Chemical Geology 362 (2013) 3–12

Contents lists available at ScienceDirect

Chemical Geology

journal homepage: www.elsevier.com/locate/chemgeo

A master of the earth: H.D. Holland and his contributions to geochemistry

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ARTICLE INFO

Article history:
Accepted 2 October 2013
Available online 11 October 2013

Keywords:
Atmosphere ocean evolution
Evaporites
Paleosols
Ores

ABSTRACT

H.D. Holland was one of the great geochemists of modern times. As a Professor at Princeton University for 22 years and at Harvard for 33, he mentored 24 graduate students and 24 postdoctoral researchers. He was a member of the U.S. National Academy of Sciences and a President of the Geochemical Society. He co-authored 179 publications in 64 years from 1949 to 2012, including four books. He edited one other book and, with Karl Turekian, co-edited the ten-volume *Treatise on Geochemistry*. His contributions to geochemistry were mainly in economic geology, hydrothermal processes, and especially the chemistry and evolution of the Earth's atmosphere and oceans, a topic to which he devoted nearly half of his publications. His most significant contributions documented changes in the composition of seawater through geologic time and the rise of oxygen in Earth's atmosphere. He pioneered the use of mineral sequences in marine evaporite deposits and fluid inclusions in evaporite minerals to determine the composition of ancient seawater. He collected extensive data on paleosols and used them to calibrate the oxygen content of the ancient atmosphere, documenting its rise in the Great Oxidation Event that peaked between 2.41 and 2.32 Ga, and writing extensively about the causes of this event, one of the most significant in Earth history.

1. Introduction

Last year saw the passing of one of the great geochemists of modern times, Dr. Heinrich Dieter Holland, on May 21, 2012, six days shy of his 85th birthday. I had the privilege of working with Dick Holland as his doctoral student, beginning in 1970 in the Department of Geology at Princeton University. Dick graciously allowed me to move with him to Harvard University in 1972, where I completed my doctorate in the Department of Geological Sciences in 1976. In 1999, as then Chair of the Department of Oceanography, I hosted Dick for the fourth of four sabbaticals he spent at the University of Hawaii, beginning in 1968. Dick was 42 and I was 21 when I met him in the spring of 1970, so I knew him for half of his life and two-thirds of mine. I was on a tour of East Coast institutions to decide where I would take my just-received Graduate Fellowship from the U.S. National Science Foundation (NSF). Dick's enthusiasm caused me to choose Princeton and, not coincidentally, to change my chosen specialty from sedimentology to geochemistry. Dick's enthusiasm had this effect on a generation of students, and the list of geochemists he mentored is long (24 graduate students and 24 postdoctoral fellows, according to Dick's C.V., Appendix 2)) and distinguished (Appendix 1).

2. Holland's childhood and education

Dick Holland was born in Mannheim, Germany, on May 27, 1927, of German Jewish parents. At the age of twelve he escaped from Nazi Germany to England with his younger brother, Hans Joachim, just before the outbreak of World War II, as part of the Kindertransport program. Also known as the Refugee Children Movement, Kindertransport was conceived by Jewish leaders in Britain in November, 1938, a few days after the frightening event of *Kristallnacht* (the Night of Broken Glass) in Germany, and operated for only nine months, ultimately rescuing nearly 10,000 children. With the cooperation of the British Prime Minister and Parliament, it permitted the admission into Britain of children from Nazi countries unaccompanied by their parents, who were then temporarily taken into British homes. Dick and his brother went to a home in the countryside outside of London, before being sent by train to Scotland and then by ship to New York City, where they were met by their mother, who had also escaped. Lacking visas, they then traveled to the Dominican Republic, where they were reunited with their refugee father and younger sister Anne. The family was able to immigrate to the United States in 1940.

Dick graduated as valedictorian from the Stony Brook School in Stony Brook, New York, and won a full scholarship to Princeton University. An academic prodigy, he graduated from Princeton Phi Beta Kappa, with high honors and a B.A. in Chemistry, in 1946, having just turned 19. He served in the U.S. Army from 1946 to 47, where he worked on classified projects which may have involved rocketry. In 1948 he earned his M.S. and in 1952 his Ph.D. in Geology from Columbia University. At Columbia Dick worked under Professor J. Laurence Kulp (1921–2006) (who was only six years older than Dick), along with fellow students Paul Gast, Karl Turekian, and Wallace Broecker. Kulp was a pioneer in radiometric dating and a leader in studies of radioactive fallout, who had obtained his Ph.D. in Physical Chemistry from Princeton in 1945, at the age of 24. Kulp and Holland thus were at Princeton at the same time, both studying Chemistry, Kulp as a

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http://dx.doi.org/10.1016/j.chemgeo.2013.10.003

doctoral student and Dick as an undergraduate. Kulp was the first to suggest, in 1953, that ^{90}Sr could be used to trace radioactive fallout and its threat to humans, and his laboratory at Columbia was the first to measure it in soils, bones, and human food (cheese); he would later become a leader in studies of acid rain.

Phil Candela, who moved into my office after I left Harvard and who reviewed this paper, provided me with Dick's own story of how he came to work with Kulp at Columbia. Prospecting for graduate students, Kulp called the Chemistry Department at Princeton asking for the names of their most distinguished recent graduates. He was referred to Dick and telephoned him. Kulp invited Dick to join him at Columbia and detailed all the innovative and exciting things they could do in geochemistry. Dick responded, "Sounds great! What's geochemistry?" The rest, as they say, is history.

