Notes

1/Prologue

1. In 1939 £1 (NZ) was approximately equivalent to $4 (US) or 16 Norwegian kroner.
2. Pabst, Adolf (1899–1991), American mineralogist, B.A., University of Illinois, 1925; Ph.D. (geology), University of California, 1928. American–Scandinavian Foundation Fellow, University of Oslo, 1928–29. Professor of Mineralogy, University of California (Berkeley), 1929–67. President, Mineralogical Society of America, 1951, Roebling Medallist, 1965.
3. Barth, Thomas Fredrik Weiby (1899–1971), was the son of a highway engineer and grew up in Trondheim, where he began his university studies at the Norwegian Technical University in 1918. He made his first acquaintance with Goldschmidt in the winter of 1919–20, when he worked at the Geological Museum assisting the visiting Finnish scientist Pentti Eskola in the chemical analysis of rocks and minerals. In the autumn of 1919 he enrolled at the University of Oslo, from which he received his doctor's degree in September 1927. From the autumn of 1924 to the spring of 1927 he worked as a scientific assistant to Goldschmidt, for whom he made over 1000 X–ray diffraction photographs and was author or co–author on 19 publications. In a recommendation written in March 1927 Goldschmidt wrote: "His remarkable scientific competence, his skill and diligence are clearly shown by his extensive series of excellent publications. I greatly appreciate his personal qualities, as an extremely reliable, conscientious and gifted co-worker." After graduation in 1927 he worked for some time in Germany, before going to the U.S. in the spring of 1929, first to Harvard University, and from the autumn of 1929 at the Geophysical Laboratory in Washington, D.C. He later remarked that his years at the Geophysical Laboratory were the happiest

in his life. In February 1936 he returned to Norway as docent in crystallography, mineralogy, and petrology at the University of Oslo, and was promoted to Professor in July 1937. He returned to the Geophysical Laboratory in September 1939, coming back to Oslo in April 1940 immediately before the German invasion. In June 1946 he accepted an appointment as Professor of Petrology at the University of Chicago, but returned to Norway in March 1949 when he was appointed Director of the Geological Museum, a position which he held until retirement in 1966. He was active in international affairs, being president of the International Union of Geological Sciences from 1964 to 1968, and he travelled widely throughout the world, frequently as a guest lecturer. He received many honors, among them the Roebling Medal, the premier award of the Mineralogical Society of America, in 1961.

Although his given name was Thomas, he always used the abbreviated form, but insisted that it be followed by a period when printed, a usage followed in this book.

4. The name on the facade is "Geologisk Museum"; the building houses the Mineralogisk–Geologisk Museum and the Paleontologisk Museum. "Geological Museum" will be used throughout this book, mostly referring to the first–mentioned. The museum is part of the University of Oslo.
5. Marie Brendingen (the name is also spelled Brendengen, Braendengen, and Brenningen; in his correspondence Goldschmidt spelled it Brendingen, and that usage is followed here) was born in 1891 and died in 1980. She joined the Goldschmidt household as a housekeeper in 1927 and ministered faithfully to him until his death in 1947. She became more than a housekeeper; she was devoted to him and provided a comfortable home where he was able to concentrate on his scientific and industrial work. He bequeathed a large part of his estate to her.
6. Lunde, Gulbrand Oscar Johan (1901–1942) was born in Bergen. He studied at the University of Freiburg in Breisgau (Germany) and received his doctor's degree in chemistry in 1924. From 1924 to 1928 he was employed by the Raw Materials Laboratory as scientific assistant to Goldschmidt, during which time he carried out extensive crystal chemical researches, resulting in some 20 publications as author or co–author. He did pioneer work on the geochemistry of iodine. From 1929 to 1940 he was director of the Norwegian Cannery Industry's laboratory in Stavanger, where he made a series of scientific investigations of importance to that industry. After Quisling founded the Nasjonal Samling (the Norwegian Nazi party) in 1934, Lunde became an enthusiastic member, and belonged to Quisling's inner circle. Quisling appointed him to his abortive "government" in April 1940, and in September

1940 he was named by Reichskommissar Terboven to the "kommissarisk statsråd" and chief for the Department of Information and Propaganda. When the Quisling government was appointed in February 1942 he became Minister of Propaganda, the Norwegian Goebbels. Lunde and his wife died in a drowning accident on October 25, 1942.

