

Turekian reflections

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Karl Karekin Turekian (1927–2013) was a man of remarkable scientific breadth, with innumerable important contributions to marine geochemistry, atmospheric chemistry, cosmochemistry, and global geochemical cycles. He was mentor to a long list of students, postdoctorate scholars, and faculty (at Yale and elsewhere), a leader in geochemistry, a prolific author and editor, and had a profound influence in shaping his department at Yale University. Karl was a true scholar and interested in everything, scientific and nonscientific. As his Yale colleague George Veronis reflected, “Karl plunged into any topic, very often far removed from his own specialty, and had heated discussions about all kinds of issues. His discussions were heated because that’s how he got himself worked up to carry on the way he did. Very often he would say something like, ‘I don’t know anything about so and so,’ when a topic was raised, and quite often he didn’t. He wanted to learn, and his own ignorance would not deter him from carrying on.” Karl’s autobiography (1) and a recent interview (2) tell his story far better than we can and make clear his vast contributions to science, especially his role in the development and advancement of the field of geochemistry. What is especially notable about Karl is his impact on people, the unanimity of the love for Karl by all who knew him well, and his unique character. We’d like to recount a little of what it was like to be on the receiving end of his warmth and wisdom.

As he has written (1), Karl began adult life by joining the Navy at the age of 17 on July 4, 1945, after a semester at Wheaton College. Fortunately for the field of geochemistry, VJ day came while he was still in boot camp. The GI Bill, along with scholarships, allowed Karl to return to Wheaton and obtain his degree in chemistry, and then in 1949 to join a graduate program in the new field of geochemistry at Columbia University under Larry Kulp, with students Dick Holland and his fellow Wheaton alumni Wally Broecker and Paul Gast. This was a propitious time, as

Columbia’s Lamont Geological Observatory had only been established a few years before.

It was during these years that Karl began to acquire the skills that led to his rapid emergence as a leader in geochemistry. His interactions with Paul Gast and his advisor Larry Kulp were particularly influential, as it was then that he began his quest to attack the largest geochemical problems by application of intellect and new measurement capabilities.

Karl began by assaulting the element strontium, measuring its concentration in everything he could get his hands on (rocks, sediments, corals, ocean waters, and so forth) and applying these measurements toward developing a broad understanding of the Earth. His work at Lamont, collaborating with Wally Broecker on sedimentary carbonates, was instrumental in developing understanding of glaciation events and their imprint on the sedimentary record. Karl had an intuitive ability not only to spot the most important problems in geo- and cosmochemistry, but also to go out and develop whatever new measurement technique was needed to wrestle each problem to the ground, be it optical emission spectrography, mass spectrometry, instrumental neutron activation analysis, or counting of natural radioactivities.

After a brief postdoctorate at Columbia University, Karl accepted a position as Assistant Professor of Geology at Yale University in 1956, where he set out to create a program in geochemistry from scratch. Karl spent the rest of his life on the Yale faculty, and was immersed in geochemistry to the end. He was deeply involved in editing a new edition of the massive *Treatise on Geochemistry*, now up to 15 volumes, until only a month before his passing on March 15, 2013.

Karl was, of course, noted for his application of strict standards to his work and life. Wally Broecker recalls that Karl decided during his bachelor days at Yale that he was waiting for the “right” woman in his life. Karl quite characteristically defined “right” as being intelligent, beautiful, Protestant–Armenian, and willing to marry him, which in his autobiography (1) Karl termed a “low



Karl Karekin Turekian.

probability event,” as each of the required features was in and of itself of low probability. Not unlike the very low, but finite probability in quantum mechanical tunneling, Karl met Roxanne at a New Year’s Eve party and they were married some three months later.

With the achievement of this most difficult quest, Karl turned to the study of deep-sea cores, and especially the analysis of trace elements, to study the wide variety of geochemical processes that are recorded there. His work with Hans Wedepohl in writing and tabulating the *Handbook of Geochemistry* (3) was a major accomplishment, and this work was used by many generations of geochemists. It was also at this time that the need for high-quality analysis of trace elements was recognized and Karl set about learning the ins and outs of instrumental neutron activation analysis that would serve as a basis for many outstanding papers and dissertations in years to come. As part of the revelation of the Earth’s geochemical secrets, Karl decided to dig into ocean sediments as the ultimate sink for the weathering of the continents, and to look closely into that portion of the Earth system. Teaming up with his graduate students and in association with Paul Gast, Karl developed a mass spectrometry laboratory at Yale and began to thoroughly investigate the Rb–Sr isotopic systematics of deep-sea clays, not only as repositories but also as sites for exchange to occur and serve as a control of the geochemistry of ocean water. This work also included measurement of the ⁸⁷Sr/⁸⁶Sr

Author contributions: M.H.T., A.M.D., L.G., and A.S.C. wrote the paper.

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ratios over short and longer time periods, with students Julius Dasch and Garry Brass.

After observing Julius Dasch, one of his earliest students, struggle to achieve a decidedly mixed academic record, Karl invited Julius into his office for a pep talk. He asked Julius what he'd like to do after leaving Yale. After thinking about it for a minute, Julius said he'd like to teach. Karl, sinking deeper into his chair, replied, "Teaching is a noble profession. It's a tremendous satisfaction to nurture a student, train him, and watch him grow into an independent scientist, ultimately transcending the teacher himself." Pausing just long enough to furrow his brow, Karl turned to him and said, "Julius, you're not transcending me."

