RETROSPECTIVE

Nicholas J. Shackleton (1937–2006)

N. J. Shackleton was a scientific explorer who developed ways to extract climate data from the sea floor and found that the periodic appearance of ice sheets is governed by Earth's orbit.

William F. Ruddiman

With Nicholas Shackleton's death on 24 January 2006 at age 69, the field of climate science lost one of its founders and a scientist still at the forefront of research. During his four-decade career, Nick received most of the major awards in this field, along with a knighthood bestowed by Queen Elizabeth II in 1998. Nick's legacy includes a long list of major scientific contributions, a full description of which would not fit within the confines of this retrospective.

Nick was born on 23 June 1937 in London, a distant relative of the explorer Sir Ernest Shackleton. Although his father was a distinguished geologist, he credited his mother with encouraging an early scientific curiosity. As a young student, he often came home from school with some new tidbit he had learned. If his mother knew something about the subject, she would talk about it with him. If not, she and Nick would search for more information.

Nick received his B.A. in 1961 and Ph.D. in 1967 at Cambridge University, where he stayed his entire career. His first major scientific contribution was the discovery that oxygen-isotopic variations recorded in calcite shells of foraminifera are dominated by ice-volume changes, rather than by the temperature at which the shells form. This insight meant that a common ice-volume signal is present in all carbonate-bearing sediments and that oxygen-isotopic signals can be used to correlate ice-age marine records on a nearly global basis. Based on this insight, the 1970s Climate/Long Range Investigation Mappings and Predictions Project (CLIMAP) used oxygen-isotope signals to determine the level of the most recent ice-sheet maximum and to reconstruct global ocean temperatures during the last ice age (*1*).

During this time, Nick also collaborated with Jim Hays and John Imbrie to evaluate the Milankovitch hypothesis of orbital control of ice sheets (*2*). They found prominent oxygen-isotopic (ice-volume) variations at the 41,000-year and 23,000-year orbital periods, with both signals lagging several thousand years behind changes in Northern Hemisphere summer insolation. This forcing-and-response relationship confirmed predictions made decades earlier by Milankovitch. In the 1980s, John Imbrie, Nick, and the Spectral Analysis and Mapping Project (SPECMAP) created a marine time scale based on the assumption that ice sheets (oxygen-isotope values) lag systematically behind driving changes in summer insolation (*3*). That time scale is still in use.

Unexpectedly, the strongest oxygen-isotopic changes occurred in a band centered near 100,000 years. Nick and paleomagnetics expert Neil Opdyke showed that this ice-volume response first emerged some 900,000 years ago (*4*). Nick was still working on this "100k problem" in recent years, but it remains unsolved.

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With the acquisition of long-undisturbed cores from deep-ocean drilling in the 1980s, Nick reconstructed the full history of Northern Hemisphere ice ages. He showed that major glaciations began near 2.5 million years ago, with dozens of ice-age cycles since that time (*5*). Textbooks of this era were still claiming that only four or five glaciations had occurred, on the basis of fragmentary evidence from land-based sequences.

In the late 1980s, Nick's attention turned to carbon isotopes, where he again made fundamental contributions. He compared ^{13}C records from planktonic foraminifera from different depths to determine the amount of "bio-pumping" of ^{12}C-rich carbon from the surface to the deep ocean; he used ^{13}C values in benthic foraminifera as an index of deep-circulation changes in the world's oceans; and he measured $\delta^{13}C$ in bulk carbonate to estimate the long-term balance between burial of organic carbon and inorganic carbonate (*6–8*).

Much of Nick's recent attention had focused on improving the geologic time scale by tuning isotopic (and other) marine records to astronomically dated signals of incoming solar radiation. An initial collaboration with Andre Berger and Richard Peltier in the late 1980s led to the radical-sounding suggestion that the potassium/argon ages of magnetic reversal boundaries during the last 2 million years were too young by several percent (*9*). Geochemists soon found evidence of systematic argon loss that convinced them that Nick's time scale must be correct. During the past 15 years, Nick and other groups have gradually pushed the tuning method back millions of years in time. Who could have imagined decades ago that cycles recorded in marine cores would become the definitive way to date the younger geologic record?

Several aspects of Nick's scientific style and modus operandi stand out in my mind. Once having chosen a new problem to explore, he forged well-chosen alliances to figure out which sediment core was best for his purposes. Invariably, he made the optimal decision and wrote the definitive paper. He also liked to take strong positions in his talks, often proposing that a particular factor was primary in a causal sense and that others could be ignored. Over the years, his designations of which factors were "primary" versus "secondary" sometimes varied, because he preferred stimulating debate more than holding to a strict consistency. Such was his reputation that he was rarely challenged, probably to his disappointment. Even in appearance, Nick was one of a kind. Not many men grew their hair so long and unstyled over four decades, nor did many favor muttonchops for facial hair. And no one else wore sandals at all times, even in subfreezing weather.

When Nick Shackleton began his research, the investigation of past climatic changes was an area of "academic" interest only. Four decades later, his lifetime achievements define the emergence of our understanding of the operation of Earth's natural climate system. This understanding of the past is now central to efforts to predict the future climate we have begun to create.

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