V.M. Goldschmidt: The British Connection

A Tribute on the 60th Anniversary of his Death

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Introduction

V.M. Goldschmidt was born in Zürich on 27 January 1888 and died in Oslo on 20 March 1947. His scientific life and work have been described in detail by Tilley (1948), Mason (1992) and Wedepohl (1996). Goldschmidt moved to Kristiania (renamed Oslo in 1925) in 1900 when his father, Heinrich Jacob Goldschmidt, became Professor of Physical Chemistry at the university. He attended the university from 1905 and was awarded his doctorate in 1911 for his work on contact metamorphism of the Kristiania region which subsequently became a classic. In 1914, he was appointed Professor and Director of the Mineralogical Institute of the university at the age of 26. He continued his work on the magmatic and metamorphic rocks of Southern Norway intermittently until 1926.

In 1917, Goldschmidt was appointed Chairman of the Commission for Raw Materials and Director of the Raw Materials Laboratory in response to shortages of raw materials in Norway under war time conditions (Mason 1992). In this, he proved adept. Amongst the projects were investigations of Norwegian ilmenites for the production of titanium dioxide for use in paint manufacture, of forsterite, a magnesium-rich olivine (Mg_2SiO_4) of which Norway has abundant supplies, as a refractory and of the carbonatite deposits of the Fen District in southern Norway. These carbonatite deposits contain high concentrations of niobium which is present as pyrochlore, $(Na,Ca)_2Nb_2O_6(OH,F)$, and of apatite which had potential as a fertilizer. All these projects were eventually successful and led to Goldschmidt earning considerable royalties from patents. His work on the phosphate deposits of the Fen area also subsequently saved him from deportation to Poland in 1942. However, the great expansion in the use of olivine as a refactory only came after Goldschmidt's death. By 1991, Norway was producing approximately three million tonnes of olivine per year (Mason 1988).

V.M. Goldschmidt on a field trip in the Stavanger area of southern Norway in 1922 where he met C.E. Tilley for the first time.

The work of the Raw Materials Laboratory was funded by the Norwegian Ministry of Commerce. Goldschmidt was therefore able to begin recruiting a remarkable group of young research associates (Mason 1992). Of these, Lars Thomassen became his principal research associate and responsible for the construction and operation of the X-ray equipment. At this time, Goldschmidt had defined the basic problem of geochemistry as finding the general laws and principles which underlie the frequency and distribution of the elements and proposed to attack the problem from the point of view of atomic physics and atomic chemistry (Mason 1992). In 1921, Assar Hadding, a Swedish colleague, had designed an X-ray spectrograph specifically for the chemical analysis of minerals and rocks. In March 1922, Thomassen built an X-ray spectrograph to Hadding's design. In addition, P. Debye and P. Scherrer had already developed the Debye-Scherrer X-ray powder diffraction method of determining crystal structure in 1916 which was much more rapid than the single crystal method of X-ray diffraction developed by the Braggs. Goldschmidt used both the Debye-Scherrer camera and the Weissenberg camera in his subsequent studies to determine the ionic radii of atoms. The analytical instrumentation in his laboratory was soon superior to that in comparable institutions abroad (Wedepohl 1996). Goldschmidt now had the people and the tools to begin his geochemical investigations in earnest.

Goldschmidt's first application of the X-ray spectrograph in conjunction with Thomassen was to search for the missing element 72 in the periodic table which they discovered in the minerals, malacon and alvite, two varieties of zircon (Goldschmidt and Thomassen 1922). Unfortunately, they were just beaten in this search by D. Coster and G. von Hevesy who named the element hafnium which is the Latin name for Copenhagen (Mason 1992). Goldschmidt and his colleagues also began investigating the distribution of the rare earth elements (REE) in a large number of rare earth minerals and established that the even-numbered elements in the REE sequence have higher abundances than the odd-numbered elements in agreement with the Oddo-Harkins Rule (Goldschmidt et al. 1925, Mason 1992).

Photograph of V.M. Goldschmidt taken by a professional photograher in Göttingen about 1930.

Goldschmidt then switched his attention to the determination of crystal structure which became possible with the determination of the ionic radii of the fluorine and oxygen anions in 1923. Goldschmidt demonstrated that the ionic radii of the REE calculated from the lattice dimensions of the REE sesquioxides decrease with increasing atomic number (Goldschmidt and Thomassen 1924, Goldschmidt 1954, Mason 1992, Wedepohl 1996) and named this phenomenon the 'lanthanide contraction.' Between 1924 and 1926, Goldschmidt and his colleagues also determined the ionic radii of cations and anions of 67 elements based on the X-ray analysis of over 200 compounds prepared for this study in addition to the data for the rare earth minerals already mentioned (Goldschmidt et al. 1926, Mason 1992, Wedepohl 1996). However, they still had to draw on crystal structures determined by colleagues elsewhere to complete their work. Linus Pauling produced his table of ionic radii using a different approach one year after Goldschmidt (Goldschmidt 1929, Mason 1992).

From his ionic radii, Goldschmidt was able to determine the coordination number of elements in crystals from the ratios of the radii of the principal cations and anions in the crystal. This work led to a consideration of the role of polarization on crystal structure which is most marked in crystals of transition element with highly polarizable anions from the IV, V and VI B groups of the Periodic Table (Goldschmidt et al. 1926, Goldschmidt 1929, Tilley 1947).

In 1923, Goldschmidt proposed a classification of the elements based on a consideration of how elements would be partitioned between the nickel-iron, troilite (FeS) and silicate phases in meteorites (Goldschmidt 1923). On this basis, he divided the elements into four groups, siderophilic (those with affinity to nickel-iron), chalcophilic (those with affinity to sulphides), lithophilic (those with affinity to silicates) and atmophile (those normally present as gases). He subsequently added biophilic elements (those occurring predominantly in living plants and animals) (Goldschmidt 1937a). This classification led to detailed investigations of the partitioning of the elements within meteorites which lasted for many years.

Goldschmidt also recognized that the glacial clay from southern Norway which consists of the finest rock flour deposited from melt water from the Fennoscandian ice sheet has an average composition similar to that of the Earth's crust (Mason 1992). From the analysis of 81 samples of this material, he was able to calculate the average major element composition of the Earth's crust which was in good agreement with F.W. Clarke's average based on the average composition of 5159 analyses of igneous rocks taken from the literature. Between 1923 and 1927, Goldschmidt and his colleagues published eight volumes of the Geochemische Verteilungsgesetze der Elemente (The laws of the geochemical distribution of the elements) for which he is perhaps best known from this period.

Despite the great success of his work in Oslo, Goldschmidt was dissatisfied with his lot. In a letter to his former doctoral supervisor, Professor Brøgger, dated July 20, 1925, he explained that his motivation to leave Oslo was not only the poor material situation but the atmosphere of narrow mindedness, envy, stupidity and malice amongst some colleagues which poisons scientific life. In Oslo, Goldschmidt had become something of a loner and was therefore very happy to be invited to Göttingen as a guest lecturer in January-February, 1928, to discuss the Professorship of Mineralogy (Mason 1992). There, he would have a new Mineralogical

Institute built to his specifications in an old school building and where there was a group of outstanding physicists in the Physikalisches Institut who were interested in collaborating with him.

In September, 1929, Goldschmidt moved to Göttingen. During this period, he built up an even larger team than he had in Oslo including many foreign scientists working to his own exacting standards which generated large amounts of analytical data. As before, Goldschmidt then published these data with his scientific colleagues. Goldschmidt was, of course, well aware that the X-ray spectrograph that he had been using in Oslo had a detection limit of only 0.01% (100 p.p.m.) and was not sensitive enough for trace element analysis. He therefore persuaded R. Mannkopff from the Physics Department in Göttingen to build him three optical spectrographs using the carbon arc technique which had a detection limit of 1 p.p.m. for many elements and which had not previously been used for the quantitative analysis of rocks and minerals. During his time in Göttingen, Goldschmidt used these instruments for the analysis of Ga, Sc, Be, the Noble Metals (Ru, Rh, Pd, Ag, Os, Ir, Pt, Au), B, Ge, the Alkali Metals (Li, Rb, Cs), Li, Sr, Ba, the lanthanides (Y, La-Lu), Cr, Mo and Se. These studies involved the analyses of both terrestrial and meteoritic material and Goldschmidt spared no effort to gather materials for his research from all quarters of the globe (Tilley 1947). With this new technique, Goldschmidt was able to revolutionize trace element geochemistry.

Photograph of V.M. Goldschmidt taken by a professional photograher in Göttingen about 1932.

One of the earliest results of this work was the discovery of the enrichment of Ge in coal ashes with contents of 1.1% being determined in the ash of coal seams from the Hartley District in Britain. Goldschmidt thought that this was related to the enrichment of Ge in the ash from litter and humus on the forest floor which can contain up to 50 p.p.m. Ge. However, the main finding of his trace element work was the role of ionic radius and charge on the capture and camouflage of elements in the crystal lattices of silicates which became known as the Goldschmidt Rules (Goldschmidt 1937a). These rules made it possible to discriminate between elements introduced early into the crystals of common rock-forming minerals and those introduced late into these minerals.

Goldschmidt also made some attempts to consider the factors controlling the composition of sea water and the distribution of sediments, although this work has no major relevance today (Goldschmidt 1937a, Goldschmidt 1954, Mason 1992).

