An Anchor in the Unknown:

The Exploration and Encounter of HMS *Challenger*

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Historical Paper

Junior Division

2,452 Words

When we have done our work abroad,
And ocean beds, are land;
Our Rope and Dredge will then afford
A fact, unique and grand.

- "A Song for the *Challenger's* Crew," Anonymous[1]

In Portsmouth, England on December 21, 1872, Her Majesty's Ship the *Challenger* launched itself into the harsh realm of the deep sea bottom where no one had dared to venture before.[2] The crew on board began their voyage for the sole purpose of appeasing their curiosity concerning the mystery of the sea. One third of the crew would not complete the passage with the others due to death, sickness, and desertion.[3] To the remaining members who endured the hardships of the one thousand day journey, the ocean revealed its hidden secrets, one by one. This epic expedition became the first quest in history to be exclusively dedicated to scientific research.[4] The HMS *Challenger* explored the mystery of the deep sea floor, encountered new marine life and environments, and laid the foundation for the modern science of oceanography.

At the time of the HMS *Challenger*, England took leisure in tranquility and wealth as the most powerful country in the world during the Victorian Era.[5] Within the nation, the British were debating the subject of science and religion.[6] This was due to the Age of Enlightenment, in which

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[1] Unknown. *A Song for the Challenger's Crew.* N.p.:n.p., n.d. Print.

[2] Corfield, Richard. *The Silent Landscape.* London: John Murray, 2004. Print.

[3] *Ibid.*

[4] *Ibid.*

[5] Steinbach, Susie L. *Understanding the Victorians.* New York: Routledge, 2012. Print.

[6] *Ibid.*

people began to separate myths and claims from facts that science could prove.[7] They became skeptical of the church and its traditional ideology that religion was the answer to all questions.[8] The desire to use logic and reason to explain the mysteries of the world quickly spread among them.[9] Hence, science seized the spotlight in Victorian England.

In 1841 of the Victorian Era, Edward Forbes navigated on the HMS *Beacon* across the Mediterranean and Aegean Seas to collect data on marine life.[10] He discovered that the amount of life decreased as water depth increased.[11] He concluded in his "Azoic Theory" that no living organism existed 300 fathoms -- equivalent to 1,800 feet below the ocean.[12] This theory was widely accepted at that time, for it seemed entirely logical that the deep ocean, which had extreme pressure, cold temperatures, and eternal darkness, would hold no life.[13] However, Charles Wyville Thomson, the future chief scientist aboard the HMS *Challenger,* came to doubt this theory because pieces of barnacles had been found attached to a broken telegraph cable retrieved from the bottom of the Mediterranean Sea.[14] Thomson was determined to disprove the Azoic theory and to properly research marine life. He stated that, due to this theory, humans made no effort towards "lifting the veil from the sea bottom" because it would prove both futile

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[7] Goldmann, Lucien. *The Philosophy of the Enlightenment.* Trans. Henry Maas. London: Routledge, 1973. Print.

[8] *Ibid.*

[9] *Ibid.*

[10] Carson, Rachel. *The Sea around Us.* Special ed. New York: Oxford University, n.d. Print.

[11] *Ibid.*

[12] Corfield, Richard. *The Silent Landscape.* London: John Murray, 2004. Print.

[13] *Ibid.*

[14] *Ibid.*

and "insurmountable" to accomplish.[15] He was thus inspired to set out on an exploration to the deep sea bottom.

Thomson persuaded the Royal Society of London, a group of prestigious scientists, to sponsor an expedition across the oceans throughout the world.[16] He and the Royal Society agreed that the objectives of the *Challenger* voyage would be to investigate organic life at different water depths, the physical conditions of the deep sea, the chemical composition of seawater, and the physical and chemical traits of sea deposits.[17] In 1872, the Royal Admiralty provided the war ship HMS *Challenger* for the journey.[18]

Charles Wyville Thomson gathered 216 crew members and Captain George Nares to conduct the crew.[19] Thomson led the scientist staff as the chief scientist, and four distinguished naturalists, including John Murray and Henry Moseley, assisted him (see Appendix A).[20] Thomson also recruited the help of an artist, John James Wild, who sketched illustrations of the intriguing new species found on the *Challenger.*[21]

By the end of 1872, the stage was finally set for the prolonged journey of the HMS *Challenger.* The ship departed from England, and went across the Atlantic four times, around

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[15] Thomson, Charles Wyville. "Geography of the Sea and the Object of the Challenger Expedition." HMS Challenger. Mar. 1873. Lecture.

[16] Corfield, Richard. *The Silent Landscape.* London: John Murray, 2004. Print.

[17] Thomson, Charles Wyville. *The Voyage of H.M.S. Challenger Narrative.* Vol. 1. New York: Johnson Reprint, 1885. Print.