Goldschmidt greatly appreciated Lunde's scientific talents, and supported his election as a member of the Videnskaps–Akademi in 1938. After Lunde revealed himself as a traitor in April 1940 Goldschmidt neither met nor corresponded with him again.

7. His silicosis experiments were aimed at substituting crushed olivine for quartz as a molding sand in foundries. The use of quartz resulted in serious lung damage to the workers.

2/Early Years: 1888–1906

1. Meyer, Victor (1848–1897), German chemist, Ph.D., University of Heidelberg, 1867. Professor of Chemistry, Eidgenossische Polytechnikum Zürich, 1872–85, where he was a colleague of Goldschmidt's father. Professor of Chemistry, University of Göttingen, 1885–89; University of Heidelberg, 1889–97.
2. van't Hoff, Jacobus Henricus (1852–1911), Dutch chemist, Ph.D. Utrecht, 1874. Chairman, Chemistry Department, University of Amsterdam, 1878–96; University of Berlin, 1896–1911. In Berlin he applied the Phase Rule to the elucidation of the mineralogy and paragenesis of salt deposits.
3. Rosbaud, Paul Wenzel Matteus (1896–1963) was born in Graz, Austria. In March 1915 he enlisted in the Austrian army and was sent to the Italian front. On November 3, 1918, he surrended to a British unit; his experiences as a prisoner of war made him a life–long Anglophile. In 1920 he entered the Technische Hochschule at Darmstadt in Germany to study chemistry, where he met his wife–to–be, Hilde Frank. He took his doctorate at the Technische Hochschule in Berlin. In January 1928 he became a scientific advisor to the journal *Metallwirtschaft*, and in this capacity met many of the leading scientists of the day, including Goldschmidt. In 1930 he joined the publishing house of Springer Verlag as scientific editor. In April 1938 he moved his wife and daughter Angela to England. In the late 1930's he established contact with the British Secret Intelligence Service (SIS), and during the war he was a British agent (code name Griffin) providing valuable technical data on German military secrets. He came under suspicion and in July 1944 was to be drafted into Organization Todt (slave labor), but was saved by the intercession of F. K.

Drescher–Kaden, Goldschmidt's successor at Göttingen. In recognition of his services he was invited to settle in England in November 1945, and he lived there till his death. He was instrumental in founding the international journal *Geochimica et Cosmochimica Acta* in 1950, and in the posthumous publication of Goldschmidt's *Geochemistry* in 1954. A book–length biography *The Griffin*, by Arnold Kramish, was published in 1986 (Houghton Mifflin Co., New York).

4. Brøgger, Waldemar Christopher (1851–1940) was born in Oslo and educated at the Cathedral School and the University of Oslo. He began his scientific career as a zoologist, his first publication in 1873 being a description of the molluscan fauna of the Oslofjord. He soon turned to geology, and he had a distinguished and versatile record in mineralogy, petrology, paleontology, and stratigraphy. In 1881 he was appointed the first professor of geology and mineralogy in Stockholm Högskola [now University of Stockholm]; during this period he described some fourteen new minerals and published a large monograph on the geology and mineralogy of the pegmatites of southern Norway. In 1890 he returned to Oslo as professor of mineralogy and geology in the university, a position he occupied until his retirement in 1916. Besides his scientific work, he was active in public affairs, as rector of the university (1907–1911), a member of parliament (1907–1909), and president of the Videnskaps-Akademi for some twenty years (1915–1935). He continued his researches after his retirement, publishing extensively until the mid 1930's. As teacher, colleague, and friend he was a major influence on the life of V. M. Goldschmidt.
5. Hiortdahl, Thorstein Hallager (1839–1925), Norwegian chemist and crystallographer, Professor of Chemistry, University of Oslo, 1872–1918. He studied relationships between chemical composition and crystal form, and made many difficult mineral analyses.
6. Birkeland, Kristian Olaf (1867–1917), Norwegian physicist, Professor of Physics, University of Oslo, 1898–1917. Developed with Sam Eyde a process for the oxidation of atmospheric nitrogen in an electric arc for the production of nitric acid and nitrates (the Birkeland–Eyde process). Commercial use of this process was initiated in Norway in 1907 by the firm Norsk Hydro.
7. Hevesy, George de (1885–1966) was born to a wealthy and distinguished Hungarian family. He received his early education in Budapest, but in April 1905 he entered the University of Freiburg, receiving his Ph.D. in physical chemistry in 1908. Goldschmidt spent several weeks in the Chemistry Department at Freiburg in the summer of 1906 and thus began a lifelong friendship. In 1911 Hevesy went to the University of Manchester to do research work in radioactivity in Rutherford's department. Here he met many

