Memorial to E-an Zen
(1928–2014)

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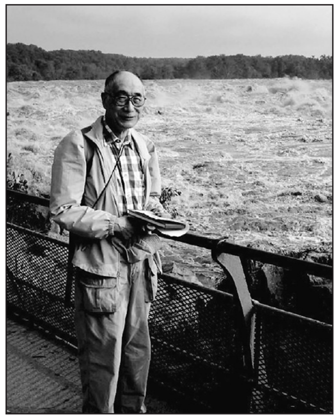

Occasionally the work of a great scientist will shift a paradigm in geology; rarely, will a single scientist shift paradigms in multiple geologic disciplines, while simultaneously taking a leadership role in matters of science policy and education. Dr. E-an Zen was one such scientist, and it is with immense respect and admiration that we honor his memory with this Memorial.

E-an was born in Peking (Beijing), China, on 31 May 1928. His father trained as a chemist, and his mother spent most of her life as a social commentator and education reformer. When war between China and Japan broke out in 1937, his family split up and left for points south and west, ahead of the advancing Japanese army. After enduring numerous difficulties during the war, they returned to "Free China" in the summer of 1942, and the family (except for his oldest sister who was already in the United States) lived in Chungking from 1942 to 1946.

In July 1946, E-an's family came to the United States on a converted troop ship, spending the summer on a farm in Oakton, Virginia. They then moved to Cambridge, Massachusetts, where E-an attended high school. Prior to this, he had never attended school except for "a few abortive attempts at 2nd, 4th, and 10th grades." His early education was primarily provided by tutors, parents, and an elder teacher, and through self-learning. At about the age of 14, he simultaneously taught himself typing and English by punching out the contents of a book written in English on a typewriter—one that had no ribbon. In Cambridge, he began his first full year of formal schooling by studying English, Latin, German, and chemistry. In that year, his first and last in U.S. high school, he conquered his fear of math (which had been instilled by his mother's antagonistic views toward Chinese education), excelled at algebra, and took first prize in German. He did well enough to earn a scholarship to Cornell University, which he attended as an undergraduate from 1947–1951.

From an early age, E-an loved maps. At Cornell, he wanted to pursue this interest by studying physical geography, but it was not offered as a major. Instead, he majored in geology as the nearest available discipline, simultaneously taking advanced chemistry. In the summer of 1950, he attended field camp in Phillips, Maine, in order to learn about mapping metamorphic rocks. This was his first field experience, about which he mused, "I don't think I learned much of anything other than some local geology which was useful in my later life."

After Cornell, E-an entered graduate school at Harvard where he studied under Jim Thompson, the famous geologist and thermodynamicist, who was his major advisor. On the advice of Thompson and Marland Billings, E-an chose the problem of Taconic klippe in

Vermont for his first foray into field research. At that time, the reality of the Taconic allochthon was far from universally accepted. E-an recognized that the internal stratigraphy was not well defined, so there was no means by which to delineate the allochthon. He was able to establish a reproducible stratigraphy halfway through his second field season:

> Well I remembered the morning, on a hill east of the north end of Lake Bomoseen, when I found another, then the westernmost, outcrop that carried tiny specks of chloritoid. The previous winter I had noted on the map the occurrence of this mineral, wondering if there's a pattern and what it might mean; with this last outcrop the pattern suddenly emerged, though not one that I had expected. I then realized I had a hook-shaped structural pattern that agreed with the data I had gathered, so there had to be a large internal nappe as well as a mappable stratigraphy. What exhilaration! To discover what was on the ground, the first time ever, despite all the big name geologists prior to that! About an hour's work was lost in silent gloating, but it was fun.

Later in his life, E-an completed the synthesis of the Taconic problem. He realized that full understanding of the literature required knowing what every use of every stratigraphic name by various authors of Taconic geology meant. This led to a thorough review of the literature in a monographic study, *Taconic Stratigraphic Names: Definitions and Synonymies*, and set the stage for the full regional time-space synthesis that was published in 1967 as GSA Special Paper 97, *Time and Space Relationships of the Taconic Allochthon and Autochthon*. "Nowadays people take the allochthon for granted, and refine the internal stratigraphy and thrust structure, but I put forth a new paradigm. It's probably my best piece of work."

After receiving his Ph.D. in 1955, E-an spent three years as a postdoc at Woods Hole Oceanographic Institute investigating sediments collected from the Peru-Chile Trench. He hoped that by using phase-equilibrium methods he could predict clay mineral transformation during sedimentation and diagenesis in young sediments, and thereby understand the mineralogy and petrology of the older, high-pressure rocks he had observed in the Appalachians. Although at present the reactivity of clay minerals is well known, it was not at that time, as Ralph Grim (widely considered the father of clay mineralogy) and others were advocating that clay minerals were inert under low-pressure, low-temperature sedimentary conditions. In a series of papers, E-an challenged these ideas, and prevailed.

