Victor Moritz Goldschmidt (1888-1947): Father of Modern Geochemistry and of Crystal Chemistry

Bob Weintraub, Director of the Libraries, Sami Shamoon College of Engineering, Beersheva and Ashdod.

"The primary purpose of geochemistry is on the one hand to determine quantitatively the composition of the earth and its parts, and on the other to discover the laws which control the distribution of the individual elements."(Goldschmidt)

"During the preceding hundred years geochemical research was largely synonymous with the analysis of those parts of the earth accessible to visual inspection and chemical assay. From the nature of things it could be little more; interpretative geochemistry, the creation of a philosophy out of the mass of factual information, had to wait upon the development of the fundamental sciences, physics and chemistry. Fundamental advancements in these sciences were made in the early years of this century, such as the discovery and exploration of radioactivity, the Rutherford-Bohr atomic structure, the discovery of x-ray diffraction and its application to chemical analysis and crystal structure. It is the mark of Goldschmidt's genius that he seized upon these discoveries. His insight and intuition, his ability to plan and expedite extensive research programs, and not least, his recruitment and inspiration of devoted research associates, revolutionized geochemistry. Thanks largely to his work and stimulus, geochemistry has developed from a somewhat incoherent collection of factual data to a philosophical science based on the geochemical cycle, in which the individual elements play their part according to established principles." (Brian Mason, 1991).

Victor Goldschmidt

Victor Mortiz Goldschmidt was born in Zürich to Jewish parents. He grew up in a series of European capitals where his father held professorial appointments. He earned his doctorate at the University of Christiania (later Oslo) in 1911, with a thesis entitled, "The Contact Metamorphism in the Kristiania Region," which has become a classic in geological literature. In 1914 he accepted the position as professor and director of the Mineralogical Institute of Oslo, where he remained until 1929, at which time he moved to Göttingen. .
(Victor Moritz Goldschmidt, Father of Modern Geochmistry: B. Mason, 1992; Prin. Goechem: B. Mason and C. B. Moore, 1982; G.B. Kaufman, Chem Educ., 1997; E.D. Goldberg, Dict. Sci. Biog.; The Griffin, A. Kramish; and references therein.)

Metamorphism

Metamorphism is the processes that cause the recrystallization of rock material that take place below the zone of weathering. Metamorphism is induced in solid rocks as a result of pronounced changes in temperature, pressure and chemical environment. The changes affect the physical and chemical stability of the minerals in equilibrium and metamorphism results from the effort to establish a new equilibrium. The rocks remain solid during this process.
Goldschmidt's thesis dealt with thermal metamorphism in the Oslo region, induced at the contacts between the Permian plutonic igneous masses with the varied groups of Palaeozoic sediments. The phenomenon is called contact metamorphism and the resulting rock types are known collectively as hornfels. He applied physical chemistry and the recently "popularized" Gibbs Phase Rule - due to the work of Roozeboom - to geological problems and in particular to rock metamorphism. Goldschmidt used his data on the hornfels to arrive at the general principal which he called the Minerological Phase Rule. This powerful rule states that the maximum number of crystalline phases that can exist in rocks in stable equilibrium is equal to the number of components. This rule limits the number of minerals present in a rock.
Goldschmidt showed the value of the phase rule in setting limits to the p-t curve of rock formation by applying it to the metamorphic reaction of siliceous limestone being converted into wollastonite:

$CaCO_3 + SiO_2 = CaSiO_3 + CO_2$
Calcite + quartz = wollastonite + CO_2.

For the next ten years he continued his work on rock metamorphism and expanded it to include all of the mountains in the south of Norway.

The Differentiation of the Earth

Goldschmidt (1922): It is conceivable that the original state of the Earth was a homogenous or nearly homogeneous mixture of the chemical elements and their compounds. Today, however, the Earth is far removed from a homogeneous state. The material distribution within the Earth has by no means reached a final equilibrium state; we observe instead an active redistribution of matter and energy. The processes which have resulted in the inhomogeneity of our planet and still contribute to the migration of material I would summarize in the expression "The Differentiation of the Earth." Godlschmidt established the basis for the new geochemistry.

Goldschmidt pointed out the importance of the primary geochemical differentiation of the elements during geological evolution. He classified the elements in the earth into four groups: siderophile, chalcophile, lithophile, and atmophile. These are groups such that the elements have an affinity for metallic iron, for sulfide, for silicate, or for the atmosphere, respectively. (Later he added biophile, for those elements commonly concentrated in organisms). The geochemical character of the element is determined to a large extent by its electronic configuration, and thus related to its position in the periodic table. It was during this period of study that Goldschmidt showed the significance to geochemistry of meteorite compositions. Astronomical and chemical evidence, point to the fact that the earth and meteorites have a common origin.