[18] *Ibid.*

[19] *Ibid.*

[20] Bishop, Tina, Dr. "Then and Now: The HMS Challenger Expedition." *Ocean Explorer.* National Oceanic and Atmospheric Administration, 16 July 2012. Web. 20 Oct. 2015. <http://oceanexplorer.noaa.gov/explorations/03mountains/background/challenger/challenger.html>

[21] Corfield, Richard. *The Silent Landscape.* London: John Murray, 2004. Print.

Africa, through the southern Indian Ocean, into the Antarctic Circle, past Australia, across the Pacific Ocean, around the tip of South America, and back home in the May of 1876 (see Appendix B).[22] During this route, the *Challenger* collected a standard set of data, including water depth, temperature, and weather conditions, as well as samples of the sea floor, plants, animals, and water in various depths at each of their 360 planned stations.[23] This was the first time in history that all the oceans worldwide were measured by the same people, equipment, and methods within one voyage, which finally made it possible to compare the five great oceans.[24]

The crew members used three major techniques throughout their voyage to make their measurements: dredging, sounding, and thermometer temperature reading.[25] The dredging procedure consisted of letting down a dredge or a beam trawl into the water and dragging it across the sea bottom for samples.[26] The dredge, a "big trough with a net over it", was useful in collecting small specimens.[27] The beam trawl, a net connected with two iron bars, brought up large animals, plants, and sediment in its haul.[28] Sounding, a process of measuring water depth, was used by letting down a weight tied to a twine line and attaching flags to the line at intervals of forty-five meters.[29] When the flags rapidly changed direction, the crew knew that the weight

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[22] Linklater, Eric. *The Voyage of the Challenger.* N.p.: Cardinal, n.d. Print.

[23] *Ibid.*

[24] *Ibid.*

[25] Murray, John. *A Summary of the Scientific Results Obtained at the Sounding, Dredging, and Trawling Stations.* 2nd ed. N.p.: Rare Books, 2012. Reprint.

[26] *Ibid.*

[27] Matkin, Joseph. Letter to Family. 30 Dec. 1872. MS.

[28] Murray, John. *A Summary of the Scientific Results Obtained at the Sounding, Dredging, and Trawling Stations.* 2nd ed. N.p.: Rare Books, 2012. Reprint.

[29] Tizzard, T.H. *Narrative of the Cruise of HMS Challenger.* London, 1885. Print.

had hit the sea bottom.[30] Then, they pulled the line back up and counted how many flags had gone down.[31] Their measurements were precise within forty-five meters, which was the most accurate data for the time.[32] To measure temperature, the crew aboard the *Challenger* used the "reversing thermometer" on their journey for temperatures at various depths.[33] The crew lowered this thermometer to a certain depth and then flipped it upside down so that the temperature was held at that certain point.[34] The scientists could then know the specific temperature of a known depth, which provided accuracy to their data.[35]

During the *Challenger* exploration, the crew encountered new marine life in the seabed. Ocean life was a major focus in their research, since they had been inspired by the Azoic Theory. The crew collected and analyzed a great number of organisms, most of them new species unknown to the scientists on board.[36] The *Challenger* arrived at the conclusion, in response to the mystery of the ocean's "dead zone", that animal life existed at all depths of the ocean, although less abundant in more extreme depths than in moderate depths.[37] They discovered that the existence of animal life depended more upon the "composition of the bottom deposits", "the supply of oxygen", and other necessary factors organisms needed for life, rather than the

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[30] *Ibid.*

[31] *Ibid.*

[32] *Ibid.*

[33] Thomson, Charles Wyville. *The Depths of the Sea.* N.p., 1873. Print.

[34] Spry, William J. *The Cruise of HMS Challenger: Voyages over Many Seas, Scenes in Many Lands.* Second ed. London: Sampson Low, Marston, Searle, Rivington, 1877. Print.

[35] *Ibid.*

[36] Murray, John. *A Summary of the Scientific Results Obtained at the Sounding, Dredging, and Trawling Stations.* 2nd ed. N.p.: Rare, 2012. Reprint.

[37] Thomson, Charles Wyville. *Voyage of the Challenger, Atlantic I and II.* New York: Harper and Brothers, 1878. Print.

conditions immediately related to the sea depth.[38] Thus, all deep-sea fauna in similar conditions bore a "close genetic relation" regardless of their location.[39] It also appeared that abyssal species migrated in a northern direction, following the movement of the "cold under-current".[40]

The organisms that the *Challenger* collected during its research were placed in jars filled with wine to preserve them through the long journey.[41] The samples were so well taken care of that there were only two broken jars when the *Challenger* returned to England.[42] John J. Wild sketched beautiful illustrations of these creatures that can be seen in the *Challenger* reports (see Appendix C).[43] By the end of the expedition, the *Challenger* discovered 4,717 new species and 715 new genera, and these organisms were catalogued and identified in the zoology reports written by John Murray.[44] Marine biologists still use the *Challenger'*s reports and collections as references in their research today because its documentations contain such a wealth of information gathered from around the globe.[45] Robert Wynn Jones, a micropaleontologist and biostratigrapher, used the *Challenger* report and collection of the foraminifera species to write his book, *Foraminifera and Their Applications*, published in 2014.[46] He stated, "The

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[38] *Ibid.*

[39] *Ibid.*

[40] *Ibid.*

[41] Matkin, Joseph. Letter to Family. 13 Jan. 1873. MS.

