Book review

Oceans: going deep into their past to understand their future

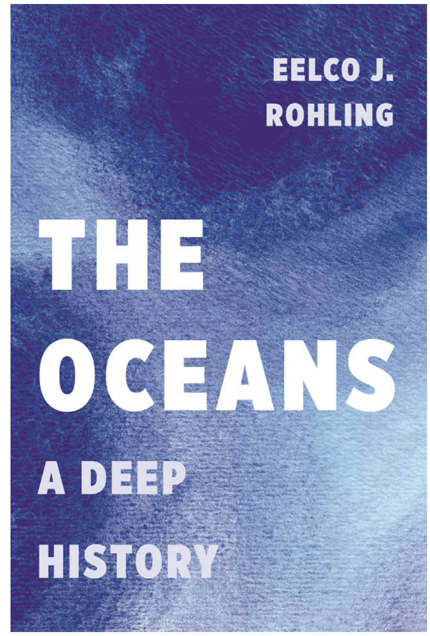
Roberto Danovaro

The Oceans: A Deep History
Eelco J. Rohling
(Princeton University Press, Oxford; 2017)
ISBN: 978-0-691-16891-3

The history of the oceans covers most of the history of Earth, and even more importantly oceans represent the system from which life originated. Eelco Rohling's new book is a fantastic attempt to impart the knowledge of the oceans to a wide audience. Using erudite yet comprehensible language, the author reports and critically discusses the main events that shaped the story of our planet across time. He believes that the actual knowledge of the oceans is limited to a small group of scientists and that we need to do more to explain the oceans' mysteries. The palaeoceanographic background of the author helps the reader to learn crucial information on the seas and their history in a simple and convincing manner. This book explains the history of the oceans, from their formation, and helps us to understand their natural evolution and to discriminate natural versus anthropogenic alterations. Approximately 500 years ago, the oceans were still almost completely pristine, but in the 19th century the oceans started to be seriously impacted by the activities of the growing human population, which had reached 1 billion. The anthropogenic impact is multifaceted and profound, and it includes overfishing, pollution, eutrophication, acidification and warming. In the last century, the development of new technologies has enabled marine research to improve our understanding of the effects of such changes. This book provides clear evidence of the role of the oceans in mitigating ongoing global change. The seas and oceans of the world have already absorbed more than a third of the CO_2 that has been produced as a result of human activities. Yet the CO_2 increase is causing a progressive acidification of the oceans, with crucial consequences for marine life. The oceans have also absorbed more than 90% of the heat associated with global warming. The history of the Earth helps us to understand the causes and consequences of such changes.

The early Earth was battered by comets, meteorites, asteroids and even proto-planets. Around 4.4 billion years ago, the cooling of the early Earth allowed surface crust to form. Between 4.1 and 3.8 billion years ago, an intense period of asteroids and comets were responsible for the so-called Late Heavy Bombardment, and about 4 billion years ago clouds and rain started to cover a large portion of the planet with what would become the oceans. The early oceans certainly did not resemble those that we see today. The origin of life from chemical compounds has always been a matter of great debate. Among the organic compounds were amino acids, nucleic acids and lipids, all of which were essential for the start of the earliest forms of life. These compounds may have been transported to Earth by comets, or they may have been formed by reactions that involved hydrogen cyanide, hydrogen sulphide and ultraviolet light. During the time of the early Earth, life developed in an anoxic environment and was sustained by either chemosynthesis or anoxygenic photosynthesis, which is still encountered in some stromatolite mounds. Little more than 1 billion years ago, the eukaryotes split into a line that had become capable of photosynthesis and started the lineages of algae and plants, as well as other lineages, such as fungi and animals.

About 2.5 billion years ago, oxygen production accelerated to create the 'Great Oxygenation Event' and multicellular algae and macroscopic animals began to develop. Several times in the Earth's history, the planet has become completely covered in ice and sea ice from pole to pole: we call this the 'snowball Earth state'. The global average temperature may have reached as low as –50°C, with a temperature of –20°C in the equatorial regions. Obviously, there was a strong, global impact on the



marine ecosystem, but life clearly survived through the episodes overall. The snowball state changed into a super-greenhouse state, with globally averaged temperatures of up to 30°C or 40°C. During the interval between two snowball Earth states, 635–542 million years ago, more complex multicellular organisms named Ediacaran biota appeared for the first time. Ocean acidification also played a crucial role in determining the history of the oceans. The first case of ocean acidification is reported to have occurred 252.3 million years ago.