The University of Göttingen was founded in 1734 by George II, King of England and Elector of Hannover, and achieved a world class reputation in the mathematical and natural sciences between 1880 and 1933 (**http://www.uni-goettingen.de**). In 1935, Goldschmidt resigned his professorship in Göttingen in protest against the treatment of "non-aryans" in Germany (as described in detail later). 50 other lecturers and professors also had to leave the university at that time because of the National Socialist Party´s rise to power. The world class Department of Physics in Göttingen was destroyed within one year when Franck, Born, Courant, Weyl and Goldschmidt left Germany (a Correspondent 1937, Hund et al. 1988). The period following 1933 was the university´s darkest chapter and ended the Göttingen Nobel Prize wonder. Goldschmidt was therefore only one of many affected by the events of the time.

When he left Germany in September 1935, Goldschmidt had to start his scientific career in Oslo all over again in difficult circumstances (as described in detail later). As usual, he was very active and arranged for Dr Mankopff to construct new spectrographs for him in Göttingen and to come to Oslo to install them in November and December 1936 (Mason 1992). However, the economic situation in Norway was difficult and Goldschmidt had a very much smaller group of coworkers than before (Mason 1992). He also had serious disagreements with Tom Barth, one of his former young scientific assistants, who was appointed Professor of Crystal-

Photograph of the author (right) with Professor K.H. Wedepohl (left) taken just outside Goldschmidt's office in the Mineralogsches Institut located at Lozzestr. 16/18. The sign 'Jews not desired' was erected on 10 August, 1935, just across the road. Goldschmidt resigned his professorship in protest the next day when the sign was not removed.

lography and Petrology and Director of the Mineralogical Institute in 1937. These were to mar his future relations in Norway until his death (Mason 1992).

Goldschmidt's major achievement during his time in Oslo was the publication of Volume IX of the Geochemische Verteilungsgesetze der Elemente (the Ninth Symphony) in 1937 (Goldschmidt 1937b). In this study, he compiled data on the abundance of elements in the solar atmosphere, meteorites and terrestrial rocks and plotted the logarithms of the ratios of atomic species in the solar system relative to the abundance of Si (Goldschmidt 1937b, Goldschmidt 1954, Mason 1992). These compilations were based on analytical data mostly obtained whilst he was still in Göttingen. From these, he was able to make inferences about the stability of atomic nuclei and their cosmic abundances. In May 1940, Goldschmidt submitted Volume X in this series on the distribution of some elements in meteorites for publication in this series and had compiled the material for volume XI by September 1941 but neither volume was ever published (Mason 1992).

The nine volumes in the Geochemische Verteilungsgesetze der Elemente (the distribution laws of the elements) which Goldschmidt published between 1923 and 1927 and in 1937 plus the eighteen papers on the geochemistry of the elements which he published in Nachrichten der Gesellschaft der Wissenschaften zu Göttingen Mathematisch-physikalische Klasse IV between 1930 and 1935 represent a magisterial standard of scholarship which Goldschmidt was never able to achieve again. 1937 therefore represents a turning point in Goldschmidt's scientific career which was marked by a significant decline in the quality of his scientific output thereafter. It is not entirely clear why this should have been. However, it seems more than likely that Goldschmidt did not have the people or the resources to adopt his normal team approach to data gathering in the reduced circumstances that he encountered on his return to Oslo.

During the period from 1917 to 1940, Goldschmidt suffered from a number of illnesses. For example, he had rheumatic fever in 1917-18 which was followed by an operation for peritonitis in 1919 which he doubted he would recover from (Mason 1992). In 1928, he had to spend one month at the spa in Bad Ems in Germany recovering from a serious lung infection caused by breathing in fumes of HF during experiments (Mason 1992). J.D. Bernal first met Goldschmidt at Bad Ems and they talked about crystal chemistry for 12 hours without Goldschmidt getting hoarse (Bernal 1949, Mason 1992). The term 'crystal chemistry' was subsequently introduced into the scientific literature by Goldschmidt in 1934. In 1937, Goldschmidt also suffered from nephritis for which he had to spend two weeks in hospital. Kidney trouble was to recur and plague him in later years (Mason 1992). These illnesses were a prelude to the many illnesses he would have to endure later.

In the rest of this article, I will focus on Goldschmidt's connections with Britain where his activities are much less well known than those in Germany and Norway and for which I have uncovered a number of documents not available to his earlier biographers. I have included a section on Goldschmidt's time under the German Occupation of Norway because it is impossible to understand the rest of his life without this plus a short section on his final months in Norway before he died.

Sources of Information

V.M. Goldschmidt has been the subject of seven biographical articles which describe his life and work in Norway and Germany in considerable detail (Rosbaud 1961; Levinson 1988; Mason 1992; Wedepohl 1996; Kauffman 1997; Bye 2000; Dons 2000) plus several obituaries which review his scientific achievements (Correns 1947, Spencer 1947, Tilley 1947, 1948, Hassel 1988). In addition, Sommerfeldt (1998) and Mason (1992) have prepared comprehensive bibliographies of Goldschmidt's scientific papers and Levinson and Sclar (1988) a pictorial tribute to Goldschmidt. Goldschmidt also has a walk on role in the biography of his friend, Paul Rosbaud, whom he first met in 1929 (Kramish 1986). Rosbaud used his position as a scientific adviser to all publications of Springer Verlag as a cover for being Britain's most important spy during World War II. In all, Goldschmidt published 223 scientific papers of which 15 (plus one book) were in English (Goldschmidt 1922, 1926a,b, 1929a,b, 1936, 1937a, 1938, 1943, 1944a,b, 1945, 1946, 1952, 1954; King et al. 1945). All his papers in English are listed in the reference list.

In preparing this article, I have been forced to rely, to a large extent, on material presented by Mason (1992) and, to a lesser extent, by Kramish (1988) for general accounts of Goldschmidt's life. However, I have also drawn heavily on letters and other material from U.K. sources to which Mason and his other biographers do not appear to have had access (see Acknowledgements section for details). I also undertook an extensive literature search for articles related to the activities of some of Goldschmidt's friends and collaborators. It is hoped that this new material casts some new insights into Goldschmidt's life and work, particularly in Britain

The British Connection (1914-1940)

Goldschmidt's connections with Britain were relatively limited during the period 1914 to 1940.

In 1914-15, Leonard Hawkes went to Kristiania as an 1851 Exhibitioner to work under W.C. Brøgger and V.M. Goldschmidt. In 1916, he was awarded a M.Sc. by the University of Durham (Armstrong College) for his thesis entitled "Some features of Icelandic geology" based on his work there. He also published a summary of his results in that year (Hawkes 1916). Hawkes was subsequently awarded the Murchison Medal of the Geological Society of London in 1946, the Wollaston Medal in 1962 and became President of the Geological Society from 1954 to 1957. In his acceptance speech for the Murchison Medal in 1946, Hawkes recalled his time in Kristiania with a brilliant group of workers which included W.C. Brøgger, F. Nansen, J. Schetelig, J. Kiær, P.A. Oyen, H. Reusch, V.M. Goldschmidt and O. Holtedahl. He learnt from all these but most of all from Goldschmidt. Hawkes considered that it had been a great privilege to have had contact with Goldschmidt's powerful and fertile mind and that he was deeply indebted to him (Hawkes 1946). Goldschmidt remained in contact with Hawkes throughout his life. His letters are held at the Geological Society of London.

According to J.D. Bernal, the British government put a tariff on organic chemicals to protect the British chemical industry under the Safeguarding of Industries Act of 1921 in which they included calcium carbide (Bernal 1949, Mason 1992). Calcium carbide was imported from Norway where it was made using hydroelectric power and was widely used in Britain for making acetylene for welding and for bicycle lamps (Mackay 1998). Goldschmidt was sent to Britain by the Norwegian government in late 1921 as an expert witness to oppose this decision. When he got there, he visited Sir William (W.H.) Bragg whom he knew and asked him to determine the crystal structure of calcium carbide. Bragg did this very quickly and not altogether satisfactorily but it was enough to show that the structure was typical of an inorganic compound and calcium carbide was exempted from the tariff as a result. Goldschmidt was rewarded for his efforts by the Norwegian government with an X-ray tube and powder camera which enabled him to begin his work on X-ray diffraction.

V.M. Goldschmidt at Göttingen railway station at 5 PM on 6 September, 1935, taking his leave from Lester Strock prior to leaving Germany for the last time.

C.E. Tilley who went on to become Professor of Mineralogy and Petrology at Cambridge in 1931 participated in the memorable gathering of international geologists which Goldschmidt had arranged in the summer of 1922 in the Stavanger region of southern Norway to demonstrate the realities of metasomatic metamorphism (Tilley 1948, Mason 1992, Dons 2000, Mason 1992). Tilley subsequently drew heavily on Goldschmidt's work on the constitution of free-silica hornfelses from the Kristiania contact rocks (Goldschmidt 1911) in his classic account of contact metamorphism of the Comrie Area of the Perthshire Highlands (Tilley 1924). This connection between these two men would explain Tilley's support for Goldschmidt when he came to Britain in 1943.

During this period, Goldschmidt was twice invited to give lectures in London. On March 14, 1929, Goldschmidt presented a lecture on 'Crystal structure and chemical constitution' before the Faraday Society. His lecture was part of a general discussion on this topic organized by the Faraday Society (Kamminga 1989). On the following day, he gave a Friday evening lecture on 'The distribution of the chemical elements' to an audience from the Royal institution. His host during his visit was Sir William Bragg, the Director of the Royal Institution. This invitation was very timely because it enabled Goldschmidt to summarize his findings on crystal structure and ionic radii in English before moving to Göttingen where he would focus on trace element geochemistry. During this meeting, it is almost certain that Goldschmidt would have met J.D. Bernal, W.L. Bragg and Kathleen Lonsdale. During 1929, Goldschmidt also wrote to W.L. Bragg to ask him for samples of cordierite, wollastonite and enstatite (Royal Institution Archives).

In March 1937, Goldschmidt gave the Seventh Hugo Müller lecture of the Chemical Society on 'The Principles of Distribution of Chemical Elements in Minerals and Rocks' in the same room at the Royal Institution in which he had given his 1929 lecture.

