James B. Thompson

1921–2011

BIOGRAPHICAL *Memoirs*

A Biographical Memoir by
Douglas Rumble

NATIONAL ACADEMY OF SCIENCES

JAMES BURLEIGH **THOMPSON**

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By Douglas Rumble

James Burleigh Thompson Jr. (1921–2011), known as "Jim" or "JBT," was a career-long student of the geology of rocks deformed and metamorphosed by tectonic plates colliding between the Green Mountains of Vermont and the Atlantic Coast of New England. Already evident in his 1950 PhD thesis at MIT, "A Gneiss Dome in Southeastern Vermont," his love of the field geology of metamorphic rocks was a primary motivator throughout his research. As an observant field geologist, Thompson was keenly aware of the patterned distribution of metamorphic mineral assemblages mapped as "isograds" in exhumed surface outcrops of sedimentary and igneous rocks previously deeply buried. He was also aware of the decades-long quest of metamorphic petrologists to apply the methods of chemical thermodynamics to gain a deeper understanding of metamorphism. As he wrote in his earliest major contribution (Thompson 1955, 67):

> *It is the hope of the present author to be able, in this paper, to resolve some of the inconsistencies in the current literature and to narrow somewhat the existing gaps between isograds, P (Pressure)-T (Temperature) curves, and differential equations.*

Thompson's diffident statement accurately forecast the direction his research was to take over the next 50 years. Thompson's personal quest to understand metamorphism led him to the works of crystallographers and chemical thermodynamicists, M. J. Buerger, J. W. Gibbs, E. A. Guggenheim, D. S. Korzhinsky, P. Niggli, F. A. H. Schreinemakers, and many others, always seeking to adapt the rigorously controlled thinking of theoretical chemistry to the beautiful mineralogy of metamorphism with its manifold, "messy" complexities of geological history and provenance. Published landmarks of discovery mark his career's progress: The thermodynamics of open systems (Thompson 1955, 1959, 1970); The mixing properties of crystalline solutions (Thompson 1967, and,

Jim Thompson, Blue-schist outcrop, Verludia Bay, Sifnos, Greece, (J. B. Brady, Smith College, June 1985.)

with D. R. Waldbaum, 1968a, 1968b, 1969a, D. R. Waldbaum, 1968a, 1968b, 1969a, 1969b); Thermally activated chemical exchange between the atomic sites of crystals (Thompson 1969, and with D. R. Waldbaum and G. L. Hovis, 1974, and with G. L. Hovis 1978, 1979); Pressure-Temperature grids of metamorphic mineral assemblages (Thompson 1961, with S. A. Norton 1968, with A. B. Thompson 1976; with A. B. Thompson and P. T. Lyttle 1976, and with A. B. Thompson, R. J. Tracy, and P. T. Lyttle 1976); The prediction of new mineral structures from crystallographic principles (Thompson 1978, 1981); and The linear algebraic analysis of the n-dimensional space defined by mineral chemical compositions (Thompson with J. Laird and A. B. Thompson 1982, 1982, 1988, 1991, 2002).

Thompson graduated from Dartmouth cum laude in 1942. In later years, he acknowledged the influence of Profs. H. M. Bannerman, J. W. Goldthwait, and Dick Stoiber, all of Dartmouth, and of his fellow undergraduate student John Rosenfeld, (professor emeritus, UCLA). After graduation, he served in the U. S. Army Air Force as a meteorologist throughout World War II. He entered graduate school at the Massachusetts Institute of Technology where he was advised by Professors H. W. Fairburn and M. J. Buerger, completing his PhD in 1950. Thompson advanced through the academic ranks at Harvard from assistant professor in 1950 to retirement as Sturgis Hooper Professor of Geological Sciences in 1992.

Thompson's diverse contributions to Earth Sciences were recognized by his election to the American Academy of Arts and Sciences in 1958 and to the National Academy of Sciences in 1967. He received the Arthur L. Day Medal of the Geological Society of America in 1964, the Roebling Medal of the Mineralogical Society of America in 1978, and the V. M. Goldschmidt Award of the Geochemical Society in 1985, the latter two the highest honors awarded by either society. Thompson served as president of the Geochemical Society and of the Mineralogical Society of America.