Crystal Chemistry

During World War I, Norway was largely cut off from overseas sources of supply. In 1917 Goldschmidt was appointed the Chairman of the State Raw Materials Committee. In this capacity he found local sources to replace previously imported materials. This period led Goldschmidt to the study of crystal chemistry. Goldschmidt: "The experimental work in the field of crystal chemistry which in recent years the Mineralogical Institute of the University had undertaken had as objective to throw light on the geochemical distribution and technical properties of practically important materials. During the carrying out of these researches, which for the most part, was by means provided by the Raw Materials Committee of the Norwegian State, there appeared a series of generally crystallo-chemical relationships which made possible a notable deepening of the principles and data of crystal chemistry."

Bernal (1948): He wanted to start work straight away, but, realizing his limited knowledge and apparatus he could not compete with the Braggs in the analysis of complex minerals like the silicates, he began on simple structures - the AX and AX2 compounds which were mostly of the rock salt, cesium chloride, rutile, corundum, and calcium fluoride types. Goldschmidt's original approach was to examine systematically binary compounds of most of the elements. What he did was a model of extensive work. In that sense he was a real chemist; a physicist would spend years working out one structure, but he spent a few months working out a very large number. In two years he and his coworkers, several of whom like Barth, Oftedal, and Zachariasen were to become noted geochemists and crystallographers, worked out structures of 200 compounds of 75 elements and in that way established the extensive basis on which to found general laws...Goldschmidt's characteristic contribution was that of using this new view of ionic size to explain the morphotrophy, or the changes of structure, which occurred in passing along any series of similar compounds on changing the atomic number. He noticed that this transition from one crystal type to another occurred when the radius of one or other of its constituent ions was altered, and, by considering groups of compounds with ions of different charge such as the halides and the oxides, that it was the radius ratio that determined the structure. This led him directly to the most fundamental concept of crystal chemistry, the importance of coordination."

He proposed the first general law of crystal chemistry: The structure of a crystal is determined by the numerical proportions, the ratio of radii, and the polarisability of its ions.

In 1925, based on his extensive studies on ionic compounds, Goldschmidt was able to draw up the first tables of empirical atomic radii for most of the ions in the periodic table. He was thus able to understand clearly for the first time the significance of the replacement laws that had made mineralogical chemistry such a confusing subject. A year later, Linus Pauling at the California Institute of Technology, published a similar table based on wave mechanic calculations. Mason: "The correspondence between the two tables was a brilliant confirmation of the theoretical background."

Goldschmidt stated the rules that relate ionic size to atomic structure: for the elements in the same group (vertical column) of the Periodic Table, the ionic radii increase as the atomic numbers of the elements increase; for the positive ions of the same electronic structure the radii decrease with increasing charge; for an element that can exist in several valance states, that is, form ions of different charge, the higher the positive charge of the ion, the smaller the radius.

Bernal: "Before leaving this field, Goldschmidt entered the last remaining large area of chemical ignorance, that of the metals and alloys. Here he early realized that the effective diameters of atoms were quite different from those in the ionic state and were always larger. The differences varied very much between the alkali metals, where they were more than twice, and the transition metals, where they were hardly anything at all…" Goldschmidt compiled the first table of metallic radii. In recognition of his work in this field, J.D. Bernal refers to Goldschmidt as one of the founders of modern alloy chemistry.

In 1924 Richard Willstätter proposed Goldschmidt to the faculty at the University of Munich as the replacement for the retiring Prof. Paul von Groth. Golschmidt's appointment was rejected by the faculty because they did not want another Jewish faculty member. Willstätter, himself Jewish, in protest announced his own resignation the evening after the faculty vote.

Even before the vote, Goldschmidt had his doubts about the appointment. He wrote to Willstätter with alarming foresight: ...Racial fanaticism is one of the evil phenomena of the present day, and I fear it will spread over the whole world...In the spring of 1914 the choice between Munich and Kristiania would not be in doubt; today I have serious reservations about Munich; no one knows what will be the state of the world in 1934."

In 1929 Goldschmidt accepted a Professorship at Gőttingen. Here he studied the abundance and distribution of the individual elements and its implications for the geochemical cycle. He worked on both terrestrial materials and extraterrestrial meteorites. He studied the geochemistry of germanium, gallium, scandium, beryllium, the noble metals, boron, the alkali metals, selenium, arsenic, chromium, nickel, and zinc. In 1934, in the course of this work, Goldschmidt published the geochemical cycle of carbon. His cycle showed overwhelmingly that the cycle of carbon is determined by biochemical reactions. In 1936 he wrote the following, in which he anticipated the significance of man-made carbon-dioxide emissions: "The carbon cycle is of special interest because it demonstrates the great significance that the industrial combustion of coal and other fuels has already had on the carbon dioxide content of the atmosphere. The amount of carbon dioxide which each year is added to the atmosphere by the combustion of fuels is two hundred times greater than that contributed by the world's volcanoes. This demonstrates that human activity in our time is a highly important factor."

Goldschmidt:

"Then in spring 1935, on May 1, there was placed in Gőttingen a big sign board, not far from the road to my institute, with the inscription, 'Jews not desired.' I gave notice that I was resigning my professorship if such board was not taken off, as I could not reconcile my presence in Gőttingen with such an open attack against Jews in the same town. Before 24 hours had gone the thing had been taken off. However, several months later (in August) a signboard of the same kind was reerected, that time just opposite my institute. I renewed my action of protest, and that time it was not removed even at my request, as such boards at the same time had been placed in all German towns by direct order of the uppermost party rulers. Consequently, next day, August 11, as an ultimate protest I resigned my position, and designated my intention to leave the country."

