BOOK REVIEWS

A Giant in Geochemistry

Victor Moritz Goldschmidt. Father of Modern Geochemistry. BRIAN MASON. Geochemical Society, San Antonio, TX, 1992. xii, 184 pp., illus., + plates. $40; to GS members, $30. Special Publication, 4.

"To find the general laws and principles which underlie the frequency and distribution of the various chemical elements in nature": This definition of the goal of the science of geochemistry, which would be an accurate introduction to a college-level course on the subject in 1993, was also the most important scientific objective of Victor Moritz Goldschmidt in founding the Norwegian Raw Materials Laboratory in 1918. At the turn of the century there was little appreciation of the extent to which chemical principles could be applied to the solution of geological problems, and such research prior to Goldschmidt's efforts had been conducted in a piecemeal and empirical fashion, with little comprehension of underlying systematics. Brian Mason, whose own studies with Goldschmidt were terminated after only three months by the German invasion of Norway on 9 April 1940, has written an enlightening and thorough biography of one of the giants of modern science.

It is astonishing, even to experienced geochemists, just how many of the important concepts in this field originated with Goldschmidt. From his Ph.D. thesis at the University of Oslo in 1911 comes the concept of contact metamorphism, the mineralogical changes that occur in rocks when hot magma intrudes nearby, and the idea that the minerals so formed are completely determined by the composition of the starting material and the temperature and pressure of recrystallization. From the Gibbs phase rule Goldschmidt derived the mineralogical phase rule, which states that the number of minerals in any given rock cannot exceed the number of components—a consequence of the formation of rocks over ranges of temperature and pressure, which yields two degrees of freedom. He became a professor of mineralogy and petrology at the University of Oslo and by 1922 had derived the concept of the primary geochemical differentiation of the Earth by analogy with meteorites. According to this idea, the Earth initially was a gas-enveloped ball consisting of three immiscible liquids whose different densities caused them to separate from each other, forming the Earth's core and mantle. Elements showing a thermodynamic preference for the dense nickel-iron liquid, the iron sulfide liquid, the low-density silicate liquid, or the gas he termed siderophile, chalcophile, lithophile, and atmophile, respectively. In the early 1920s, his laboratory was engaged in both crystal structure determination by x-ray diffraction and chemical analysis of rocks and minerals by x-ray spectrography; from these data he laid the foundations of crystal chemistry. In 1925 he discovered the lanthanide contraction. The next year he prepared the first table of ionic radii, discovered the distinct distribution in nature of europium compared to all other rare earth elements, known today as the europium anomaly, and correctly attributed this anomaly to the unique ability of europium among rare earths to form a divalent ion of significantly different size from those of the trivalent rare earths under reducing conditions. In the same year, he demonstrated the relationship between radius ratio and coordination number in ionic crystal structures and used his new crystal chemical principles to clarify the concepts of isomorphism, polymorphism, solid solution, and the secondary geochemical differentiation of the Earth by fractional crystallization and density separation of dense iron-magnesium silicates from less dense quartz and feldspar. In 1929 he used 81 analyses of glacial clay to arrive at an estimate of the composition of the Earth's crust that was remarkably similar to that proposed five years earlier by Clarke and Washington on the basis of 5159 superior analyses of igneous rocks. He attributed the differences between the two estimates to solution effects on the clays.

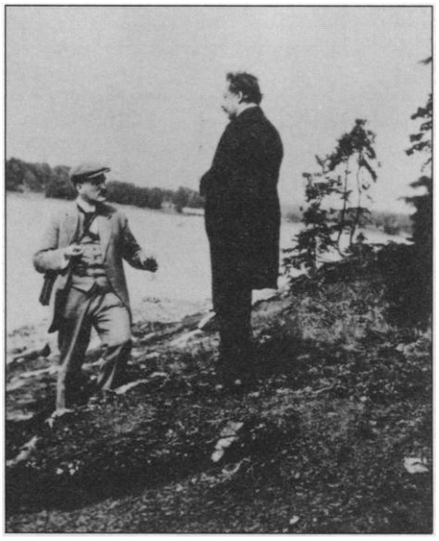
"V. M. Goldschmidt and R. Pohl (physicist) on an excursion in the Habichtswald, near Kassel, 1934. The notice reads: 'It is forbidden to approach the ruins because of danger to life.'" [From *Victor Moritz Goldschmidt*]

After becoming professor of mineralogy at the University of Göttingen and building a new mineralogical institute there in 1929, Goldschmidt concerned himself with quantifying the redistribution of individual elements during sedimentary processes. In 1934 he discovered the importance of ionic potential in predicting the behavior of an element during weathering, solution, and precipitation and was the first to realize that the anthropogenic input of CO_2 to the atmosphere greatly exceeds the volcanic input. He and his colleagues refined emission spectroscopy with the carbon arc and used this technique for the rapid and accurate determination of many rare elements in rocks for the first time. Later, he proposed reasons for discrepancies between the amounts of specific elements supplied by rock weathering to the oceans and the amounts actually found in seawater. Two years after the Nazis took power in Germany in 1933, Goldschmidt fled the country, returning to Oslo. Around this time he predicted the ionic charge and radii of the actinides; and in 1938 he published a review of all available data on the abundances of the elements, most of them from his Göttingen institute, in which he combined meteoritic and solar data into a table of cosmic abundances that, when plotted against atomic number, show many of the major features of modern estimates upon which current models of stellar nucleosynthesis are based.

