Charts (Series F), which displayed seasonal sightings by species, giving whalers what amounted to a graphical database from which to make hunting decisions and biologists a census of sightings and behavior.¹⁵ These later series were even more innovative in their depiction of Maury's imagined ocean, and further from the traditional naval chart. The storm and rain charts, for instance, divided the ocean into a grid, within each square of which a smaller table of numbers explained average seasonal conditions as experienced by Maury's sources. The chart thus represented the experience of ocean travel rather than the geographical boundaries of a voyage, while the whale charts refilled the void that had been emptied of its fantastical inhabitants with a more biological—and commercial—understanding of the ocean's occupants.

CONSTRUCTING THE OCEAN'S THIRD DIMENSION

One of Maury's most novel representations of the ocean, though it would perhaps not be as immediately useful as he hoped the rest of his charts to be, was a chart of the North Atlantic Ocean basin published in 1853 (figure 5.1). While Maury would not yet use the word *bathymetric* to describe measurements of the ocean depths and the charts on which they were depicted, his 1853 image attempted to chart the depths not just near the shores, as would be necessary for safe navigation through shoaling water, but across the entire extent of the Atlantic. Maury recorded the depths of the minimal number of deep-sea soundings available, a number probably in the dozens at that point for the entire Atlantic. He displayed appropriate skepticism at the deepest of them; the contours they implied seemed excessively steep, and he recognized that as soundings got deeper sailors could no longer feel the moment the lead hit bottom through the line, and the line involved was now heavy enough to continue paying out, especially if caught in a current. Over the course of his career, Maury and his lieutenants would work out new means of determining the bottom of a sounding that relied upon timing the payout of the line and noting a slowdown when the lead was no longer falling through the water.

Once Maury charted these scattered soundings, he then filled in the contours of the ocean basin in soft curves that still imagined the ocean as a largely empty place. A shallower swath stretches down the middle of the basin, south and slightly west of the Azores, a hint of the Mid-Atlantic Ridge that would be revealed a century later, but Maury's imagined ocean bottom was largely flat, empty, and still. He quickly revised this as additional soundings became available, and he was able to attribute the inaccuracies of the deepest early soundings to strong bottom currents. Indeed, he increasingly imagined the bottom as mountainous and rugged terrain, an undiscovered country whose exploration would elucidate the physical phenomena—the waves, currents, and tides—of the ocean it held.



FIGURE 5.1. “Basin of the North Atlantic Ocean.” Matthew Fontaine Maury, *Explanations and Sailing Directions to Accompany the Wind and Current Charts*, 5th ed. (1853). National Oceanic and Atmospheric Administration (NOAA) Photo Library.

Still, even when imagined as empty, these spaces held value—in some cases literal, commercial value—as Maury’s support for the first efforts to lay a transatlantic submarine telegraph cable show. Soundings conducted by one of Maury’s lieutenants across the Atlantic could be interpreted as a plateau of moderate depth, conveniently located along the great circle route between Newfoundland and Ireland. At the same time, one of his lieutenants had designed a new sounding tool which allowed the capture and return to the surface of small samples of bottom sediment.¹⁶ These showed a landscape littered with the fragile shells of microscopic sea creatures, suggesting currents at the bottom were gentler than he had thought. Maury assured naval superiors and cable entrepreneurs alike that the plateau was as well suited for a cable as if it had been placed there for that purpose.¹⁷

DREDGING THE GLOBAL OCEAN

This new attention to the ocean’s third dimension, and the use of biological data to elucidate its features, presaged the expansion of scientific investigation and accompanying redefinition of the global ocean in the second half of the century. The first and widest-ranging scientific expedition to study the global ocean in all its dimensions was the Challenger Expedition, a joint project of the British Royal

Navy and the Royal Society of the London.¹⁸ Over the two-and-a-half-year period between December 1872 and May 1875, HMS *Challenger* circumnavigated the globe with a naval crew and a team of embarked civilian naturalists. While this was not the first effort to sound or even collect samples and specimens from the ocean bottom, the Challenger Expedition was the first whose primary purpose was the scientific study of the ocean itself.¹⁹ The expedition's naturalists made significant zoological efforts; more than forty of the fifty official results volumes published in the twenty years after the expedition's return were on zoological topics. They also contributed to understanding ocean currents and firmly established the tradition of shipboard laboratory work. At the same time, the expedition significantly expanded the bathymetric understanding of the ocean that Maury's charts had begun.²⁰

