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BOOK REVIEW

***Hot Carbon: Carbon-14 and a Revolution in Science*. Columbia University Press, New York, NY. 264 pp.**

This most readable book presents an exhaustive review of the radioisotope carbon-14 and its many applications in science that have had an impact on our daily lives. The book reveals some of the secrets involved in developing our understanding of this important, naturally occurring isotope that were discovered during the second half of the twentieth century. Chapters 1 and 2 begin by describing the discovery of carbon-14 at the Berkeley Radiation Laboratory in California in 1940. The discovery of radiation and how it is measured are reviewed in Chapter 3. Chapter 4 describes how the natural occurrence of carbon-14, created by cosmic radiation bombarding atmospheric nitrogen, allows the dating of any substance that accumulates carbon during its lifetime. The role of carbon-14 in unraveling the details of photosynthesis, the process that converts carbon dioxide into organic matter, is discussed in Chapters 5 and 6. The next, Chapter 7, describes how the advent of accelerator mass spectrometry to measure carbon-14 allowed the development of techniques for radiometric dating. Various applications of carbon-14 in dating archeological relics are reviewed in Chapter 8. Chapters 9 and 10 consider the role of carbon-14 in understanding the circulation of the deep ocean, the Earth's carbon cycle, and how the carbon cycle affects the Earth's climate. The role of carbon-14 in studying the productivity of the ocean is reviewed in Chapters 11 and 12 while Chapter 13 concludes by addressing the application of carbon-14 to climate studies. This fascinating technical story is made very readable by including personal information on the principal players who conducted the research and by describing in considerable detail the events that actually happened behind the scenes.

The author, John Marra, was a graduate student in the Department of Oceanography at Dalhousie University in the 1970s. The department was chaired at the time by Gordon Riley, an eminent oceanographer, who moved to Dalhousie from Yale University in 1965. John was the last of Riley's PhD students and went on to spend most of his career studying marine productivity at the Lamont Doherty Earth Observatory of Columbia University, and later at Brooklyn College.

He includes in the book some his own personal experiences working with carbon-14 that are most interesting.

John describes in considerable detail the controversy that erupted over the accuracy of carbon-14 in measuring global ocean productivity, a controversy in which Gordon Riley played a central role. During the 1930s and 1940s, developing an understanding of ocean productivity was based primarily on measuring and comparing the biomass of the food-web components, namely phytoplankton, zooplankton and fish. Riley was a leader in this field. He also attempted to measure phytoplankton photosynthesis directly by following changes in oxygen concentration when water samples were incubated in glass bottles. In the early 1950s, a Danish botanist named Einer Steeman Nielson began using carbon-14 to measure phytoplankton photosynthesis by adding isotopically labeled sodium bicarbonate to seawater samples and measuring the radioactivity in particulate matter after incubation. This method was relatively simple to use and won the day with new oceanographers eager to measure ocean fertility, and its variability in both space and time. However, a controversy erupted when the rates of photosynthesis determined by the two methods were compared in the Sargasso Sea off Bermuda. The rates determined by Riley using the oxygen method were at times on the order of ten times higher than those measured by Steeman Nielsen using the carbon-14 method. Steeman Nielson attacked Riley and claimed his numbers were wrong. Riley in turn defended his results. This controversy simmered for many years without resolution. However, the sensitivity and ease of the carbon-14 method proved strong and Steeman Nielsen prevailed. During the 1960s and 1970s, his carbon-14 method was widely used to measure the productivity of lakes, estuaries and the ocean. Nevertheless, concerns about using carbon-14 to measure productivity persisted, especially when it was discovered that bacteria, also consumers of production, were much more abundant in seawater than previously thought.

Much of this 30-plus year controversy was resolved after Riley moved to Dalhousie, and John Marra played a leading role in this. Part of the difference in results could be explained by the fact that two different ocean regimes had been sampled in the earlier studies. Then in early 1985, John participated in a cruise to the Sargasso Sea and measured phytoplankton production using the carbon-14 method. His results were closer to Riley's earlier results using the oxygen

method than Steeman Nielsen's results using carbon-14. John communicated these results to Riley who was relieved to learn that his work was verified. This occurred just before Riley's death. Later that year, John participated in a 30-day experiment called PRPOOS (Plankton Rate Processes in Oligotrophic OceanS), headed by Richard Eppley of Scripps, which was carried out in the Pacific Ocean off Hawaii. The purpose of this major experiment was to compare rigorously, and for the first time, the different methods for measuring ocean production at a single ocean location, including both the oxygen and carbon-14 methods. The results indicated that the productivity of the ocean in this region was approximately double than previously thought. Steeman Nielson based his conclusions about ocean productivity on what happens in a bottle, while Riley favoured evidence based on a broader set of trophic variables. Steeman Nielsen's earlier low numbers for production have not withstood the test of time. Current opinion is that Riley's estimates for global ocean production were about a factor of two too high, while those of Steeman Nielson were a factor of two or three too low.

I highly recommend this book to anyone with an interest in radiochemistry, Earth processes, oceanography, marine production, climate change and human history. It is easy to read, enjoyable and informative. It contains numerous illustrations, including photographs of the principal players, as well as notes, key scientific references and an index. The book is available in both hard copy and on line.

D.C. Gordon
1 Prince Street Suite 502
Dartmouth, NS B2Y 4L3
Email: donald.gordon@ns.sympatico.ca