NATIONAL ACADEMY OF SCIENCES

KONRAD BATES KRAUSKOPF
1910—2003

A Biographical Memoir by

W. G. ERNST

Any opinions expressed in this memoir are those of the author and do not necessarily reflect the views of the National Academy of Sciences.

Biographical Memoir

Konrad B. Krauskopf

KONRAD BATES KRAUSKOPF

November 30, 1910–May 4, 2003

BY W. G. ERNST

On may 4, 2003, Konrad B. Krauskopf died peacefully in his Stanford campus home. He was 92 years old. Konnie, as he was known to everyone, had been a member of the Stanford faculty since 1939, first as professor, then after 1976 as professor emeritus. The son of a chemistry professor at the University of Wisconsin, Konnie was born in Madison on November 30, 1910. He grew up there, and received his A.B. degree in chemistry at the University of Wisconsin in 1931. While a Wisconsin undergraduate, Konnie took a geology course from Professor William Twenhofel, that sparked his interest in the subject. However, the spark wasn't quite strong enough to cause Konnie to deviate from his path in chemistry—at least not at that time. He attended the University of California, Berkeley, for graduate study in chemistry and received his Ph.D. degree in 1934. His doctoral dissertation was entitled "Photochemical Studies: I. The Role of Oxygen as an Inhibitor for the Photosynthesis of Hydrogen Chloride. II. A Method for Deriving Reaction Mechanisms from Empirical Rate Laws for Chain Reactions. III. The Photochemical Reaction between Chlorine and Formaldehyde."

The Great Depression was still affecting the job market, and his Berkeley professors recommended him for a one-year

Modified from W. G. Ernst. *Proc. Am. Philos. Soc.* 149(2005):421-425

instructorship there, which he gladly accepted. Still in need of a permanent job in 1935, Konnie traveled down the San Francisco Peninsula to Palo Alto to discuss the possibility of an instructorship in either the Department of Chemistry or the Department of Geology at Stanford University. His meeting with the geology faculty there apparently was far more exciting than that with the chemistry faculty, so he decided to matriculate into the Ph.D. program in geology.

For his doctoral research Konnie worked with Professor Aaron C. Waters on the geology of the Okanagan Valley in northeastern Washington state. Konnie's thesis, completed in 1938, was entitled "Geology of the Northwest Quarter of the Osoyoos Quadrangle, Washington." He admitted that continuing to do bench chemistry was far less interesting to him than the fieldwork that geological studies permitted. At the same time, Konnie convinced Professor Robert E. Swain, a well-known chemist who was head of the physical sciences program at Stanford, that he would make a competent instructor of an undergraduate physical science course that combined his expertise in chemistry with his newfound, intense interest in geology. So Konnie served in this capacity while also working toward his doctorate in geology.

During this period, Konnie married Kathryn McCune, better known as Kay. His lifelong companion over 64 years, she spent many summers in the field with Konnie during his early mapping forays, as did their four children. Kay passed away in 2001 after a brief hospitalization. Their children, Karen Hyde, Frances Conley, Karl Krauskopf, and Marion Foerster vividly and fondly remember their school vacations spent in geologically interesting but remote mountainous areas. Not surprisingly—for above all, Konnie was a truly modest man—the children were almost completely unaware of their father's many intellectual accomplishments until the memorial service at Stanford on June 3, 2003.

His life was one of extraordinary achievement in both geology and geochemistry. Konnie's remarkably broad, doubly deep educational background equipped him for a scholarly career characterized by pioneering interdisciplinary scientific advances. He made numerous original contributions in all aspects of academic performance that we deem critically important—research, instruction, and public as well as professional service.

Conciseness and simplicity of expression characterized Konnie's teaching style. This resulted in crystal clarity and intense illumination of subjects generally considered especially challenging. Lectures were methodically and unhurriedly delivered; they were polished in terms of exactitude and precision—he chose his words very carefully. Konnie did not use lecture notes. In guiding the research of advanced students he allowed them considerable latitude to explore their projects but was ready to provide incisive guidance when and as appropriate. He was a teacher's teacher.

Konnie published a remarkably diverse spectrum of internationally recognized research investigations, broadly arching across the fields of hard-rock geology, petrology, aqueous geochemistry, engineering geology, and mineral deposits—bringing a new degree of quantification to all of the topics he studied. He provided seminal investigations regarding the trace-element constitution of seawater and the solubilities of silica and the manganese + iron oxides. Marine waters are strongly undersaturated in the 13 minor elements Zn, Cu, Pb, Bi, Cd, Ni, Co, Hg, Ag, Cr, Mo, W, and V, the behavior of which he analyzed and elucidated: adsorption and to a lesser extent, precipitation of sulfides were shown to control concentrations except for those of V, W, Ni, Co, and Cr, for which reduction, hydration, and organic reactions were noted in this early work. Extremely

low SiO_2 dissolution kinetics were shown to account for the lack of attainment of silica equilibrium concentrations in seawater.