Biological questions served as the primary motive for the voyage, as British naturalists were inspired by and hoped to compete with recent Swedish work that had retrieved unusual biological specimens from 300 fathoms—about 550 meters—a depth then considered extreme.²¹ Historian Rodolfo John Alaniz has argued that the publication of Charles Darwin's groundbreaking *Origin of Species* in 1859 provided further inspiration. Finding, or failing to find, the intermediate species whose existence Darwin had predicted in the seas provided an opportunity to test his assertions about the mechanisms of natural selection (Alaniz 2014, 228–29). However, the Challenger naturalists were also quite interested in geology. They and the ship's crew used sounding machines similar to those of Maury and his lieutenants but also deployed other tools adapted from fishers and oystermen, such as the trawl and the dredge. These were variations on a similar idea: a net held open by an iron bar or bars is dragged along the bottom at the end of a line by the movement of the ship above, gathering fauna, flora, and detritus in its path. Naturalists had begun to adapt the dredge by the mid-eighteenth century, but in the nineteenth its use from rowboats and other small craft to retrieve specimens of marine sea life was popularized by British naturalist Edward Forbes. Forbes understood this zoological work to have geological implications, noticing the similarity between the benthic fauna he retrieved and studied to similar fossil finds in now-terrestrial strata ashore. He predicted that a thorough understanding of the conditions under which these creatures lived—including pressure, temperature, and darkness—was key to understanding their natural history, from which naturalists could in turn extrapolate to understand the conditions under which the ancient terrestrial fossil beds had formed. Though Forbes died in 1854, others continued this work, including Scottish marine zoologist C. Wyville Thomson, who originally proposed the partnership that would lead to the Challenger trip.

During short, preliminary cruises of a few months each on naval survey ships, Thomson and his colleagues worked out which tools and implements were best suited to address their questions, the best practices for how to deploy them, and how a relationship between scientists and naval personnel would function aboard

ship. With this background, the expedition proper could begin aboard *Challenger*. From 1872 to 1875, seven “scientifics,” including Thomson, joined the ship’s officers and crew for a scientific circumnavigation studying every sea except the Arctic.²² A committee established by the Royal Society laid out the voyage’s potential goals, including the investigation of the physical conditions of the deep sea, the chemical composition of sea water, the characteristics of bottom sediment, and the distribution of life.²³ In all, *Challenger* traveled 68,890 nautical miles, sampling the sea bottom at 362 points along the way, from the littoral to the deepest spot in the ocean (a location near the Mariana Trench now called Challenger Deep for just this reason).

The dredge was the key tool for sampling the bottom, and was soon modified to accommodate even smooth and rocky bottoms, from which it had originally returned empty. Dredging off the coast of Scotland during the preliminary cruises, the embarked naturalists brought up “a bluish-white tenacious mud” mixed with the microscopic shells of globigerina, a genus of planktonic marine foraminifera. The remains of these tiny animals had been found in abundance even by rudimentary earlier soundings of the North Atlantic bottom (Carpenter 1868). They had first been reported by Jacob Whitman Bailey, an American microscopist and professor at West Point, who examined samples obtained as part of Maury’s program in the 1850s. Bailey reported that with the exception of only one sounding, “the bottom of the North Atlantic Ocean . . . from the depth of about 60 fathoms, to that of more than two miles (2000 fathoms), is literally nothing but a mass of microscopic shells.”²⁴

Now possessed of their own samples, however, Thomson and his colleagues could reimagine the ocean’s place in geological history just as Forbes had suggested. In 1836, German microscopist Christian Ehrenberg had established through microscopic examination that the deposits of porous white limestone in Cretaceous strata in England and beyond—known as “the Chalk”—contained the remains of marine fossils, evidence that these layers had been laid down when the area was at the bottom of an ancient sea.²⁵ Now these sedimentary soundings from the Atlantic and beyond found these same creatures in the process of living, dying, and drifting into an accumulating layer at the bottom of the modern sea. This offered powerful support for uniformitarianism—the idea posited in the early 1830s by geologist Charles Lyell’s (1831–33) influential volumes *Principles of Geology*, which argued that the earth had been shaped over an extremely long period of time via slow-moving processes, processes that were still acting at that time—but Thomson took it further.²⁶ This was not simply evidence of the same mechanism in operation today that had formed the Cretaceous Chalk in the past, he argued. Indeed, he claimed, “it is not only chalk which is being formed in the Atlantic, ‘but *the* chalk, the chalk of the cretaceous period’” (Thomson, Carpenter, and Jeffreys 1873, 472, emphasis in the original). Other naturalists pushed back on the claim “that we might be regarded in a certain sense as still living in the

cretaceous period.” Thomson eventually changed his wording (after all, geological periodization is “thoroughly indefinite”) but maintained, with Carpenter and Jeffreys, “that the balance of probability is greatly in favour of the chalk having been uninterruptedly forming over some parts of the area” that is now the Atlantic Ocean (Thomson, Carpenter, and Jeffreys 1873, 471–72). He thus used these sediments to reimagine not just the geographical space of Europe and the Atlantic, but their geological time, as well.