Mason's book provides sufficient detail to allow the reader to speculate on the reasons why so many fundamental principles were discovered by this one man. Was it his surroundings, the influence of the people around him, the era in which he lived? Living in southern Norway certainly must have helped, for the area's beautiful minerals and unusual rocks sparked

his interest in earth science as a teenager and influenced much of his early work. His closeness to his father, a distinguished professor of physical chemistry, was probably important in developing his instinct for applying the principles of that field to geology. The ideas and expertise of the many talented scientists attracted to his laboratories and with whom he worked certainly contributed greatly to his research effort. Moreover, he lived at a time when great discoveries were being made in the basic sciences of chemistry and physics. The most important factor, however, was the man himself. A dedicated hard worker with an encyclopedic memory and a talent for creative thinking, he grasped those new developments in chemistry and physics and almost immediately exploited them for his geochemical research. For example, just six years after Debye and Scherrer developed the powder method of x-ray diffraction in 1917, Goldschmidt began publishing papers on crystal structures determined by this technique in his laboratory. Similarly, the year after Hadding designed an x-ray spectrograph specifically for mineral analysis in 1921, Goldschmidt was using one built in his own laboratory. Although the rapid transfer of new principles and techniques of chemistry and physics to the field of geology was resisted by many North American earth science departments even through the 1960s, this approach pioneered by Goldschmidt has now become ingrained in modern geochemistry, just as undergraduate training in mathematics, physics, and chemistry in addition to earth science, such as Goldschmidt received, has become a prerequisite to graduate study of modern geochemistry.

Mason has skillfully interwoven accounts of these scientific discoveries with details about Goldschmidt's personal life, including his work habits, his sense of humor, his professional rivalries and alliances, and his interactions with family members, friends, and pets. The book contains many excerpts from his personal papers, almost all of which were translated from their original Norwegian, Swedish, or German by Mason himself. Particularly well documented is the gripping story of how Goldschmidt narrowly escaped three separate attempts by the Nazis to deport him to the death camps in Poland along with the rest of Norway's Jews. Appendixes to the book contain memorials written by fellow scientists, a complete bibliography of Goldschmidt's writings, his medical history, a list of his scientific honors, and, for the nonspecialist, tables of chemical symbols and geological time periods and a glossary of technical terms. Profusely illustrated and extensively annotated, most interestingly with brief biographies of his colleagues and acquaintances, this masterly book is a fitting tribute to this towering figure.



"V. M. Goldschmidt and Albert Einstein (in long black coat) at one of the islands in Oslofjord where they were looking at lower Paleozoic sediments. Goldschmidt is holding a specimen(s) which he is in the process of showing Einstein." [From *Victor Moritz Goldschmidt*]

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From Plant to Planet

Scaling Physiological Processes. Leaf to Globe. JAMES R. EHLERINGER and CHRISTOPHER B. FIELD, Eds. Academic Press, San Diego, CA, 1993. xvi, 338 pp., illus., + plates. $69.95 or £56. Physiological Ecology.

One of the most exciting scientific developments of the last 20 years has been the recognition of the fundamental changes in the Earth's atmosphere being wrought by human activities. Climatologists, oceanographers, geologists, computer scientists, and experts in remote sensing envision a forbidding future of global warming, caused by rising levels of carbon dioxide and other trace gases and triggered by the combustion of fossil fuels and tropical forests on an unprecedented scale. Until now, ecologists have contributed rather little to such analyses, even though regional differences in plant reflectance and photosynthesis play key roles in affecting global energy exchange and CO_2 levels.

This volume represents a first attempt by physiological ecologists to show how the leaf-level processes of photosynthesis and respiration might scale up to broader levels and provide a better understanding of global atmospheric trends. Physiological ecologists study how a plant's characteristics help determine its gas exchange, growth, and competitive ability in different environments; such work would be immediately relevant to questions involving global change if the traditional focus on individual plants were shifted to whole communities, landscapes, or continents. This elegant idea is the central theme of this volume, a collection of 20 essays based on a symposium held at Snowbird, Utah, in 1990.

Levin provides a conceptual framework for studying ecological interactions at a variety of spatial and temporal scales. Communities and landscapes are inherently patchy and dynamic; these flickering mosaics exhibit different patterns, processes, and disturbance regimes at almost every scale, and attempts to formulate or understand scaling laws must incorporate such variation. Schimel and his colleagues vividly illustrate this idea by describing the first landscape-scale model for exchanges of energy and matter between the atmosphere and biosphere. In the Flint Hills of Kansas, local and remote sensing techniques were integrated to obtain a picture of heat and CO_2 fluxes over 256 square kilometers of prairies. Habitat patches differed in plant biomass, reflectance, and gas exchange depending on topography, grazing intensity, and fire history. Clouds rolling over the landscape were one of the strongest influences on plant photosynthesis and water loss; cloud formation, in turn, was influenced by the stature, roughness, reflectance, and transpiration of the vegetation carpeting that landscape, suggesting a deep tie between vegetation and atmosphere at the scale of a few kilometers.

Six chapters discuss the problems involved in scaling rates of carbon gain and water loss from leaves to canopies to communities. Norman provides a clear overview of attempts to model canopy photosynthesis, from the "big leaf" analogy, to light-stratified canopies, to complete models involving stratification of light, water vapor, and carbon dioxide with plant feedbacks on each. Eddy transfers of heat and matter within plant canopies are reviewed by Baldocchi. Jarvis and Reynolds *et al.* debate the relative merits of "bottom-up" models for biosphere-atmosphere interactions based on ecophysiology, vs. "top-down" models based on empirical data on mass action at broad spatial scales. Running and Hunt review the successful analysis of carbon uptake and water loss by conifer forests along continental climatic gradients,