Each of these lectures was published as a scientific paper which give an excellent account of his work up to this time (Goldschmidt 1929a,b, 1937a). However, they were not published in mainstream geological journals and would not have been well known within the British geological community. Furthermore, there was no systematic study of geochemistry in Britain universities at that time. Nonetheless, these papers were amongst the few publications Goldschmidt wrote in English before his arrival in Britain in 1943.

In 1933, Sir William Bragg invited G. Nagelschmidt from Germany to study clay mineralogy at the Royal Institution in London (Loveland et al. 1999). This invitation was probably made on the recommendation of C.W. Correns, although Loveland et al. (1999) has suggested that Goldschmidt may have brought Nagelschmidt to Bragg's attention when he lectured in London in 1929. Nagelschmidt subsequently became a close colleague of Goldschmidt at Rothamsted in 1944.

Goldschmidt also corresponded with Dr John Shearer of the Department of Physics of the University of Western Australia from 1935-1945. These documents are held at the Australian National Library in Canberra (MS 3839).

Shearer had visited Goldschmidt in Göttingen in March 1935. In 1937, he wrote to Goldschmidt about some 'unpalatable sentiments' expressed in an article in Nature (a Correspondent 1937) which he wished to verify. In that article, it stated that Professor Goldschmidt was liable to dismissal from the University of Göttingen as a foreigner and that many professors had signed a memorial that he might be retained. He was allowed to stay for a time, but his life was rendered unendurable and work impossible and he was given no protection by the Rector and the other authorities at the university. He therefore resigned and accepted a chair at Oslo.

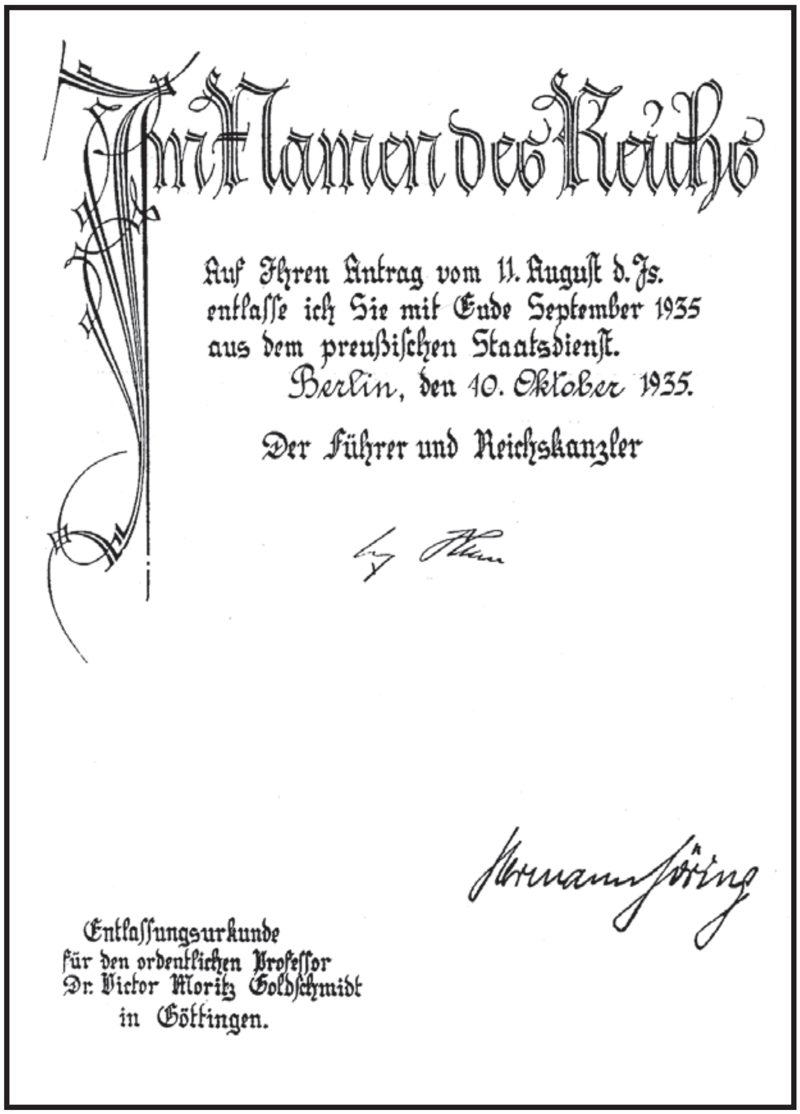
Goldschmidt replied to this letter at some considerable length on June 29, 1937 and pointed out that much of this information was seriously misleading. In particular, he stressed that the authorities at the university had always treated him in a most pleasant and agreeable manner, and had given him any facilities for scientific work that he required. He felt that the general attitude to "non-aryans" at that time was a very great misfortune but that it was his duty to science and his coworkers at the institute to keep his work going at Göttingen through the years 1933, 1934 until the summer of 1935, an attitude that was encouraged in every manner by the authorities. However, he had already felt it necessary to resign from the chairmanship of the 'Gesellschaft Deutscher Naturforscher und Ärzte, Naturwissenschaften Hauptgruppe' (corresponding to the British Association) at a time when his colleagues who were "non-aryan" like himself were being driven from their positions.

However, on May 1, 1935, a large sign was placed not far from his institute with the inscription 'Jews not desired'. Goldschmidt then gave notice that he would resign his professorship if this sign was not taken down because he could not reconcile his presence in Göttingen with such an open attack on Jews in the same town. Within 24 hours, the sign was removed. However, in August, a similar sign was erected just opposite the institute and Goldschmidt renewed his protest. This time the sign was not removed because these signs had been placed in all German towns on direct orders from the uppermost party rulers. On the next day (11 August, 1935), Goldschmidt resigned his position in Göttingen and expressed his intention to leave the country.

Goldschmidt emphasized that all his negotiations with the university were made in a most friendly manner and that the university authorities had supported him by making agreeable terms for his emigration back to Norway when they realized that his decision could not be changed. However, under the financial restrictions in Germany at that time, Goldschmidt and his father had to leave all their financial resources in Germany, although they were allowed to take their furniture and his library and instruments for research back to Norway. His emigration did, of course, involve great financial risk because he had no other position on offer.

That his departure from Göttingen was effected in a friendly manner is shown by the fact that the entire laboratory, including students, assistants, artisans and officials gave a party for him before he left and that there had been friendly cooperation between his former institute at Göttingen and his new institute in Oslo ever since his departure including the exchange of assistants and scientific cooperation.

Goldschmidt naturally felt the injury done to his colleagues, who were "non-aryans" like himself, very deeply but added that he himself had been treated in a friendly and correct manner by all authorities, even if it was not agreeable to live in a place where people of his own race were injured and persecuted only for the sake of their race. When that reached a certain limit, he had resigned his professorship as a protest against the iniquity. He felt that anyone in his position would have done the same.



Im Namen des Reichs

Auf Ihren Antrag vom 11. August d. Js. entlasse ich Sie mit Ende September 1935 aus dem preußischen Staatsdienst.

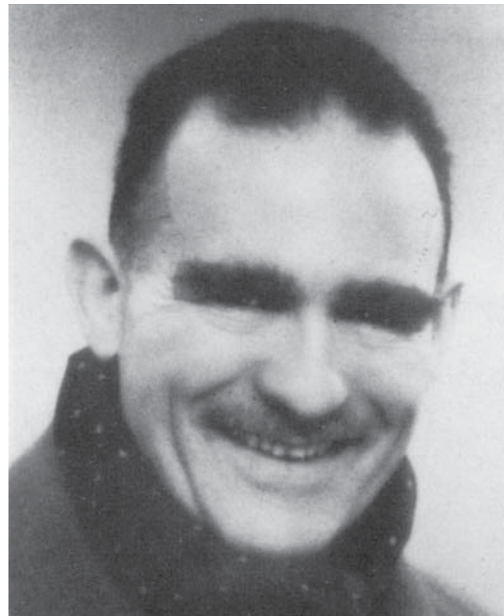
Berlin, den 10. Oktober 1935.

Der Führer und Reichskanzler

Entlassungsurkunde
für den ordentlichen Professor
Dr. Victor Moritz Goldschmidt
in Göttingen.

Letter of dismissal of Dr. Victor Moritz Goldschmidt, Ordentlicher Professor in Göttingen, dated 10. October 1935 and signed by Adolf Hitler (Reichskanzler) and Hermann Göring (Minister Präsident Preussens)

On September 5, 1935, Goldschmidt left Germany with his father and they went to Oslo where he had no academic position but lived from industrial work. He had already started industrial research work on refractories for metallurgical processes many years previously and the licence fees from his patents made it possible for him to survive. In addition, his father had his pension as an Emeritus Professor from the university. Some months later, Goldschmidt's colleague, Professor Schetelig, died after years of illness. Goldschmidt applied for his position as Professor of Mineralogy and Geology and Director of the Geological Museum of the University of Oslo and was appointed in March 1936. Since then, he had reorganized the laboratories for geochemical research and the facilities became even better than those in Göttingen.


Photograph of V.M. Goldschmidt taken in Stockholm in January 1943.

Goldschmidt felt it was necessary to give his reasons for leaving Germany in spite of his devotion to the University of Göttingen where he spent the most active years of his scientific career. He emphasized that neither his own attitude nor the treatment he had received had been that of a martyr, and that he had only done what he considered to be correct and necessary. He did not consider his fate to be tragic since he was now directing laboratories superior to the ones he had left in Göttingen as well as developing industrial processes. However, he admitted that the last years had been very strenuous and up to the limit of his health in some instances as well as a strain on his conscience.