Based on the earlier American observations and their own on the preliminary cruises, the *Challenger* naturalists had set out expecting to find “a more or less universal chalk formation at the bottom of the ocean” (Buchanan 1919, 35). Yet as *Challenger* continued into deeper water, they noticed a shift from the “globigerina ooze” they had been retrieving to a red clay with no signs of foraminifera. The transition from organic to inorganic sediment was not abrupt but first passed through a transitional region of “gray ooze” at depths of between about twenty-two hundred and twenty-six hundred fathoms, where “the shells gradually lose their sharpness of outline, assume a kind of ‘rotten’ look and a brownish color, and become more and more mixed with a fine amorphous red-brown powder, which increases steadily in proportion until the lime has almost entirely disappeared” (Thomson 1878, 212–13). The naturalists thought it unlikely that the foraminifera that had thus far proved ubiquitous did not live in these areas, and the extremely fine texture of the remaining sediment made it unlikely that some sort of current swept them away. The gradual transition—with foraminifera shells in the intermediate area showing increasing degradation—instead suggested a chemical reaction.

Unlike earlier expeditions, whose specimens had frequently had to wait for analysis ashore, *Challenger*’s onboard laboratory included chemical apparatus and microscopes. When expedition chemist John Buchanan subjected a sample of globigerina ooze to weak acid in the onboard chemical laboratory, the resulting product was a reddish mud (Thomson 1878, 215–17). This new theory, though, did not stand further testing; chemical reaction explained the disappearance of the globigerina, but when these creatures were captured in surface nets and subjected to the same chemical process, red clay did not result (Buchanan 1919, 34). Murray then suggested that the clay was in fact the result of decomposing pumice, expelled by volcanoes and left to drift globally until it finally sank and slowly decomposed. Under the microscope, the red clay proved to contain glassy feldspar and to lack quartz, evidence to support its volcanic origin (Buchanan 1919, 34).

As the ship proceeded into deeper water, the sediment samples showed another shift. Below three thousand fathoms’ depth, the red clay began to accumulate the shells of radiolaria, a planktonic protozoa whose shells consist of silica instead of the calcium carbonate of the globigerina. Again, the transition was gradual, until eventually the red clay gave way to a siliceous “radiolarian ooze.” This, too, reflected ancient geological conditions Ehrenberg had observed in Europe (Murray and

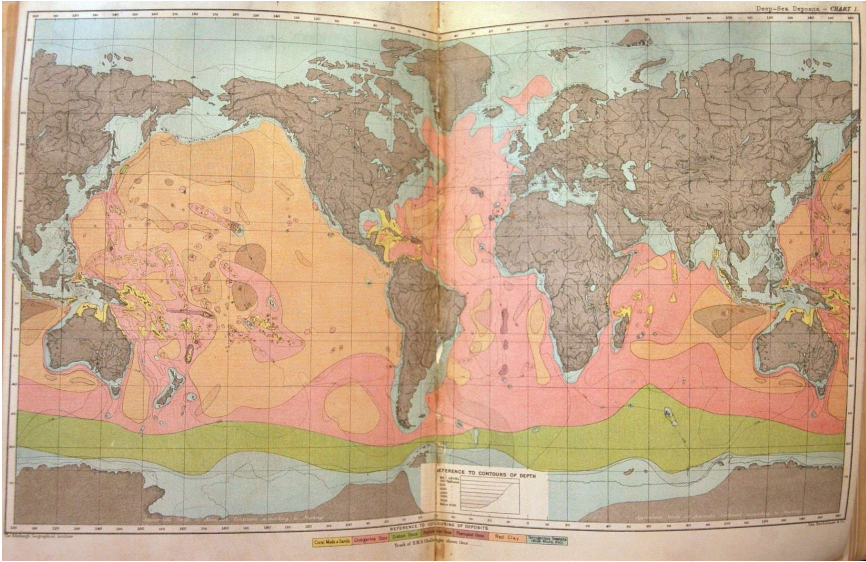


FIGURE 5.2. Deep-Sea Deposits. Chart 1. From John Murray and A.F. Renard, *Deep-Sea Deposits*, volume of *Report of the Scientific Results of the Voyage of H.M.S. Challenger during the Years 1873–1876* (London, 1891). NOAA Central Library Historical Collections.

Renard 1891, xxi). This alignment of depth, distance from shore, and nature of sedimentary fauna again allowed the naturalists to reexamine strata ashore. Since they now knew what conditions in the modern ocean were producing a layer of siliceous ooze, for instance, they could argue that the landscape that contained a siliceous stratum ashore must once have been under those same conditions. Examining the precise mix of fossilized fauna under a microscope could provide an even closer window onto the geological past, dictating an even narrower band of conditions in which the observed layers must have formed.

