

WILLI DANSGAARD (1922–2011)

Willi Dansgaard, distinguished professor emeritus at the Niels Bohr Institute and head of the Geophysical Isotope Laboratory at the University of Copenhagen, Denmark, died in Copenhagen on January 8, 2011 at the age of 88. He is recognized as one of the world's foremost authorities on past climate change as revealed in polar ice cores.

Dansgaard will be remembered best for his considerable contributions in the field of the Earth's past climate and its abrupt climate changes (with H. Oeschger, University of Bern) and by his students and co-workers whom he trained and inspired. His groundbreaking discovery of the seasonal variations and rapid changes in climate over short time intervals was established by measuring variations in the stable oxygen isotope ratio data (O^{18}/O^{16}) in the 1390 m deep core recovered at Camp Century, Greenland. This core, the first to bedrock, was obtained in 1966 by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire. Dansgaard's climate record of the deep core reflected annual accumulation layers dating back to 8300 years BP, and additional accumulation years back to the bottom at 115 000 years BP, with less accuracy.

Dansgaard was born and raised in Copenhagen, and essentially spent his entire life there, except for numerous field trips for research and educational purposes. His career was long and varied. He worked primarily as a mass spectroscopist, but he had broad interests in past climate and environmental conditions affecting the Earth's atmosphere. Early in his career, Dansgaard became interested in meteorology and spent the year 1947 on Disko Island, Greenland. He worked for the Danish Meteorology Institute and thereafter held the "frozen land" close to his heart (as do many Danes) for the rest of his life. After the Greenland assignment, Dansgaard returned to Copenhagen to begin his PhD studies. In 1954–55, he was invited to visit the research groups and study at the University of Chicago and Northwestern University.

In early 1958, Dansgaard participated in the Arctic Institute of North America's Greenland Expedition, to gather additional snow surface samples for laboratory analysis. Later that year he joined P. Scholander, University of Oslo, Norway, to participate in an adventurous four-month-long ocean voyage along the west coast of Greenland. In addition to sampling air bubble gases in the floating icebergs for Scholander's investigations of the chemical compositions and measuring the carbon-14 content for dating purposes, Dansgaard also collected thousands of meltwater samples of the icebergs for his oxygen isotope measurements. From 1959 to 1967, the International Glaciological Greenland Expedition (EGIG) conducted a traverse along the route of Alfred Wegener's German Expedition in the 1930s, crossing the mid-latitude of the Greenland Ice Sheet to continue some of Wegener's research objectives in geodesy and seismic surveying. The Europeans hand-augured several shallow firn cores (10–20 m deep) for Dansgaard's ever-growing collection of isotope samples.



Willi Dansgaard at age 75 in 1997. Photo: Sigfus Johnson.

Dansgaard received his PhD in Copenhagen in 1961, with a thesis entitled *The Isotopic Composition of Natural Waters*. His first assignment at the university was to set up a laboratory for a new mass spectrometer, a relatively new, powerful instrument, to investigate applications of the stable isotopes of oxygen and nitrogen to biology and medicine, as well as isotope meteorology in rain water.

From 1960 to 1973, Dansgaard was also involved in a new research project to help establish a network of about 100 field sites throughout the world that would be used for systematic monthly collecting of atmospheric air and precipitation samples. The program was under the auspices of the International Atomic Energy Agency/World Meteorological Organization network. During the several years of its operation, each of the 100 stations provided monthly samples for measurements of tritium and other isotopes, which were used to monitor airborne pollution of material from nuclear bomb tests and unintended leakage of radioactive substances from nuclear power plants into the atmosphere.

In 1964, Dansgaard and H. Clausen visited Camp Century, Greenland, for the first time. Their purpose was to collect tons of easily accessible snow and firn samples from the inclined tunnel walls in the under-snow camp for silicon-32 dating purposes. With the collection completed, Dansgaard wandered around the camp and became aware of a deep ice-core drilling project being conducted in Trench 12. His appetite was whetted; he envisioned that he had found what

he had long been searching for—a chance to obtain some sequentially layered ancient ice samples. Dansgaard was not associated in any way with the drilling part of the Camp Century deep ice core, but he made that extraordinarily valuable isotope investigation of it. Although I was responsible for handling and studying the cores, I was not yet at Camp Century, since the drill was under repair.