Employing first principles, Konnie also showed how contrasting pH-Eh-governed solubilities allow the stratigraphic separation of Mn and Fe during sedimentation. Krauskopf was one of the first to study quantitatively the geochemistry of ore-forming supercritical aqueous fluids. Economic mineral deposits are of diverse origins, but all are characterized by the marked concentration of scarce elements in the earth's crust. Many are the products of a multistage evolution, and the dissolution + aqueous transport as metal complexes followed by precipitation are governed by the laws of physical chemistry.

Detailed petrologic studies by Konnie included illuminating the origin and petrogenetic evolution of a number of Sierra Nevada and White-Inyo Range granitic plutons in eastern California (a lifelong interest), gneissic basement terranes in the Pacific Northwest, and the regional petrologic development of coastal Norway. His seamless integration combining meticulous geologic mapping, geochemical bulk-rock analyses, and radiometric dating studies of the full range of investigated rock types showed how gradational many deep-seated granitic batholiths are at midcrustal levels, as well as the difficulty (even inappropriateness) of distinguishing genetically separate plutonic bodies. The final upper crustal emplacement of granitic magma exhibits contrasting origins as well, including piecemeal stoping, shouldering aside of preexisting wall rocks, and subsolidus metasomatism.

In a very different sort of study Krauskopf illuminated the process of eruption of the brand-new volcano, Parícutin, in the Transmexican volcanic belt by demonstrating that high-standing lava in the volcano's conduit continuously

spilled over into a network of fissures while large quantities of SO_2-rich gas vented directly from the crater pit.

Concurrent with these more theoretical and analytical works he generated both mineral deposit maps and general geologic maps for the California Division of Mines and for the U.S. Geological Survey (USGS), chiefly in the Sierra Nevada Range and the White-Inyo Mountains of eastern California.

Krauskopf wrote many seminal and—through their wide usage in education—highly influential books on application of the principles of physics and chemistry to the earth, having provided geoscientists with discipline-defining texts in geochemistry and physical geology over a span of five decades. Acclaimed books include *The Third Planet, Introduction to Geochemistry, Fundamentals of Physical Science, The Physical Universe, Radioactive Waste Disposal and Geology,* and *Introduction to Earth Science*. Most of these texts have run through several (up to 10) editions. These seminal works focused on and illuminated the fundamental chemical and physical foundations of the geological sciences. Special emphases have included elucidation of aqueous solution-metal complex equilibria as well as thermodynamic applications to solid-melt-fluid partitioning These pathfinding texts were published at a time when most earth scientists were mapping quadrangles. Konnie did that too, having published four USGS quadrangle maps with a combined area of approximately 975 square miles. Visitors in the field were greatly impressed with his wide-ranging geologic abilities as well as an encyclopedic knowledge of limericks—the latter enlivening campfire discussions over many years.

He was a civilian member of the military geology division of the U.S. Army during World War II. In 1947 he was appointed chief of the G-2 geographic section in Tokyo, and

received a citation for meritorious civilian service. Krauskopf served for more than a decade as a member, then chair, of the National Research Council Board on Radioactive Waste Management. His work on that board was in large part responsible for a series of outstanding, problem defining and quantifying National Academy reports on the subject.

Konnie received many honors during his long career. He was a recipient of Fulbright, Guggenheim, and National Science Foundation fellowships for research study abroad. Krauskopf was elected to membership in the National Academy of Sciences in 1959, and in the American Philosophical Society in 1967. He served as president of the American Geological Institute in 1964, received its Ian Campbell Medal in 1984, and its Legendary Geoscientist Award in 2000. In 1961 he was awarded the Arthur L. Day Medal of the Geological Society of America (GSA), and was elected GSA president in 1967. Konnie served as president of the Geochemical Society in 1970, and received its V. M. Goldschmidt Medal in 1982. These medals and awards are among the highest honors given by these professional societies. In addition, he was honored with the Mineralogical Society of America Distinguished Public Service Award in 1994.

With such an internationally acclaimed set of scholarly contributions, one might imagine that Konnie was only comfortable in the towers of academia, but he was also an accomplished field geologist. Starting in 1978 I began fieldwork in a part of the White-Inyo Range previously mapped by Konnie. In 1971 he had published a single-authored USGS quadrangle map of the Mount Barcroft area, the result of just three summers of work. Although impressed by its detailed accuracy, I fully expected to be able to improve upon it but couldn't during the course of more than 20 field seasons. Moreover, I mapped only a quarter of the complex geology

covered earlier by Konnie. Few theoretical geochemists or textbook writers are that kind of field geologist.

Konnie was more than active—he was almost hyperactive—bounding up the stairs two at a time. You couldn't catch him as he briskly walked through the Stanford campus, or cut across the golf course. On occasion he and Kay would invite colleagues and spouses for a memorable Sunday picnic at their rustic cabin set in the redwoods of the midpeninsula. Somehow the suggested stroll after lunch generally involved several hours devoted to clearing brush from nearby mountain trails. One evening he and Kay arrived late to a small banquet we were attending at a local Chinese restaurant. Driving in, they had had a flat tire a few blocks away, and slowly crept along to the parking lot running on the rim. Afterward in the pitch dark Konnie doggedly refused help as he changed the tire and mounted the spare, gripping the jack handle menacingly when we offered to take over, or at least to assist him. He was determinedly independent.