Over the three-and-a-half years of the *Challenger* voyage, the bottom became a familiar place to the naturalists. The various oozes and clays and their constituent parts entered the naturalists' everyday vocabulary. They were able to classify sedimentary layers as terrigenous (occurring in the littoral, in shallower water, and generally consisting of materials washed into the sea from the land), pelagic, or benthic, and they sketched them onto the contours emerging from the accompanying soundings. The result was a visualization of the bottom as a knowable, even colorful territory—with grey and blue and red clay, and chocolate oozes—delineated by depth and distance from shore (figure 5.2). The naturalists thus constructed the bottom as a site for study which they could visit virtually through the use of technology, though none of them could ever observe it in situ.

At the same time, their comparisons with shore-based paleontology helped them understand the inhabitants of the benthic landscape as multidimensional, existing in time as well as space, and in chemistry and geology as well as biology.

CLAIMING THE OCEAN BED

While the *Challenger's* primary mission during the expedition was scientific, it remained a naval vessel, so its naval officers were tasked with hydrographic studies of their own even as they worked to support the naturalists' efforts. The soundings and positional fixes that they obtained alongside and between each round of dredging and sampling allowed the naturalists to make exact claims about the provenance of their specimens and environmental data, but they also accumulated an expert knowledge about the ocean's dimensions, contributing to the long effort to map the globe.²⁷ The officers charted this positional data and returned it home to the Admiralty independent of the scientific results. Both these sets of knowledge—the positional fixes and the accumulated biological, geological, and environmental information associated with them—contributed to an ongoing British imperial project to “rule” the waves by thoroughly knowing them.

The British were not the only ones to stake these kinds of knowledge-based territorial claims. As new technologies were developed that allowed both navies and scientists to more accurately chart the bottom, they found each other to be good partners in the ongoing process of filling in the bathymetric map that Matthew Fontaine Maury had first begun. Along the way, they named the features they felt out along the bottom, and this process of labeling staked claims to a certain possession embodied in knowledge, even when attached to landscape features in a territory that could not be subject to literal territorial claims of ownership. The *Challenger* officers had named various bays and straits after their colleagues aboard—and the naturalists had reciprocated when assigning scientific names to the previously unknown fauna discovered in their dredge hauls—but the unveiling of new bottom topography provided whole new chains of mountains and valleys on which to impose the names of their discoverers. Challenger Deep in the Pacific was not the least of these, and the expeditions that followed in the next century continued in the same tradition.

In the second decade of the twentieth century, still smarting from their defeat in the Great War and from the punishing terms of the Treaty of Versailles that ended it, the German navy partnered with German oceanographers and the *Notgemeinschaft der Deutschen Wissenschaft*, a nongovernmental organization with a commitment to fund German science, to assemble a scientific expedition to study the Atlantic Ocean—the *Deutsche Atlantische Expedition*. The postwar context was important to their efforts, as both navy and scientists were suffering from real and perceived exclusion from what they saw as their rightful place among the

superpowers. The Versailles terms forbade the navy to build or arm new warships. The treaty had also stripped Germany of its colonies, something the navy saw as symbols of great power status. The colonies had served another purpose for scientists, providing friendly and accommodating centers for field research. In the wake of the war, Germans felt—and to a degree were—locked out of international funding and research opportunities, so the loss of these colonial spaces for fieldwork and the loss of domestic funding brought on by the country's precarious postwar economic situation made scientists fear they would fall from the top tier of scientific research that Germany had occupied before the war (Crawford 1988; Kevles 1971). The oceans, however, provided a space for both doing science and demonstrating the German navy's continued ability to operate, and from which they could not be barred or restricted. These benefits proved sufficient motivation to scrape together the funding for a two-year expedition to thoroughly study the South Atlantic from the deck of the gunboat-turned-surveying-vessel *Meteor*.

