Science and Technology Illustration: An Effective Tool for Compelling Communication

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ABSTRACT

Scientists often communicate their research to a wide variety of audiences, but outside of the scientific community there may be challenges with how much of this research is understood. Science illustration can play an important role in helping to explain complex scientific issues to the general public. The Monterey Bay Aquarium Research Institute (MBARI) conducts a wide array of complex marine research. As the science and technology illustration intern I created illustrations for three separate groups of scientists and engineers. Two of the illustrations involved the Southern Ocean surrounding Antarctica and technology that has been or is currently being engineered at MBARI. The third set of illustrations involved methane-mound cold seeps of the seafloor and the chemistry occurring within them. Each illustration visually explains the complex science and engineering behind the individual topics and will be useful in various presentations and educational materials both online and in print.

INTRODUCTION

During the 15th century Italian and Dutch Renaissance artists began concentrating on keen observations and mathematical perspectives for accuracy of details. Leonardo da Vinci created anatomically accurate drawings and other scientific musings in his sketchbooks, and Dutch flower painters began the tradition of botanical illustration, which is still practiced today. Accuracy and keen observation are still the basis of modern science illustration but, with greater technological advances in photography, a science illustrator may find it challenging to make their existence relevant.

Science illustration stands apart from photography because of the illustrator's ability to create novel views. An illustrator can show the inside and outside, microscopic and macroscopic, and above and below surfaces. They can reconstruct an extinct, or a difficult-to-photograph species or geographical feature. A science illustrator can add missing pieces discovered through research, or add emphasis to specific regions, and can explain complex science and engineering through visual means. Most importantly a science illustrator creates compelling visual communication that clarifies difficult subjects and makes them accessible to a wide variety of audiences.

The Monterey Bay Aquarium Research Institute (MBARI) conducts many complex research and engineering projects. While the use of video is a large part of some MBARI research, much of what is recorded is too large or too complex to be understood by one photographic image. The ocean is vast and a large portion of ocean science being conducted by MBARI is on the microscopic level including microbiology, chemistry, and biogeochemistry. To understand marine science one must understand what cannot be seen by the naked eye. Science illustration brings this unseen world to the public for their understanding, support, and continued funding for this important research.

Upon my arrival for the summer internship, my mentor, Nancy Barr, had three projects available for me: The first one focused on free-drifting icebergs of Antarctica which are being studied by Ken Smith, Alana Sherman, Brett Hobson, and Steve Rock. This illustration would involve three pieces of technology: a small remotely operated vehicle (ROV), an autonomous underwater vehicle (AUV), and a Lagrangian sediment trap (LST), all being engineered to study and map the icebergs as they drift through the

Southern Ocean. As the icebergs melt, they release micronutrients such as iron into the surrounding ocean waters, which attracts an influx of zooplankton, phytoplankton, and continuing up the food chain to sea birds and marine mammals.

The second illustration was to be of the seafloor chemistry of methane mounds studied by Peter Brewer, Ed Peltzer, and Peter Walz, and would show three separate methane mounds, one in the Pacific Northwest in Barkley Canyon, and two in the Santa Monica Basin off the coast of Southern California. Each mound varies in its biology due to variations in depth and oxygen levels. The Barkley mound's interior consists of frozen methane called hydrate, and the Santa Monica mounds both contain dissolved methane. Victoria Orphan, a geobiologist who was a collaborator on the study of the Santa Monica mounds, supplied pertinent information for the explanation for the interior of the two mounds. The illustration would show both the biology and the chemistry of these seafloor mounds.

The third illustration was presented to me as an optional project depending on my comfort level with the time frame of 10 weeks. It was to be about Autonomous Profiling Explorer (APEX) floats with biogeochemical sensors to be deployed in the Southern Ocean, a project with Ken Johnson and Hans Jannasch. In the beginning I was unsure how much I could accomplish in 10 weeks so I decided to leave the third as optional until I could make sufficient progress on the first two.