[42] Bishop, Tina, Dr. "Then and Now: The HMS Challenger Expedition." *Ocean Explorer.* National Oceanic and Atmospheric Administration, 16 July 2012. Web. 20 Oct. 2015. <http://oceanexplorer.noaa.gov/explorations/03mountains/background/challenger/challenger.html>.

[43] *Ibid.*

[44] Prager, Ellen J., and Sylvia A. Earle. *The Oceans.* New York: Mc-Graw Hill, 2000. Print.

[45] Corfield, Richard. *The Silent Landscape.* London: John Murray, 2004. Print.

[46] Jones, Robert Wynn. *Foraminifera and Their Applications.* New York: Cambridge University, 2014. Print.

Challenger's collection is the most important, most cited, and most consulted collection of Foraminifera."[47]

The scientists aboard the *Challenger* also experienced new marine environments, where they made many unexpected discoveries. Among their findings were the manganese nodules. The crew's trawl brought up a material that looked like a "metallic burned potato with multiple layers" at one point in the Atlantic (see Appendix D).[48] Afterwards, the *Challenger* also found these rocks in other oceans, especially in the Pacific.[49] The *Challenger* exposed these curious rocks to the world for the first time.[50] Modern scientists have named these rocks manganese nodules, which are rich of resources such as manganese, cobalt, iron, copper, and nickel that are very useful to modern industry.[51] In the current situation where much of the land resources have been consumed and marine resources are rapidly gaining attention, many countries are researching the amount of manganese nodules they possess and the advantages of using this resource.[52] In the United States, cobalt, one of the main compounds in manganese nodules, is required to build powerful tools and jet engine parts.[53] As of today, the United States must import

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[47] *Ibid.*

[48] Corfield, Richard. *The Silent Landscape.* London: John Murray, 2004. Print.

[49] Winchester, Simon. *Atlantic: Great Sea Battles, Heroic Discoveries, Titanic Storms, and a Vast Ocean of a Million Stories.* New York: HarperCollins, 2010. Print.

[50] *Ibid.*

[51] Prager, Ellen J., and Sylvia A. Earle. *The Oceans.* New York: Mc-Graw Hill, 2000.

[52] "Marine Minerals." *World Ocean Review* 2010: 1-2. Print.

[53] Tujillo, Alan P., and Harold V. Thurman. *Essentials of Oceanography.* N.p.: Prentice Hall, 2011. Print.

its cobalt supply from South Africa.[54] However, the U.S. is now considering that it would be more reliable to obtain cobalt from deep sea manganese nodules within its own territories.[55]

The expedition also revealed a strange feature in the ocean floor. When the *Challenger* scientists mapped the soundings in a certain location where they had measured unexpected depths, they realized that they had discovered a mountain range in the middle of the Atlantic.[56] This range had been previously theorized to exist by Matthew Fontaine Maury, an American oceanographer.[57] In 1925, a German Meteor expedition found the entire ridge, now known as the Mid Atlantic Ridge.[58] This is the longest mountain range on Earth; it extends for 10,000 miles from the Arctic Ocean to the southern tip of Africa (see Appendix E).[59] The Mid Atlantic Ridge is the diverging boundary of the Eurasian and North American Plates.[60] These two plates diverge, and expand up to one inch per year as lava spews through the space between them.[61] The *Challenger* also discovered the Mariana Trench in the Philippines, a converging boundary in which the Pacific Plate is driven beneath the Mariana Plate.[62] The Mariana Trench is the deepest

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[54] *Ibid.*

[55] *Ibid.*

[56] *The Voyage of HMS Challenger 1873-1876*. London: John Murray, n.d. Print.

[57] Aleshire, Peter. *Ocean Ridges and Trenches.* New York: Chelsea, 2007. Print.

[58] *Ibid.*

[59] Winchester, Simon. *Atlantic: Great Sea Battles, Heroic Discoveries, Titanic Storms, and a Vast Ocean of a Million Stories.* New York: HarperCollins, 2010. Print.

