E-An Zen

1928–2014

BIOGRAPHICAL *Memoirs*

A Biographical Memoir by
Daniel H. Doctor
and Susan W. Kieffer

NATIONAL ACADEMY OF SCIENCES

E-AN **ZEN**

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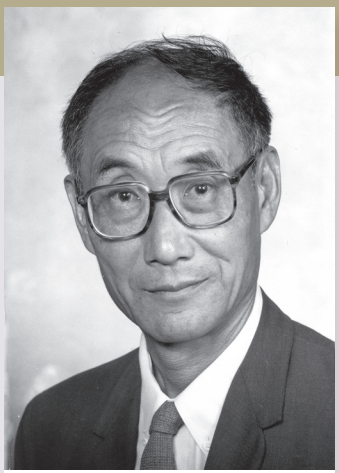

By Daniel H. Doctor and Susan W. Kieffer

E-an Zen,[1] a pioneer in multiple geologic disciplines and a leader in science policy and education, spent most of his career at the U.S. Geological Survey (USGS). His research efforts spanned metamorphic petrology, igneous petrology, geomorphology, phase equilibria, the topology of complex phase diagrams, and field relations in complex geologic settings. He considered his best work to be deciphering the stratigraphy of the Taconic allochthon. Zen also served the scientific community more broadly through his vision of the role of scientists as citizens.

Born in Beijing, China, to a chemist father who spent nearly his entire professional life in science administration and higher education, rising to become director of the Institute of Chemistry of Academia Sinica; and to a historian mother who long served as a social commentator and education reformer. E-an and his family resided in Beijing until 1942, when, amid the disruptions of World War II, they relocated to Chongqing in "Free China" and remained there until 1946.

In July of that year, the family came to the United States and settled in Cambridge, MA, 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 provided primarily by parents, tutors, and self-learning. At about age 14, he taught himself typing and English simultaneously by punching out the contents of a book written in English on a typewriter—one that had no ribbon.

In Cambridge, E-an began his first full year of formal schooling by studying English, Latin, German, mathematics, and chemistry. During that year, his first and last in a U.S.

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high school, he conquered his fear of math (which had been instilled by his mother's antagonistic views toward Chinese education) and consequently excelled at algebra. He also took top prizes in German and chemistry. E-an did well enough that year to earn a scholarship to Cornell University, which he attended as an undergraduate from 1947 to 1951.

E-an loved maps, and guided by this passion he intended to study physical geography at Cornell. Fortunately for geology, geography was not offered as a major there, so he majored in geology as the nearest related discipline, simultaneously taking advanced chemistry.

Following graduation from Cornell, E-an went to Harvard University for graduate work from 1951 to 1955. Jim Thompson, the famous geologist and thermodynamicist, was his advisor, and E-an chose the problem of Taconic klippe in Vermont for his field research. At that time, the reality of the Taconic allochthon was far from universally accepted. E-an realized that the internal stratigraphy of the allochthon was not well defined, so there were no means by which to delineate the allochthon. In only his second field season, he accomplished a feat that no prior geologists had—establishing a reproducible stratigraphy:

> *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 the specific use of each stratigraphic name, by various authors of Taconic geology, actually meant. This led to a thorough review of the literature, published in 1964 as a monograph, *Taconic Stratigraphic Names: Definitions and Synonymies*, that set the stage for the full regional time-space synthesis that was published in 1967 as Geological Society of America Special

Paper 97, *Time and Space Relationships of the Taconic Allochthon and Autochthon.* About this latter accomplishment he said: "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 the Woods Hole Oceanographic Institute, investigating sediments collected from the Peru-Chile Trench that Bernie Kummel and Henry Stetson had collected using the Atlantis 1. E-an reflected that this was "probably not a bad decision, though understanding of the Trench was to wait another 15 years or so, when plate tectonics came along."

E-an hoped that by using phase-equilibrium methods he could predict clay mineral transformation during sedimentation and diagenesis in young sediments, and thereby to understand the mineralogy and petrology of the older high-pressure rocks he had studied in the Appalachians. At Woods Hole, he began his studies of X-ray clay mineralogy with the help of Bill Bradley of the Illinois State Geological Survey. Although at present the reactivity of clay minerals is well known, it was not at that time, and in a series of papers E-an challenged the ideas of Ralph Grim, widely considered the father of clay mineralogy, and others who were advocating that clay minerals were inert under low-pressure low-temperature sedimentary conditions. In a series of papers, E-an prevailed in this challenge.

He then accepted a visiting assistant professorship at the University of North Carolina at Chapel Hill, but he continued making trips north to work with colleagues, several of whom were now at the USGS in Washington, D.C. For example, Ben Morgan, a member of E-an's Cornell class, had gone on to become the chief geologist of the USGS. When approached by Preston Cloud to consider joining the USGS, E-an accepted; and he wrote a convincing précis of work he thought could be done on sedimentary phase petrology. His first project was an experimental study of the gypsum-anhydrite equilibrium, which he undertook to see if he "could do competent experimental work." He soon saw that the answer was yes. E-an stayed with the USGS from 1959 until his retirement in 1989, having gone on sabbatical about once a decade (Caltech in 1962, MIT in 1972, and Princeton in 1981).