Then, during the second week of the summer internship, I attended a presentation by Ken Johnson on this project, and chatted with him. He mentioned that collaborators at Princeton University were looking for an illustration for an article to be published in their research magazine, *Discovery*. This prompted my realization that with this opportunity it would be foolish of me not to do the third project so, it suddenly became a priority with a deadline of less than two weeks. Unfortunately, only a few days later the *Discovery* article was put on hold. Then a week or so later, Ken Johnson said he would like to use such an illustration in a presentation he was to give at Woods Hole Oceanographic Institution, so this project again took priority.

MATERIALS AND METHODS

Due to the size and scope of the three projects, I decided to create the illustrations digitally. I find the digital process faster than traditional illustration methods due to the elimination of a few steps such as mixing colors, drying time for paint, and photographing the painted piece to make an accurate digital copy. I am most comfortable creating my original sketches with graphite pencil and some colored pencil on tracing paper. The tracing paper is used to make changes easily by overlaying a new piece of paper while retaining the original. All initial concept sketches were presented in this manner to each team. Upon approval from each member from each team the sketches were scanned and I began to develop them into digital paintings using Adobe Creative Suite 6 Photoshop and Illustrator, depending on the needs. I obtained Solid Works e-drawings of the mini ROV and the APEX float from MBARI engineers. This allowed me to trace them in Illustrator to create line work to place into Photoshop for painting. Illustrator was also used for arrows, line work on other complex objects, and text.

Sources

The Expedition Database on MBARI's internal website was my primary source for imagery on the Peter Brewer cruises of Barkley Canyon 2006, 2009, and 2011 as well as, the Peter Brewer cruises of Santa Monica Basin of 2010 and 2013.

