# OCEANOGRAPHY—THE NEXT 50 YEARS

By John A. Knauss

*The convenors of the Fifth International Congress on the History of Oceanography thought that it might be an interesting change of pace, after nearly two weeks of discussing the past, to have someone talk about the future. This is a shortened version of that talk.*

IN PREPARATION for this talk I spent some time reviewing the past. What has happened in the last 50 years and why? I also asked myself the question: should a reasonably astute young man coming into the field at the end of World War II (as I did) have been able to predict what we see around us today? I believe he might have got some of it right but he would have missed a lot and the difference, I believe, is illuminating. Many of the fundamental questions are the same now as then. How old is the deep water? What controls species-species interaction? What are the processes that control energy and particle transfer at the ocean-atmosphere interface? How does one interpret the climatic and geological history of the earth from deep sea cores?

The status of some issues is little changed. Wally Broecker's "conveyor belt", which traces the path of water from the Atlantic to the Pacific and back again, is not all that different from the pathways that Sverdrup hypothesized 50 years ago in his famous Chapter 15 of *The Oceans.* The problems of dealing with inhomogeneous distributions of organisms, or patchiness, remain almost as difficult today as they did for Alister Hardy when he first posed the problem before World War II.

On the other hand, some fields have changed dramatically. Fifty years ago deep sea echo sounding was just beginning. Except for the few dives of Beebe and Barton in the bathysphere, no human eye had peered far beneath the surface. Equally important, no one had photographed the bottom. Today we know about spreading centers, hydrothermal vents, submarine canyons that can be traced hundreds of miles. Nothing expresses the difference more graphically than a typical Carte Bathymetrique of 50 years ago based on lead line soundings, and the modern multi-beam bathymetric charts of NOAA and other groups. Many of the questions that marine geologists are asking today were beyond our ability to formulate 50 years ago because we did not know such phenomena existed.

The difference is technology. What makes oceanography today so different from what it was 50 years ago are the tools we have at our disposal. Where technology has contributed, progress has been made. The fundamental questions may be the same, but they are better formulated and the range of uncertainty has lessened. Where technology has contributed little, progress has been slow. In biological oceanography, for example, the nets we tow are at most first cousins of those we had half a century ago. What has changed is that our new microscopes allow us to look at ever smaller species. There is much more out there to understand than we knew about half a century ago.

I believe the key to a successful forecast 50 years ago would have been to forecast the advances in technology, and I believe that predicting correctly the technology of the future is the key to a successful forecast of where oceanography will be in 2043. How much of today's technology might have been foreseen at the end of World War II? I believe some could have been but not all, and again the difference between what might have been foreseen and what not is illuminating. One might have forecast the CTD, the various instrumented anchored and floating buoys, the small research submarines, and the increased use of sound for transmitting information. These are all improvements on oceanographic technology that existed in some primitive state 50 years ago.

What I believe could not have been foreseen, at least by someone in the oceanographic community, is technology from outside oceanography, for example satellites, computers, and microelectronics. Fifty years ago it was difficult to make many chemical measurements to parts per thousand. I very much doubt that even the most imaginative chemist in 1943 could have predicted measurements in parts per billion and even parts per trillion, and often made more rapidly than those of 50 years ago.

The technical revolutions in analytical chemistry, computers, microelectronics, etc., have often contributed more to what we now accept as part of the oceanographer's tool box than have the advances we have made in traditional oceanographic technology, and I have no reason to believe that process will not continue. Fifty years from now we will be monitoring the ocean in real time as the meteorologists now do in the atmosphere. We will have satellites, an ocean covered with buoys both anchored and floating, and untethered remotely operated vehicles. We will have a vast array of instruments along our coasts to monitor pollution and the general health of the ocean. Advances in signal processing will increase further the use of underwater sound for the transfer of information within the ocean. The ocean will be less opaque than it is today. There will

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still be research vessels, but they will supply an ever-decreasing share of the information that oceanographers will use to study the ocean.

By the standards of 50 years ago, the data stream of 1943 has become a raging torrent, but 50 years from now I expect our future colleagues will be hard pressed to understand our concern. They will be able to assimilate and manipulate their much larger data stream with more skill and ease than we can today. They will have computer models for nearly all oceanic processes, and those models will be continuously tested against an array of near real time data that we can scarcely imagine today.