In December 1999 a symposium was held at Stanford in honor of Konnie. It was attended by many of his students and professional associates. The meeting resulted in a two-part Krauskopf Volume, vol. 1, *Frontiers in Geochemistry: Global Inorganic Geochemistry*, and vol. 2, *Organic, Solution, and Ore Deposit Geochemistry*, published jointly by Bellwether Publishing and the Geological Society of America. When published in 2002, several of us were able to present him with his copy. I know that he really appreciated this symposium and his volume, but it was a small tribute for such an intellectual giant. Geochemistry has come a very long way, thanks to scientific leaders such as Konnie. I can think of no other geochemist who so conscientiously, selflessly, and effectively served the earth and environmental science profession in such far-ranging ways, being enormously impactful in all of

them, as geologist, geochemist, and science-technology adviser to the nation. Konrad B. Krauskopf was a scientific icon. His purposeful stride, keen wit, sage advice, and numerous insightful scientific contributions are greatly missed.

SELECTED BIBLIOGRAPHY

1941

Intrusive rocks of the Okanogan Valley, Washington and the problem of their correlation. *J. Geol.* 49:1-53.

With A. C. Waters. Protoclastic border of the Colville Batholith, Washington. *Geol. Soc. Am. Bull.* 52:1355-1417.

1943

The Wallowa Batholith [Oregon]. *Am. J. Sci.* 241:607-628.

1948

Mechanism of eruption at Parícutin Volcano, Mexico. *Geol. Soc. Am. Bull.* 59:711-731.

1951

Physical chemistry of quicksilver transportation in vein fluids. *Econ. Geol.* and *Bull. Soc. Econ. Geol.* 46:498-523.

The solubility of gold. *Econ. Geol.* and *Bull. Soc. Econ. Geol.* 46:858-870.

1955

Sedimentary deposits of rare metals. In *Economic Geology,* ed. A. H. Bateman, p. 411-463. Urbana, Ill.: Economic Geology Publishing Co.

1956

Dissolution and precipitation of silica at low temperatures. *Geochim. Cosmochim. Acta* 10:1-26.

Factors controlling the concentrations of thirteen rare metals in seawater. *Geochim. Cosmochim. Acta* 9:1-22.

1957

Separation of manganese from iron in sedimentary processes. *Geochim. Cosmochim. Acta* 12:61-84.

1959

The use of equilibrium calculations in finding the composition of a magmatic gas phase. In *Researches in Geochemistry,* ed. P. H. Abelson, pp. 260-278. New York: John Wiley.

1964

The possible role of volatile metal compounds in ore genesis. *Econ. Geol.* and *Bull. Soc. Econ. Geol.* 59:22-45.

1967

Source rocks for metal-bearing fluids. In *Geochemistry of Hydrothermal Ore Deposits,* ed. H. L. Barnes, pp. 1-33. New York: Holt, Rinehart, and Winston.

1968

A tale of ten plutons (GSA presidential address). *Geol. Soc. Am. Bull.* 79:1-17.

1969

Thermodynamics used in geochemistry. In *Handbook of Geochemistry,* vol. 1, ed. K. H. Wedepohl, pp. 37-77. New York: Springer-Verlag.

1971

The source of ore metals. *Geochim. Cosmochim. Acta* 35:643-659.

Geologic map of the Mount Barcroft Quadrangle, California-Nevada. U.S. Geological Survey Bulletin, Geologic Quadrangle Map, GQ-0960, 1 sheet.

1972

Geochemistry of micronutrients. In *Micronutrients in Agriculture,* eds. J. J. Mortvedt, P. M. Giordano, and W. L. Lindsay, p. 7-40. Madison, Wis.: Soil Science Society of America.

1977

Geologic map of the Glass Mountain Quadrangle, Mono County, California, and Mineral County, Nevada. U.S. Geological Survey Bulletin, Geologic Quadrangle Map, GQ-1099, 1 sheet.

1984

Mariposa Quadrangle, Mariposa and Madera counties, California: Analytic data. *U.S. Geol. Surv. Bull.* 1613:1-14.

1985

Geologic map of the Mariposa Quadrangle, Mariposa and Madera counties, California. U.S. Geological Survey Bulletin, Geologic Quadrangle Map, GQ-1586, 1 sheet.

1986

Aqueous geochemistry of radioactive waste disposal. *Appl. Geochem.* 1:15-23.

Thorium and rare-earth metals as analogs for actinide elements. *Chem. Geol.* 55:323-335.

1987

With P. C. Bateman. Geologic map of the El Portal Quadrangle, west-central Sierra Nevada, California. U.S. Geological Survey, Miscellaneous Field Studies Map, MF-1998, 1 sheet.

1988

Geology of high-level nuclear waste disposal. *Annu. Rev. Earth Planet. Sci.* 16:173-200.

1990

Disposal of high-level nuclear waste. Is it possible? *Science* 249:1231-1232.