(https://mww.mbari.org/expd/log/postcruise.asp) ,

RESULTS

Free-drifting icebergs of Antarctica

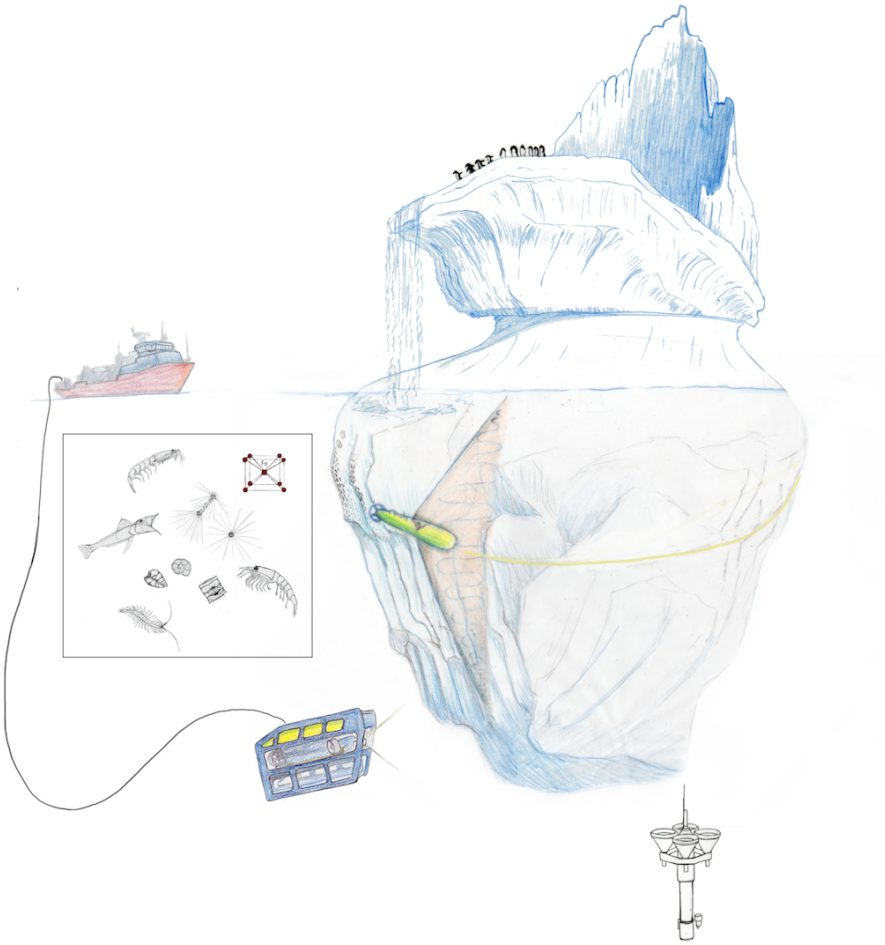

Figure 1. This original sketch of free-drifting icebergs in Antarctica in blue graphite and colored pencil was presented to the research team of Ken Smith, Alana Sherman, Brett Hobson, and Steve Rock. Team feedback suggested I take out the waterfall, take away the box around the microscopic biology and spread the biology all around the iceberg, have the trail of the AUV stand further away from the iceberg, and keep the ROV level. Later recommendations included adding whales in the distance and penguins swimming.

Figure 2. The completed illustration of free-drifting icebergs detailing the biology around the iceberg and the technology used to conduct research.

APEX floats with biogeochemical sensors

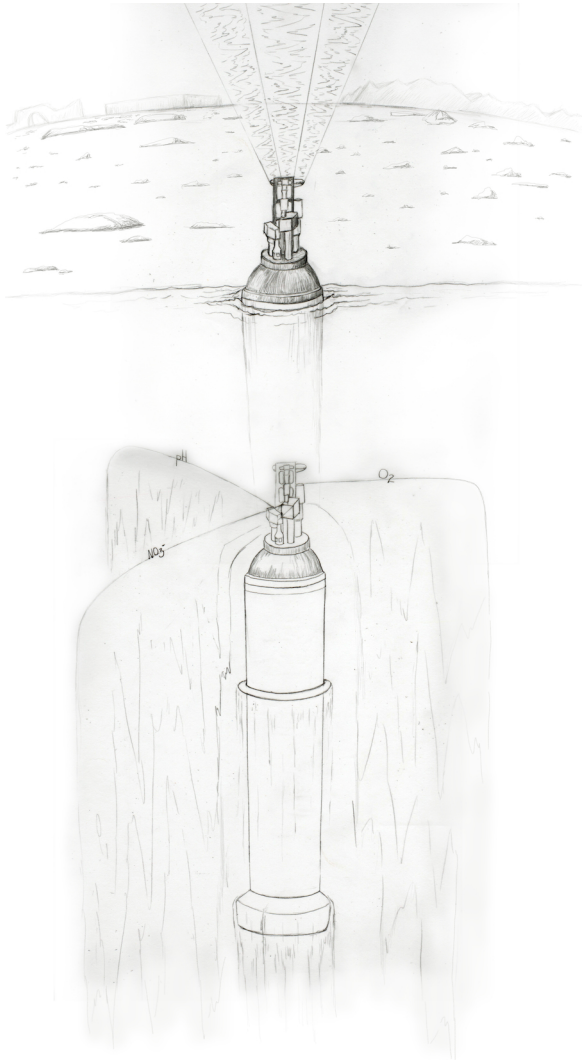

Figure 3. This original concept sketch in graphite presented to researcher Ken Johnson shows the APEX float underwater, collecting data and sending that data to the satellite once the float is on the surface.