However, he was encouraged by the petition of all his colleagues in Germany to prolong his stay there, the very friendly attitude of the Norwegian authorities and his success in organizing new laboratories in Oslo in cooperation with several of his former Norwegian assistants which made the effort worthwhile.

Of course, Goldschmidt was gilding the lily somewhat in this letter. His resignation from Göttingen must have been a huge blow. The few years in Göttingen up to 1933 were perhaps the happiest in Goldschmidt's life (Tilley 1948, Rosbaud 1961). There is no doubt that, in normal times, he would have spent the rest of his career in Göttingen but fate decreed otherwise. However, this letter emphasizes Goldschmidt's integrity in a very difficult situation. Goldschmidt's comment that his laboratories in Oslo had become even better than those in Göttingen is also highly debatable. By that time, his spectrographs had been installed for only a few months and a great deal of time and effort would have been required for his associates to gain experience in the use of carbon arc emission spectrography (Wedepohl 1953).

On 23 September 1937, Goldschmidt again wrote to Dr Shearer to inform him that his father had died three days earlier from a stroke. He explained that his father had been quite well and happy until the last minute and that the previous day he had gone for a long walk in the woods. Goldschmidt was very glad that his father had spent the last two years of his life in Norway as a free man in a free country enjoying his health and his love of nature. His only regret was that the evil news from certain countries had cast a dark shadow on his father's friendly soul.

In January 1940, Goldschmidt took on Brian Mason from New Zealand as a Ph.D. student to work on the geochemistry of tellurium. However, the German invasion of Norway on April 9, 1940, forced Mason to flee across the border into Sweden two hours in advance of the German army. He completed his Ph.D. at Stockholm University on the mineralogy of iron-manganese minerals from the Langban mine in western Sweden in May 1943 (Mason 1947, Mason and Nathan 2001). Goldschmidt must have made a lasting impression on Mason because Mason went on to write the definitive biography of Goldschmidt 50 years later (Mason 1992).

On September 11, 1939, L.R. Wager, then at the university of Reading, wrote to Goldschmidt to seek his advice on the use of biotite as a substitute for imported potash fertilizers, a topic on which Goldschmidt had worked whilst Director of the Raw Materials Laboratory in Kristiania after 1917 (**http://www.a2a.org.uk**; File NCUACS 84.5.99/F1). At that time, Wager was attempting to arouse interest in this topic in Britain in view of likely wartime shortages in fertilizers, particularly at the Macaulay Institute for Soil Research at Aberdeen where a meeting was held in October 1939 to organize a joint research programme between Wager and members of the Institute's staff. Goldschmidt wrote three letters to Wager between mid-September and mid-October. In particular, he emphasized the importance of working on fresh, unweathered biotite-rich rocks and offerred to send Wager a copy of Paul Solberg's results on agricultural tests made before 1929. However, it seemed clear by May 1940 that the potash content extracted from the rocks would not be economic taking into account the quantities required and the costs of crushing and extraction. Field experiments continued at the Macaulay Institute but there was no large-scale development. These letters are the only known correspondence between Goldschmidt and Wager. This topic was presumably Wager's first contribution to the war effort.

During this period, Goldschmidt was elected a Foreign Fellow of the Geological Society of London in 1931 and an Honorary Member of the Mineralogical Society in 1933.

Although this brief catalogue might give the impression that Goldschmidt was a peripheral figure in British geology in the inter-war years, Tilley's (1948) masterly overview of Goldschmidt's scientific contributions suggests that his work was very influential in Britain, at least in some quarters.

Under German Occupation (1940-1943)

The Germans invaded Norway on 9 April 1940. Norway was important to Germany as a base for U-boats and to secure iron shipments from Sweden. Historians have described the German occupation of Norway as brutal as a consequence of both passive and active resistance of the Norwegian people to the occupation. This applied particularly to the Jewish population. According to Hollander (2003), 763 of the original Jewish population of 1800 in Norway were deported of whom 762 (or 42.3%) were killed. This contrasts with the situation in Denmark where 464 of the original Jewish population of 7800 were deported of whom 60 (or 0.8%) were killed. However, there is some uncertainty about the number of Jews who were exterminated in Norway. In letters to Dr Franz Simon, an exile from Berlin at the Clarendon Laboratory in Oxford (held at the Royal Society), Goldschmidt reported that, "of the 1000 Jews in Norway arrested on the same day as me and deported to Poland, only 10 including me are still alive today" (23.9.45). Goldschmidt later found out that, in a subsequent deportation order, he had been "billeted at Auschwitz, a place which is not really recommendable" (1.11.45).

In spite of the very difficult conditions in Norway under the German occupation, Goldschmidt worked without interference from the occupying authorities until January 1942 when he completed his work on plutonium (Kramish 1986, P. 124). During this time, he was quite productive and published several scientific papers all of which were in Norwegian (Mason 1992). Goldschmidt had stopped writing in his native German (and even speaking it except when tired) in 1939 (Rosbaud 1961). Of these, two papers are of particular significance. One was on superuranium (plutonium) which paralleled the secret work of Glen Seabourg and his associates in the United States and ultimately led to the production of plutonium for the atom bomb dropped on Nagasaki (Goldschmidt 1941/42). This work was essentially a follow up to his earlier studies of the uranium group of minerals (uranium oxide, thorianite, cleveite and bröggerite; Goldschmidt and Thomassen 1923, Tilley 1948) in which he had speculated on the chemical properties of the trans-uranium elements which he had called the thorides but are now known as the actinides (Mason 1992). Seabourg subsequently wrote that he had been familiar with the work of Goldschmidt for a long time and had been one of his admirers (Kramish 1986). The second one was on the origin of the elements (Goldschmidt 1944c) and was a brief follow up to his definitive study on this topic (Goldschmidt 1937b). Goldschmidt also stepped up the work of the Raw Materials Laboratory, especially on the utilization of the low-grade phosphate deposits of the Fen area as a source of phosphate fertilizer during this time (Mason 1992, P. 85). According to Bernal (1949), Goldschmidt also deceived the Germans about the mineral resources of Norway during the early part of the war leading them to waste an enormous amount of effort in searching for non-existent minerals.

Goldschmidt's home was located in Holmenkollen in the northern suburbs of Oslo near the site of the ski jump for the 1952 Olympics and had a fine view. In June 1940, it was confiscated on the grounds that it was a strategic asset and was converted into a German army command post. As a result, Goldschmidt was forced to move into an apartment in Holmendammen Terrace (Kramish 1986; Mason 1992). In February 1942, all the Jews in Norway were required to fill out a questionnaire. Goldschmidt declared that all four of his grandparents were Jewish even though at least two of them were not members of the Jewish religious community; Mason 1992). He then had a J stamped in his passport (Rosbaud 1961). In March, 1942, Vidkun Quisling declared that all Jews in Norway were illegal immigrants.

On October 25, 1942, Goldschmidt was arrested at his home (Kramish 1986) and taken to Berg concentration camp which was located on the outskirts of Tønsberg near Oslo (Kauffman (1997). Conditions in the camp were described as abominable (Kramish 1986, P. 133) and Goldschmidt became very ill with severe pains of the back, headache, nausea and disturbances of vision (Mason 1992). The camp doctor was therefore given permission to take him to the hospital in Tønsberg on October 31 (Kramish 1986, Mason 1992). During this time, Goldschmidt's friends complained to the authorities that no one else was able to solve certain urgent and critical problems related to fertilizers (Kramish 1986). On November 8, he left the hospital and was released from the camp (Mason 1992). However, in the second week in November, his name was published in the newspaper in a list of Jews whose remaining property was to be confiscated.

In what appears to be a foreword to his proposed volume on geochemistry (undated draft of the Foreword for his Geochemistry book lodged at the Macaulay Institute in Aberdeen which was never used), Goldschmidt reported that the Gestapo searched his home, confiscated his funds in Germany, confiscated all his personal belongings including his library and his instruments which were his personal belongings and placed restrictions on his travel. The instruments included microscopes, X-ray equipment and other instruments. In this document, Goldschmidt also mentions that some of his academic colleagues were active in promoting these interruptions to his academic work but he did not name them. Goldschmidt made a vigorous protest about this situation and was promised he could keep his instruments but, on November 26, he was arrested once again (Kramish 1986). The following day, he was taken with 531 other Norwegian Jews to await boarding on the Donau for transportation to Auschwitz. However, the same policeman who had arrested Goldschmidt the previous day came and asked if Victor Moritz Goldschmidt was present. When he answered in the affirmative, he was told he was free and could return to his home. Goldschmidt subsequently found out that he had been released on the initiative of Professor Halvor Solberg, Dean of his Faculty at the University, and Adolf Hoel, the Rector of the University and a member of the ruling Quisling Party who was Norway's foremost Arctic scientist after the death of Fridjof

Nansen (Mason 1992). They had gone to the chief of the state police and impressed on him that Goldschmidt must be released because he was involved in work vital to the state.


V.M. Goldschmidt walking in procession to receive the honorary degree of Doctor of Law (LL. D.) from the University of Aberdeen on June 29, 1944.

Goldschmidt tried to continue his work and get his instruments returned (Mason 1992). However, in the undated document mentioned above, Goldschmidt claims to have received clear evidence that an influential colleague had taken steps which made it most unlikely that his instruments would be released. On December 18, he had an acrimonious meeting with Professor Hoel about the confiscation of his property, the repeated arrests and the threats of deportation which were equivalent to a death sentence. He then made it clear that, whilst he had previously considered it his duty to continue with his work and beneath his dignity to leave the country, he would now have to reconsider his position because it was impossible for him to continue his work.