research workers, and was particularly impressed by Niels Bohr and H. J. G. Moseley, both of whom greatly influenced his future career. On the outbreak of World War I he returned to Vienna and joined the army, from which he was assigned to work in the armaments industry. After the war he accepted a position in the University of Budapest, but political difficulties persuaded him to accept Bohr's offer of a position in his institute in Copenhagen, from April 1, 1920. He then became greatly interested in geochemistry, applying X-ray spectrography to the analysis of rocks and minerals. This led to the discovery in 1922, with Dirk Coster, of element 72, which they named hafnium. He was appointed Professor of Chemistry at the University of Freiburg in April, 1926, but after the Nazis came to power in 1933 he resigned and returned to Bohr's institute in Copenhagen.

He next developed the use of isotopes as biological tracers, firstly with deuterium and later with a radioactive phosphorus isotope; the significance of this work was recognized by the award of the Nobel Prize for Chemistry in 1943. When the persecution of the Jews began in Denmark in 1943 he escaped to Sweden and accepted a research position in the University of Stockholm, where he remained until his retirement in 1961. He remained in close contact with Goldschmidt throughout the latter's life. Hevesy was a keen skier and took many vacations in the Norwegian mountains, usually staying for a few days with Goldschmidt in Oslo, and Goldschmidt frequently visited Hevesy in Copenhagen. There is extensive correspondence between them in the Goldschmidt Archives.

3/The Petrographic Years: 1907–1921

1. See Appendix F for the geological time scale.
2. Eskola, Pentti (1883–1964) was the son of a landowner in southwest Finland and received his doctoral degree in geology from the University of Helsinki in 1914. His doctoral thesis "On the petrology of the Orijärvi region in south-western Finland" applied Goldschmidt's principles of equilibrium in metamorphic rocks to an area of complex regional metamorphism. In 1919–20 he spent almost a year in Goldschmidt's institute in Oslo and developed his concept of the mineral facies of rocks. "The term facies to designate a group of rocks characterized by a definite set of minerals which, under conditions obtaining during their formation, were in perfect equilibrium with each other" (*Norsk Geologisk Tidsskrift*, vol. 6, p. 145, 1920). In his acknowledgements he wrote "Professor Goldschmidt has had a very effective share

in my work. During frequent colloquies with him most of the problems here treated were discussed, and many of the ideas developed have grown from his suggestions." The facies concept has been a guiding principle in elucidating the mineralogy and petrography of metamorphic rocks. Eskola was appointed professor of geology and mineralogy at the University of Helsinki in 1924, a position he retained until his retirement in 1953. Goldschmidt and he were fast friends, and corresponded frequently; Eskola sent many of his students to study and do research in Goldschmidt's institute.