The expedition was equipped to perform thorough oceanographic and meteorological work at three hundred sampling points, called stations, arranged along fourteen latitudinal cross-sections of the Atlantic, called "profiles," from about 20°N to below 60°S. At sea, a typical station involved the lowering of numerous thermometers and sample bottles via a large winch on the aft deck; another winch forward was available as a backup. Each carried 8,000 meters of aluminum-bronze stranded wire rope, with a high tensile strength and an 830-kilogram breaking strength. The aluminum-bronze alloy meant the line required no grease to prevent corrosion. Sample bottles were spaced along the line at intervals, their number determined by the depth, and each could be triggered in sequence by a falling weight to capture 1.25 liters of seawater. A four-liter bottle at the bottom was rigged to sample seawater with no contact with metal (Spiess 1985, 94–95). Laboratory facilities on board and later analysis ashore would analyze the seawater chemistry of these samples, including salinity. The lines carried reversing thermometers, both pressure-protected and unprotected, alongside the water samplers. Once the line reached the desired depth, it would be left for twenty minutes for the thermometers to register accurately, and a messenger weight sent down the line would trigger both the water sample capture and the thermometer's reversal, locking the temperature reading at depth. The resulting temperature and salinity data together provided useful information about the movement of water throughout the ocean. The comparison of the protected thermometer with the unprotected, which was thus affected by pressure, provided a calculated depth based on the known effect of pressure on temperature and the regular increase of pressure with depth, which could double-check the sounding line. The thermometers could be calibrated in port with a bucket of ice water. To check that the water samplers closed at the desired depth, the resulting samples were analyzed for their hydrogen ion concentration, as that too varies regularly with depth (Spiess 1985, 96, 99).

This was a more thorough study of the ocean's dynamical aspects than had been conducted before, but not otherwise completely novel—a difference in quality and quantity of data rather than kind. What was truly new on board the *Meteor* were two new echo-sounding devices: one of completely German origin, developed by the Kiel-based Signalgesellschaft and thus named the Signal sounder, while the other was a product of the Submarine Signal Corporation in Boston, Massachusetts, sold to the Atlaswerke in Bremen. The latter equipment was renamed the Atlas sounder, despite being of American origin and barely having even been tested by the Germans before its last-minute deployment (Höhler 2002a, 140). To back up and verify the state-of-the-art echo sounders, *Meteor* carried two line sounders: a Thomson sounding machine, originally developed by William Thomson, Lord Kelvin, in the 1870s, and a Lucas machine, designed in the 1880s.

Echo sounding had been proposed as a means of depth-finding quite early; by 1858 Matthew Fontaine Maury reported that a number of methods had been tried, including the use of explosives or bells to create the sound signal, but “out in ‘blue water’ every trial was only a failure repeated” (Maury 1856, 243–44). A device to find depth by using a sound pulse had been patented in Germany for navigational use as early as 1912, and in the wake of the *Titanic* disaster that April inventors and maritime officials experimented with the same concept to measure distances horizontally or find objects (such as icebergs) in the water surrounding a vessel.²⁸ The Great War's interference in civilian shipping retarded the spread of the navigational technology and obscured much of the other experimentation beneath the cloak of military secrecy. By the 1920s, though, the United States, France, and Britain all experienced some success in developing these tools and were deploying them in limited fashion aboard moving ships. In 1922, an American warship sounded a continuous profile across the Atlantic, resulting in a depth cross-section that displayed the ocean's bottom contours along one line, as if along a single latitudinal “slice.” While this demonstrated that such a feat could be accomplished, it hardly cast much more light on the topography of the Atlantic basin than had Maury's few dozen scattered line soundings. The following year the U.S. hydrographic office published a bathymetric chart of the California coastline incorporating five thousand sonar measurements conducted by two warships over thirty-eight days, but even this, while it represented a vast increase both in area covered and in time and labor spent, barely touched the rim of the vast Pacific (Höhler 2002a, 136; “Echo Sounding” 1923; Schott 1923).

In addition to the Signal and Atlas sounders described above, *Meteor* carried two iterations of earlier acoustic sounders. The Behm sounder worked essentially along the principles Maury and others had suggested; a blast cartridge detonated at the surface, sending a pulse of sound into the water and starting a timer that the returning echo stopped. It was only useful to 750 meters and even then was not terribly accurate. The free sounder, also known as the bomb sounder, was another

product of the Signalgesellschaft. It used the direct sound of an explosive, rather than its echo, to measure depths in fairly shallow water (less than 200 meters). An explosive designed to fall through water at a constant rate was released, and its descent timed until it exploded upon contact with the bottom. The duration of its descent allowed calculation of water depth, ignoring the speed of sound in such shallow depths (Hoheisel-Huxmann 2007, 58).

The two new, state-of-the-art sounders, though, promised much more precise measurement, and the Germans hoped to provide the first comprehensive survey of the Atlantic. The Signal sounder was successfully tested during a preliminary, trial expedition, but the Atlas was not ready in time and thus went directly into service during the main expedition. Both operated by the emission of a 1,050 Hz sound pulse, which reflected off the bottom and returned to the ship after a delay that depended on the depth beneath the ship's keel. A receiving membrane on the hull detected the reflected signal. The sounding apparatus calculated the depth automatically based on the delay, using a preset approximation of the speed of sound in seawater.²⁹ Soundings could thus be conducted in any depth, in all weather, while the ship maintained speed. At every oceanographic station, an old-fashioned line sounding verified the echo sounding results (Spiess 1985, 151).