Following this meeting, Goldschmidt left for Sweden the same evening as previously arranged by the Norwegian resistance (Mason 1992). In the undated draft of the Foreword for his Geochemistry book, Goldschmidt mentioned that the Swedish government had three times offered him the privilege of immediate bestowal of Swedish citizenship in the autumn of 1942, an offer which would have granted him his liberty and release of his belongings. Three times he rejected this generous offer because he would not accept an offer which was not also open to all of his academic colleagues and because he would not save his life by accepting foreign citizenship when Norway was involved in a war for her existence. Now he was forced to flee to save his life.

In a letter to Ole Nielsen dated October 30, 1945, Goldschmidt recalled tramping through a birch forest over the frontier to Sweden and being warmly welcomed by the soldiers at a small barracks, together with almost 40 escapees, among them a boy only three years old who was traveling alone to join his father. And the next morning, breakfast on white bread, butter and cocoa, and enjoying a sauna. Goldschmidt was deeply grateful for those who aided his escape from Norway, the people who guided them over the border, carried an amputee on a stretcher, and helped old ladies and young children. He had, of course, to abandon all his belongings to save his life (undated draft of the Foreword for his Geochemistry book).

During his time in Oslo, Goldschmidt was visited twice by Hans Suess (Suess 1988). On the first occasion in early 1942, Suess was on this way to work for the German military as a consultant on heavy water production at the Norsk Hydro Plant in Vermork. He found Goldschmidt in a confident mood and sure that there would soon be a new German government which would make peace with the allies. At this time, Suess told Goldschmidt that he and his colleagues Hartek and Jensen were very interested in his element abundance values which had been calculated in part to study the origin of the elements and Goldschmidt invited him back soon. On the second occasion when he arrived with Hans Jensen just prior to Goldschmidt's departure from Oslo, the mood was quite different. Goldschmidt had just been released from the Donau. As they were leaving, Goldschmidt said to them "Wenn ich nun doch in den sauren Apfel beißen sollte …" (If I now have to bite the sour apple (to leave Norway), then give my regards to all our friends).

With the war coming of the end, Suess was able to spend more time considering the cosmic abundances of the elements based on Goldschmidt's plots of the logarithms of the ratios of the number of elements relative to 100 Si atoms compiled from data for the atmosphere, the sun, meteorites and terrestrial rocks and of the log ratios of atomic species in the solar system which Goldschmidt (1937b) had previously published in his "Geochemische Verteilungsgesetze der Elemente IX". Subsequently, Maria Mayer and Hans Jensen shared the Nobel Prize in 1963 for their discovery of spin-orbit coupling in nuclear structure (Mayer and Jensen 1955) and

William Fowler the Nobel Prize in 1984 for his theoretical interpretation of the nuclear abundance distribution (Burbidge et al. 1957). Without Goldschmidt's data on nuclear abundances, their contributions to nuclear physics could hardly have been possible at that time (Jensen and Suess 1947, Suess and Urey 1956, Suess 1988). Neither of these two papers acknowledged or referenced Goldschmidt's work.

In Sweden, Goldschmidt was based at the Mineralogical Institute of Stockholm University (Mason P. 95). He planned to give ten lectures on his geochemical research in February, 1943, but gave only three. After his first lecture, he suffered internal bleeding and heart disease and was in hospital for three weeks. He could have stayed in Sweden and taken up the chair of mineralogy at Uppsala University but he felt that his knowledge of technical developments in Norway would be of great value to the Allied cause.

Several conclusions can be derived from Goldschmidt's time under the German occupation. He was a man who acted with great personal integrity under very difficult conditions. He had become a Norwegian patriot, if he was not already one. His health had deteriorated markedly under the stress of the occupation. These health problems would dog him for the rest of his life and ultimately lead to his premature death at the age of 59.

Freedom, Honours and Health (1943-1946)

On March 3, 1943, Goldschmidt was ex-filtrated from Sweden by the British Secret Intelligence Service (SIS) and flown from Stockholm to the SIS airbase in Huntingtonshire (Kramish 1988). He was then taken to London where he spent the next several days being thoroughly debriefed by Lt. Cmdr Eric Welsh of the SIS and Leif Tronstad (Kramish 1988). Welsh had lived in Norway since 1919 and had become technical manager of International Paints and Compositions Ltd there. He was therefore well aquainted with Goldschmidt who held a number of paint patents (Kramish 1988). Based on the recommendations of Welsh, it was decided that Goldschmidt should be exiled from London because he was deemed to be too talkative about sensitive matters (Kramish 1986). In spite of this, Goldschmidt spent a very busy 5 months living in a hotel in South Kensington in London at the expense of the Norwegian government in exile (Mason 1992).

Passport photograph of V.M. Goldschmidt taken in England by Lafayette in 1944.

During this time, Goldschmidt was heavily involved in discussions with the Norwegian and British authorities on German exploitation of raw materials and production of heavy water in Norway amongst other things (Mason 1992). He also attended conferences in Cambridge, Manchester, Sheffield, Edinburgh and Aberdeen and gave a lecture to the British Coal Utilization Research Association on the occurrence of rare elements in coal ashes (Goldschmidt 1943). However, after some time without paid employment, he was finally informed by the Norwegian Prime Minister Johan Nygårdsvold that his call to London had not been made any responsible minister but by some subordinate official, and that the Royal Norwegian Government had no use for his services (undated draft of the Foreword for his Geochemistry book). Goldschmidt was also embarrassed financially by the illegal seizure and withholding of his American patents and income by the Alien Property Custodian in spite of numerous protests made by the Norwegian Embassy in Washington. On August 7, 1943, it was agreed that the British authorities would give Goldschmidt employment under the Agricultural Research Council. The ARC would refund three-quarters of Professor Goldschmidt's salary of 112 per month to the Royal Norwegian High Command and meet his traveling or other special expenses in connection with the research which he would undertake for them (Mason 1992). On August 26 1943, Goldschmidt moved to the Macaulay Institute for Soil Research in Craigiebuckler, Aberdeen. In going to the Macaulay Institute, Goldschmidt had an enormous stroke of luck because he came under the influence of the Director of the Institute, Dr W.G. (later Sir William) Ogg, who was to become his Patron for the rest of his stay in Britain.

After his arrival at the Macaulay Institute, Goldschmidt spent six weeks in the Royal Infirmary in Aberdeen suffering from the overproduction of red blood cells which was successfully treated by deep X-rays (Mason 1992). In a letter to Dr Ogg on December 18, 1943 (held at Rothamsted Experimental Station), Goldschmidt was able to tell Dr Ogg that his health had very much improved as a result of his treatment at the infirmary and that he had subsequently given two lectures in Edinburgh and to the staff to the Macaulay Institute. On January 24, 1944, he gave a lecture on crystal chemistry and geochemistry at the University of Aberdeen, which was subsequently published (Goldschmidt 1944a). He also published a paper on the geochemical background of minor-element distribution which may well have been prepared originally as a lecture (Goldschmidt 1945). Both papers were essentially summaries of his earlier work in German. At the urging of Dr Ogg, Goldschmidt spent much of his time at the Macaulay working on his magnum opus on geochemistry (Mason 1992) and took great interest in soil research through his contacts with Dr Ogg, Alex Muir and others (Rosbaud 1961).

Dr Ogg was invited to become director of the prestigious Rothamsted Experimental Station after the retirement of Sir John Russell on 30 September 1943 but remained an honorary director at the Macaulay Institute until 1945. However, Goldschmidt remained at the Macaulay Institute for almost a year after Dr Ogg left. At that time, British agriculture was still struggling to come to terms with the upheavals of the war years and the attendant food shortages (White 2004).

In September 1943, Goldschmidt was instrumental in setting up a committee to discuss research into the sorption of water by clays, an area which was assuming increasing importance (Loveland et al. 1999). Interest in this field was based on the optimistic assumption that studies of clay minerals would help to elucidate the complexities of soil formation which in turn would improve Britain's self sufficiency in food. In April, 1944, Goldschmidt visited L.E. Sutton in Oxford to discuss this project. In a letter to Dr Ogg from Oxford dated 1 April 1944, Goldschmidt explained that this would involve the determination of the bonding strength of soils in water by measuring the dielectric constants of wet soil minerals in alternating fields at various frequencies in the same way that P. Debye had done with organic liquids. Dr Sutton had previously worked with Debye in Leipzig in 1928. However, progress on this project was disappointingly slow (letter from Dr Sutton to Dr Ogg in 1948) and the results were not published until long after Goldschmidt's death.

The study involved building an apparatus to determine the dielectric loss in finely-divided soils (Stuart et al. 1959) followed by measurement of the dielectric constant and dielectric loss of the system kaolinite with adsorbed water and determination of the adsorption isotherms and surface areas of nitrogen on the kaolinite (Nelson et al. 1969). The results indicated that the adsorbed water molecules held on the surface of the kaolinite were not in the ordinary liquid state and that adsorption of these molecules occurs in clusters. Unfortunately, in the absence of any input from Goldschmidt, the project seems to have become purely a study in Physical Chemistry with little relevance to soil science.

In addition, Goldschmidt prepared a memorandum entitled 'Development of Geochemical Research in Great Britain and in the British Commonwealth' dated January 24, 1944 (Document held at the Royal Society) in which he gave his opinions on the future development of geochemistry in Britain. In particular, he reviewed progress on geochemistry in other countries over the past 25 years and the application of geochemistry to problems of industrial and agricultural importance. As a result, he proposed the setting up of an institute to undertake systematic studies of geochemistry which could lead to increased use of the mineral resources of the British Empire and advise on the most profitable use of soil. In this regard, he considered the future evolution of geochemistry to be of the utmost importance from both a scientific and an economic (agriculture, mining and industry) standpoint. In February and March, 1944, there was some desultory correspondence between J.L. Simonsen FRS of the Colonial Products Research Council and Sir Alfred Egerton FRS of Imperial College, London, about the possibility of Goldschmidt moving to Imperial College on a permanent basis if outside money could be made available (correspondence held at the Royal Society) but nothing came of this.

