In memoriam Waldo Zagwijn (1928-2018): West European Neogene and Quaternary climate- and chronostratigraphy

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In memoriam Waldo Zagwijn (1928-2018): West European Neogene and Quaternary climate- and chronostratigraphy

At the age of 89 professor Waldo Heliodoor Zagwijn died after having dedicated his life to geology and palaeobotany. He developed the climate- and chronostratigraphical framework of Western Europe and he painted a 3-dimensional understanding of The Nether-lands-below-the-surface.

Waldo Zagwijn (16 October 1928-26 June 2018) studied geology at the University of Leiden from 1947 to 1952. In 1954 he joined the Geological Survey of The Netherlands and he would spend his life at the Survey's Department of Paleobotany and Stratigraphy. In 1960 he obtained his PhD cum laude, supervised by prof. dr. I.M. van der Vlerk with his dissertation *'Aspects of the Pliocene and early Pleistocene vegetation of the Netherlands'.* He showed for the first time

that the Pleistocene included more than the four conventional ice ages known in the 1950s.

Waldo Zagwijn (1995) with a special journal issue on the occasion of his retirement; centrally: his secretary; right his colleague Jan de Jong.

He also documented important climate oscillations during the Pliocene evidencing that the Pleistocene series of ice ages had not a sudden start and that the concept of 'a first ice age' is misleading. Later he included the Miocene as well in his studies, and the more recent part of the Pleistocene as well as the Holocene. In 1949 Willard Frank Libby discovered the method of radiocarbon dating, and Waldo took this new challenging opportunity to improve his chronostratigraphy and he dated his newly described 'Amersfoort Interstadial' at around 75,000 years.

As an employee of the Netherlands Geological Survey Zagwijn was supported by technicians for the analyses of pollen, diatoms and sediments. His research focused on geological issues within The Netherlands and adjacent areas in Germany, Belgium and the North Sea basin. He also contributed with his knowledge to several review papers. The 1971 book chapter by Van der Hammen, Wijmstra and Zagwijn *'The floral record of the Late Cenozoic of Europe'* is still an unbeaten account which became a 'classical' paper (reprints and pdf available from the first author).

Integrating understanding of geology, palaeobotany, palaeoclimatology, palaeogeography and stratigraphy Zagwijn placed the 3-dimensional view on the complex stratigraphical structure of The Netherlands-below-its-surface along the time line and he developed a 4-dimensional understanding how The Netherlands came into existence. The suite of ice ages, of which two covered the northeastern part of The Netherlands with ice, and the frequently changing courses of the rivers Scheldt, Meuse and Rhine challenged his imagination. His series of palaeogeographical maps published in 1975 are examples of thorough data syntheses and show how The Netherlands developed from Upper Pliocene to Holocene times (Zagwijn, 1975). Ongoing research gradually improved Zagwijn's initial maps and Peter Vos' current map series shows in much detail how The Netherlands developed since 9000 BC (Vos et al., 2011); scientifically a master piece and educationally a document that will fascinate people from all ages.

The Italian-American geologist Cesare Emiliani discovered periodic variations in the ratio of $^{18}O/^{16}O$ and noticed the relation with glacial-interglacial cycles (Emiliani, 1955). Nick Shackleton (Cambridge, UK) further developed the marine $\partial^{18}O$ stratigraphy into a climate- and chronostratigraphical tool of global relevance (Shackleton, 1967). At the same time Waldo Zagwijn developed a terrestrial stratigraphy for Western Europe that can be considered an equivalent of the marine $\partial^{18}O$ stratigraphy. The extremely successful Ocean Drilling Program, and it successor the International Ocean Drilling Program, provided many long and continuous marine sediment cores. In contrast, sedimentary archives in northwestern Europe are fragmentary; the northernmost long and

continuous continental pollen record comes from Grande Pile in northern France (Woillard & Mook, 1982). Waldo had to deal with numerous relatively short pollen records and was confronted with a stratigraphical jigsaw puzzle that stretched into 4 dimensions. Waldo's encyclopedic knowledge of dozens of published West European pollen records gave him the right arguments for a composite Pleistocene climate-based chronostratigraphy which was remarkably well in agreement with the marine oxygen isotope stratigraphy.

In the marine record the Pleistocene started for a long time at the Olduvai magnetic reversal at 1.77 Ma, a boundary position that could be practically identified on a global scale. However, considering the terrestrial sequence of glaciations the 1.77 Ma boundary as the start of the Pleistocene was without logics. In several papers Zagwijn discussed the start of the Pleistocene, nailed down at the first occurrence of 'significant glacial' climatic conditions: the Pre-Tiglian (Zagwijn, 1963, 1974, 1975, 1985, 1992). Moreover, the Pre-Tiglian was the start of a long period in which the European flora lost its warm floral elements due to the suite of ice ages that would follow (Van der Hammen, Wijmstra and Zagwijn, 1971). As temperature oscillations were also found during the Pliocene, at present-day so well documented in the global oxygen isotope stack record of Lisiecky and Raymo (2004), a 'first ice-age' is a difficult concept. Zagwijn was pleased to see 'his' Pliocene-Pleitocene boundary was finally accepted (Gibbard et al., 2009). Zagwijn's composite Quaternary stratigraphy became the standard in Europe and he developed into an internationally respected authority.

Zagwijn's merits were rewarded in 1972 with the *Albrecht Penck Medal* of the German Quaternary Association (DEUQUA). In 1974 he received the *Van Waterschoot van der Gracht Medal* issued by the Royal Netherlands Geological and Mining Society, the highest distinction in Dutch earth sciences. He was appointed by the Queen *Officier in de Orde van Oranje Nassau*. In 1980 he was elected a member of the Royal Netherlands Academy of Sciences (KNAW) and he used this new connection to make liaisons between the industrial and academic communities of earth-sciences.

Zagwijn served in the Committee for Vegetation Science of the Royal Dutch Botanical Society, he was chairman of INQUA Netherlands, a member of the IUGS Sub-commission for Stratigraphical Nomenclature, secretary of the INQUA Sub-commission for European Quaternary Stratigraphy, and a member of the editorial board of the Review of Palaeobotany and Palynology.

Waldo was a sympathetic and sharp debater; in discussions his encyclopedic knowledge of the literature allowed him to use loads of arguments. In 1989 he was appointed professor in Quaternary Palynology at the Vrije Universiteit in Amsterdam; Limited by time Wim Hoek was his only PhD student who published his PhD thesis on *Palaeogeography of Lateglacial vegetations* in 1997.

During his appointment in Amsterdam in the early 1990s, Waldo was working on Eemian and Holocene climate reconstructions based on carefully selected pollen diagrams from the literature. He was inspired by Iversen and Grychuk, using well-known climate indicators *Hedera, Ilex* and *Viscum* as well as other thermofilous tree taxa (Zagwijn 1994, 1996), and produced two well cited papers on the climate of Holocene and Eemian in Western and Central Europe (Zagwijn, 1994; 1996). Waldo's retirement in 1993 was marked by a large symposium held at the Royal Academy in Amsterdam. The proceedings were published in a 510 pages volume *'Neogene and Quaternary geology of north-west Europe; Contribution on the occasion of Waldo H. Zagwijn's retirement'* (Herngreen et al., 1995) to which 67 authors contributed. This volume also provides a list of Zagwijn's one hundred publications (De Jong, 1995).

We remember Waldo Zagwijn as a sympathic and eminent scientist who developed an

understanding how the kilometers of sediments below The Netherlands' surface had developed, and he was the architect of the frame of continental chronology and climate stratigraphy showing the dynamic history of Western and Mediterranean Europe during the last five million years.

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