Dick's first published paper (Holland and Kulp, 1949), "The distribution of accessory elements in pegmatites. I. Theory", was co-authored with Kulp, and is typical of Dick's later work in combining measurements with theory. It is always dangerous to label a paper as Part I, for Part II was apparently never published, although there was a follow-up application (Holland, 1956, Dick's first sole-authored paper), "The chemical composition of vein minerals and the nature of ore forming fluids". Dick's doctoral thesis was published in two parts in 1954 (Holland and Kulp, 1954a,b) and dealt with riverine fluxes, ocean sedimentation, and hence the geochemical cycles of uranium, ^{230}Th, and radium. The titles of these two papers sound very modern, as this type of study has since become a staple in geochemistry.

3. Holland's academic career

Dick Holland began teaching in the Department of Geology at his *alma mater*, Princeton University, in 1950, as an instructor, while still working on his doctorate at Columbia (Figs. 1 and 2). Dick told me more than once how uncomfortable he was during his first few years of teaching at Princeton, as he was actually younger than most of the graduate students in the department! Dick would teach at Princeton for nearly 22 years before answering the siren call of Harvard in 1972 (Figs. 3 and 4). Dick retired stepwise from Harvard, from teaching in 2000 and from the research faculty in 2005, after 33 years there, the last ten as H.C. Dudley Professor of Economic Geology. Besides four sabbaticals at the University of Hawaii between 1968 and 1999, and his last sabbatical, at Hebrew University in Jerusalem, Dick spent time as an NSF Postdoctoral Fellow at Oxford University (1956–57), a Fulbright Lecturer at Durham University (1963–64), a Guggenheim Fellow at Imperial College, London (1975–76), a von Humboldt Senior Fellow at Heidelberg University (1980–1981), and a visiting professor at the Pennsylvania State University (1985–86 and 1992). During his distinguished career he served as Vice President (1969–70) and President (1970–71) of the Geochemical Society. He received the Alexander von Humboldt Senior Scientist Award (1981–82), the V.M. Goldschmidt Medal of the Geochemical Society (1994), the Penrose Gold Medal of the Society of Economic Geologists (SEG) (1995), and the Leopold von Buch Medal of the Deutsche Geologische Gesellschaft (1998). Dick was Distinguished Lecturer for SEG in 1969 and Thayer Lindsley Lecturer in 1981–82. He was a Fellow of the American Academy of Arts and Sciences, the American Geophysical Union, and the Society of Economic Geologists, and a member of the U.S. National Academy of Sciences. His 1984 book, *The Chemical Evolution of the Atmosphere and Oceans*, was named the year's most outstanding book in Physical Sciences by the Association of American Publishers. After his retirement from Harvard, Dick moved with his wife Alice to Philadelphia in 2006, where he took up the position of Visiting Scholar in the Department of Earth and Environmental Science at the University of Pennsylvania. In this role he continued to interact with students and to pursue his geochemical interests until his death in 2012.

During all this time I would receive the occasional phone call from Dick, once or twice a year, invariably because he wanted to pick my brain about some specific geochemical question, usually concerning hydrothermal processes. He last called me in April, 2012, only a few weeks before his death, to talk about the *Treatise on Geochemistry*, the second edition of which he was co-editing with his life-long friend and colleague, Karl Turekian (and for which I co-edited Volume 8, with Harry Elderfield).

Fig. 1. Dick Holland in formal attire, with a winning smile, about the time (1950) he began to teach at Princeton.

4. Holland's published work

Dick's *Curriculum Vitae* lists some 179 works, published during the 64 years between 1949 and 2012. Were I evaluating him for tenure or promotion, I would quickly calculate a publication rate of 2.8 per year (3.0 up to the time of his retirement in 2005), a rate not too different from my own much more feeble record. It appears there are two ways to accumulate a long publication list: publishing many papers per year, or having a very long career! Dick did both. He published early (at age 22) and long (till nearly age 85). His rate of publication was good but not exceptional; he made his mark because of the depth, breadth, and significance of his contributions, and their concentration within a limited number of largely complementary topics, as well as from their sheer number. The *Web of Science* (webofknowledge.com) lists 3654 citations of his 73 papers published since 1980 (excluding self-citations), for an h-index of 31. His work has averaged 261 citations per year since 2005. Since 1980 he has 12 publications that have each been cited 100 times or more; his most-cited paper published since 1980 (Bekker et al., 2004) has been cited 337 times. Of his 179 publications, an amazing 51 (28%) are sole-authored, including the two most original of the four books he wrote or co-wrote: *The Chemistry of the Atmosphere and Oceans* (Holland, 1978) and *The Chemical Evolution of the Atmosphere and Oceans* (Holland, 1984). Dick's first book, *Hydrothermal Uranium Deposits* (Rich et al., 1977), was co-authored with his Harvard colleague Ulrich Petersen and their graduate student Robert Rich. His fourth book, *Living Dangerously: the Earth, its Resources, and the Environment* (Holland and Petersen, 1995), is an undergraduate textbook in Earth Science (and Dick complained to me that it had sold only a few thousand copies). Dick co-edited a fifth book, *Mineral Deposits and the Evolution of the Biosphere* (Holland and Schidlowski, 1982), as well as the ten-volume masterpiece, the *Treatise*