[60] *Ibid.*

[61] *Ibid.*

[62] Aleshire, Peter. *Ocean Ridges and Trenches.* New York: Chelsea, 2007. Print.

point in the world with a depth of 8000 meters.[63] It was later named "Challenger Deep" in acknowledgement to its first explorers.[64]

Much research was done to understand how these geographical features found by the *Challenger* were formed. This resulted in the creation of the Plate Tectonic Theory, which explains that the Earth is divided into seven major tectonic plates that continuously diverge and converge.[65] This theory proves that the surface of the Earth is constantly changing and states "why mountains are rising and eroding, oceans expanding and shrinking, volcanoes erupting, and earthquakes striking."[66] Today, geologists focus their research on the changes of Earth's surface, specifically on the prediction of earthquakes, since this natural disaster inflicts the greatest damage upon humans.[67] Through studies, geologists discovered that earthquakes mostly occur along ridges and trenches created by plate boundaries.[68] 90% of the world's earthquakes occur in the Pacific Ring of Fire, a zone with around twelve trenches.[69] Using this knowledge, aftershocks are now overall successfully forecasted, yet the first hits are still unable to be detected before they strike.[70] The investigations on predicting earthquakes still continue.[71]

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[63] *Ibid.*

[64] *Ibid.*

[65] Prager, Ellen J., and Syvlia A. Earle. *The Oceans*. New York: Mc-Graw Hill, 2000. Print.

[66] Cowan, Angela M. "Plate Tectonics." *National Geographic* 2003: n.page.Print.

[67] Baxter, Roberta, and Duncan Agnew. *Seismology: Our Violent Earth.* Minneapolis: Essential Library, an imprint of Abdo, 2015. Print.

[68] *Ibid.*

[69] *Ibid.*

[70] Musson, Roger. *The Million Death Quake: The Science of Predicting Earth's Deadliest Natural Disaster.* New York: Palgrave Macmillan, 2012. Print.

[71] *Ibid.*

Throughout the voyage, the *Challenger* collected data on salinity at various depths in the ocean, from which the *Challenger'*s work on marine chemistry was launched. William Dittmar, a German chemistry professor, analyzed the salinity data that the *Challenger* sent during its expedition, and organized his results in the *Challenger Report on the Specific Gravity of Samples of Ocean Water*.[72] This report introduced important concepts regarding salinity in the explanation of seawater composition.[73] William J. Wallace, a marine chemist, stated, "Dittmar's report on the chemistry of the 77 water samples of the 'Challenger' Expedition represents the most extensive seawater analysis performed before or since."[74] Dittmar's analysis of salinity first accurately proved the Forchhammer Theory, which addressed that although the salt level in seawater is different at various areas, the ratio of major components in salts that make up seawater was constant in most regions.[75] As a result of Dittmar's new understanding, the amount of chlorinity, a major constituent in salinity, could be used to find the total salinity percentage in a water body.[76] This method was widely used up to the 20th century to measure the salinity of seawater.[77] Dittmar's contribution to the knowledge of salinity established the foundation for marine chemistry.[78]

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[72] National Research Council. *50 Years of Ocean Discovery.* Washington D.C.: National Academy of Sciences, 1950. Print.

[73] *Ibid.*

[74] Wallace, William J. *The Development of the Chlorinity/Salinity Concept in Oceanography.* Amsterdam: Elsevier, 1974. Print.

[75] *Ibid.*

[76] *Ibid.*

[77] *Ibid.*

[78] *Ibid.*

In 1876, the very long and strenuous voyage of the *Challenger* came to an end as the ship sailed back into England.[79] Shortly after its return, the scientists began to document the samples and data they had collected into the *Report on the Scientific Results of the Voyage of H.M.S. Challenger*.[80] This fifty volume, 30,000 page report consisted of charts, surveys, and biological investigations and took 20 years to write.[81] The *Challenger* reports have been reprinted and circulated to universities and libraries across the globe and are now easily accessible. The seabed samples collected on the HMS *Challenger* are still preserved at the National History Museum of London in both the John Murray and HMS *Challenger* collections.[82]

The *Challenger* also had an equally significant intangible accomplishment. Its discoveries, which became a sensation in the nineteenth century, were the driving force for a revolution of explorations to the great oceans. Consequently, sailors and scientists of all kind have explored the depths of the sea bottom with "increasing precision, rapidity, and success."[83] Through these events, the field of oceanography was founded and an immense movement in the study of the ocean began.[84] During this movement, in 1968, the Deep Sea Drilling Program began with the research ship Glomar *Challenger,* named after the first oceanographic research ship, the HMS *Challenger,* because the program was created in inspiration of the HMS

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[79] Corfield, Richard. *The Silent Landscape.* London: John Murray, 2004. Print.

[80] Linklater, Eric. *The Voyage of the Challenger.* N.p.: Cardinal, n.d. Print.

[81] *Ibid.*

[82] Miller, Giles, Dr. "Ocean Bottom Deposit Collection." *Natural History Museum.* Natural History Museum of London, n.d. Web. 6 Apr. 2016. <http://www.nhm.ac.uk/our-science/collections/mineralogy-collections/ocean-bottom-deposit-collection.html>.

[83] Murray, John. "The State of Ocean Science." 1899. MS.

[84] Corfield, Richard. *The Silent Landscape.* London: John Murray, 2004. Print.