As historian Sabine Höhler has pointed out, the use of a sound moving through water to calculate distance rendered the water itself the medium of measurement, instead of the lines and weights of the previous generations of sounders. The properties of seawater that affected the behavior of sound within it thus became important objects of study for the purposes of their participation in this technology, rather than just as an end in itself (Höhler 2002a, 122). This would prove immensely important to the future direction of physical oceanography as a field, turning the world's blue water navies into important patrons of oceanography and simultaneously guiding the direction of study as the field developed over the course of the next several decades.

The results were as good as could have been hoped. The two modern echo sounders performed flawlessly; they remained in continuous use during the thirty-month expedition with no technical difficulties, usually taking individual measurements every twenty minutes, which placed them at two- or three-mile intervals (Spiess 1985, 83). When the bottom topography seemed particularly interesting, the interval was shortened. The morphology thus charted often determined the location or interval of oceanographic stations, as it suggested the contours of ocean basins, information that could, when augmented with the thermal and chemical results gained by sampling, elucidate the movement of deep currents. The resulting charts of Atlantic topography represented a significant legacy of the expedition and formed the basis for a three-dimensional, bottom relief model of the South Atlantic displayed in the Berlin Museum of Oceanography (Höhler 2002b, 234–46).

As with most major expeditions, the voluminous results of the Deutsche Atlantische Expedition led to the publication of numerous volumes of results on the various subjects examined during the voyage. In them, German oceanographers used the sounding data to reimagine the ocean, in some cases assigning new names and features, in others rearranging the ocean bottom, naming new contours and assigning old ones to newly differentiated basins, as Theodor Stocks and Georg Wüst did in *Die Tiefenverhältnisse des offenen Atlantischen Ozeans*. New data led to a finer-grained geographical understanding, though Stocks and Wüst were careful to point out that it “must naturally remain hypothetical in some parts” (1935, 32). In places, these new features bore German names—as did the Alfred Merz Plateau, near Bouvet Island in the South Atlantic, named for the chief scientist and expedition leader who had died in the course of their voyage. Even when they did not, their publication by German scientists in charts of the ocean’s basin labeled as products of German science constituted a symbolic claiming of territory, as Sabine Höhler has argued; if Germans could no longer claim colonies ashore, they could, in the act of mapping, claim the bottom of the ocean (Spiess 1985, 149; Höhler 2002b).³⁰ I have elsewhere extended her argument to suggest that the expedition’s meteorological efforts similarly laid claim to the currents of the air over the Atlantic (Hardy 2017). While the meteorologists on board both wrote their own reports and sent data home for further analysis, much of their results volume consists of hundreds of pages of tabulated data, an assertion of German data dominance to support the symbolic seizure of aerial territory. German oceanographers used their technologically derived knowledge of the ocean bottom to assert their—and their nation’s—continued membership in the top tier of science and thus their continued claim to be a Great Power.

CONCLUSION

Over the course of the nineteenth and twentieth centuries, scientists used increasingly sophisticated technologies to build a detailed picture of the ocean floor. In doing so, they turned that picture to the overlapping purposes of science, government, and industry, imagining it as, among other things, a cradle for telegraph cables, an embodiment of geological history, and a territory to be ordered and named. That is not to say that any of these actors believed their understanding of the ocean’s contours to be final; Maury revised his mental image of the bottom quickly as new soundings undermined his previous conceptions, and the German oceanographers understood their maps, though based on the then-state-of-the-art technology and the most detailed yet produced, “must naturally remain hypothetical in some parts” (Stocks and Wüst 1935, 32). Yet at the same time, these scientists understood their maps to be true, and with them they fostered their nation’s commercial destiny, found evidence for deep geological time, and defended national pride.

Our conception of the bottom of the ocean continues to say as much about the structures of human science and politics as it does about the ocean itself, as the fluid understanding of both three-dimensional ocean and the water that fills it are recruited to commercial, scientific, and thus political enterprises. Oceanographers have vastly improved understanding of the ocean, most notably with the mid-twentieth-century discovery that the Mid-Atlantic Ridge first charted on the *Meteor* is in fact part of a forty-nine-thousand-mile-long, global structure and the key to the modern conception of plate tectonics (Felt 2012, 251). Yet at the same time, oceanographers continue to point out the many ways in which the ocean bottom remains unknown. It is a trope of oceanography to note that we know more about the surface of the moon—or sometimes Mars or beyond—than we do about the bottom of the ocean. In the Cold War, this conception of the ocean as unexplored fueled pleas for funding in a field that saw itself competing with space exploration for support. Despite the various forms of public and private funding expended on efforts to know the ocean since, the bottom remains unknown enough to continue supporting arguments for further funding and ship time.