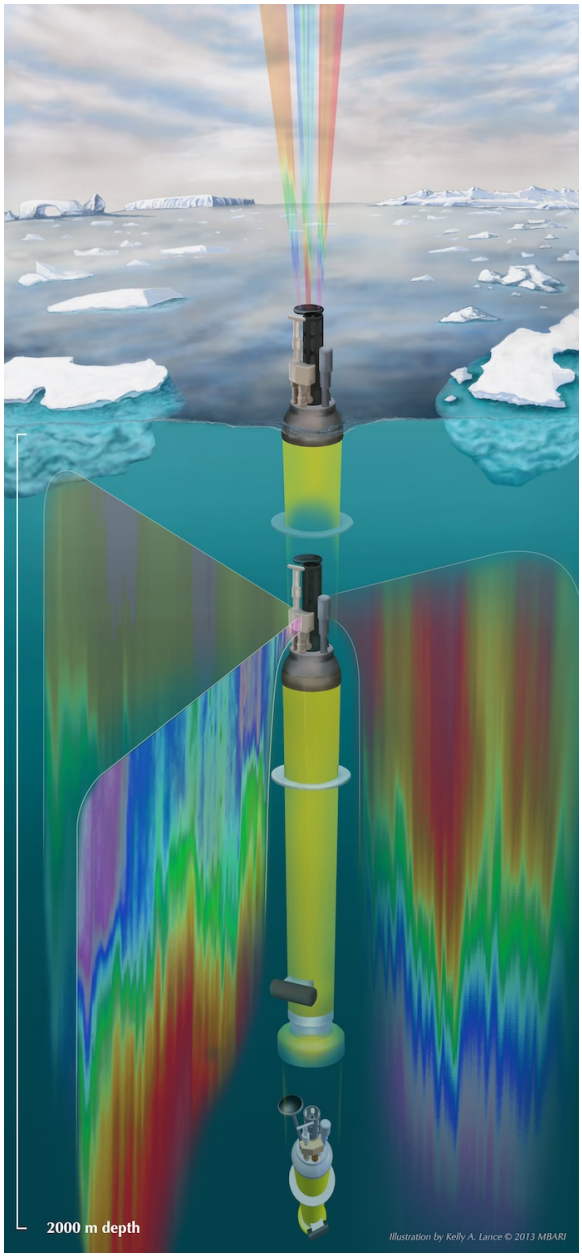

Figure 4. The completed illustration of the APEX float with biogeochemical sensors. This illustration is a full color digital painting with the actual mapped data of oxygen, nitrogen, and pH.

Seafloor chemistry of methane mounds

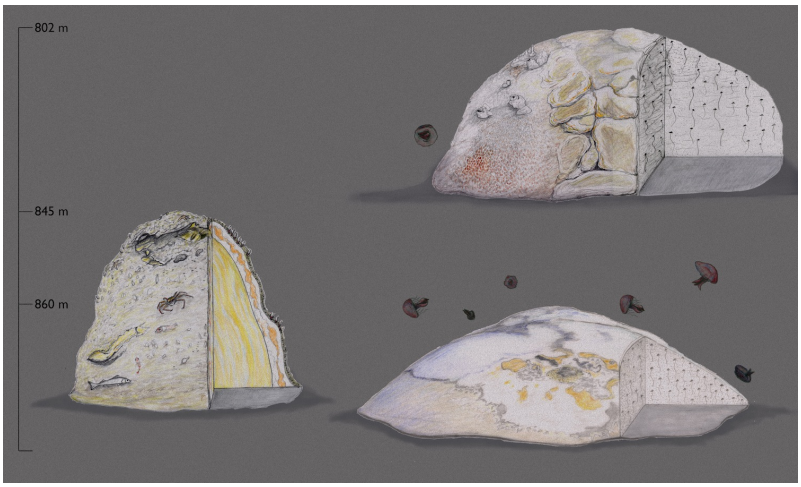

Figure 5. The original sketch of seafloor chemistry of methane mounds presented to chemist Ed Peltzer. The individual mounds were sketched on tracing paper with graphite and colored pencil and scanned into Adobe Photoshop for placement onto a colored background, and then into Adobe Illustrator for the line-work for the depth chart.