Challenger's expedition.[85] This forty year program was the first devoted to scientific ocean drilling.[86] The Glomar *Challenger*'s main objectives were to study the sediments of the ocean floor and collect sediment from under the seabed.[87] The Deep Sea Drilling Program was extremely successful, and it was replaced by another drilling program in 1985, the JOIDES Resolution, which remains to this day.[88]

With the desire to know the mystery of whether life existed deep in the ocean, the *Challenger* crew headed deeper and further into the wilderness of the oceans. Along its route, the ship found many forms of life in the sea that entirely overturned the general belief of the time that the deep ocean was a dead zone. The *Challenger* also made remarkable discoveries exploring the physical features of the ocean and what phenomena the sea floor held, which served as the cornerstone for the modern science of oceanography. These incredible feats were only achieved because the HMS *Challenger* dared to pave a way to exploring the unknown sea floor when others deemed it impossible.

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[85] Deep Sea Drilling Project. *Deep Sea Drilling Project.* Technical rept. no. 3. N.p.: National Science Foundation, 1971.Print.

[86] *Ibid.*

[87] *Ibid.*

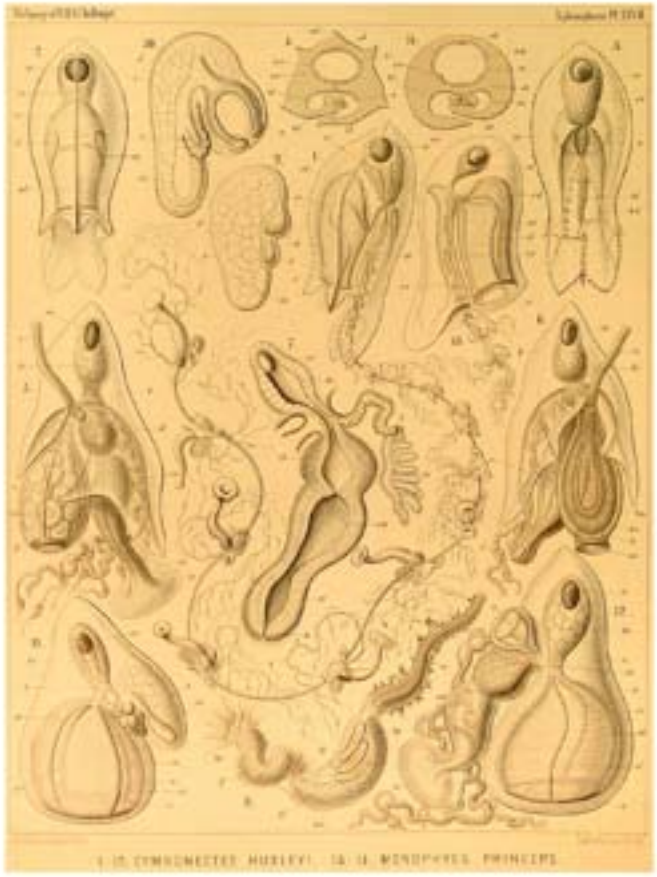
[88] *Ibid.*

Appendix A

"HMS Challenger October, 1872." *Ocean Explorer.* National Oceanic and Atmospheric Administration, n.d. Web. 25 Jan. 2016. <http://oceanexplorer.noaa.gov/explorations/03mountains/background/challenger/challenger.html>.

This photo of the HMS Challenger crew was taken shortly before their voyage. The man dressed in all white in the front row was Charles Wyville Thomson. The man dressed in white behind Thomson was Captain Nares.