In October 1944, Dr Ogg and Professor Tilley made submissions on the possibility of setting up a geochemical department at Rothamsted in which they emphasized the application of modern geochemistry to the study of soils, particularly in relation to pedogenesis and soil fertility (Dr Ogg) and to the development and use of the Earth's mineral wealth (Professor Tilley; documents held at the Royal Society). However, these submissions did not result in any significant developments during the remainder of Goldschmidt's stay in Britain.

Goldschmidt was also the recipient of three major honours whilst at the Macaulay Institute. On May 20, 1943, he was elected a Foreign Member of the Royal Society (one of 50) for his work on the metamorphic petrology of Norway, the crystal structure of ionic compounds and the terrestrial distribution of the elements (certificate held at the Royal Society). His nomination was supported by 18 Fellows of the Royal Society including C.E. Tilley. In January, 1944, he was awarded the Wollaston Medal, the highest award of the Geological Society of London, and, in February, 1944, he was awarded an honorary degree of Doctor of Law (LL.D.) by the University of Aberdeen which was conferred on June 29, 1944. Sir William Ogg (as he became in 1949, White 2004) was subsequently awarded the same degree by the University of Aberdeen in 1951. In May 1945, Goldschmidt was also elected an Honorary Member of the Chemical Society (Mason 1992). These awards clearly show the high esteem with which Goldschmidt was held in Britain at this time

At the presentation of the Wollaston Medal on March 15, 1944, the President of the Geological Society, Professor W.G. Fearnsides, stated that Goldschmidt had suffered to uphold the cause of knowledge and freedom and saluted him as a distinguished representative of an allied nation. Amongst other things, Professor Fearnsides emphasized the importance of Goldschmidt's classic researches in measuring the ionic radii of elements and determining the crystal structures of ionic compounds by quoting W.H. and W.L Bragg who had written that the crystal chemistry of inorganic compounds was built on the foundations laid by V.M. Goldschmidt.

In his reply, Goldschmidt pointed out that three times in his life he had to organize and equip new laboratories, for a great part at his own expense, and to train new staffs for research in geochemistry. However, he now felt fully confident to be able to reorganize his research work on geochemistry and could visualize geochemistry becoming closely connected with astrophysics, leading to the final problem of the origin and evolution of matter itself. In particular, he acknowledged the generous hospitality of Swedish and British friends and of the British authorities after his escape from Norway which had made it possible for him to recover his health. He also felt that the award of the Wollaston Medal would give him new strength and courage to continue a line of work which would open new aims and activities for pure and applied geology as it has done for chemistry and physics. Goldschmidt finished his speech by offering sincere thanks to Norway where he had had the privilege to live part of his boyhood, his student days and nearly all his later life in a free country. He bowed his head most respectfully to the fighting and suffering men and women of Norway. In this optimistic assessment of his personal future, Goldschmidt was to be disappointed. His continuing health problems meant that his hopes of resuming his scientific career as it had been before were not possible.

Whilst still at the Macaulay Institute in July 1944, Goldschmidt went to Edinburgh to discuss the structure of water with his old friend, Max Born, from Göttingen. There he had a minor relapse and had to spend 10 days in an Edinburgh clinic being treated for a heart attack (Mason 1992). Dr Ogg wrote to Goldschmidt advising him to postpone his departure for Harpenden but Goldschmidt replied on July 21 that he had not come to Britain to rest in a nursing home but to do some useful work if possible (Mason 1992). Goldschmidt finally went to work at Rothamsted sometime after August 1944 where he lived very quietly with his friend, Dr Ogg and his family (letter to Dr Franz Simon dated 19.10.45 (held at the Royal Society).

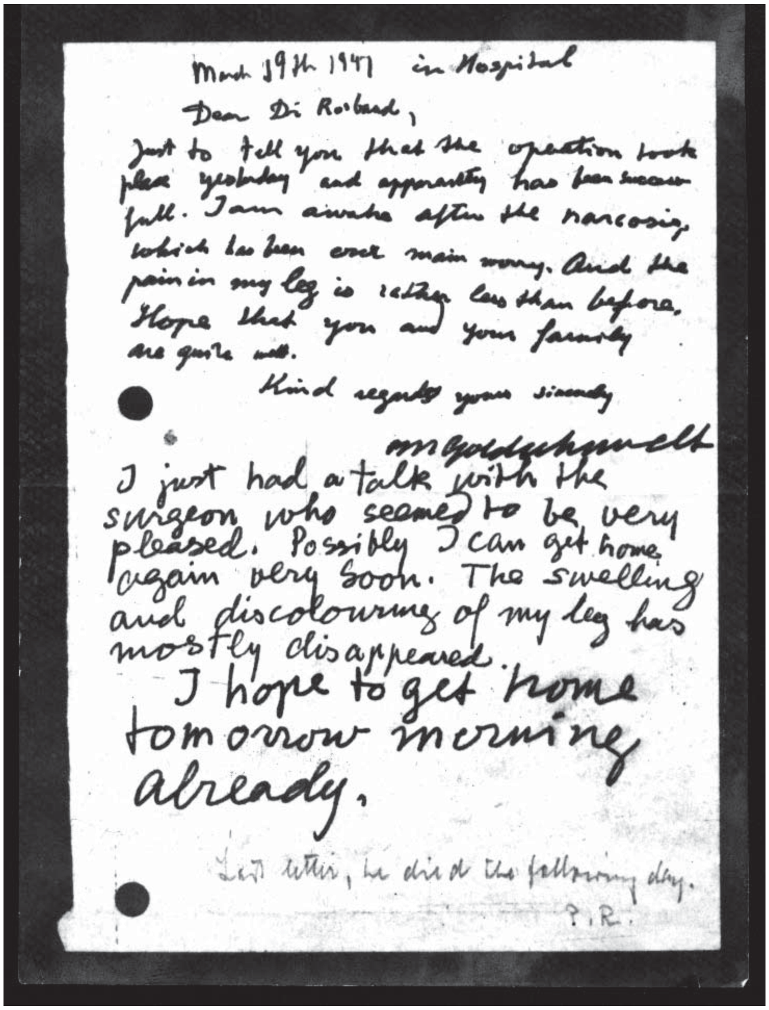
Goldschmidt's activities at Rothamsted were severely circumscribed by a major, near fatal, heart attack which occurred on the night of December 14, 1944 (Mason 1992). Goldschmidt was rushed to hospital and kept alive with oxygen and injections. He then spent several weeks in hospital before moving to Miss Debenham's Nursing Home in Harpenden where he remained for the duration, apart from occasional visits to London. Goldschmidt liked to attend the meetings of his club, the Society for Visiting Scientists, in London when possible but was unable to do so for 10 months following his heart attack (letter to Dr Franz Simon dated 27.9.45 held at the Royal Society). Paul Rosbaud saw Goldschmidt in January, 1946, after his return to Britain and found him greatly changed in appearance (Rosbaud 1961). He had lost weight and looked like a survivor from a concentration camp but he was still strong in spirit. From then on, Rosbaud went to Harpenden once or twice a week to spend the day with him.

During this time, Goldschmidt wrote two manuscripts which were not published in his life time (Rosbaud 1961 One was on the geochemical aspects of the origin of complex organic molecules on Earth as precursors to organic life. Goldschmidt himself would never have agreed to its publication in its unfinished form but it was nonetheless published after his death (Goldschmidt, 1952). In this, Goldschmidt became the first (with J.D. Bernal) to recognize the role of clay minerals in transforming organic molecules into the precursors of organic life (Arrhenius 2003). This topic remains an active field of research to this day (Ferris 2005). The other manuscript was written in collaboration with G. Nagelschmidt on Album Graecum which is formed from dog faeces which have become white through the conversion of insoluble phosphates into soluble ones on exposure to air. Album Graecum was used in the old days in the manufacture of high-grade leather but Goldschmidt thought it might make an ideal fertilizer for poor soil.

During his last six months at Rothamsted, Goldschmidt returned to the silicosis problem with which he had previously been concerned (Editor's Notes to Goldschmidt 1954). This work was supported by the Norwegian Ministry of Commerce which ordered him to stay in Britain until this work was finished (letter from Goldschmidt to Dr Ogg 20 August, 1945). G. Nagelschmidt had also become involved in the study of the mineralogical aspects of silicosis in 1943 (Loveland et al. 1999). Together, they participated in a study of the effect of olivine on the lungs of rats (King et al. 1945). The results suggested that silicosis could be reduced by the use of olivine sand rather than silica sand in foundries.

Goldschmidt (1946) also wrote a short letter in Nature whilst still at Rothamsted pointing out that the ionic radius of the Cu^{2+} ion attributed to him by Professor Wells was incorrect and that no accurate ionic radius of this ion was available. Wells (1946) replied that the Cu (II) does not form any simple ionic compounds and that it prefers square planar coordination. However, the anomalous behaviour of Cu^{2+} ions had to await the development of crystal field theory and an understanding of the distortions in crystal structure imposed by the Jahn-Teller effect before the nature of this problem could be understood (Orgel 1960).

Goldschmidt made a good impression in Britain. At Rothamsted, he was liked by everybody and was affectionately called 'Goldie' (Kauffman 1997). In return, he deeply appreciated the help extended to him at Macaulay and Rothamsted (Tilley 1948). However, he was determined to return to Oslo (Mason 1992). This decision was not universally welcomed in Norway. For example, he was publicly upbraided at the Society for Visiting Scientists in London on February 26, 1945, by Professor H.S. Solberg (Dean of the Faculty of Science at the University of Oslo) as a deserter who had left Norway in December 1942 without informing him and Rector Hoel, thereby endangering their lives as possible hostages (Mason 1992). Others such as Professor Tom Barth, his former student, would have preferred him not to return. In spite of this, Goldschmidt booked a flight to Oslo in early April. However, this had to be delayed because of illness. On June 26, 1946, he finally returned to Norway.



