G E O P H Y S I C I S T S

Ian S. E. Carmichael (1930–2011)

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Ian S. E. Carmichael, who had a highly imaginative research career and was legendary for his successful mentoring of graduate students, died in Berkeley, Calif., on 26 August 2011. Ian applied thermodynamic theory, experiment, and the ground truth of fieldwork to the study of magmatic rocks. Throughout the arc of his career, he played a critical role in transforming igneous petrology from a discipline that was largely descriptive to one that is rigorously quantitative.

Ian was born in London on 29 March 1930 and was educated at Westminster School. He spent 2 years in the British Army (as a parachutist and a second lieutenant in the Corps of Royal Engineers), where he saw service in Egypt, Palestine, and Sudan. He obtained his B.A. and M.A. in geology at Cambridge University in 1954 and then traveled to Canada, where he prospected for copper and wintered in the Arctic. Ian returned to England and obtained his Ph.D. in 1958 at Imperial College London. His thesis, on Thingmuli volcano in eastern Iceland, addressed one of the most contentious issues in Earth science at the time (before the days of isotope geochemistry and plate tectonics), namely, the origin of silicic magma from basalt in the absence of preexisting continental crust. The problem went to the heart of crustal evolution.

On the completion of his Ph.D., Ian joined the faculty at Imperial College London and then moved to the University of California, Berkeley in 1964. At that time, the study of magmatic rocks was largely descriptive. In contrast, the questions that Ian was beginning to ask, well before their time, were whether the crystals in erupted lavas could be used to reveal the temperature, pressure, dissolved water concentration, and oxidation state of the magmatic liquids from which they crystallized. These questions required a thermodynamic approach, which was a reasonably developed tool in the field of metamorphic petrology but nearly nonexistent for igneous petrologists studying crystal-liquid equilibrium. The problem was the lack of information on the thermodynamic properties of magmatic liquids under in situ high-temperature conditions. Thus, the barrier to the quantitative study of magmatic rocks was immense throughout the 1960s and 1970s.

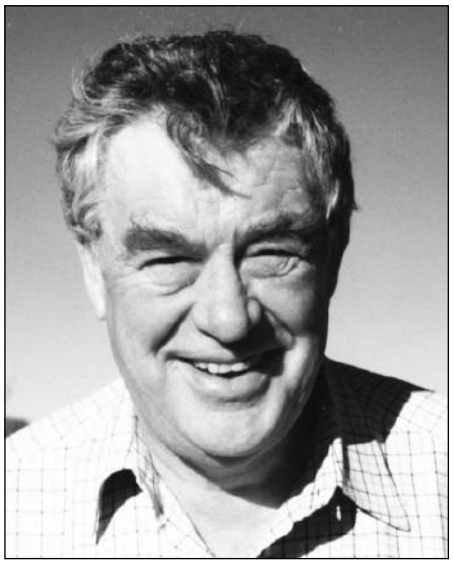
Although Ian arrived at Berkeley with little training in thermodynamics, he soon rectified matters by sitting in on thermodynamics courses in the chemistry department, working on problem sets and exams side by side with his graduate students. It was not long before a "mothballed" drop calorimeter from the Hearst Mining Building was moved into Ian's laboratory, and he and his students began to systematically obtain enthalpy and heat capacity data for high-temperature silicate liquids. Soon after, he pursued a parallel program with his students to measure the density and compressibility of silicate liquids.

For Ian, the thermodynamic property data were never a goal unto themselves; it was the application of these data to volcanic rocks through a thermodynamic model that fully captured his imagination. With his student Mark Ghiorso, the first version of a crystal-liquid thermodynamic model applicable to magmatic systems was published in 1983. Ghiorso continued to develop this model over the ensuing decades into the widely used MELTS software package. It was during the early development of MELTS that Ian spawned a series of experiments that provided the first definitive model of how the oxidation state of a magmatic liquid (as recorded by its ferric-ferrous ratio) varies with melt composition, oxygen fugacity, temperature, and pressure.

Throughout the decades that Ian was making tremendous strides in the thermodynamics of magmatic systems, he was consistently pursuing field-based studies throughout the western United States, as well as in far-flung locales including Africa, New Guinea, New Zealand, and the Aleutian Islands. For the last 30 years of his career, Mexico was the principal site of his field program. Ian's fieldwork at this volcanic arc led him to begin an experimental program with his students to quantify the role of water in magmatic processes, thus helping extend the MELTS thermodynamic model to hydrous systems.

One of the most powerful aspects of Ian's approach to the study of magmatic rocks was the consistent interplay among theory, experiment, and field studies. This may explain why his publications have well over 12,000 citations with an *h*-index that exceeds 60, reflecting the depth and breadth of his impact. He has been widely recognized for his research achievements through the N. L. Bowen Award (AGU), the Arthur L. Day Medal (Geological Society of America), the Murchison Medal (Geological Society of London), the Schlumberger Medal (The Mineralogical Society), and the Roebling Medal (Mineralogical Society of America). He was elected a Fellow of the Royal Society in 1999.

What is particularly impressive about Ian's research record and his mentoring of students is that they were achieved while he was deeply involved with editorial duties and university administration. For 17 years he was editor in chief of *Contributions to Mineralogy and Petrology,* and for another 14 years afterward he continued as an associate editor. After two tours as chair of the Department of Geology and Geophysics (now Earth and Planetary Science), he was an associate dean and associate provost on the Berkeley campus for 17 years. For the last 7 years of his career, he was the director of the Lawrence Hall of Science, Berkeley's public science center, and for two of those years, he was also acting director of the botanical gardens at the university.



Ian S. E. Carmichael

Perhaps Ian's greatest reputation was as an advisor to 29 Ph.D. students, many of whom now populate major universities and the U.S. Geological Survey. There are three aspects of Ian's character that may explain his remarkable success as a mentor. First, he gave enormous freedom and encouragement to his students to follow their own interests. He loved it when they went off to pursue a topic that he (and they) initially knew little about, because it meant that he was going to learn something new. He knew from his own experience that you did not have to apprentice to someone to learn a specific skill; you could go off and teach yourself. Second, he had an enormous work ethic and capacity to push himself hard that were fueled by his infectious enthusiasm for the thrill that comes with discovery and achievement. He never asked his students to work harder than he did, but the bar was set awfully high by his own example. Finally, and most important, the outpouring of ideas from Ian's creative and fertile imagination undoubtedly led to his intellectual generosity—he continuously and freely shared his ideas with his students and was thrilled to see them run with an idea, develop it, and become the ones identified with it.

For all of us who crossed paths with Ian, he left an indelible mark. None of us escaped being shaped, in some way, by the hurricane force of his personality. For so many of us, his exuberant pushing and prodding forced us to stretch ourselves and realize potentials we never knew we had. For this, he will never be forgotten.

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