3. Becke, Friedrich (1855–1931), Austrian mineralogist and petrologist, Ph.D., University of Vienna, 1880. Professor, University of Czernowitz, 1882–90; University of Prague, 1890–98; University of Vienna, 1898–1927. After Goldschmidt studied with him in the winter of 1908–09 they were friends for the rest of Becke's life. He is remembered by the widely-used Becke method for determination of the refractive indices of small grains by immersion in liquids of known refractive index.
4. Groth, Paul Heinrich (1843–1927) was educated at the Mining Academy at Freiberg in Saxony and at the University of Berlin. From 1872 to 1883 he was Professor of Mineralogy at the University of Strasbourg in Alsace, and then at the University of Munich, a position he held until his retirement in 1924. Both in Strasbourg and in Munich his institute was for many years the center of training for crystallographers and mineralogists from all parts of the world. He was an inspiring teacher, and he did more than anyone else in stabilizing crystallographic nomenclature and methods. He first met Goldschmidt on a mineral collecting trip in Norway in 1910 and they became fast friends; Groth proposed Goldschmidt as his successor at the University of Munich, which failed because of anti-Jewish feeling among the faculty.
5. Johnson, Mimi (1890–1980) graduated in mineralogy from the university in Oslo in 1912. She was appointed assistant in the museum in 1913 and was promoted to curator in 1917. She assisted Goldschmidt during the summers of 1913–17 in his field work in the Norwegian mountains. She married in 1919, becoming Mrs. Johnson-Høst. From 1924 to 1931 she was a research associate in Goldschmidt's laboratory, during which time she and Gulbrand Lunde developed and applied microchemical methods for the determination of trace amounts of gold, silver, and the platinum metals in rocks and minerals. In 1930 she spent four months in Göttingen teaching a course in petrographic microscopy. She then became a medical student, graduating in 1940 and practising for many years as a physician in a small town near Oslo.

6. Berner, Endre Qvie (1893–1983), field and laboratory assistant for Goldschmidt, 1913–17, later Professor of Chemistry, University of Oslo, 1934–62.
7. Amundsen, L., *Videnskapsakademi Historie,* vol. 2, p. 27. Oslo, 1960.
8. *J. Washington Acad. Sci.,* vol. 51, p. 69–76, 1961; translated from Norwegian by G. Kullerud.
9. In his obituary of Goldschmidt, C. E. Tilley commented: "(Goldschmidt) was unaware, it is clear, of the much earlier zonal work of Barrow in the southeast Highlands of Scotland." (*Obituary Notices of Fellows of the Royal Society,* vol. VI, 1948–49, p. 51). However, Barrow's work had been generally overlooked, perhaps because of the rather non-informative title of his publication—"On an intrusion of muscovite-biotite gneiss in the south-east Highlands of Scotland" (*Quart. J. Geol. Soc. London,* vol. 49, p. 330–358, 1893).
10. The Geological Museum in Oslo has a large map of the Stavanger–Trondheim area prepared by Goldschmidt, closely spaced with colored pins denoting rock types at specific localities. He used it in his lectures and had a special box made to transport it.

4/The Raw Materials Laboratory

1. Prior to the founding of the Raw Materials Laboratory, Goldschmidt had already developed some industrial contacts, as consultant to the Norwegian companies A/S Electroverk and A/S Titan. In 1916 his consultant fees equalled his professor's salary (7000 kr/year). When he was appointed Director of the Raw Materials Laboratory he gave up his consultancies, and the Commerce Department paid him an honorarium of 6000 kr/year. The amount of this honorarium remained unchanged until his death in 1947.

   The Raw Materials Laboratory produced a series of publications, most of which were issued as bulletins of the Geological Survey of Norway.
2. *Norsk Vidensk. Selsk. Skrifter. I. Math.-Naturv. klasse,* No. 9, 1921.
3. Laue, Max von (1879–1960), German physicist, who in 1912 discovered the diffraction of X-rays by crystals, for which he received the Nobel Prize in Physics in 1914. Professor of Physics, University of Zürich, 1912–14; Frankfurt am Main, 1914–19; Berlin, 1919–43; Göttingen, 1946–51. Director of the Fritz Haber Institute for Physical Chemistry, 1951–58.
4. Bragg, William Henry (1862–1942), British physicist, joint winner with his son, W. L., of the Nobel Prize in Physics in 1915 for the

determination of crystal structures by X–ray diffraction. Professor of Physics, University of Adelaide (Australia), 1886–1908; Leeds, 1908–15; London, 1915–25; Director of the Royal Institution (London), 1925–42.