Dansgaard wrote to me in the fall of 1966, and shortly afterward visited the CRREL laboratory in Hanover to confer with laboratory management. He requested some form of an association with the lab so that he could obtain small samples of the entire Camp Century core to measure the stable oxygen isotopes. The CRREL organization was a small, relatively new government laboratory at the time of the Camp Century drilling project and was limited in expanding the ice-core drilling and core study team members beyond its existing complement of about five to six scientists and engineers. Student hires and technicians were used in support roles for fieldwork. The solution suggested by CRREL was to solicit and collaborate on a worldwide basis with existing experienced university specialists. Dating the ice core was a high-priority study in the CRREL science plan. Dansgaard's powerful use of the isotope technique had such great potential, and his technical qualifications, experience, and productivity were unmatched, so it was not difficult to convince CRREL and the National Science Foundation (NSF), which shared some of the overall expenses of the ice core study program with CRREL, to agree that Dansgaard would be an excellent fit in that program on a cost-sharing, co-investigator partnership basis. Hans Oeschger, University of Bern, Switzerland (deceased, 1998), had already become a partner in the CRREL research team in 1962. He was deeply engaged in the study of the greenhouse gases and the carbon-14 content of the enclosed air bubbles in the CRREL ice cores, as well as other field projects on the same subjects.

Dansgaard's results of the climate record in the 1966 Camp Century ice core were first presented in the United States at a symposium held at Yale University in 1969 (Dansgaard et al., 1971). The talk challenged the audience's conventional understanding of what occurred in the geological past with the Earth's climate systems and the rapidity at which the climate had often changed. It was an eye-opening, turning-point lecture that awakened increased interest in the United States in ice core science and in polar glaciology, which was viewed by some as an area with a "limited research future." Dansgaard had discovered and developed an outstanding new and exciting field of climate research and had surrounded himself with a cadre of exceptionally qualified faculty, students, technicians, and collaborators.

Dansgaard's eventful discovery can be traced back to the International Polar Year (IPY), (then known as the International Geophysical Year [IGY]) and the pioneering efforts by the U.S. Army laboratories to recover deep ice cores for scientific purposes in both Greenland and Antarctica. The Snow, Ice, and Permafrost Research Establishment (SIPRE) of the U.S. Army Corps of Engineers,

the Army's predecessor to CRREL, obtained the very first continuous "deep" ice core (to 300 m) in 1957, and then, because late fall and darkness were quickly approaching, two more core runs were augured at 350 m and 411 m at Site 2, NW Greenland. The Chief Scientist of SIPRE, Henri Bader, was a strong proponent of revisiting and conducting a new attempt to deep core drill into polar ice sheets, a long sought after objective of several past polar expeditions. Bader proposed the project in a pre-IGY planning conference of the National Academy of Sciences' Technical Panel on Glaciology as a worthy and potentially significant scientific contribution to the U.S. program. The Site 2 ice core was experimentally investigated, by state-of-the-art methods available at the time, soon after arriving at the SIPRE lab in Wilmette, Illinois. The studies included measuring a number of physical and chemical property parameters, as well as a collaborative stable oxygen isotope ratio investigation at the California Institute of Technology (Caltech) by S. Epstein and C. Benson (1959). This study successfully revealed annual isotopic accumulation layers down to 411 m in a dry snow zone environment (no summer melt) and affirmed the existence and continuity of discrete, annual stratigraphic oxygen isotope layers below the depth at which firn transforms to metamorphic ice. At Site 2, this depth is at 68 m, which is the starting level of zero permeability (closed pore spaces) in that depositional environment and the point where air bubbles begin to appear in polar glacier ice. All research studies on the 1957 ice core were published as they were completed and later in a compilation report (Langway, 1970).

In a recent article in the *Los Angeles Times*, a reporter questioned the Army's ability to investigate the Camp Century ice core, writing that "the Americans didn't really know what to do with the core and they gave Dansgaard access to it" (Maugh, 2011). This is incorrect, as explained above and below. SIPRE and CRREL had recovered and studied polar ice cores and published reports on them since 1957. Until Dansgaard's groundbreaking climate study, the difficulty lay in finding individuals interested in seriously studying ice cores. The U.S. Army laboratories had comprehensive in-house and cooperative ice-core study plans that began almost 10 years before the Camp Century project. Much of this history on the evolution of the expanded interests in ice-core science is discussed in the book by science journalist John Cox (2005) and most recently in a 2008 CRREL report (Langway, 2008).

