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KARL OTTO MÜNNICH (1925–2003): IN MEMORIAM†

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Karl Otto Münnich
1925–2003

Karl Otto Münnich (KO) came to the field of radiocarbon by accident. Born in Heidelberg, Germany, in 1925, he had studied nuclear physics at the local university. KO planned to continue a career as a nuclear physicist when, after finishing his studies in 1952, Prof. Otto Haxel (inspired after meeting Willard Libby) offered him a position to set up a radiocarbon laboratory. Haxel had recognized KO's experimental skills in an advanced lab course. Since this was outside KO's main interest at the time, he was initially reluctant to do so. His friends convinced him that "he would be an idiot" not to accept such a rare, well-paid position at the time.

KO succeeded to develop a method to purify CO_2 gas sufficiently well to be used as counting gas in a proportional counter, and he optimized the counter technology and electronics during his doctoral project, granted in 1957. In the same year the first Heidelberg date list was published in *Science* (Münnich 1957), including calibration measurements on wood dendrochronologically dated back to 1400 AD, an estimate of fossil CO_2 contribution in modern plants, and ^{14}C ages of 58 archaeological samples (bone, wood, peat, plants) ^{14}C

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dated all the way back to Late Glacial. Archaeologists immediately turned to the new dating laboratory, but KO also recognized right from the start the significance of ^{14}C as tracer in the environment.

Already in this early period, KO's sense for the big picture became obvious. Together with John Vogel (Pretoria), who worked on his physics doctoral project in 1955–1959 in Heidelberg, he published the first measurements in Europe showing the ^{14}C signal from atomic bomb tests in plant material. Together with corresponding data from the Southern Hemisphere, they were able to make a first estimate of the hemispheric residence time of air of about 1.5 years (Münnich and Vogel 1958). At the same time, they started to apply ^{14}C dating to groundwater (Brinkmann et al. 1959; Münnich 1963). This topic evolved strongly over the next two decades (Sonntag et al. 1980). A comprehensive summary of KO's insight into the potential of ^{14}C as universal tracer is given in his overview in 1963 (Münnich 1963).

During his career, KO targeted an impressive range of other stable and radioactive isotopes in the environment. Bomb-tritium and natural deuterium in water were already studied since 1963 (Zimmermann et al. 1966). In 1969, KO participated in the GEOSECS test cruise, together with W. Broecker in the Pacific, off Baja, California. This event opened the way for the Heidelberg ^{14}C laboratory to join the German section of GEOSECS in two cruises of RV *Meteor* in the Atlantic Ocean, with KO as chief scientist. These transects resulted in dense depth profiles of various chemical and isotopic species, among them tritium, ^{13}C, and ^{14}C (Roether and Münnich 1972, 1974; Ribbat et al. 1976; Roether et al. 1980).

The large number of ocean ^{14}C samples and the high demands on precision (< 3‰ error) required by the small ^{14}C gradient in ocean deep water lead to a new design of the low-level CO_2 gas counters of the Heidelberg laboratory: 9 counters of 4 L each were mounted in a system of 5 flat guard counters (Schoch et al. 1980). The CO_2 samples were purified chromatographically with charcoal resulting in highest purity, allowing high pressure in the counters. Eventually a total of 19 counters were installed in an underground counting room (Kromer and Münnich 1992), used for ^{14}C samples of ongoing ocean cruises on RV Polarstern to the Arctic Ocean and the Weddell Sea (Schlosser et al. 1989, 1990) and extensive tree-ring based calibration.

Potential variations of the past atmospheric ^{14}C level, i.e. calibration of the ^{14}C clock, was an early-on topic of collaboration among the European ^{14}C laboratories, especially with Groningen (Münnich et al. 1958; Willis et al. 1960). In the mid-1970s, KO contacted Bernd Becker of the botanical laboratory of Hohenheim University, Germany about tree-ring chronologies. From here, a very close collaboration originated in ^{14}C dating, as well as in fieldwork to recover subfossil trees. Initially an AD section was measured and a 200-yr solar cycle identified (Bruns et al. 1980b). From then onwards initially floating tree-ring sections of the mid- and early Holocene were studied, expanded and finally linked dendrochronologically (Kromer et al. 1986, 1994, 1995; Becker 1993; Becker and Kromer 1993; Kromer and Becker 1993, 1995).