5. Bragg, William Lawrence (1890–1971), British physicist, son of W. H. In 1919 he succeeded Rutherford as Professor of Physics, University of Manchester, where he built up a school distinguished for crystal structure determinations. Professor of Physics and Director of the Cavendish Laboratory, Cambridge University, 1937–53 (again in succession to Rutherford). Director, Royal Institution (London), 1953–66.
6. Bernal, John Desmond (1901–1971), British physicist and X-ray crystallographer, Professor of Physics (1938–63) and Crystallography (1963–68), University of London.
7. *J. Chem. Soc.* (London), p. 2108, 1949.
8. Oftedal, Ivar Werner (1894–1976) was born in Larvik, Norway. He began his studies at the University of Oslo in 1913. In 1918 he began his long association with the Geological Museum as a student assistant to Goldschmidt in mineralogy, eventually rising to the position of senior curator (and acting director during Goldschmidt's time in England and briefly after his death). During the 1920's he worked closely with Goldschmidt on crystal chemical investigations, but later developed his own interests in mineralogy and geochemistry. After Goldschmidt's death in 1947 he succeeded him as Professor of Mineralogy, until his retirement in 1964.
9. Thomassen, Lars (1896–1972) was born in Oslo and graduated in chemical engineering from the Norwegian Institute of Technology in Trondheim in 1919. From 1919 to 1924, and again from 1927 to 1929, he was Goldschmidt's principal research associate. He was largely responsible for the construction and operation of the X–ray spectrographs which played such a large part in the Oslo researches, and in 1926 he published a comprehensive account of this technique for the detection and measurement of concentrations of the chemical elements down to a level of 0.1%. In December 1924 he went to the California Institute of Technology in Pasadena on a fellowship from the International Education Board, to work with Professor R. A. Millikan. He presented a thesis and was awarded a Ph.D. before returning to Norway in September, 1927. In 1929 he was appointed professor in the Department of Chemical Engineering of the University of Michigan, specializing in metallurgy, where he remained until retiring in 1966.
10. Stenvik, Kristoffer (1892–1959) was born at Ytterøy in the Trondheimsfjord. At the age of 16 he began work as a mechanic and worked for industrial and mining companies until June 1921,

when he accepted an appointment as technical assistant in the Raw Materials Laboratory. He studied mineralogy, petrology, and chemistry at the university, and became Goldschmidt's right-hand man. They complemented each other in a remarkable manner—Goldschmidt with his theoretical knowledge and fertile ideas, and Stenvik with his technical expertise. They worked together closely throughout Goldschmidt's life, especially in the development of Norwegian olivine rock as a refractory, beginning around 1925. They took out several patents together. In October 1947 the company A/S Olivin was formed to exploit the olivine deposits in Norway, and Stenvik managed the operations for almost ten years, before returning to the Raw Materials Laboratory in 1957.

11. A more detailed Periodic Table is given in Fig. 7.
12. Hadding, Assar Robert (1886–1962), Swedish geologist and mineralogist, graduated from the University of Lund 1913 and appointed docent, advanced to professor 1934; Rector of the University of Lund, 1947–51. Hadding was a many-sided researcher who worked over practically the whole field of geological science. His pioneer work on the application of X-ray spectrography and X-ray diffraction to mineralogical and geochemical problems was an outstanding contribution, and was highly esteemed by Goldschmidt; they were good friends throughout his life.

5/Intermezzo: The Search For Element 72

1. This chapter is partly based on the article "The era of cosmochemistry and geochemistry, 1922–1935," by Gustaf Arrhenius and Hilde Levi, published in G. Marx (editor): *George de Hevesy, 1885–1966.* Akademiai Kiado, Budapest, 1988, pp. 11–36.
2. *Chemical Analysis by X-rays and its Applications,* p. 182. McGraw-Hill Book Co., New York, 1932.
3. Letter dated February 7, 1925, Translated from Norwegian by Professor Gustaf Arrhenius, University of California, San Diego.
4. The yearly demand for hafnium in the U.S. now exceeds 50 tons. It is used for control rods in atomic reactors, and to a minor extent as a component of special alloys.

