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Viktor Moritz Goldschmidt (1888–1947) and Vladimir Ivanovich Vernadsky (1863–1945): The father and grandfather of geochemistry?

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ABSTRACT

Vladimir Ivanovich Vernadsky (1863–1945) and Viktor Moritz Goldschmidt (1888–1947) are indisputably the two most important founders of and theoreticians within geochemistry. In 1910 Vernadsky provided the first definition of geochemistry, and therewith the basis of the scientific discipline concerned with the processes governing the distribution of the elements in the Earth System. In 1911, Goldschmidt, then 25 years younger, and commonly considered as the 'Father of modern geochemistry' in the western world, defended his Ph.D. thesis 'Die Kontaktmetamorphose im Kristianiagebiet' (The contact metamorphism in the Kristiania area). His thesis and his 'Geologisch–petrographische Studien im Hochgebirge des südlichen Norwegen' (Geological and petrographic studies in the mountains of southern Norway) published in the following years were primarily dedicated to answering questions about the mineralogy and petrology of the area. With the foundation of the Raw Material Laboratory of Norway in 1917, of which he was the first director, Goldschmidt carried out a systematic program of chemical analysis of rocks, soils and minerals and, therewith, began to address fundamental questions about geochemical processes. Goldschmidt's lecture 'Der Stoffwechsel der Erde' (The metabolism of the Earth) published in 1922 subsequently opened the era of investigation of the distribution of the elements in the Earth's crust, meteorites and solar system and of the laws controlling this distribution. With this new approach, Goldschmidt followed the definition of process-controlled geochemistry which had been formulated by Vernadsky 12 years earlier.

In this study the influence of Vernadsky on Goldschmidt's oeuvre has been analyzed by referring to private correspondence, biographical publications and other documents. The exchange of letters, hitherto largely unknown, proves that exchange of scientific ideas between the two men took place over a long period. Goldschmidt invited Vernadsky for several visits to Oslo in 1927 and to Göttingen in 1932. The exchange is documented in 38 surviving letters written between 1913 and 1939, justifying the conclusion that Goldschmidt's work was substantially inspired and influenced by Vernadsky, at least after 1922. However, Vernadsky's influence on Goldschmidt was mostly restricted to the theoretical background of geochemistry and the processes responsible for distribution of elements in the Earth's crust rather than analytical developments and documentation of element distributions.

1. Introduction

Geochemistry is a relatively young discipline within the geosciences, having developed at the turn of the 20th century and first defined in its contemporary understanding by Vernadsky in 1910 (Krüger et al., 1990; Vernadsky, 1910;). Vernadsky was obviously not the first scientist, who addressed geochemical questions. Three schools contributed decisively and almost simultaneously to the establishment of geochemistry as a scientific discipline. First, there was the US-American school under the leadership of Clarke (1847–1931), second, the Russian-Soviet school under Vernadsky (1863–1945) and Fersman (1883–1945), and, third, the Norwegian–German school under Goldschmidt (1888–1947) (e.g. Krüger, 1983).

Clarke and his colleagues postulated that the quantitative determination of the chemical composition of the earth is the principle objective of geochemistry. In 1889 Clarke published the first extensive collection of rock analyses, followed in 1908 by the compilation of 'The data of geochemistry' (Clarke, 1889, 1908). In 1922, together with Washington, he published 'The average chemical composition of igneous rocks' (Clarke and Washington, 1922). The school around Clarke and Washington and their successors focused on the collection of précis analyses and on the classification of the 'present chemical state' of geological objects (Herlinger, 1927; Krüger, 1983; Larsen, 1941).

The Russian-Soviet school around Vernadsky promoted the aim of geochemistry as the investigation and explanation of the laws governing the distribution of the chemical elements in the Earth's crust. At the turn of the 20th century Vernadsky developed geochemistry as an independent science originating with fundamental mineralogical

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and chemical questions. In his 'History of the minerals of the Earth's crust' in 1898, he presented initial concepts of the dynamic nature of geochemical processes, but without formulating the ideas clearly (e.g. Krüger, 1983). It was not until 1909 that Vernadsky defined geochemistry as a new and independent geoscientific discipline (Vernadsky, 1910). The development of the idea of the process-controlled distribution and migration of chemical elements in the Earth's crust can be traced through his publications (Vernadsky, 1909, 1924, 1927a, 1930). From 1926 Vernadsky included the geochemistry of living organisms in his studies (Vernadsky, 1926) and, finally, the impact of human activity on geochemical processes (Vernadsky, 1944).

The Norwegian–German school of geochemistry around Goldschmidt evolved from crystal chemistry and petrography, in the narrower sense the application of thermodynamics to metamorphic rocks. Goldschmidt, on his appointment as head of the Raw Material Laboratory of Norway in 1917, began systematic analysis of minerals, rocks, meteorites and soils. From 1922, utilizing his broad knowledge of crystal chemistry, he started to investigate the laws governing the distribution of elements as conceived in Vernadsky's definition of geochemistry. In the western world, Goldschmidt is often regarded as the "father of modern geochemistry" (e.g. Mason, 1992), a view that fails to acknowledge Vernadsky's earlier contribution to the foundation of geochemistry as an autonomous geoscientific discipline.

The aim of the present paper, which was presented at the Vernadsky conference organized by the Leibniz-Sozietät der Wissenschaften e.V. in Berlin in March 2013, is to summarize the main achievements of Goldschmidt's scientific career in the field of geochemistry and the history of his scientific correspondence and exchange with Vernadsky to demonstrate the influence this had on Goldschmidt's work. Evidence from 40 surviving letters and other documents is reviewed and discussed.[1] The biographical data and scientific achievements of Goldschmidt, which form the main thread of this paper, have been obtained chiefly, if not otherwise specified, from the book 'Victor Moritz Goldschmidt: Father of modern geochemistry' by Brian Mason (Mason, 1992) and from the Goldschmidt archive of the Norwegian State Archive in Trondheim, Norway. Mason was himself a geochemist and one of the last pupils of Goldschmidt.