KO was also a pioneer in using ^{14}C and ^{222}Rn as tracers for soil processes (Zimmermann et al. 1966; Zimmermann 1967; Bruns et al. 1980a; Dörr and Münnich 1980; Dörr et al. 1983; Dörr and Münnich 1986, 1989). This research prepared the basis for soil studies following the Chernobyl accident (Dörr and Münnich 1987).

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Already in the late 1950s KO saw the key role of ^{14}C as atmospheric tracer in two aspects: (1) bomb ^{14}C to study atmospheric mixing and gas exchange with the ocean, and (2) the quantification of fossil fuel in anthropogenic fluxes of CO_2. He started the continuous, bi-weekly collection of CO_2 at an Austrian alpine site (Vermunt) in 1959 and then a set of sampling stations in the Northern and Southern hemispheres (Levin et al. 1987) was added, some of which are still operated to this day (Levin et al. 1985, 1992, 2010, 2013). The data of these sampling stations cover the longest atmospheric ^{14}C series worldwide, and provide evidence to assess the fate of the Paris Agreement (Levin et al. 1989, 1992).

Right at the beginning of the laboratory work in Heidelberg, KO and Haxel tested all kinds of materials for their suitability for radiocarbon measurements and how they should be pretreated. For example, from the beginning bone samples in Heidelberg were pretreated using dialysis tubes of 10 kDalton separation, similar to the ultrafilter step of 30 kDalton, to eliminate short chained fragments. Environmental aspects found their way into research by e.g. sampling plants from close to the motorway between Heidelberg and Mannheim or shells from the nearby rivers Rhein and Neckar. This curiosity to explore contexts was one of his trademarks.

KO was not only a leader in isotope studies in the field, but also in developing laboratory experiments to study the basic properties of such tracers. From 1972 to 1974 KO Münnich was director of the Institute of Physical Chemistry, Jülich Nuclear Research Center, Germany, before he returned to Heidelberg University in 1975 as founding director of the Institute of Environmental Physics, a position he kept until his retirement in 1992. He designed a small circular wind tunnel of 1 m diameter to explore crucial parameters for quantification of air/water exchange (Münnich et al. 1978; Jähne et al. 1979; Siegenthaler and Münnich 1981). In the early 1980s a circular wind tunnel of 4 m diameter was built in the institute and used intensively (Jähne et al. 1987). When the Institute of Environmental Physics moved to a new building in 1999, the largest instrument of this type worldwide was built with a diameter of 10 m. On a suggestion of Münnich, it was named Aeolotron. In the early 1980s, as a member of the scientific advisory board to the German Government, KO initiated the development of an electrically cooled gamma detector to identify nuclear waste in the environment in a mobile system (Kromer et al. 1985). This concept became suddenly essential after the Chernobyl accident, resulting in an installation of 20 mobile units in Germany.

KO also contributed ideas to AMS techniques, collaborating with the AMS laboratories of ETH Zurich, Switzerland, and Lund, Sweden (Bonani et al. 1987; Kromer et al. 1987; Schlosser et al. 1987).

As is evident from this short outline of his career, Karl Otto Münnich was highly creative in many fields of environmental sciences. Once he had an idea (and he had so many), he designed a project and handed it over to a student or collaborator in his institute. He followed closely the progress of any project, often writing short papers on key aspects or solution to key problems (he called them f-papers, f file). Over time, he left us with more than 1500 of such internal f-papers. In commemoration of an inspiring and at the same time endearing scientist, we named the Central Radiocarbon Laboratory of the Integrated Carbon Observation System Research Infrastructure (ICOS), which is hosted at the Institute of Environmental Physics, the "Karl Otto Münnich ^{14}C Laboratory".

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