Thompson made fundamental contributions to understanding the field geology, mineralogy, and petrology of metamorphic rocks worldwide, and to rocks specifically in his "home turf" of New England. With his creative imagination, superior three-dimensional visualization, and long-striding legs, he was intellectually and physically equipped to master the two-dimensional outcrops of New England, overcoming dense forests and glacially steepened slopes to do so. It was the inexhaustible puzzles presented by these heated, compressed, and deformed rocks that inspired his brilliant excursions into physical chemistry to understand complex geological histories of origin.

Thompson was a pivotal figure in the history of petrology as a leader in driving the field from earlier, largely descriptive, studies to modern research firmly grounded in fundamental principles of chemistry and physics. But he insisted that theoretical models of origin must be grounded in the observational facts of Nature and not vice versa. His acceptance speeches of the Day Medal of the Geological Society of America and the Roebling Medal of the Mineralogical Society of America speak directly to the imperative to understand the natural world on its own terms:

> *Mineral crystals are among the most varied and complex known. They are related to many of the substances studied by our purer colleagues in much the way that the strokes of an artist are related to straight lines and circles. (Roebling Medal acceptance: 1979, Am. Min. 64:664–665.)*

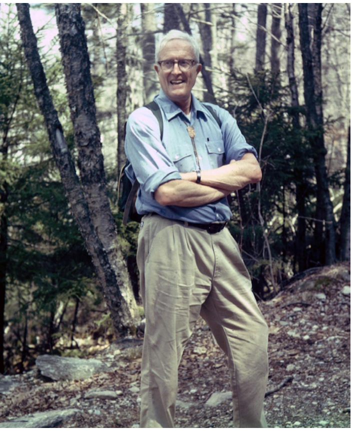
> *In the application of chemistry and physics to, say, petrology, we must not, in our enthusiasm, lose sight of the rocks. They are the source of our problems and the final court in which our hypotheses must be tried—at least if they are to be anything more than purely chemical or physical hypotheses...It would be embarrassing indeed if we were to construct an internally consistent geology, chemically and physically sound, perfect in fact but for one flaw—the lack of a planet to fit it. (Day Medal acceptance: 1964, Proceedings of the Geological Society of America)*

Thompson's legacy includes pioneering contributions to petrology, mineralogy, crystallography, and tectonics. In petrology, his early publications provide serial chapters of a practical textbook in application of J. W. Gibbs's chemical thermodynamics and the power of projective geometry to the difficult task of understanding the origin of rocks.

A visionary program of the now routine quantitative analysis of rock-forming processes with chemical thermodynamics was outlined in "The Thermodynamic Basis for the Mineral Facies Concept" (Thompson 1955, 65–103). A rigorous method for graphical representation of equilibrium among multi-component minerals in multi-component rocks first appeared in "The Graphical Analysis of Mineral Assemblages in Pelitic Schists" (Thompson 1957, 842–848). Coupled to a petrogenetic (pressure-temperature) grid, such diagrams provide a complete description of relations among minerals, mineral compositions, rock composition, temperature, and pressure for metamorphosed shale. Analogous diagrams have since been developed to represent metamorphism of a wide range of other rock types and for representation of mineral-melt equilibria in igneous petrology. The essence of metamorphic petrology is mineral reaction. Thompson presented the first, and to-date only, rigorous method for counting and identifying all possible chemical reactions that can occur in multi-component systems containing multi-component mineral solid solutions (Thompson 1982c, 33–52).

Left to right: Gerry Wasserburg, Karl Turekian, Joe Boyd, Jim Thompson, Ian Carmichael, Hal Helgeson.