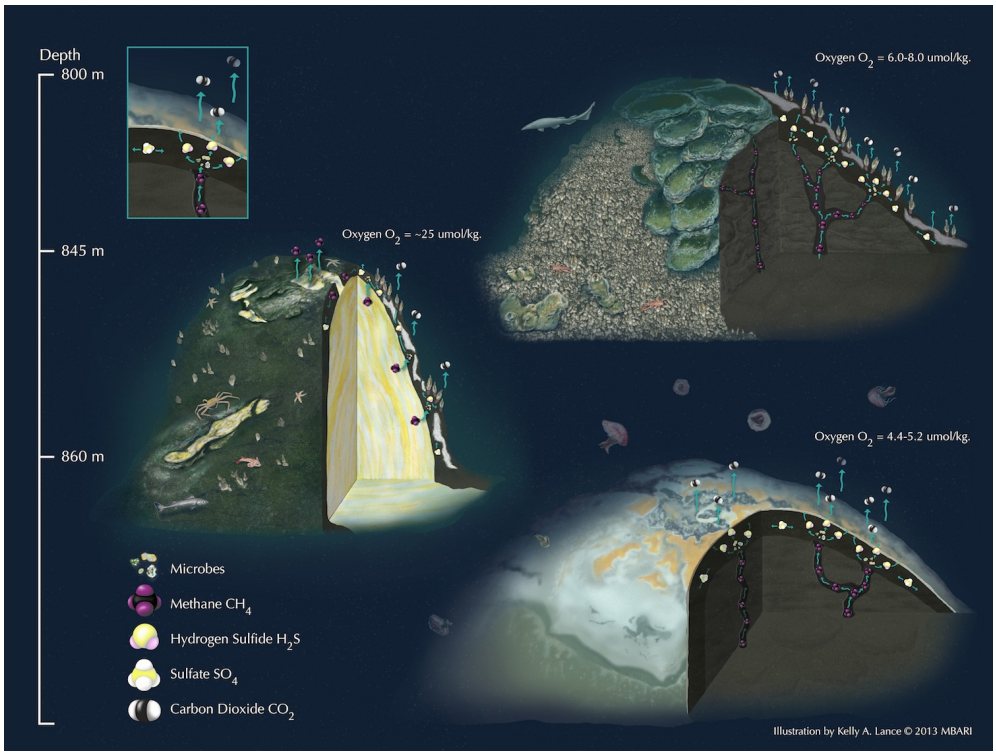

Figure 6. The completed illustration of the seafloor chemistry of methane mounds. It is a full color illustration painted digitally in Adobe Photoshop and line work, arrows, molecules, and depth key created in Adobe Illustrator.