March 19th 1947 in Hospital

Dear Dr Rosbaud,

Just to tell you that the operation took place yesterday and apparently has been successfull. I am awake after the narcosis, which has been ever main worry. And the pain in my leg is rather less than before. Hope that you and your family are quite well.

Kind regards yours sincerely

VMGoldschmidt

I just had a talk with the surgeon who seemed to be very pleased. Possibly I can get home again very soon. The swelling and discolouring of my leg has mostly disappeared.

I hope to get home tomorrow morning already.

Last letter, he died the following day.

P.R.

Last letter of V.M. Goldschmidt to his friend, Paul Rosbaud, dated 19 March, 1947, written the day before he died informing Rosbaud of the success of his operation.

Return to Norway (1946-1947)

On June 28, 1946, Goldschmidt sent a telegram to Dr Ogg 'Perfect Journey Happy Landing.' On the same day, he wrote to Dr Ogg and told him that he had moved back into his old flat and had stretched his legs under his old dining room table, slept on his own bed and shaved before his own mirror. There were also letters waiting for him from China inviting him to organize raw materials research there and from Göttingen offering him back his old chair (Rosbaud 1961).

On the following afternoon, there was a great forenoon reception for him at the Raw Materials Research Laboratory to celebrate 'father's return.' And the joy was compounded by the arrival of Professor Zachariasen from America. He is one of the foremost atomic scientists who had started in Goldschmidt's laboratory at the age of 17 in 1923 and had become chairman at the Department of Physics in Chicago. Goldschmidt considered Zachariasen without doubt the most prominent of his pupils and one who had remained a most loyal friend during all the years. The officials at the Ministry of Commerce also gave Goldschmidt a very hearty welcome. So, it was really a great day and old Uncle V.M. of Smestad felt grand!

Despite this, his friends who went to meet him at the airport hardly recognized him. He was stooped, hollow cheeked and had dark circles under his sunken eyes. It was clear that he was a very sick man and he had to spend the first three weeks back in Oslo in hospital (Mason 1992). Only after this was he able to take up his positions as Director of the Geological Museum and of the Raw Materials Laboratory (Mason 1992).

Dr Ogg received two more letters from Goldschmidt in an optimistic vein. However, on October 10, 1946, Goldschmidt wrote to Dr Ogg to inform him that the black spot on his leg had turned malignant and had had to be removed surgically to be followed by radium treatment. On December 5, 1946, he then wrote to explain that that the wound from his melanoma had been healing so he had ventured to have his varicose veins treated surgically which resulted in very heavy bleeding. As a result, he had been rather ill and had to have an extended stay in hospital (letter dated December 27, 1946).

Goldschmidt also mentioned in this letter that a very few persons had been sadly disappointed by his return but had been forced to continue their fight in the open sunshine which was a most unprecedented situation for the heroes of the dark. For Goldschmidt, this was a brisk and animated struggle, not at all to his disadvantage, nor dissatisfaction.

On February 9, 1947, Goldschmidt was able to inform Dr Ogg that his health continued to improve. In that month, he was invited to be a guest of the Chemical Society at an International Chemical Conference to be held in London on July 17-24, 1947, and to be chairman of Section 1 (Inorganic and Geochemistry) (Mason 1992). Goldschmidt accepted and proposed to give two lectures 'The Principles of Modern Geochemistry' to Section 1 and 'Forsterite and Olivine as Refractories' to Section 11.

However, the next letter that Dr Ogg received was from Dagfinn Dahl, Goldschmidt's attorney, informing him that Goldschmidt had died the previous day (March 20, 1947) after an operation for cancer (his sixth). He had just been brought home when he died suddenly from a brain haemorrhage. Goldschmidt was cremated and his ashes were placed in an urn at the Western Crematorium in Oslo (Mason 1992, P. 107, Plate 43). The urn was made of the beautiful green olivine rock which Goldschmidt had developed as a refractory material from 1925 onwards (Rosbaud 1961, Mason 1992).

Goldschmidt appears to have been busy following his return to Oslo. He published ten articles in Norwegian in 1946 but all seem to have been minor contributions (Mason 1988). On July 17, 1946, he was nominated to be a member of the Advisory Board of the new journal, Acta Crystallographica, along with Sir Lawrence (W.L. Bragg) at a meeting of the Journal Subcommittee held at the Cavendish Laboratory in Cambridge (Kamminga 1989). On September 11, 1946, L.E. Sutton, Goldschmidt's friend from Oxford, visited him in his laboratories and stayed for lunch (letter from Goldschmidt to Dr Ogg dated 11 September, 1944). However, progress on the dielectric prioperties of water remained slow.

In 1986, Goldschmidt's ashes were buried in the graveyard next to the crematorium along with those of his mother and father. The urn is now preserved at the Geological Museum in Oslo. Goldschmidt's return to Oslo therefore had a tragic ending. There is no doubt that his premature death at the age of 59 was caused by the harsh treatment he was forced to endure during the German occupation of Norway from which his health never properly recovered.

In Britain, C.E. Tilley wrote Goldschidt's obituary for the Royal Society (Tilley 1948) and J.D. Bernal gave the memorial address before the Chemical Society (Bernal 1949). It is not possible to pay greater tribute to the life and work of V.M. Goldschmidt than those given by Tilley and Bernal. Fittingly, Bernal's address was given as the Ninth Hugo Müller lecture of the Chemical Society 11 years after Goldschmidt had given the Seventh lecture and in the same room where he had given his lectures to the Chemical Society in 1929 and 1937.

Postwar Developments (1947-1970)

The most important task after Goldschmidt's death was the publication of his book 'Geochemistry' (Goldschmidt 1954). According to the Editor's Notes to Goldschmidt (1954), the book was begun at the suggestion of Sir William Ogg. However, the manuscript for the book had only been partially completed by Goldschmidt at Macaulay and Rothamsted before his death. In the summer of 1948, Brian Mason visited Goldschmidt's old institute in Oslo and found Ivar Oftedal working through hundreds of pages of manuscript intended for this volume (Mason 1992). However, some of the chapters had not even been started and much of the material was in Goldschmidt's own handwriting which was difficult to decipher. Goldschmidt himself was of the opinion that the book scarcely came up to his own standards being written in hospital after the loss of all his own library and notes from the last 20 years (undated draft of the Foreword for his Geochemistry book lodged at the Macaulay Institute in Aberdeen which was never used). In fact, Goldschmidt did very little on this book during his last six months in Rothamsted because of his involvement in the silicosis work or during his time in Oslo before his death (Editor's Notes to Goldschmidt 1954).

The book would almost certainly have never been published if Alex Muir (who was Head of the Pedology Department at Rothamsted and a colleague of Goldschmidt at both the Macaulay and Rothamsted Institutes) had not undertaken to edit and compile it from Goldschmidt's own very incomplete notes (Ogg 1962). Goldschmidt considered Muir to be his friend and the person most capable of completing the book (letter to Dr Ogg dated June 2, 1945, held at Rothamsted). However, as described in the Editor's Notes to Goldschmidt (1954), this was a formidable proposition which involved major contributions from several British, Norwegian and Swedish colleagues. Although Part II of the book which was 577 pages long had almost been completed, Part I which was 125 pages long had hardly been started. In both parts of the book, material had to be translated from German and then substantially edited prior to incorporation in the volume. The book was only completed after years of hard work by Alex Muir in collaboration with A Kvalheim, Goldschmidt's successor in the Raw Materials Laboratory in Oslo (Rosbaud 1961). The motivation to publish this volume probably came from the desire to see geochemistry established an important academic discipline in Britain. Prior to this time, geochemistry had only been a subject for study in the Soviet Union, Germany, the United States and Scandinavia.

Interestingly, 'Geochemistry' was published by Clarendon Press in The International Series of Monographs on Physics. This was entirely appropriate. Goldschmidt regularly attended the weekly Physics colloquia at the Physikalisches Institut in Göttingen during its Golden Age until 1934 (Hund et al. 1988). He also studied the structure of crystals from a physical viewpoint and his (1937b) volume clearly demonstrated that he was very knowledgeable about atomic physics.

The importance of Goldschmidt's 'Geochemistry' volume can not be overemphasized. It made Goldschmidt's ideas known to a much wider English-speaking audience. At that time, there were only two other text books on geochemistry available (Rankama and Sahama 1950 and Mason 1952). Goldschmidt's book therefore became a standard text on geochemistry for a number of years, although rapid advances in analytical chemistry coupled with the multi-element approach to geochemistry adopted by Wager and Mitchell (1951) soon rendered it somewhat dated. However, Goldschmidt's future status in the English-speaking world was undoubtedly derived from the publication of this book. Without it, he would probably have remained a somewhat peripheral figure similar to V.I. Vernadsky whose work is still poorly known in the west (Glasby 2000, Behrends 2005). 'Geochemistry' made Goldschmidt's name in the English-speaking world and would not have been published without a very substantial input from British colleagues.