These types of forecasts are fairly easy to make. One needs only to extrapolate from what we see around us today. What I find more difficult is to foresee the implications of advances in other fields. Will advances in composite materials trivialize the still-formidable problem of working at great depths? Will we finally have a battery, or other energy storage device, that will allow us to keep our instruments untended in the ocean for years at a time? I expect the answer to both of these questions is Yes. But if the past provides any clues to the future, I believe we can expect several significant technical advances in fields far removed from the present oceanographic horizon. I have no idea where and what these will be, but I expect them to have a significant impact on the development of future ocean technology.

Finally, it is necessary to address a tacit assumption. Oceanography has been very well supported these last 50 years. Will that support continue? If it does not, then progress will be slower and the next 50 years may have characteristics significantly different from the last 50. Simple curiosity has always been one reason for supporting oceanography, and I fully expect it will provide some base level of future support, but oceanography is an expensive field science. If there were no compelling social or economic reasons for learning about the ocean, the effort today would be significantly smaller than it is. Fifty years ago the primary reason for the support of oceanography was the military; fisheries was a poor second. Later came off-shore oil and gas and concern about the health of the coastal environment. Most recently it has been the role of the ocean in climate change, from forecasting the El Niño, to detecting global warming, to understanding the role of the ocean in sequestering carbon.

All have contributed to the support of oceanography, but the most important has been the military, both in the direct support of oceanography broadly defined and in the support and development of technology which oceanographers have adapted for their own uses. Will that support continue? The government plan is to maintain a high level of research and development, even as existing forces and weapon systems are reduced. If this plan holds, it will be the first time in the history of this country, and perhaps of any country, when the transition from war-time, or near war-time, to peace has been conducted in a rational and systematic manner. History does not suggest that the present plans will hold, but neither does history suggest that we will enjoy 50 years without military threat. I expect there will continue to be military support for oceanography in the next 50 years, but I also expect that proportionally it will be significantly less than it has been in the past.

However, I do not expect that the reduction in military support for oceanography, even if that reduction should continue for the next half century, will result in a significant reduction of total support. Unlike some of my colleagues I continue to be bullish about the future of oceanographic research. Let me list those reasons:

1. Concern about ocean pollution and the health of the ocean will continue to grow. An ever higher percentage of our expanding population will be living in coastal communities. We will become better at recycling our wastes, and we will spend more money in protecting our environment, but society will want to know how well we are doing, and that requires research in a very complex environment.

2. For a weather forecast of a few days, one can safely ignore ocean-atmosphere interactions and treat the ocean surface as a boundary condition. Most workers believe that changes in the average climatic conditions from one decade to the next are mostly regulated by the ocean. The recent success in understanding the ENSO phenomena suggests that we may be on the threshold of a deeper and richer understanding of the ocean-atmosphere system. With that understanding will come the ability to make meaningful forecasts of climate variability. The possibility of generating useful forecasts of next year's average temperature and rainfall (say a 70% success rate) would be of such economic significance to the world that this program alone would generate sufficient support for oceanographic research and technology development, more than compensating for any reduction in military support.

3. For some years there have been energetic and often persuasive proponents for one or another economic use of the oceans in addition to transportation, fisheries, and oil and gas. I expect that before 2043 one or more of the following will be an economically significant ocean resource: marine pharmaceuticals, the mining of manganese nodules and crusts, ocean thermal energy, and the use of the seabed or subseabed for the disposal of certain kinds of non-recyclable waste material. Each requires a significant research component.

4. I expect we will see a dramatic increase in marine archeology in the next 50 years. I am impressed with the technology now available, but 50 years from now we will look back at this period as the primitive beginnings.

5. I side with those scientists who believe increased greenhouse gases will cause significant global warming. I am not convinced that significant mitigation on a global basis is a politically viable option. If I am correct then environmental science will have an ever more important role in the next half century as we attempt to predict the future and learn to adapt. One example: as the earth warms and sea level rises, do we move back from the shore, or do we adopt the Dutch approach and build dikes? If we adopt the latter strategy, how do we protect wetlands?

For the above reasons, and others I am certain will appear, I expect that any slack in oceanographic research generated by reduced military support will be taken up by other social and economic needs. I expect the oceanographic enterprise of 50 years hence will be larger, more broadly based in terms of support, and addressing a wider range of topics than we do today.