The three columns of the time scale in Fig. 1 summarize important political events and the biographical data of Vernadsky and Goldschmidt which had a significant effect on the lives of both men. Both scientists were affected by the difficult times during and between the two world wars. The great achievements of both scientists are therefore even more worthy of recognition. Goldschmidt was Jewish and for that reason suffered discrimination and arrest and was almost sentenced to death by the Nazis. Only at the last second with the help of colleagues, friends and members of the Norwegian resistance, did he escape being transported to Auschwitz and gassed.

2. Goldschmidt's childhood (1888–1906)

During childhood, Goldschmidt's family was traveling and moving (Fig. 2). Goldschmidt was born in 1888 in Zurich, but after five years the family moved to Amsterdam where his father Heinrich Goldschmidt accepted a position as lecturer in chemistry at the University of Amsterdam. Three years later the family moved to Heidelberg in Germany, where the father became professor of chemistry. The family spent four years in Germany, after which Heinrich Goldschmidt accepted a professorship at the University of Oslo in 1901 and Norway became the home country of the young Goldschmidt. From 1903 to 1905 Goldschmidt attended the secondary school in Oslo. During this period he developed a strong interest in mineralogy, certainly inspired by the work of his father. During an excursion in the summer of 1904 Goldschmidt found quartz crystals in Gudbrandsdalen north of Oslo. The crystals showed a strong thermoluminescence which is not common for natural quartz. Goldschmidt described the discovery to Professor W. Brøgger, who was a colleague and friend of his father and director of the Geological Institute of Oslo University. Brøgger recognized the potential of the young man and gave him more quartz samples to study. In 1906 this study resulted in Goldschmidt's first publication entitled 'Die Pyrolumineszenz von Quarz' (Goldschmidt, 1906). At that time he was only 19 years old.

3. The petrographic years (1907–1917)

In 1907 Goldschmidt commenced his first large scientific study, which, in 1911, resulted in his 483-page Ph.D. thesis, entitled 'Die Kontaktmetamorphose im Kristianiagebiet' (The contact metamorphism of the Kristiania area) (Goldschmidt, 1911). In his Ph.D. Goldschmidt described and interpreted the mineralogy of hornfels that formed at the contacts between Paleozoic sediments and Permian granites in the intra-continental Oslo graben. Goldschmidt was the first to recognize the relationship between the chemistry of the rock before metamorphism and the mineral paragenesis of the metamorphic product. He concluded, that the mineral content of the hornfels is the result of a thermodynamic equilibrium and, therefore, that the Gibbs Phase Rule could be applied. The rule defines how many mineral phases can occur in an equilibrium assemblage in a rock composed of a specific number of chemical components. The application of the Gibbs Phase Rule to rocks became known as Goldschmidt's Mineralogical Phase Rule. The application of the phase rule became the key to interpreting phase transitions and mineral reactions in metamorphic rocks. It also formed the basis for mineralogical phase diagrams that are used today for predicting the temperature and pressure conditions under which given mineral assemblages are formed in rocks. Goldschmidt initiated this revolution by the investigation of the pressure- and temperature-dependent reactions of calcite and quartz to form wollastonite and carbon dioxide (Goldschmidt, 1912a). The results of Goldschmidt's Ph.D. immediately attracted international attention, particularly in Western Europe.

While Goldschmidt worked on his Ph.D., Vernadsky, who was 25 years older, presented his paper 'The paragenesis of the chemical elements in the Earth's crust' at the 12th Congress of Russian physicians and natural scientists in Moscow in December 1909. In this presentation published in 1910 Vernadsky provided the first definition of geochemistry as an independent science (Vernadsky, 1910). It marks Vernadsky's strict dedication to geochemical studies. In contrast to his American colleague Frank Clarke, who in 1908 published the remarkable compilation 'The data of geochemistry', in his talk Vernadsky described geochemistry in terms of dynamic processes. Later, he condensed the statements from 1910 in the following definition: 'Geochemistry is the scientific investigation of the chemical elements, i.e. the atoms of the Earth's crust and, wherever possible, of the entire planet. This involves studying the history of elements, their distribution and migration in space and time as well as their genetic interactions on our planet' (e.g. Vernadsky, 1930).

After the completion of his Ph.D. Goldschmidt extended his regional studies to the south Norwegian Caledonides and applied his phase rule in order to determine the temperature and pressure conditions during the Caledonian orogenesis. The results were published in five volumes entitled 'Geologisch–petrographische Studien im Hochland des südlichen Norwegen' (Geological–petrological studies in the highlands of southern Norway) between 1912 and 1921 (Goldschmidt, 1912a, 1912b, 1912c, 1915, 1916, 1921b). In addition to studying metamorphic rocks, Goldschmidt carried out detailed investigations of magmatic rocks and developed the 'Stammbaum magmatischer Gesteine' (The family tree of magmatic rocks). The family tree of magmatic rocks is based on the

[1] Three sources of letters have been identified and used in the frame of this study. First, the Archive of the Russian Academy of Science (ARAN; 26 letters), second, the Goldschmidt Archive of the Norwegian State Archive, Trondheim, Norway (6 letters) and, third, the Columbia University Libraries, New York, USA (8 letters). Copies of all letters are provided in the accompanying file.