The water itself, too, retains a fluid identity: it is measured, and it is also a technology of measurement. Stefan Helmreich (2011), examining the popular modern conception of the ocean's depths embodied in the Google Ocean application, has noted the “odd sensory feature” experienced when a user “flies” under the virtual surface to view the bathymetry of the ocean floor: the water itself is not present. This is somewhat ironic, for Google's engine constructs its image of seafloor topography from mathematical data that is in turn derived from a combination of the measurement of minute variations in satellite-based radar measurements of the water's surface that reflect the topography below and echo-soundings of the bottom, as Helmreich notes (1226). This means that the medium of measurement is water, just as it was for the *Meteor*'s soundings in the 1920s, though Google's imagined ocean renders both water and math invisible.

In the twenty-first century, the global ocean and the water that fills it have assumed another role in the measurement and representation of the oceans among scientists who use their various properties—pH level, oxygen content, ice coverage—to index the changes associated with the warming global climate. Ocean acidification, oxygen depletion, and the changing albedo, shifting global currents, and rising sea levels produced by shrinking ice caps thus provide a new reimagining of the ocean as bellwether for changes that will affect the terrestrial portions of the globe in turn. They thus still fuel arguments over geological history, as many believe Earth has now entered a new epoch in which human activity is the major motive of change: the Anthropocene. In pointing to the scientific knowledge about the oceans while engaging the excitement of its remaining mysteries, scientists and the activists who rely on their work thus build arguments and appeals from ocean data, asking their audiences to consider the fluid identity not just of the watery two-thirds of the planet, but of the entire Earth.

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NOTES

1. While this chapter concentrates on Western efforts, other peoples had their own approaches to knowing the oceans. Pacific Islanders have a long tradition of navigation using methods that do not require graphic representation. Ming dynasty China had a large fleet that navigated over a significant portion of the global ocean in the medieval period, but this activity ended with the death of Emperor Zhu Di in 1424. Ironically, as Michael S. Reidy, Gary Kroll, and Erik M. Conway (2007, 4–5) have pointed out, this meant China turned away from ocean exploration just as the era of extensive European ocean navigation was beginning. Mei-Ling Hsu (1988) provides an analysis of the extant early Chinese navigational charts (96–112); however, historians have not yet produced a concentrated body of scholarship on the history of ocean mapping in Asia to the degree that has been done for the West. Jakobina K. Arch, personal communication to the author, May 29, 2019.
2. Historians and philosophers of technology have spilled much ink defining the term, but I use it here to mean tools, techniques, and systems employed to accomplish goals or embody knowledge. In this case, those goals might include measurement of certain data points, their employment to make arguments, or their communication in graphic form. As Eric Schatzberg (2018) and others have shown, this is a modern interpretation of the word, so I am not suggesting that it was a category that the historical actors considered here would have used to describe the things I call technology.
3. For more on the changing role of the ocean in the scientific, public, and political imagination, see Adler (2019).
4. It is important to note that Maury's scientific work was inextricably entangled with his lifelong support of white supremacy and the institution of racial slavery. See Hardy and Rozwadowski (2020).
5. The US Coast Survey should in theory have been printing charts, but it had experienced a series of slowdowns and setbacks since its founding in 1807 that prevented it from producing broadly useful charts. Also, its work was limited to the American coast and the Gulf Stream.

6. Maury to Captain F.H. Gregory, USN, USS *North Carolina*, New York, August 29, 1843, vol. 1, "Letters Sent" (LS), RG 78, National Archives Building (NAB), Washington, DC.

7. Deep-sea sounding efforts date back at least to Magellan, though he gave up without finding the bottom. John Ross sounded as deep as one thousand fathoms in Baffin's Bay in the late 1810s, and in 1840 his nephew James Ross sounded well over two thousand fathoms in the Southern Ocean. Rice (1975). Naturalist George Wallich sounded and dredged on an 1860 cable survey, but he complained about the lack of science being done on the trip (see Rozwadowski 2005, 93, 140–41).

8. Maury to Gregory, August 29, 1843, vol. 1, "Letters Sent," RG 78, NAB.

9. "Suggestions for the Attention for the Home Squadron," October 3, 1843, vol. 1, "Letters Sent," RG 78, NAB. The petition came from a committee formed at the 1844 annual meeting of the Association of American Geologists and Naturalists, of which Maury was a member; Maury, H[enry] D[arwin] Rogers, [Edward] Hitchcock, [James Pollard] Espy, [William Charles] Redfield, [James Dwight] Dana, and [Joseph P.] Couthouy to [John Y. Mason,] secretary of the navy, November 11, 1844, vol. 1, LS, RG 78, NAB.