Goldschmidt returned to Oslo where a position was made available to him. He worked now on the cosmic and terrestrial distributions of the chemical elements and studied the significance of the isotropic compositions of the elements in minerals. Hans Suess later wrote that the concept of "magic numbers" that define the structure of the nucleus of the atom was first discussed by Victor Goldschmidt in a 1938 paper, and that he and Jensen had appropriated the idea without giving credit. For work in this area, Jensen was awarded the 1963 Nobel Prize in Physics. Between the years 1929 and 1936, Goldschmidt was ten times unsuccessfully nominated for the Nobel Prize, twice by Max Planck and twice by Fritz Haber, among others.

Occupied Norway

In April 1940 the Germans occupied Norway. Until January 1942, Goldschmidt continued to work without interference of the Germans. He was interested in the work of Fritz Houtermans and Robert Atkinson and their theories of the fusion of the elements that created thermonuclear reactions in the sun and stars. That January, Goldschmidt completed his work on the chemistry of what he called "superuranium", or plutonium, and published it in Norwegian. His work paralleled the secret work of Glenn Seaborg in the United States. According to A. Kramish, had Heisenberg and his colleagues come to a proper appreciation about plutonium, "The one person under Hitler's control who might have put the German atomic program on the right track was the Norwegian Jew Victor M. Goldschmidt, still in occupied Norway."

In February 1942, the 2000 Norwegian Jews were required to fill out questionnaires about their "ancestry." Goldschmidt's passport was now stamped with the letter J. In March, Vidkun Quisling decreed all Jews to be illegal aliens. In October 1942, Goldschmidt was arrested and sent to the Berg concentration camp near Tönsberg, 50 miles south of Oslo. He was released in early November. He was rearrested later on in November and was sent to the docks for immediate deportation to Poland. He was again released. Goldschmidt believed that his life was saved due to the importance placed on his current work by the Ministry of Agriculture. The carbonates in the Fen area contain the phosphate mineral apatite. During this period, Goldschmidt was working to extract the phosphate mineral for use as fertilizer.

On December 18, 1942, Goldschmidt was picked up by Norwegian Resistance and transported to Sweden. During the war, the resistance sent 1100 Jews to Sweden. Of the 760 Jews that were sent to Poland, only 24 survived the war to return to Norway.

Goldschmidt was offered the chair of mineralogy at Uppsala University. He felt strongly, however, that it was his duty to continue on to England, that his knowledge of technical developments in Norway and of the German interest in them would be of great value to the allies. He went to London in March 1943, and attended 150 conferences in which he detailed the German exploitation of Norwegian raw materials, the production of heavy water, among others. He accepted a position in Scotland, and in 1944 moved to the Rothamsted Experimental Station near Harpenden, England. In June, 1946, he returned to his former position in Oslo. He died in March, 1947.

The Wisdom of Moses Katz and Lesser Rosenblum

Paul Rosbaud related the following (Goldschmidt's friend; WWII hero who under the cover of scientific advisor to Springer-Verlag in Germany was a secret agent who provided vital intelligence on weapons systems to the British; Rosbaud made use of Norwegian students studying in Germany to transport intelligence to occupied Norway, and from there it was sent to neutral Sweden.):

"One episode influenced V.M. deeply and occupied his mind until the end of his life: it happened early in November 1942, in the County Hospital in Tönsberg, Norway, which was then the internment camp for Norwegian Jews. After a day of humiliation and torment by his jailers, V. M. talked to two other prisoners, whose names deserve to be recorded: Moses Katz, an orthodox Jew, and a hosiery peddler, and Lesser Rosenblum, socialist, atheist, and manufacturer of umbrella handles. V.M. suggested that they should remember the names of their tormentors, so that any survivors might extract retribution. The reply of the pious Moses Katz was a surprise to V.M.: 'Revenge is not for us; that must be left to the Almighty.' With the arrogance of a scientist confident of his superior knowledge, V.M. asked what prayers would be permissible to God from men in their position. Katz replied without hesitating a moment: 'You may pray that the hearts of your enemies may be enlightened.' Goldschmidt, still not admitting defeat, turned to the atheist Rosenblum and asked for his view. His reproof was equally unexpected: 'We must break the evil circle of retribution, or there can never be an end to evil.'

Goldschmidt became very humble after this experience. He had escaped, but his two friends from Tönsberg were facing death in Poland's gas chambers. He regarded their sayings as lucid and practical improvements on the Old Testament. Through them he learned not to forget, but to forgive...

In one of his last letters to me he wrote:

The wisdom of the Moses Katz principles is undeniable…And I am fully convinced that it is my duty towards science and decency to stand firm in continuing my work as long as health permits, thus giving an example to at least some of my junior colleagues. Often I think that (to maintain principles) to be even more important than my contributions to scientific and industrial research, and my scientific teaching. To set a new standard of morality is a matter of great urgency in these times…