The Danish, Swiss, and CRREL partnerships continued for almost three decades, with many scientific challenges, harmonious relationships, and great scientific results. The collaboration was capped by an 11-year field and laboratory research program, the Greenland Ice Sheet Program (GISP), which started in 1971. The research was jointly conceived, planned, coordinated, conducted, and successfully completed in 1981, with the recovery of a core to bedrock at Dye 3. The results were presented at a symposium of the American Geophysical Union in Philadelphia in 1982 and published in 1985 (Langway et al., 1985).

The GISP program involved an investigation of a sizeable portion of the entire Greenland Ice Sheet by CRREL, NSF, the University of Buffalo, the University of Copenhagen, the University of Bern, and the Technical University of Denmark, with the objective of locating the optimum ice-sheet location for drilling the next deep ice core to bedrock. We took full and thankful advantage of the authorization to piggyback on the logistical support of the U.S. Army, U.S. Air Force, and other facilities in Greenland, at all field sites as available, and at prorated costs. Field research consisted of coring numerous shallow firn cores (10 to 100 m deep); three intermediate-depth thermally augured ice cores, to depths of 372 m, 398 m, and 405 m, with a CRREL thermal drill; and finally, in 1981, a deep ice core to bedrock at Dye 3 at 2037 m, using the new Danish “ISTUK” drill that was designed, constructed, and operated by S. Johnson, N. Gunderstrup, N. Reeh, of Copenhagen, and other team members. Multiple research reports were published by all the laboratories.

Dansgaard also participated in the U.S. Ross Ice Shelf Project (RISP) in Antarctica in the early 1970s. First, he gathered near-surface snow deposits from over the ice shelf for oxygen isotope analysis. He made a second visit in January 1975 to the RISP site and to the Soviet Vostok Station, accompanied by John Splettstoesser (RISP), to sample firn from a snow pit dug before his arrival by station staff under the direction of N. Barkov and to obtain other selected samples from the available Vostok deep ice core.

My activity with GISP concluded when I retired from the University of Buffalo in 1994, but the two other GISP teams, in Copenhagen and Bern, went on to engage successfully in additional new deep ice sheet core drillings and core studies, in Greenland and Antarctica, often together, with a number of new and old American, European, and Japanese organizations, universities, and individual scientists.

After Willi Dansgaard retired in 1992, Claus Hammer was appointed Head of the laboratory, served for four years, and was followed by Dorthe Dahl-Jensen, who is currently serving as head. The isotope laboratory has changed its name to the “Centre for Ice and Climate,” but not its innovative research efforts or directions: the lab is still working full throttle, continuing on the path established by the legacy of the Great Dane.

Dansgaard had an active and successful career and was the recipient of many prestigious awards and memberships in scientific societies, such as the Crafoord Prize, given by the Royal Swedish Academy of Science; the Tyler Prize (presented at the University of Southern California), the United States’ highest award in environmental science; the Seligman Crystal, awarded by the International Glaciological Society; the Vegas Medal, from the Royal Swedish Society of Geography and Anthropology; and the Hans Egede Medal, from the Royal Danish Geographical Society. His professional memberships included the Royal Danish Academy of Science and Letters, the Royal Swedish Academy of Sciences, the Icelandic Academy of Science, and the Danish Geophysical Society.

Dansgaard’s death was widely reported internationally, as was his due. A few days after his passing, the Internet recorded over 8000 hits listing his obituary, and the *Los Angeles Times* published an astonishing full half-page account of his life and career. Dansgaard’s book, *Frozen Annals: Greenland Ice Sheet Research*, published in 2004 by the Niels Bohr Institute, Copenhagen, is a well-illustrated, witty, and informative tale of the impressive accomplishments of this respected and productive research scientist. The following year an English version of the book was made freely available online as a PDF file (<http://www.iceandclimate.nbi.ku.dk/publications/FrozenAnnals.pdf/>).

Professor Willi Dansgaard is survived by his three children, Brigitte, Finn, and Trine; six grandchildren; and one great-grandchild.

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