RETROSPECTIVE

Wallace Broecker (1931–2019)

Explorer of Earth's climate past and prophet of its future

By **Aaron E. Putnam**[1] *and* **Robert F. Anderson**[2]

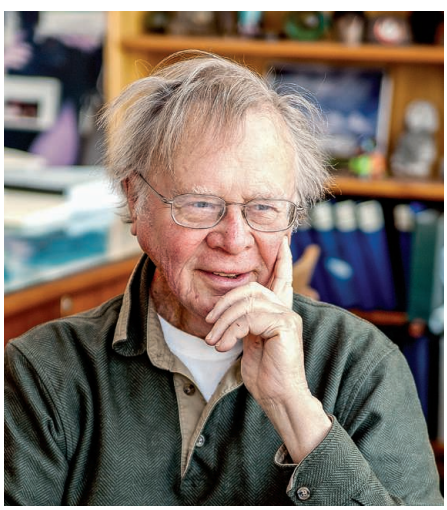
Wallace ("Wally") Smith Broecker died on 18 February at the age of 87. One of the most influential Earth scientists of the past century, Wally made foundational discoveries about the behavior of the climate system, the chemistry and circulation of the oceans, and the carbon cycle. Although he will probably be remembered most for his prescient work on global warming, his primary quest was to unravel the secrets of how the Earth system operates.

Born in Oak Park, Illinois, on 29 November 1931, Wally attended Wheaton College in Illinois, where he met Grace Carder, his future wife of 53 years and mother of their six children. At the urging of his friend Paul Gast, he transferred to Columbia University, where he graduated in 1953. After also completing his Ph.D. in geology from Columbia in 1958, he joined the Columbia faculty. Wally spent his entire career at the Lamont-Doherty Earth Observatory of Columbia University.

The premise that the past holds the secrets to a unified understanding of the Earth system formed the backbone of Wally's research. He was interested in the role of oceans in ice-age cycles and abrupt climate change. Wally tackled these scientific problems by land and by sea, delving into climate records unearthed from the highest domes of the polar ice sheets to the deepest depths of the ocean.

In graduate school, Wally joined the research group of geochemist J. Laurence Kulp, where he applied novel radiocarbon dating techniques to problems in archaeology, paleoclimatology, and oceanography. The time scale for ventilation of the deep ocean was virtually unknown then; Wally would recount how it was thought that deep-sea water masses were replaced every 10,000 years or so, with each cycle of deep-water replacement forming the basis for an ice age. Wally's pioneering measurements of radiocarbon in water from depth quickly dispelled that idea, demonstrating that ventilation time scales occurred approximately every 1000 years.

Revolutionary at that time, those early radiocarbon data were too sparse to derive precise information about ocean circulation. Encouraged by physicist Henry Stommel, Wally organized the international Geochemical Ocean Section Study (GEOSECS) to systematically survey ocean chemistry. These global measurements of radiocarbon and other chemical tracers offered unprecedented insight into ocean circulation. Wally's synthesis of GEOSECS results also gave him a unique understanding of the interplay between ocean circulation and biogeochemistry that regulates the CO_2 content of Earth's atmosphere. Thus, when ice-core studies revealed that the CO_2 content of the atmosphere during the last ice age was substantially lower



than in the preindustrial modern era, Wally was poised to define the ocean processes that could have been responsible. His two seminal 1982 papers continue to guide research on carbon-climate connections today.

Coupling knowledge of ocean processes with emerging evidence from ice cores, Wally defined the paradigm-shifting concept that the ocean-atmosphere system switched rapidly between different modes of operation in the past and may well flip again in the future. Wally, who had coined the term Great Ocean Conveyor to describe the ocean's thermohaline circulation, put his uncanny ability to intuitively distill complex problems to use once again: He warned that humans were poking an "angry climate beast" by burning fossil fuels and could push the system into another climate mode. Later in his career, Wally aimed to "fix climate." He teamed up with Lands' End founder and climate-science philanthropist Gary Comer and then-Columbia scientist Klaus Lackner to design technology that could efficiently capture CO_2 directly out of the atmosphere and thus save the world from a "bad CO_2 trip."

Field observations were central to Wally's insights into the Earth system. Interested in causes of planet-wide warmings that ended recent ice ages (as context for the current global warming), Wally and I (A.E.P.) inspected glacial landscapes in Switzerland, coastal Maine, and New Zealand. We also traversed the Taklamakan Desert of western China in a quest for clues about shifts of Earth's rain belts during a cold spell of recent centuries known as the Little Ice Age. Despite his passion for science, Wally was never too busy for a practical joke. On a long GEOSECS cruise across the North Pacific, Wally secretly molded deep abyssal clays into the shape of a brownie. After eating a real brownie himself, Wally presented this sediment brownie as a "gift" to his friend and long-time Lamont colleague Taro Takahashi. After a single bite, Taro's delight turned to disgust.

Perhaps in part because of his dyslexia, Wally enjoyed talking with people to learn and debate science. He was known for visiting the offices of colleagues to exchange ideas. Wide-ranging discussions at Lamont often closed on Friday evenings at a nearby bistro. Joined by his close friends and long-time Lamont colleagues Dorothy Peteet, George Kukla, and Dennis Kent, Wally would tell stories of how our field of science came to be, comment on the latest findings, or challenge and encourage his colleagues on their projects. When his health declined, Wally was delighted when, to his surprise, his Lamont colleagues brought the Friday "colloquia" to his apartment in Manhattan, which he shared with his wife Elizabeth Clark (also a Lamonter, whom he married after Grace's death). During his final month, he was still planning to bring together Columbia engineering colleagues who worked on carbon capture and sequestration and Lamont scientists who worked on the natural carbon cycle [including one of us (R.F.A.), who collaborated with Wally for more than 30 years)] for a seminar exploring strategies to mitigate global warming.

If there was one unifying component to Wally's expansive career, it was his reverence for Earth's natural history. The geologic record holds the clues to Earth's oceans and climate. These clues are just waiting to be decoded so that we may chart a path toward restoring a habitable planet. Such was the lifelong passion of Wally Broecker, always seeking answers to Earth's greatest puzzles. ■

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