The author continues to describe the more recent and better documented acidification events, such as the Palaeocene–Eocene Thermal Maximum, which occurred 56 million years ago. This period began when CO_2 levels were still very high, between 650 and 1050 ppm. The Palaeocene–Eocene Thermal Maximum itself marks a remarkably sharp shift in carbon isotope data due to an increase in the proportion of carbon-12 over carbon-13. The event lasted fewer than 200,000 years, and the time from first signal to peak only lasted approximately 20,000 of these years, with the remainder of the time dedicated to recovery from the disturbance. The Palaeocene–Eocene Thermal Maximum was a relatively brief, hot event atop a slower, longer-term temperature rise towards a period known as the warm Early Eocene Climatic Optimum, which spanned from about 54 to 48 million years ago. This was a dynamic period in terms of the rearrangement of tectonic plates due to the then ongoing breakup of Pangaea. Important ocean basins and passages opened up, and massive mountain ranges began to form. By the time of the Eocene, the Tethys Ocean was closing fast between Africa and Eurasia. Finally, Australia started to separate from Antarctica about 45 million years ago. The Early Eocene Climatic Optimum ended with the onset of a long, variable cooling trend, which was interrupted by a warming of up to 5°C around 45 million years ago known as the Middle Eocene Climatic Optimum. This increase in temperature has been attributed to both intensified volcanism and seafloor spreading and the fact that Australia moved away from Antarctica, making way for the appearance of the Antarctic Circumpolar Current. From 40 million years ago, the overall cooling trend took over again, but it would take until 14 million years ago before heavy, perennial ice conditions appeared in the north. As soon as the glaciation became established, sea-ice conditions were intensified, leading to seasonal productivity peaks capable of supporting krill biomasses and the animals that exploited this enormous food source, such as baleen whales. During the late Oligocene there were two major intervals of glaciation at around 24.4 and 23 million years ago. After these phases, the climate stayed generally cool until a relatively warm period called the Middle Miocene Climate Optimum, which occurred around 17 to 15 million years ago. At the end of this period there was a sharp drop in CO_2 levels of 100–150 ppm, and this has been attributed to a phase of increased uplift, weathering and erosion in the Himalayas. In the last few centuries, human activities have increased the CO_2 concentration in the atmosphere significantly: currently the level is equivalent to that last seen about 3 million years ago, when the global temperature was 2–3°C higher than today. Most emission projections that account for ongoing trends argue that we are likely to exceed 700 ppm by the end of this century. Moreover, at the current emission rates, we will be reaching values 30 times higher than that of the Palaeocene–Eocene Thermal Maximum in upcoming years. The toll for the rising temperatures and global change is a higher rate of species extinction, difficult to calculate yet. A direct consequence of the CO_2 increase is the decrease of the pH in seawater: this has dropped by about 0.1 units from the pre-industrial levels (from 8.2 to 8.1) and is equivalent to a 25% increase of acidity over the past two centuries. In a business-as-usual scenario, the pH of the oceans is expected to decrease to 7.7–7.8 by the end of this century, with potentially important consequences for marine life.

According to Eelco Rohling, the analysis of the palaeoceanographic data, when compared with the ongoing rates, reveals that these changes are posing serious risks to the functioning of the planet as we know it, and this makes the reduction of CO_2 emissions in the atmosphere absolutely necessary. However, nature is full of complex responses and feedbacks, and global changes are having dramatic effects in some regions and moderate in others. Similarly, some regions may become seriously impoverished, while other regions may even experience a net benefit as a result of new opportunities and changing conditions. The consequences of human-induced carbon emissions on ocean circulation are difficult to predict. Unfortunately, the geologic record does not provide any robust information about deep-ocean circulation, at least in terms of slowdown or acceleration in cold or warm climates. Geologic evidence indicates that we may expect a weakening of North Atlantic Deep Water formation in relation to increasing water column stratification and ice-sheet melting, and recent findings support this expectation [1]. Therefore, it is necessary to apply adequate large-scale monitoring plans to detect ongoing changes [2] and the potential consequences of such changes, especially in deep-sea ecosystems [3]. Moreover, warming is coupled with a rise in sea levels, which rose by 0.3 meters between the years 1700 and 2000 and are expected to rise a further 0.5 to 1 meters by 2100. The scenario of a rise in the sea level by up to 2 meters by the year 2200 may be expected. Therefore, mitigation measures are an absolute priority to reduce the impact of such changes.

It is difficult to provide in a few words a clear idea of the incredible richness of information and stimulating thoughts contained in this book, but the fortunate readers who will have a chance to dig into its pages will make an intriguing journey through the history of the oceans. It has often been said that “we know more about the moon than we do about our own oceans”, but this book shows that palaeoceanography can reveal much more about the oceans than we believed was possible.

In this book, Eelco Rohling traces the history of the last 4.4 billion years of the oceans, from their formation, and introduces the reader to the secrets of the oceans, shedding light on their role in controlling global climate changes. The book is also a journey across time in which the interrelationships between the oceans, the climate, the solid part of the Earth, and life on the planet are revealed. This book is not only an invaluable introduction to the cutting-edge science of palaeoceanography but also a crucially important text for students approaching all different fields of marine sciences.

The Oceans: A Deep History allows us to see ongoing global change and its potential consequences on the oceans and life in a wider perspective, and it suggests that our actions today are shaping the oceans and climate of tomorrow and that we should continue in such a way that the future might resemble something experienced in the past, when man had not yet appeared on Earth.

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Department of Marine Biology and Ecology, Università Politecnica delle Marche, Via Brecce Bianche, Ancona 60131, Italy.
E-mail: r.danovaro@staff.univpm.it