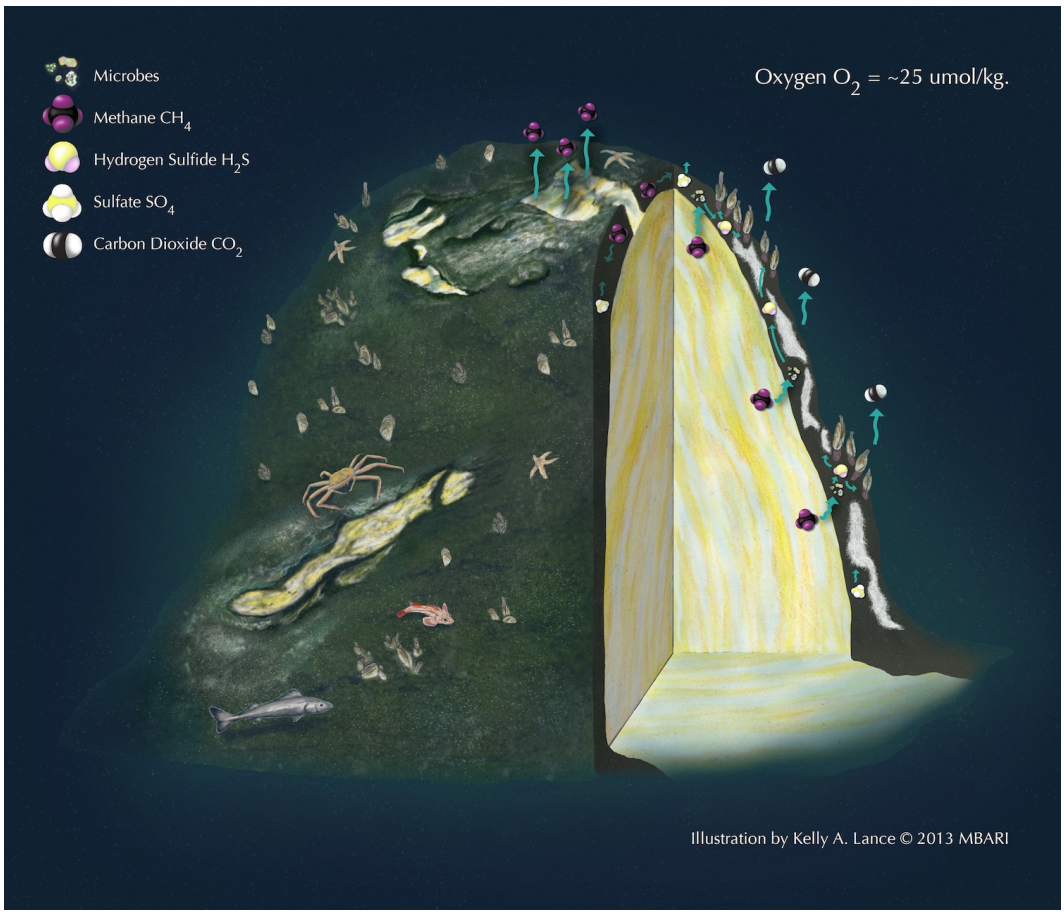

Figure 7. The completed Barkley mound image is a full color illustration digitally painted in Adobe Photoshop with the arrows, molecules, and text created in Adobe Illustrator. This illustration shows the interior of the mound with the frozen methane, or hydrate, and gashes in the surface of the mound exposing the hydrate, which then causes the methane to dissolve into the water. The Barkley mound has the highest concentration of biology of the three mounds. Depicted here are vesicomyid clams; chemosynthetic bacteria; sablefish, *Anoplopoma fimbria;* thornyhead rockfish, *Sebastolobus* sp.; tanner crab, *Chionoecetes tanneri;* and starfish.