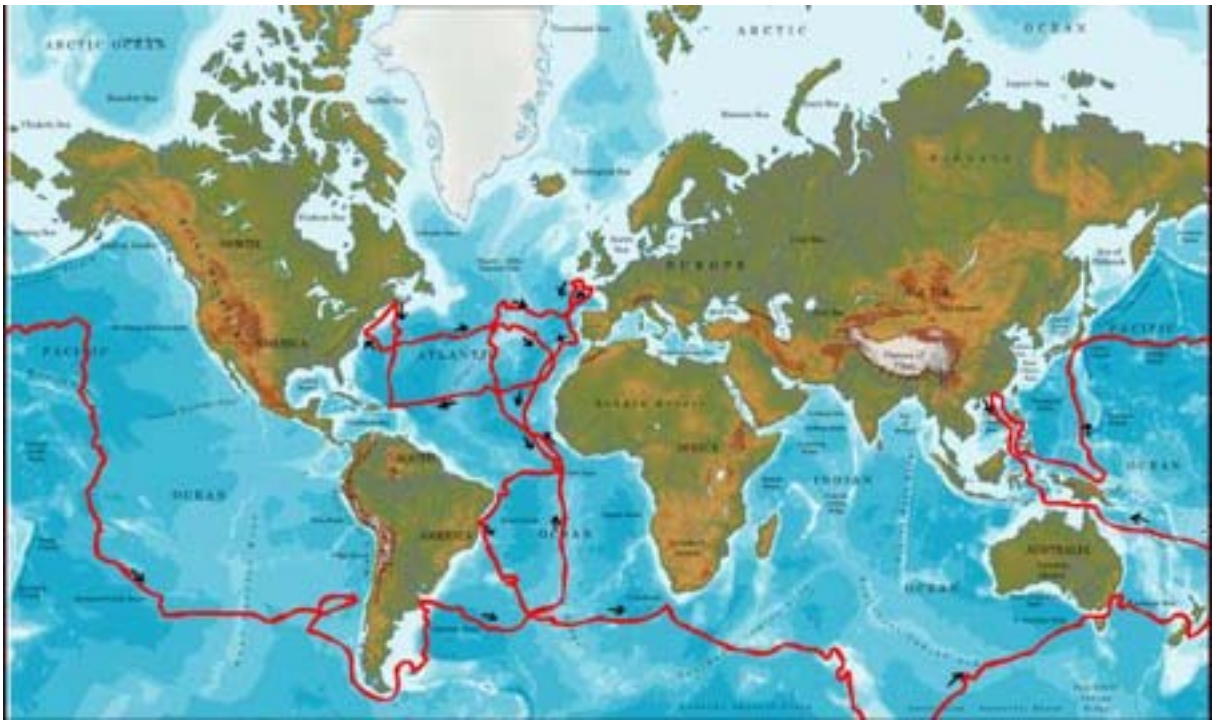
Appendix B



Wild, John. J. Brachipoda. 1888. Illustration. Zoology Report 77.

These are multiple sketches of a new species called Brachipoda by the *Challenger'*s artist John J. Wild. It portrays how carefully and detailed the drawings of the new species were.

Appendix C



"HMS Challenger Route." *The Voyage of HMS Challenger.* Initiative for Interstellar Studies, 30 July 2012. Web. 25 Jan. 2016. <http://i4is.org/the-starship-log/the-voyage-of-hms-challenger>.

This map illustrates the route of the HMS *Challenger.* One can see how intricately the *Challenger* toured around the oceans and the world.

Appendix D

"Manganese Nodules." *Mining the Seafloor for Rare-Earth Minerals.* New York Times, 8 Nov. 2010. Web. 25 Jan. 2016. <http://www.nytimes.com/2010/11/09/science/09/seafloor.html?_r=0>.

This image displayed both the layered, inner structure of the manganese nodule and its outer appearance. One can realize why the *Challenger* crew described these nodules as burnt, metallic potatoes.

Appendix E

Murray, John. *Bathymetrical Chart of the Oceans.* N.d. Illustration. National Oceanic and Atmospheric Administration.

This illustration is the mapping of the depths sounded on the *Challenger.* It was made by John Murray, a naturalist aboard the ship. The Mid Atlantic Ridge is the very long, light vertical strip between the continents.

Works Cited

Primary Sources

Matkin, Joseph. Letter to Family. 13 Jan. 1873. MS.
This letter explained what would happen when the dredge was pulled up on the HMS Challenger. It gives insight on the excitement of the scientists, and how they would go about caring for the samples.

- - -. Letter to Family. 30 Dec. 1872. MS.
This letter explained what the dredge that the Challenger used look like. It also had detail on the dredging procedure, which was essential for the Challenger research.

Murray, John. *Bathymetrical Chart of the Oceans*. N.d. Illustration. National Oceanic and Atmosphere Administration.
This is John Murray's illustration and mapping of the depths that the Challenger sounded. From this image, I could see the Mid Atlantic Ridge (the long, very light strip between the continents).

- - -. "The State of Ocean Science." 1899. MS.
This essay by John Murray explained his beliefs in the legacy of the Challenger. It also included what the situation of ocean science was at that point, and how the Challenger had affected that field of science. This information was helpful when writing about the Challenger's legacy.

- - -. *A Summary of the Scientific Results Obtained at the Sounding, Dredging, and Trawling Stations*. N.p.: Rare, 2012. Reprint.
This report briefly explained the processes of dredging, sounding, and trawling. It also reported the results that the Challenger scientists gained from stations.

- - -. *The Voyage of HMS Challenger 1873-1876*. London: John Murray, n.d. Print.
This book had a detailed report on the findings of the voyage of the HMS Challenger. It recorded how and when it founded the Mid Atlantic Ridge, which was beneficial in understanding the historical part of the Challenger journey.

Spry, William J. *The Cruise of HMS Challenger: Voyages over Many Seas, Scenes in Many Lands*. Second ed. London: Sampson Low, Marston, Searle, Rivington, 1877. Print.
This report by one of the crew, William J. Spry, explained general information and findings one needs to know about the HMS Challenger. It also gave insight on what the situations on board the ship were actually like. It explained the tools that were used on board, such as the Miller-Casella Thermometer.