Thompson introduced E. A. Guggenheim's models of crystalline solutions to mineralogists, demonstrating their power to quantitatively describe the solid solution properties of multi-component minerals in "Thermodynamic Properties of Simple Solutions" (1967, in *Researches in Geochemistry* 2, 340–361, P. H. Abelson, ed., John Wiley). Specific, detailed applications to the most common mineral in Earth's crust, feldspar, soon followed in collaboration with D. R. Waldbaum (1968, *Amer. Mineral.* 53, 1965–1999; 1968, ibid. 53, 2000–2017; 1969, ibid. 54, 811–838; 1969, ibid. 54, 1274–1298). Thompson presented a pioneering analysis of cation and anion exchange reactions that occur within multi-component mineral solid solutions in his presidential address to the Mineralogical Society of America, "Chemical Reactions in Crystals" (Thompson 1969b, 341–375). His approach later became the foundation for a comprehensive investigation of order-disorder phenomenon in triclinic feldspar crystals (Thompson and Hovis,



Jim Thompson. Mt Monadnock, New Hampshire, USA, (Photo Mark van Baalen, 1995.)

1978, 1979). In crystallography, Thompson demonstrated in classroom lectures how crystal structures can be effectively visualized in terms of polyhedral building blocks. Consideration of the single- and double-I-beam structures of pyroxene and amphibole led to his prediction of several then-unknown mineral structures. Crystallographers soon confirmed Thompson's predictions with the discovery of the triple-I-beam minerals Jimthompsonite and Clino-jimthompsonite, as well as two novel minerals with a double-triple-I-beam structure (Thompson 1978a, 238–249).

In tectonics, Thompson's geologic field mapping opened a new chapter in the understanding of the structure of the Northern Appalachian Mountains. Although well-known in the Alps for decades, where rocks are beautifully displayed in three dimensions with little or no vegetative cover, Thompson was the first to recognize near-horizontal km-scale folds (nappes), the signature tectonic feature of collisional fold mountain belts, in New England. With his extraordinary ability to visualize in three dimensions, he recognized how nappe structures were projected onto the low topographic relief of two-dimensional outcrops in the forests of New England (with P. Robinson, T. N. Clifford, and N. J. Trask, Jr., 1968).

Former students unfailingly describe Thompson's teaching as legendary. Thompson expected high levels of seriousness and rigor from students both in the classroom and the field. He taught with integrity. Every mathematical derivation presented in class was backed up by equation-packed pages of faded yellow legal pads. Some of his most profound insights were presented in classroom lectures but never published. His high expectations were frequently amply rewarded. Students learned from him to recognize key mineral assemblages in the field and to associate them with an appropriate phase equilibrium context. The elegant graphical illustrations of J. W. Gibbs (1906 reprint v. 1, Longmans, *On the Equilibrium of Heterogeneous Substances* pp. 123–128) were taught for students to develop an intuitive understanding of projecting Gibbs free energy surfaces of minerals onto compositional coordinates. His students found new applications for such diagrams in igneous petrology and economic geology. With Thompson's inspiring lectures as guides, students could make the transition from a microscopic view of a mineral association, for example, exsolution lamellae in intergrowths of Fe-Ti oxides, feldspars, amphiboles, or pyroxenes to a phase diagram for binodal-spinodal decomposition of solid solutions. Mineralogy and crystallography students were led by his lectures to the discovery of new minerals.

Thompson, best known as a petrologist, was the last of the giants who also knew as much structural geology, mineralogy, crystallography, and geochemistry as the best structural geologists, mineralogists, crystallographers, and geochemists. On the occasion of Thompson's retirement and periodically afterwards, former students, friends, and colleagues gathered in Cambridge to honor Thompson, reminisce, and express gratitude. The last gathering, shortly before he would have turned 90, included field and structural geologists, experimental petrologists, geochemists, mineralogists, crystallographers, metamorphic petrologists, ore geologists, thermodynamicists, and an Apollo astronaut. Rarely has one scientist been such a lasting inspiration to have had such a lasting influence on so many. Thompson's legacy lives on, as well, from his generous bequest to the Geological Society of America, which inaugurated and continues to support the society's Thompson Field Forums program.

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