E-an then took up a visiting assistant professor position at the University of North Carolina at Chapel Hill, but continued making trips north to work with colleagues, several of whom were now at the U.S. Geological Survey (USGS) in Washington, D.C. When approached by Preston Cloud to consider joining the USGS, E-an wrote a convincing précis of work he thought could be done on sedimentary phase petrology, and Cloud undertook the difficult task of hiring a non–U.S. citizen into the USGS. E-an stayed with the USGS from 1959 until his retirement in 1989, going on "sabbatical" to teach at a top-notch academic institution about once a decade (Caltech, 1962; MIT, 1972; Princeton, 1981).

E-an's next most satisfying work was on the topology of phase diagrams, which has become some of his most well-known work, yet he spoke modestly of it: "It is awkward, but that's because I had no paradigm to guide me. Again, these days multisystem networks are the norm, but I think I contributed to its understanding; simple things like, how many invariant points and univariant lines may surround any given divariant field? How does one explain Ostwald's rule of what we would today call successive metastability? I regret I never found any collaborator to work on the topological group theory aspect of the problem. I still think that is the way to reach a general solution for n components and p phases."

Theoretical work, however, could not keep E-an out of the field, and he chose another field area in Montana "in order to get away from the Appalachians for something entirely different." In Montana, he found the stratigraphy to be straightforward, so he focused on the igneous rocks, then known only as "Mesozoic quartz-monzonite," which led to his interest in the formation of granite. Using his background in metamorphic phase petrology, he asked questions about the phase assemblages of igneous rocks, which, even though varying in age from place to place, still retained some interpretable early history. This led him to practically invent the field igneous geobarometry, a means of deducing the pressures of formation of igneous rocks, which he called his "next major creative work." With colleagues Jane Hammarstrom and Dave Brew, he continued to look at granitic rocks in Idaho, Oregon, Washington, British Columbia, and southeastern Alaska.

As remarkable as these scientific achievements were, E-an never lost sight of his role as a citizen in society, always active in promoting his values and ideals. Although his abilities to inspire, organize, and effect change were formidable, they were underutilized within the USGS. E-an's only administrative assignment within the USGS was from 1975–1977, when he was asked to be the head of the Massachusetts Cooperative Project, which was then in a state of disarray, and lacked strong leadership. Yet, he was told at the outset that he "was their second choice." He felt charged "to lead it out of the wilderness" and managed to do so, with the goal being to make two state maps, one bedrock and one surficial. E-an headed the bedrock effort, and led a congenial and productive group that finished the colossal endeavor in two years.

E-an retired from the USGS in 1989, still full of intellectual vigor, but in so doing adhered to his call to the administration to create space for young people at a time when an aging cadre of scientists and restricted hiring were problems. He was quickly invited to be an adjunct professor at the Department of Geology at the University of Maryland, and held that position with great enjoyment and gratitude effectively until 2007.

Retirement meant new opportunities, and E-an pursued his lifelong passion for geomorphology. He indulged his curiosity about how pothole features were formed in the Mather Gorge area of the Potomac River. With his usual skepticism of established views, he could not accept that they all formed solely by vertical excavation of a bedrock channel only to be later breached by erosion, stating, "[T]hey just didn't look like that." He measured a great number of them, and conceived of the idea of lateral potholes that formed on the sides of channels, with an entirely different paleohydraulic implication. He then wondered if they formed a pattern on the ground, and might reveal some insight into a long history of bedrock gorge incision, so he started to map them. This led him to decipher the geomorphic history at Great Falls, a project that grew to encompass the entire North Branch of the Potomac River, and he published a series of now-classic USGS reports.

After retirement, E-an became especially active in promoting science education. When he served on the National Research Council's Geological Sciences Board (which became eventually the Board on Earth Science and Resources), there was a move to have the board look into the state of earth science education in secondary schools. E-an was a member of that team, and became its chairman. While later serving as a counselor of the Geological Society of America (GSA), E-an proposed that GSA get involved in K–12 earth science education, and spearheaded an effort to get a committee going within the national headquarters. E-an chaired the ad hoc geoscience education committee of the GSA Council, and later served on the permanent committee. E-an's efforts culminated in the establishment of the Geoscience Education Division while he was acting president of GSA in 1991 (due to Doris Curtis's terminal illness and untimely passing), a tenure extended by election the next year.

As GSA president, his first act was to appoint a blue-ribbon committee to recommend what GSA should do to further the long-term welfare of the Earth's future. This group evolved into the Critical Issues Committee (now Caucus) of GSA. This concern with the Earth's future became a major focus for him throughout the latter part of his life. He wrote and published several essays on sustainability in *GSA Today,* and continued in his advisory capacity to the National Research Council. E-an was also deeply involved in human rights activities through service on the Committee on Human Rights of the National Academy of Sciences. He naturally became a point-man on matters concerning China. After his formal service ended, he remained active as an emeritus member.

E-an's many elected and honorary positions include: president, Geological Society of Washington, 1973; president, Mineralogical Society of America, 1975–1976; elected to the National Academy of Sciences, 1976; elected to the American Academy of Arts and Sciences, 1982; and president, Geological Society of America, 1991–1992 (acting president, 1991). E-an's overriding hope was to be "more often lighting candles than cursing the darkness," and he stated that he would like his epitaph to be "he tried." We who mourn him believe that he indeed tried, succeeded, and lit many candles along the way.

This Memorial is based on conversations with E-an as well as his autobiographical sketch.

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