Thomson, Charles Wyville. *The Depths of the Sea*. N.p., 1873. Print.
This book was very specific about how the Challenger took measurements of the depths of the ocean and what tools they used. I used this to explain the processes of dredging, sounding, and temperature reading.

- - -. "Geography of the Sea and the Object of the Challenger Expedition." HMS Challenger. Mar. 1873. Lecture.
This lecture by Thomson explained the motives for the voyage of the Challenger and what knowledge the time period before the Challenger had of the ocean. He stated that the past had not explored the deep oceans because of the widely accepted belief that there was nothing in the oceans.

- - -. *The Voyage of H.M.S. Challenger Narrative*. Vol. 1. New York: Johnson Reprint, 1885. Print.
This narrative helped explain the general overview of the voyage of the HMS Challenger. It was helpful that this text was written by a member of the crew on board because it displayed what real circumstances were like. Thomson also stated the mission of the HMS Challenger that he and the Royal Society of London had agreed upon.

- - -. *Voyage of the Challenger, Atlantic I and II*. New York: Harper and Brothers, 1878. Print.
This report of two volumes explained all that the HMS Challenger encountered and discovered in the vast Atlantic Ocean. It provided much detail in the techniques and processes of how the Challenger discovered its findings. I also used this report to understand what conclusions the scientists of the Challenger arrived at concerning marine life.

Tizzard, T. H. *Narrative of the Cruise of HMS Challenger*. London, 1885. Print.
This book gave general information on the dredging, sounding, and temperature reading processes aboard the Challenger. T.H. Tizzard was a sailor on the Challenger, which provided accuracy to its information since he was a first hand witness of the exploration.

Unknown. *A Song for the Challenger's Crew*. N.p.: n.p., n.d. Print.
This was the anthem song of the HMS Challenger that Joseph Matkin disclosed in one of his letters. The origin of the song is unknown.

Wild, John J. Brachipoda. 1888. Illustration. Zoology Report 77.
This sketch made by John J. Wild during the Challenger Expedition exhibits the careful drawings he made of each new species found on the Challenger. The sketches were made as a method to preserve and remember the appearances of the animals.

Secondary Sources

Aleshire, Peter. *Ocean Ridges and Trenches*. New York: Chelsea, 2007. Print.
This informational book informed me about ocean ridges and trenches. This related to my topic because the HMS Challenger found the Mid Atlantic Ridge and the Marinara Trench. Specifically, it explained the history of the Mid Atlantic Ridge before and after the HMS Challenger.

Baxter, Roberta, and Duncan Agnew. *Seismology: Our Violent Earth*. Minneapolis: Essential Library, an imprint of Abdo, 2015. Print.
This informational book provided me with information on seismology and earthquakes, which was helpful when I was writing about the Challenger's findings on plate tectonics. I specifically used this book to understand the process of earthquakes and seismic waves.

Bishop, Tina, Dr. "Then and Now: The HMS Challenger Expedition." *Ocean Explorer*. National Oceanic and Atmospheric Administration, 16 July 2012. Web. 20 Oct. 2015. <http://oceanexplorer.noaa.gov/explorations/03mountains/background/challenger/challenger.html>.
This article explained to me background information about the HMS Challenger. It compared some of HMS Challenger's past characteristics to its modern ones, and displayed some of the legacies of the HMS Challenger. It gave information about the crew of the Challenger as well.

Carson, Rachel. *The Sea around Us*. Special ed. New York: Oxford University, n.d. Print.
This book explained general facts about the sea to me. I used the information to learn more about Forbes and his Azoic Theory that the Challenger later came to disprove.

Corfield, Richard. *The Silent Landscape*. London: John Murray, 2004. Print.
This book was of immense help to me. It described all of the HMS Challenger's findings very specifically and gave me the scientific background for each accomplishment. After the details, it gave a very helpful overview of the accomplishments of the HMS Challenger in the conclusion section.

Cowan, Angela M. "Plate Tectonics." *National Geographic* 2003: n. pag. Print.
This article explained what plate tectonics were and what effect they had on the movement of the Earth. This information was necessary because the HMS Challenger found evidence of plate tectonics.

Deep Sea Drilling Project. *Deep Sea Drilling Project*. Technical rept. no. 3. N.p.: National Science Foundation, 1971. Print.
This report explained the coming together of the Glomar Challenger and its accomplishments. This was helpful when I was writing about the Glomar Challenger, which was inspired by the HMS Challenger.

Goldmann, Lucien. *The Philosophy of the Enlightenment*. Trans. Henry Maas. London: Routledge, 1973. Print.
This essay was published as a book and it relates information on the Age of Enlightenment. It displayed what attacks were made on religion through Enlightenment. This was necessary in explaining what led up to the voyage of the HMS Challenger.

"HMS Challenger October, 1872." *Ocean Explorer*. National Oceanic and Atmospheric Administration, n.d. Web. 25 Jan. 2016. <http://oceanexplorer.noaa.gov/explorations/03mountains/background/challenger/challenger.html>.
This photo of the HMS Challenger crew was taken shortly before the voyage. It gave me a visual of all the naturalists and officers on board.