10. Maury to Crane, October 25, 1845, vol. 2, LS, RG 78, NAB.

11. House of Representatives Report no. 449, March 15, 1842, 27th Congress, 2nd session; Maury to Warrington, Washington, DC, January 16, 1848, vol. 2, LS, RG 78, NAB.

12. Maury to Robert Walsh, US Consul, Paris, July 9, 1847, vol. 2, "Letters Sent," RG 78, NAB; Maury to Adams, November 17, 1847, vol. 2, LS, RG 78, NAB.

13. Maury to Warrington, September 1848, vol. 3, LS, RG 78, NAB.

14. Maury, *Explanations and Sailing Directions to Accompany the Wind and Current Charts*, 4th ed. (1852), 41–42, cited in Williams (1963, 180); Maury to Warrington, September 1848, vol. 3, LS, RG 78, NAB.

15. These chart series have been enumerated by the American Geographical Society Library at the University of Wisconsin Milwaukee, "Matthew Fontaine MAURY Ocean Charts at AGS Library," updated May 18, 2012, <http://uwm.edu/libraries/wp-content/uploads/sites/59/2014/06/maury.pdf>.

16. Brooke (1980, 55–56); Maury to Duncan N. Ingraham, chief of the Bureau of Ordnance and Hydrography, January 16, 1857, "Letters Received" (LR), RG 45, NAB.

17. Maury to J.C. Dobbin, Secretary of the Navy, February 22, 1854, in Caskie (1928, 110–112). As Maury was deeply religious, this was likely more than a turn of phrase; his science retained an element of natural theology that was already becoming old-fashioned in scientific circles, and a belief in American Manifest Destiny that was not. For the recent oceanic turn in historical understanding of Manifest Destiny, see, for example, Rouleau (2014); Morrison (2017); and Smith (2018).

18. Earlier expeditions had carried naturalists to sea, but their focus had largely been ashore, with the ship providing transportation to that terrestrial destination. However, Alistair Sponsel (2016) has recently argued that Charles Darwin's work on board HMS *Beagle* relied heavily on hydrographer's techniques.

19. In addition to the efforts of Maury's lieutenants and of John Ross and James Ross (see note 11 above), naturalist George Wallich sounded and dredged on an 1860 cable survey, but he complained about the lack of science being done. See Rozwadowski (2005, 93, 140–41).

20. For these other contributions, see, for instance, Laloë (2012); Mills (2009); Rozwadowski (1996); and Adler (2014).

21. A fathom is a measurement of depth equal to six feet.

22. While the sailors called them "scientifics" or philosophers, Thomson and company would have thought of themselves as naturalists (or chemists in the specific case) or natural philosophers (for all of them). The fields now broadly called science were beginning to acquire that title, but still fell under the rubric of natural philosophy in the nineteenth century, especially in Britain. While the term "scientist" had been coined jokingly in 1833 by William Whewell, it did not enjoy broad (and serious) use until the latter part of the century in the United States, and near or even after the turn of the twentieth century in Britain (where it was avoided in part because Americans used it). William Whewell, "Art.

III—On the Connexion of the Physical Sciences by Mrs. Somerville,” *The Quarterly Review* 51 (1834): 58–61, cited in Ross (1962).

23. “Report of the Committee appointed at the Meeting of the Council held October 26th [1871], to consider the Scheme of a Scientific Circumnavigation Expedition,” reproduced in Thomson (1878, 75).

24. S[amuel] P[hillips] Lee and H.C. Elliott, *Report and Charts of the Cruise of the U.S. Brig Dolphin, Made under Direction of the Navy Department* (Washington, DC, 1854), notes page at end; Bailey, “Microscopical Examination of Deep Soundings from the Atlantic Ocean,” *Quarterly Journal of Microscopic Science* 3 (1855): 90. Quote is from the latter.

25. “Article XII: Recent Discoveries and Improvements in Science and the Arts,” *The American Eclectic*, September 1841, 389.

26. By contrast, catastrophism posited a geological history divided into epochs by occasional global catastrophes, thus bringing about sharp and sudden changes.

27. In navigation, the latitude and longitude measured at a particular location at sea is used to fix a ship’s position on a chart, so the combined data set for one location is called a fix.

28. Ronald Rainger (2007, 135–38) placed the beginnings of American interest in oceanography in this context. The U.S. Coast Guard established its International Ice Patrol in 1914 to monitor icebergs in the Arctic and North Atlantic, and a dynamical understanding of ocean currents was necessary to understand their movements.

29. This was 1470 meters per second for the Signal sounder, or 1490 m/s for the Atlas (Hoheisel-Huxmann 2007, 58).

30. In this article and elsewhere, Höhler’s argument follows Bruno Latour’s depiction of the collection of data into charts as a rendition of time and space into stable but portable form (Höhler 2002a).