Karl was a major player in a revolutionary marine geochemistry campaign known as the Geochemical Ocean Section Study (GEOSECS). GEOSECS was part of the International Decade of Ocean Exploration in the 1970s, which took aim at measuring and understanding the distribution of geochemical tracers for circulation and biogeochemistry in the world's oceans. Sampling of North-South traverses of all of the world's oceans at all depths was a massive undertaking, to say the least. It was here that Karl began to apply radioactive lead and polonium measurements to understand geochemical cycling through the oceanic water column and the role of sediment surfaces. It was also within this same time period that another large-scale "geochemical" sampling program, known as Apollo 11, came along. Here Karl used his instrumental neutron activation analysis techniques to examine some of the first returned lunar samples for their trace elements. It was also at this time period that Larry Grossman did his doctorate work with Karl and did the first quantitative thermochemical calculations of what sequence of minerals one would expect to condense from a gas of cooling nebular composition. As fate would have it, it was just at this time that the Allende meteorite fell and the minerals contained within, the so-called calcium-, aluminum-rich inclusions, agreed beautifully with what Larry Grossman had calculated. Karl was particularly proud of being the holder of the Silliman Chair and being curator of the Yale meteorite collection. In a continuation of Karl's foray into cosmochemistry, Andy Davis came to Yale to study with Karl and Sydney Clark. Andy used instrumental neutron activation

analysis to investigate the trace-element composition of pallasites and to establish their role in planetary processes at the core-mantle boundary.

There must have been only a few times in his career when Karl didn't have a solution for some dysfunctional social interaction. One such occasion occurred when he returned from lunch at his College one summer day, only to stumble upon two graduate students engaged in an actual physical altercation over whose turn it was to use the mass spectrometer. After ordering them to stop and ushering them into his office, Karl removed his overcoat, slumped into his chair and demanded an explanation for the unusual behavior. Standing side-by-side before him, each of them, now disarmed, disheveled, and sweating profusely, explained why he was the one who had the right to use the machine at that instant. Mentally straining to render a Solomonian decision, all Karl could muster was, "I just want everybody to play nice!"

As a student of the Earth system, Karl was an equal-opportunity researcher, and he developed a technique to measure naturally produced ^{35}S (87-day half-life), produced by cosmic ray spallation of argon, with Nori Tanaka. From the amount of ^{35}S in SO_2 , aerosol sulfate, and rainwater, he was able to determine the rates of gas-phase oxidation of SO_2 and its deposition. In a conversation with Karl on this subject, one of the authors (M.H.T.) observed Karl's great scientific care and foresight, claiming that before they did the first radiogenic sulfur sampling, they did a most careful analysis of the entire Earth and determined that there was only one single site that could be used to represent the entire planet. As fate would have it, that site happened to be the roof of the Kline Geology Laboratory at Yale!

Karl was a pioneer of osmium isotope geochemistry: he dreamed of using osmium isotopes in the 1970s, but no analytical techniques were available. Karl and Jean-Marc Luck made a splash in 1983 by showing that osmium in the high-iridium layers at the Cretaceous-Tertiary (K-T) Boundary was of meteoritic, not crustal, isotopic composition.

This geologic boundary corresponded to a mass-extinction event and the demise of the dinosaurs. Karl's osmium insights proved that the high iridium content previously measured in K-T Boundary strata had resulted from the impact of a massive bolide with the Earth. Over the next 20 years, Karl's group led the way in using this isotopic system for exploring weathering rates through time, marine geochemistry, and age of black shales.

Karl loved to lecture about the potential meaning of each new measurement, excited to be the first to break new ground. In fact, it was not uncommon for Karl to give an hour-long lecture based on a single data point. After one such memorable attempt at the University of Chicago, a member of the audience commented, "But, Karl, your whole story is based on only one data point." Karl, anticipating the comment, snapped back, "It's one more data point than anyone else has!"

Equally important to the legacy of what Karl did for science in his research contributions on and across the planet, was his influence on scientists. Karl's legendary daily coffee hours were a training ground for many generations of students, postdoctorate scholars, and visitors, as well as a proving ground for Karl's own ideas. His love of a vigorous scientific debate was legendary and, as George Veronis shared, when Karl was a visiting Fairchild Fellow at the California Institute of Technology, his son Vaughn talked about hearing his father screaming at Clair Patterson, a renowned geochemist who was the first to determine an accurate age for the Earth. When walking away, Vaughn apparently asked of Karl "Why do you visit him? You just hate him." Karl's reply was "What are you saying? He's one of my best friends!" Karl loved to question and be questioned. Nothing was sacred and, in the act of questioning—as in exploring—new science arises. He was extraordinarily supportive of people, always had time to discuss and listen, and helped everyone, from students to his fellow faculty at Yale. Karl was twice department chair and even when not chair, a steady influence in times of departmental difficulty.

1 Turekian KK (2006) Threads: A life in geochemistry. *Annu Rev Earth Planet Sci* 34:1–35.

2 Turekian KK, Cochran JK (2012) A conversation with Karl K. Turekian. *Annu Rev Mar Sci* 4:1–10. For a video of this interview, see www.annualreviews.org/doi/abs/10.1146/

annurev-marine-090611-134351. Accessed September 11, 2013.

3 Turekian KK (1969) The ocean, streams and atmosphere. *Handbook of Geochemistry*, eds Wedepohl KH, et al. (Springer, Berlin, Heidelberg, New York), pp 297–323.