"HMS Challenger Route." *The Voyage of HMS Challenger*. Initiative for Interstellar Studies, 30 July 2012. Web. 25 Jan. 2016. <http://i4is.org/the-starship-log/the-voyage-of-hms-challenger>.
This map sketched with the route of the HMS Challenger helped me track the ship on its journey around the world. It showed to me just how far the HMS Challenger went.

Jones, Robert Wynn. *Foraminifera and Their Applications*. New York: Cambridge University, 2014. Print.
This book aided me in understanding how the Challenger reports are still used today by scientists in the marine biology field. This resource specifically described the importance of the Challenger Reports on the Foraminifera species.

Linklater, Eric. *The Voyage of the Challenger*. N.p.: Cardinal, n.d. Print.
This book helped give me an overview of the accomplishments and findings of the HMS Challenger. It related what actions Thomson had to take to start the exploration and outlined the route of the Challenger.

"Manganese Nodules." *Mining the Seafloor for Rare-Earth Minerals*. New York Times, 8 Nov. 2010. Web. 25 Jan. 2016. <http://www.nytimes.com/2010/11/09/science/09seafloor.html?_r=0>.
This image displays the inner layered structure of the manganese nodules as well as its outer surface. It helped me understand why the Challenger crew described manganese nodules as metallic potatoes.

"Marine Minerals." *World Ocean Review* 2010: 1-2. Print.
This article from the World Ocean Review magazine explained the potential benefits and harms of using manganese nodules. This information was essential because the HMS Challenger found these resources for the first time and I needed to understand specifically what this resource was.

Miller, Giles, Dr. "Ocean Bottom Deposit Collection." *Natural History Museum*. Natural History Museum of London, n.d. Web. 6 Apr. 2016. <http://www.nhm.ac.uk/our-science/collections/mineralogy-collections/ocean-bottom-deposit-collection.html>.
This is the homepage of the Natural History Museum of London. There was information on the HMS Challenger and John Murray collections on this site. There are also images of the Challenger collections on this website, which was very interesting to gaze through.

Musson, Roger. *The Million Death Quake: The Science of Predicting Earth's Deadliest Natural Disaster*. New York: Palgrave Macmillan, 2012. Print.
This book informed me about growing interest in the prediction of earthquakes in the scientific society. I learned that the particular science has developed in predicting after shocks, but not as much so in the first major hits of the earthquake. This book explains how technology is advancing and what progress is being made.

National Research Council. *50 Years of Ocean Discovery*. Washington D.C.: National Academy of Sciences, 1950. Print.
This book provided me with invaluable information on the HMS Challenger's data and Dittmar's study in chemistry. It also benefitted in understanding the complicated salinity measurements Dittmar explored.

Prager, Ellen J., and Syvlia A. Earle. *The Oceans*. New York: Mc-Graw Hill, 2000. Print.
This book had everything regarding background information I needed to know about oceans to write this essay. It had a variety of topics, including a section on the HMS Challenger. It explained the marine life findings of the Challenger, including exactly how many species the ship found.

Roberts, Callum. *The Ocean of Life*. New York: Pearson, 2012. Print.
This book explained the fate of man and sea; how men explored the oceans and what they found. This book was helpful in understanding the Mid Atlantic Ridge and Maury's "Dolphin Rise" Theory.

Steinbach, Susie L. *Understanding the Victorians*. New York: Routledge, 2012. Print.
This book gave me further explanation on the Victorian Era. I needed this information to understand the time period of the HMS Challenger and to contextualize how the voyage fit in with the Victorian Era.

Tobin, Harold J., Prof. *Oceanography: Exploring Earth's Final Wilderness*. Chantilly: Great Courses, 2011. Print.
This book gave me a background on the history of oceanography. It explained who made accomplishments in this field and what has happened in oceanography up to now.

Trujillo, Alan P., and Harold V. Thurman. *Essentials of Oceanography*. N.p.: Prentice Hall, 2011. Print.
This book provided me with information on the potential use of manganese nodules in the United States. It displayed how manganese nodules could become an important resource in the near future because it supplies many useful compounds such as cobalt.

Wallace, William J. *The Development of the Chlorinity/Salinity Concept in Oceanography*. Amsterdam: Elsevier, 1974. Print.
This detailed book by Wallace explains Dittmar and the Forchhammer Theory. I learned of the legacy of Dittmar's findings in this book.

Winchester, Simon. *Atlantic: Great Sea Battles, Heroic Discoveries, Titanic Storms, and a Vast Ocean of a Million Stories*. New York: HarperCollins, 2010. Print.
This book had much I needed to know about the Atlantic. The Challenger made many discoveries in the Atlantic, so this book was essential in understanding the accomplishments. It gave information on the uses of manganese nodules and how the Mid Atlantic Ridge was found.