Harry Elderfield

(1943–2016)

Geochemist who deciphered chemical signatures in the modern and ancient oceans.

Henry 'Harry' Elderfield showed how the distributions of chemicals in seawater and sediments can reveal the ocean's role in historical climate change.

Elderfield, who died on 19 April, was born in 1943, at the height of the Second World War, in North Yorkshire, UK. A few days before his birth, his father, Henry, was reported missing in action, presumed drowned, a loss that may have contributed to Elderfield's draw to the oceans as well as to the past. After obtaining a degree in chemistry from the University of Liverpool, UK, in 1965, he completed a postdoctoral fellowship at Imperial College London, in 1969, and started a lectureship at the University of Leeds, UK, even before completing his PhD.

In 1977, Elderfield headed to the University of Rhode Island in Kingston for a sabbatical year. There he met geochemists Gary Klinkhammer, John Edmond and Wallace Broecker. Discussions with these scientists would have a major influence on the research questions that he later pursued.

Back at Leeds, Elderfield's laboratory technician, Mervyn Greaves, was told to make himself useful in the lab of another faculty member, Chris Hawkesworth. Hawkesworth had established a way to analyse rare-earth metals — a group of 17 elements — in 1-gram rock samples. Elderfield's biggest scientific splash came when he and Greaves applied a modified version of this method to 50-litre samples of seawater and made the first measurements of the tiny concentrations of ten rare earths from samples collected from the North Atlantic. They were present in picomolar amounts (on the order of 10^{-12} moles per kilogram).

Elderfield established how the composition of rare earths in a sample, and the specific properties of the elements, could be used to identify different water masses — deep water bodies from different parts of the ocean that have distinct physical properties. He also predicted — correctly — that these signatures could be extracted from the ocean sediments covering the sea floor and used to track how ocean circulation has changed over time. (The composition of rare earths in the sediment of a particular geological age reflects the composition of the elements in the ocean water at the time that the layer was formed.)

In 1982, Elderfield moved to St Catharine's College at the University of Cambridge, UK. Here he was one of the first to realize how

CAMBRIDGE UNIVERSITY

isotopes that decay radioactively over time could be used to solve marine geochemical puzzles. With Martin Palmer, who had been a student of Elderfield's at Leeds, he developed the strontium isotope curve for seawater for the past 75 million years. Analysing the ratios of strontium isotopes taken from sediments of known age, the pair mapped the changes in the isotopic ratio in the ocean over time.

This isotopic curve, recorded globally in limestone, shows the shifting effects of continental weathering and hydrothermal vents. These sea-floor features spew spectacular plumes of geothermally heated water and chemicals into the ocean, and are the major suppliers of strontium to the ocean. Strontium isotope stratigraphy, a term coined by Elderfield to describe the mapping of strontium isotopes in layers of rock, is now widely used to date sediments. It has also proved useful for climate scientists. Weathering pulls carbon dioxide out of the atmosphere and vents release the gas, so the strontium isotope curve provides a proxy for tectonic processes that are crucial to the carbon cycle.

In 1985, Elderfield's group participated in a cruise that produced the first photographs of a hydrothermal vent called the TAG vent site (P. A. Rona *et al. Nature* **321,** 33–37; 1986). This was the first vent discovered in the Atlantic Ocean or indeed on any slow-spreading mid-ocean ridge. (In subsequent years, Elderfield explored the role of vents in ocean chemistry, as well as fluid flow through the sea floor.)

Around the same time, Elderfield and Edmond, who then was at the Massachusetts Institute of Technology (MIT) in Cambridge, arranged sabbaticals in each others' labs. But as a result of slightly haphazard planning they never overlapped in the same place. At MIT, Elderfield instead spent much of his time with the palaeochemist Edward Boyle, who was then trying to relate the chemistry of the shells of foraminifera, single-celled organisms known as protists, to the chemistry of the seawater in which they lived.

In the shell material, foraminiferal calcite, trace metals of similar size sometimes replace calcium; even trace anions can take the place of the carbonate ion. Elderfield pioneered the exploitation of these 'mineralogical mistakes' to gain insight into past ocean compositions. He established, for instance, that the temperature of the ocean at the time that the foraminifera formed can be inferred from the magnesium–calcium ratio in shells. This ratio provides a way to distinguish between the shifts in oxygen isotopes in the shells caused by changes in ocean temperature from those caused by changes in the size of Earth's polar ice sheets. Ultimately, Elderfield helped to reveal the independent history of changes in global temperature from the waxing and waning of Earth's ice sheets over thousands or millions of years.

Harry was a warm, playful, family man. He had a mischievous sense of humour and a taste for fine art, music, wine and unusual spirits. He also had an incredible knack of teasing sense out of disorder — or in his words, of finding the "really interesting" trends in "unascribable scatter".

I was one of his PhD students in the 1990s. On one tumultuous day I discovered that another group had reported findings similar to those at the heart of my PhD. Harry dissipated my fears with one sentence: "It just shows you are doing exciting science." After a pause and a wry smile, he added, "But let's do it better". ■

Rosalind E. M. Rickaby *is professor of biogeochemistry at the University of Oxford, UK. Harry Elderfield was her PhD supervisor at the University of Cambridge, UK, from 1995 to 1999.*
e-mail: rosalind.rickaby@earth.ox.ac.uk