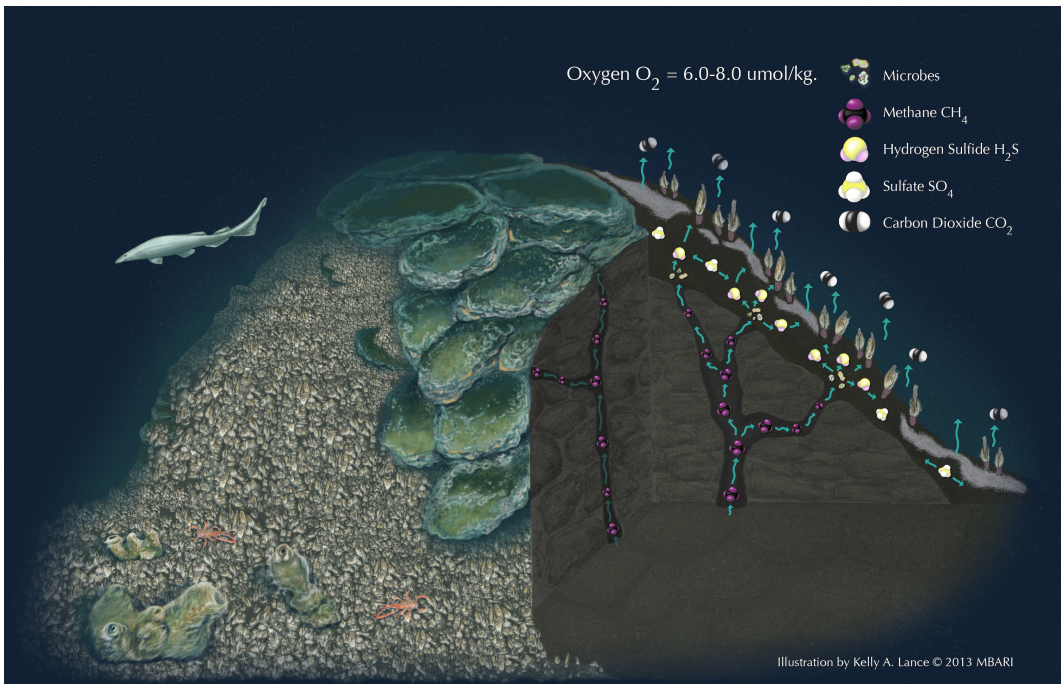

Figure 8. The completed illustration of the northeast mound of the Santa Monica mounds. It is a full color illustration digitally painted in Adobe Photoshop with the arrows, molecules, and text created in Adobe Illustrator. This mound has low oxygen and therefore few fishes; a cat shark, *Apristurus brunneus,* is depicted with vesicomyid clams and squat lobsters, *Pleuroncodes planipes*. This mound also has large quantities of exposed carbonate and carbonate chimneys. The cutaway details how the dissolved methane travels through fractures in the carbonate, the microbes take in the methane and expire hydrogen sulfide, and the chemosynthetic bacteria and clams take in the hydrogen sulfide and the sulfate present in the sediment, then expire carbon dioxide into the water.

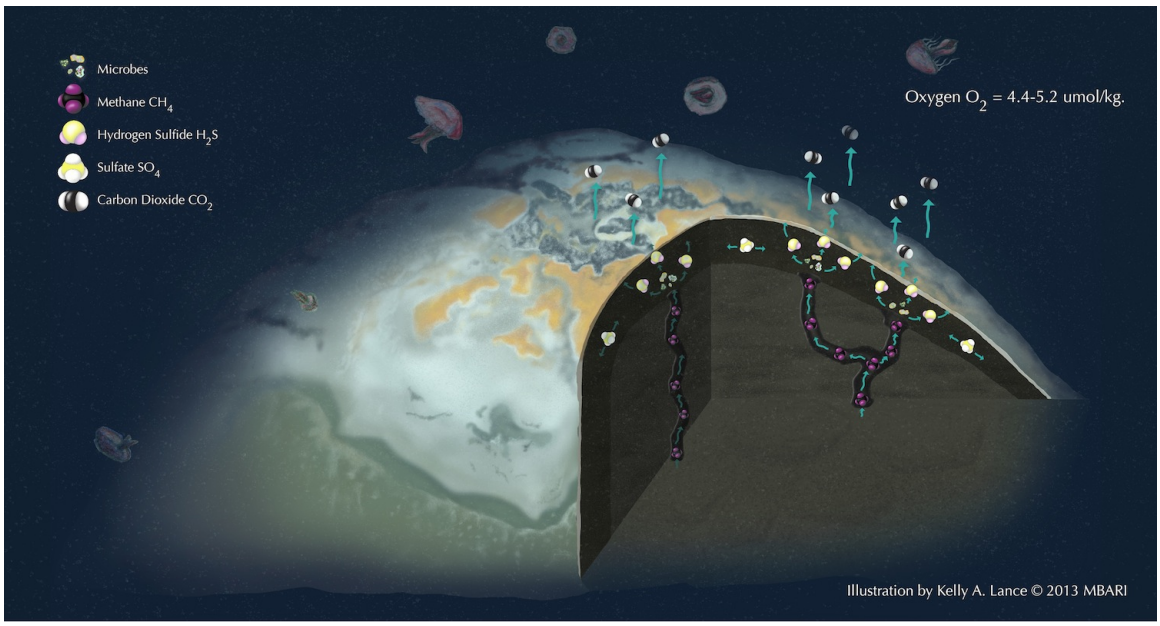

Figure 9. The completed illustration of the southwest mound of the Santa Monica mounds. This mound has the lowest depth and oxygen of the three and is a microbial habitat containing only chemosynthetic bacteria. Many jellyfish, *Poralia rufescens,* drift by in the current. The cutaway detail is the same as Fig. 8 minus the vesicomyid clams.