E-an's first field area was the northern end of the Taconic Mountains in Vermont. For his second field area, he chose the southern end of the Taconics in Massachusetts, where he studied the internal stratigraphy of Stockbridge limestone. This latter work contributed to knowledge of the "low Taconics" (the slate belt) vs. the "high Taconics." In particular,

Doug Rankin (left) and E-an Zen (right) walking along the Champlain thrust fault at Lone Rock Point, Vermont, during a geological field trip, summer, 1981. (Photo by Wally Bothner.)

it showed that these two regions are the near-craton, as opposed to the more distal facies of the accretionary wedge in the early Paleozoic Iapetus Ocean. He then decided to leave the Appalachians to do something entirely different—investigating the origin of granite in western Montana. He applied his techniques from metamorphic-phase petrology to investigate the mineral assemblages of igneous rocks and practically invented the field of igneous geobarometry, which deduces the pressures of formation of igneous rocks. With colleagues Jane Hammarstrom and Dave Brew, he studied granitic rocks not only in Montana but also in Idaho, Oregon, Washington, British Columbia, Alaska, and eventually Australia.

Some of E-an's most satisfying research was on the topology of phase diagrams; in fact it came to rank among his most well-known works, 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."*

E-an Zen in the Snowy Mountains, Australia, 1991. (Photo by Susan Kieffer.)

Jeff Grossman of the USGS proposed an annual Grand Inquisitor award in E-an's honor to recognize those who ask the most questions.

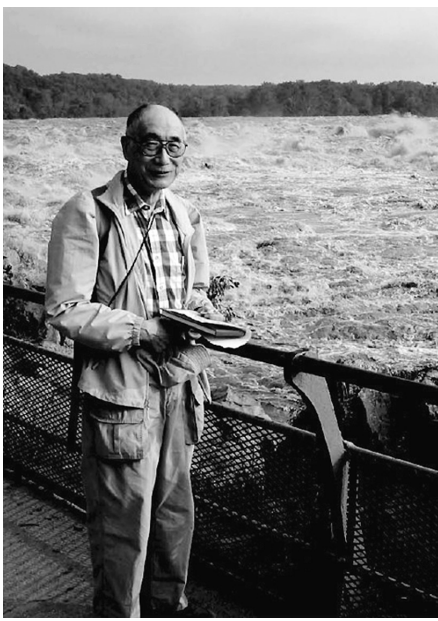
Throughout his career, E-an was aware of his role as a citizen scientist. He mentored three postdocs (Ed Grew, Janet Hoffman, and Ralph Haugerud) during his USGS career and served as an informal advisor to many others. He led a panel to formulate a vision statement for the Geologic Division in the late 1970s. His only administrative assignment with the USGS was from 1975 to 1977, when he headed the Massachusetts Cooperative Project, whose goal was to make two state maps, one of bedrock and the other surficial; his congenial and productive group in the bedrock effort finished its colossal endeavor in two years.

In 1979, E-an participated in USGS research on geologic disposal of high-level radioactive waste by examining repository size as a factor in design.

E-an delighted in sharing his latest observations at the microscope with colleagues, as well as in his awful puns. He always treated his junior colleagues as equals, insisting that he be called "E-an" rather than "Dr. Zen." After joining the Geological Society of Washington (GSW) in 1959, he became known for what he termed the "modern era of questioning" at GSW meetings. His questions reached a peak of nearly one per talk in 1985, setting a trend that continues to the present day. Jeff Grossman of the USGS proposed an annual Grand Inquisitor award in E-an's honor to recognize those who ask the most questions.

After E-an retired from the USGS in 1989, he was quickly invited to be an adjunct professor in the Department of Geology at the University of Maryland. He held this position for 18 years, with great enjoyment and gratitude.

Retirement meant new opportunities both in science and service. For example, E-an indulged his curiosity about how pothole features were formed in the Mather Gorge area of the Potomac River. With his usual



E-an at Great Falls during high-flow conditions after Hurricane Isabel in September 2003 (Source:USGS)

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. "They just didn't look like that," E-an said. So he measured a great number of lateral potholes and, with Karen Prestegaard, conceived of the idea of that they formed on the sides of channels, with an entirely different paleo-hydraulic implication. E-an then wondered if they formed a pattern on the ground, and if so might reveal some insight into a long history of bedrock gorge incision. Thus he started to map them, which led him to decipher the geomorphic history at Great Falls—a project that grew to encompass the entire North Branch of the Potomac River. E-an published this now-classic work in a series of USGS Open File 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 the appointed team, and became its chairman.

A proposal to the National Science Foundation to hold a conference on the state of geoscience education came to naught, but E-an was hooked. In 1983, at the Geological Society of America (GSA) annual meeting in Indianapolis, a symposium was presented on the topic of earth-science education in public schools; E-an was particularly taken by an eloquent plea of Preston Prather. Later, while serving as a counselor of the GSA, E-an proposed that it become involved in K–12 earth-science education, and he spearheaded an effort to get a corresponding committee established within the national headquarters. He chaired the ad hoc geoscience-education committee of the GSA Council and later served on the permanent committee. Members included active teachers, who gave the committee a sense of urgency needed for the effort.

Along with Pete Palmer, then the part-time coordinator of education for GSA, E-an attended various scientific and teacher organizations' meetings, which helped him get into the network so that he was no longer considered just an academic outsider. 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 his election the following year.

As president, E-an's first act was to appoint a blue-ribbon committee to advise the GSA on how it could further the long-term welfare of Earth's future environment; the group evolved into the Critical Issues Committee (now Caucus) of GSA. This concern with

Earth's future became a major focus for E-an throughout the latter part of his life. He wrote and published several essays on sustainability in *GSA Today*, and he 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. Moreover, 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; Distinguished Service Medal, U.S. Department of the Interior, 1979; elected to the American Academy of Arts and Sciences, 1982; Day Medal of the Geological Society of America, 1986; president, Geological Society of America, 1991–1992 (acting president, 1991); Roebling Medal of the Mineralogical Society of America, 1991; John Coke Medal, Geological Society of London, 1992; Thomas Jefferson Medal, Virginia Museum of Natural History, 1995.

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 read, "He tried." We who mourn him believe that he indeed tried, succeeded, and lit many candles along the way.

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