On a more minor scale, Goldschmidt also played a role in founding Geochimica et Cosmochimica Acta in 1951 (Shaw 2003). After the war, Goldschmidt had discussed the idea of launching a journal devoted to geochemistry with his friend, Paul Rosbaud. The decision to go ahead with this journal was made during a meeting in Durham in May 1950 which was attended by F.A. Paneth, L.R. Wager and P. Rosbaud. At this meeting, Rosbaud emphasized that Goldschmidt would have given every possible support to this journal if he were still alive. The first editors of this journal were C.W. Correns, E. Ingerson, S.R. Nockolds, F.A. Paneth, L.R. Wager and F.W. Wickman and the journal was published by Pergamon Press which had been founded by Robert Maxwell in 1950. Paul Rosbaud negotiated the establishment of the journal on behalf of Pergamon Press. The Foreword to the first edition declared that the scope of the journal would be wide and that geochemistry as conceived by the pioneers – F.W. Clarke, V.M. Goldschmidt and V.I. Vernadsky – would be the leading theme of this journal.

Goldschmidt had a very high reputation in Britain during this period, particularly at Oxford where L.R. Wager was Professor from 1950-1965. One of the objectives of geochemical research at Oxford at that time was to test the validity of the Goldschmidt Rules by applying them to the Skaergaard Intrusion in S.E. Greenland. This aim was set out very clearly in Wager and Mitchell's (1943) original publication which dealt with the distribution of trace elements in whole rock samples from Skaergaard and was published before Wager's arrival in Oxford. In this study, whole rocks were analyzed by emission spectrography. However, only in certain cases were the variations in the concentrations of the trace elements shown to be related to ionic charge and radius. In later studies, variations in the amounts of given elements in the same mineral at different stages of the fractionation sequence were studied (Wager and Brown 1968).

In their classic paper, Wager and Mitchell (1951) hand picked individual mineral grains from coarser grained rocks after grinding and sieving the rocks and analyzed the grains by emission spectrography. Although it was shown that some elements are incorporated into the minerals according to the Goldschmidt Rules, the importance of other factors such as the sequence and quantity of the crystal phases in controlling the amounts of trace elements incorporated into a series of minerals produced by fractionation were emphasized. After 1958, the Skaergaard samples were in many cases analyzed by Instrumental Neutron Activation Analysis (INAA) in order to improve the accuracy of the data (e.g. Wager et al. 1958, Vincent and Bilefield 1960, Esson et al. 1965, Henderson et al. 1971). In his overview of 25 years of work on the distribution of trace elements in the Skaergaard Intrusion based on what he considered to be an impressive data set, Vincent (1974) emphasized the inadequacy of the Goldschmidt Rules in explaining the trace element distribution in these rocks. However, it should be emphasized that these detailed studies of trace element distributions were based on the analysis of individual minerals taken along a fractionation sequence in one particular intrusion and differed from Goldschmidt's earlier investigations which were based on the study of trace element compositions of minerals from many localities (Wager and Mitchell 1951).

During this period, theoretical studies were also undertaken at Oxford which questioned some of the fundamental assumptions of the Goldschmidt Rules. For example, Ahrens (1964, 1966) examined the influence of covalent bonding in the primary silicate minerals in rocks on the uptake of trace elements. Whittaker (1967) subsequently showed that the assumed relationship between melting point and bond strength within crystals which forms the basis for the Goldschmidt Rules is not generally valid. Whittaker and Muntus (1970) also recalculated the ionic radii of 86 elements in various coordination states which they considered to be the most suitable set of values for use in silicate geochemistry at that time.

Oxford chemists were also active in the development of crystal field theory which played an important role in understanding the uptake of transition elements into silicate minerals and rocks (Orgel 1952, 1960, Williams 1959, Phillips and Williams 1966). In addition, Burns (1970) reviewed some of the factors controlling the distribution of trace elements in the Earth's crust and showed that attempts to explain the distribution of transition metal ions in crustal rocks and minerals in terms of empirical rules such as the Goldschmidt Rules were generally unsatisfactory.

These studies at Oxford and elsewhere therefore emphasized that the Goldschmidt Rules are an approximation, a fact which Goldschmidt himself was well aware (Tilley 1948, Goldschmidt 1954). More rigorous methods for studying the uptake of trace elements within crystals involving the determination of partition coefficients between crystals and melts coupled with theoretical calculations of lattice strain are now being developed which will make the Goldschmidt Rules redundant (Blundy and Wood 2003).

In spite of this, Goldschmidt's ideas on the classification of the elements and the importance of ionic radii in explaining the uptake of 'impurities' in minerals and rocks are still considered to be important in the newly emerging field of medical geology (Davies et al. 2005, Garrett 2005).

The two major overviews of Goldschmidt's life (Mason 1992) and scientific achievements (Wedepohl 1996) were published at a much later date. The decision to prepare a biography of Goldschmidt was taken by the council of The Geochemical Society at its Annual Meeting in 1986 in order to mark the centenary of Goldschmidt's birth in 1988 (Mason 1992). Aslak Kvalheim, Goldschmidt's successor as director of the Norwegian Raw Materials Laboratory, had planned to write a biography of Goldschmidt but had suffered a stroke. He had then offered his material to Professor G. Kullerud to write the biography but he died in 1990. Brian Mason, Goldschmidt's former Ph. D. student, was then left with the onerous task of writing the biography. This entailed foraging through the 144 file boxes which comprised the Goldschmidt archives to find material of interest, most of which was written in German and Norwegian.

Professor Wedepohl began his career as a student in Göttingen in 1946 and became Professor at the newly founded Institute of Geochemistry in 1964. He is now an Emeritus Professor at the University of Göttingen and has a collection of memorabilia of Goldschmidt including most of his publications written in German as well as one of the optical spectrographs built by Dr Mannkopff which was used in Goldschmidt's studies in Göttingen.

V.M. Goldschmidt as Icon

In 1958, the Deutsche Mineralogische Gesellschaft (DMG) inaugurated the Viktor-Moritz-Goldschmidt-Preis to honour young, internationally recognized mineralogists who did not hold permanent professorial positions and were typically below the age of 38. In 1972, the Geochemical Society instituted the Goldschmidt Medal as the highest award of the society (Mason 1992). Lester

Strock, Goldschmidt's American associate in Göttingen from 1933 to 1935 and in Oslo from 1937 to 1938, endowed this medal with a monetary stipend. Amongst the winners of this medal was Hans Suess who received the award in 1974.

In 1988, the first Goldschmidt Conference was held in Hunt Valley, Maryland, to mark the hundredth anniversary of Goldschmidt's birth (Hitchon 1988). This conference was attended by 463 geochemists. By 2006, the number of participants at the 16th Annual Goldschmidt Conference in Melbourne, Australia, had increased to more than **1400.** These conferences are presently organized by European Association of Geochemistry in conjunction with The Geochemical Society and are the biggest event in the geochemical calendar.

Although other geochemists may rank in terms of scientific achievement, Goldschmidt id undoubtedly the best know geochemist in the world today and has become the standard bearer for the profession. In this sense, he may be considered to be an icon. His status depends principally on his scientific reputation rather than on the vagaries of his life which are less well known.

Concluding Remarks

Publication of the nine volumes of the Geochemische Verteilungsgesetze der Elemente between 1923 and 1927 and in 1937 and the eighteen papers in Nachrichten der Gesellschaft der Wissenschaften zu Göttingen Mathematisch-physikalische Klasse IV between 1930 and 1935 represents a remarkable achievement for Goldschmidt and his colleagues in Oslo and Göttingen. Essentially, these papers defined the subject of geochemistry as Goldschmidt conceived it. Goldschmidt was also highly regarded intellectually in Göttingen even in the prestigious Physikalisches Institut. Max Born, for example, described him as a having a very original mind and a stupendous memory (Tilley 1948, P. 62, Mason 1992, P. 55) and Heinz Meir-Leibnitz considered him to be a great chemist (Hund et al. 1988) and a genius. His status in Göttingen can perhaps be judged by the fact the he was nominated for the Nobel Prize ten times between 1929 and 1936 (Kauffman 1997).

In spite of his very considerable achievements, Goldschmidt's life can nonetheless be described as tragic in the Greek sense of the word. In Göttingen, Goldschmidt had found his intellectual home and there is no doubt that, under normal circumstances, he would have stayed there for the rest of his career but he felt honour bound to resign his professorship in 1935 in protest against the persecution of members of his own race. Between 1940 and 1943, he was subject to great hardships under the German occupation of Norway from which he never properly recovered. As a result, 1937 marks the turning point in his life. After publishing what was probably the outstanding paper of his career on a topic which was ripe for further investigation, he never produced anything of a comparable standard again. His status as a world class scientist at the forefront of his profession therefore essentially ended in 1937 at the age of 49. One can only speculate on what he might have gone on to achieve had the fates allowed. There is no doubt that he had the potential to become one of the great scientists of the Twentieth Century.

In considering Goldschmidt's connections with Britain, these were somewhat limited during the period from 1914 to 1940. His work was respected but not widely known. When he arrived in Britain in 1943, he was essentially a penniless refugee in poor health. It was at this stage that the bond developed. Goldschmidt was clearly perceived by some as the leading authority on geochemistry who could help Britain develop an expertise in that field. This was prevented by the exigencies of war. Goldschmidt made great efforts to collaborate with his British colleagues and to disseminate his knowledge of geochemistry but this was frustrated by his increasingly poor health. However, his scientific achievements were recognized by three major awards including election as a Foreign Member of the Royal Society. Goldschmidt made many influential friends in Britain and could have stayed but he preferred to return to Norway instead when this became possible.

It was really after the war that the British connection paid off. The decision to go ahead with the posthumous publication of Goldschmidt's 'Geochemistry' required years of hard work by Alex Muir and his associates but it was this that essentially made Goldschmidt's name in the English-speaking world. Goldschmidt also enjoyed a high reputation in Britain as one of the founders of modern geochemistry, particularly at Oxford where much effort was expended on testing the validity of the Goldschmidt Rules. Goldschmidt's present iconic status therefore derives in no small measure from his British friends keeping the flag flying in the post war years.

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