DISCUSSION

All of the illustrations will be used in various presentations by the individual scientists and on the MBARI website and in print applications. I have provided MBARI layered Photoshop files and, where applicable, the associated Illustrator files so they may turn on and off different aspects of the illustrations for future use and add text where needed.

In general all the parties involved seemed very pleased with the finished products. As of the date of this writing, Ken Johnson has already used the APEX float illustration in a presentation at Woods Hole Oceanographic Institution.

The two illustrations incorporating technology will be useful as educational and outreach tools as long as the technology depicted is relevant. The seafloor chemistry illustration should be useful for as long as MBARI wishes to keep it in circulation since it is describing the natural phenomena of the seafloor chemistry of cold seeps.

CONCLUSIONS/RECOMMENDATIONS

The experience at MBARI as a science illustrator was fascinating because every project involved technology with the science. I was a little concerned about this prior to arriving, but now that I look back on my time here and with the work I created, it seems perfectly obvious to me to show both the technology and the science in one illustration. It was more fun than daunting and my portfolio and my experience have certainly benefitted. I also had to tackle my most feared subject, chemistry, but the process of breaking it down into visuals made the subject much more appealing and understandable. As you can see, one person already benefitted from these illustrations, me.

My biggest challenge was learning how to use a Windows PC all over again. I have been using Mac computers for a long time but I am grateful for the refresher course. There was also a learning curve with the internal website, but I was comfortable within a few days. Future interns should benefit from knowing that they are not going to have 10 weeks to complete their projects. The first week or so has a learning curve to being introduced to a new environment and new people and the last couple of weeks will or should be all about the presentation and paper.

Future science and technology illustration interns need to be very mindful of their schedules and should probably plan on working often outside of the time frame of the normal working hours at MBARI. Also, these future interns should be aware that the summer program is geared for budding scientists so discussions from resumes and CV's to the paper at the end are all based on a career in science. Hopefully they will have received information on how to write an artists resume in school, but learning all of this is also beneficial for the science illustrator. I now understand the structure of a scientific paper better, which I often read for research.

As far as my particular projects go, I wish I could have been able to do more for Ken Johnson's illustration. He wanted to have the Keeling Curve meshed with the dissolving pteropods, or marine snails. I also really would have liked this addition to the illustration. I just didn't have the time and he and I never reached the best conclusion on how it

should be portrayed. But Ken told me he was very happy with what I completed for his project and that I didn't need to worry about the Keeling Curve. His project was also a bit of a roller coaster of emotions due to the excitement of Princeton wanting to publish my illustration, then canceling, and the immediate need again for the illustration for a talk at Woods Hole Oceanographic Institution. It was a good introduction to the reality of working in the sciences, where funding and media attention can change rapidly.

ACKNOWLEDGEMENTS

I would like to thank George Matsumoto and Nancy Barr for selecting me for the 2013 Science and Technology Illustration Internship. Furthermore, thank you George for organizing the amazing summer internship experience and for taking such an active interest in making sure the interns are exposed to many people and organizations to help launch our continued education and careers. I would also like to give further thanks to my mentor, Nancy Barr. Working for and with Nancy was an honor. She held me to a very high standard and offered concise constructive criticism that made me want to work harder. I am grateful for her guidance on many levels.

I would like to thank everyone with whom I met and worked with during my time here at MBARI. All the scientists and engineers of my three projects: Ken Smith, Alana Sherman, Brett Hobson, Steve Rock, Peter Brewer, Ed Peltzer, Ken Johnson, and Hans Jannasch.

I would like to thank Kim Fulton-Bennett for sharing his office with me and taking the time to answer all of my questions, no matter how banal, as well as offering constructive criticism when I would ask for feedback.

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I would like to thank all of MBARI and the David and Lucile Packard Foundation for opening their doors to all of us fortunate enough to have been chosen for the internship program. It has been an honor to be here and my experience has expanded my horizons

more then I ever could have imagined. I am excited to go forth and prosper into the world of marine science illustration. Thank you.

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