6/Crystal Chemistry and Geochemistry in Oslo: 1922–1929

1. *Chemical Products,* p. 2, March–April 1944.
2. Zachariasen, Fredrik William Houlder (1906–1979) was born in Langesund in southern Norway, the center of one of the world's

great mineral localities. In 1923 he entered the University of Oslo and joined the team of young researchers in the Mineralogical Institute. He soon showed his remarkable talent in the X–ray analysis of crystal structures; he was a co–author on *Verteilungsgesetze* VI and VII, and in 1928 received his doctor's degree for a 168–page monograph *Untersuchungen über die Kristallstruktur von Sesquioxyden und Verbindungen ABO_3* (Investigations of the crystal structure of sesquioxides and compounds with the formula ABO_3.) After graduation he worked for some time with W. L. Bragg at the University of Manchester before joining the faculty of the Physics Department at the University of Chicago, where he remained until his retirement in 1974. Among his many contributions was his work for the Manhattan project on the crystal structure and crystal chemistry of the actinide elements—thorium, protactinium, uranium, neptunium, plutonium, americum, curium. Goldschmidt considered him one of his most gifted students and collaborators, and tried unsuccessfully to get him a research professorship in Norway in 1936.

3. Ulrich, Frantisek (1899–1941) was born at Boharyne in eastern Bohemia and was educated at the Charles University in Prague, receiving his doctor's degree in mineralogy. In 1923 he received a fellowship from the Rockefeller International Education Board and joined Goldschmidt's research group in Oslo. He was a co–author in Part IV of the *Geochemische Verteilungsgesetze* on the crystal structure of the rare earth oxides, he determined the structure of Al_2O_3, and collaborated with Zachariasen on the structures of greenockite (CdS) and wurtzite (ZnS). He returned to Prague in 1925 and organized an X–ray laboratory in the Mineralogical Institute of the Charles University; he was appointed Professor of Experimental Mineralogy in 1934. He was murdered by the Gestapo in 1941.
4. Welsbach, Auer von (1858–1929), Austrian chemist, was a foremost investigator of the chemistry of the lanthanides, and the inventor of the lighter "flints" which are an alloy of the lanthanide elements, and of the incandescent lamp mantle made of lanthanide and thorium oxides. Contemporaneously with Georges Urbain, he discovered element 71 which he named cassiopeium, but Urbain was awarded priority with his name lutetium.
5. Thus the cell edge of NaF, 4.62Å, is the sum of the diameters of a sodium and a fluoride ion. From Wasatjerna's figure of 1.33Å for the radius of the fluoride ion, it follows that the radius of the sodium ion is 0.98Å.
6. Today one can hardly visualize the experimental difficulties with X–ray investigations in the 1920's. X–ray tubes were temperamental and required constant attention, obtaining a satisfactory vacuum could take hours of pumping, films were slow so exposure times were long, and computers were non–existent (even in 1942,

when I was doing X-ray crystallographic research, all calculations were made on a hand-operated mechanical calculator).

7. *Chemical Products*, p. 4, March–April 1944.
8. *Norsk geol. Tidsskr.*, vol. 9, p. 258, 1928.
9. Machatschki, Felix Karl Ludwig (1895–1970) was born in Arnfels, Styria, Austria and educated in Graz, receiving his doctor's degree in mineralogy and petrology. From 1927 to 1930 he worked closely with Goldschmidt, except for a period in Manchester in 1928–29. During that time he published a landmark paper in which he enunciated the modern theory of the crystal structure of the silicates: "Zur Frage der Struktur und Konstitution der Feldspate (Gleichzeitig vorlaüfige Mitteilungen über die Prinzipien des Baues der Silikate," in *Centralblatte der Mineralogie*, Abteilung A, p. 97–104, 1928). As he acknowledges, this was based on the data on ionic radii and isomorphism in Goldschmidt's *Geochemische Verteilungsgesetze der Elemente*. In 1929–30 he was guest lecturer at Goldschmidt's institute in Göttingen. In 1930 he was appointed Professor of Mineralogy at the University of Tübingen, followed by similar positions at the University of Munich (1941–44) and Vienna from 1944. His great contributions to the crystal chemistry of minerals were recognized by numerous honors, among them the Roebling Medal, the highest award of the Mineralogical Society of America.
10. Wyckoff, Dorothy (1900–1982) was born in Massachusetts, the daughter of a Congregational minister. She entered Bryn Mawr College in 1917 and received the A.B. degree in 1921, majoring in Greek and Latin. After a period of school teaching she returned to Bryn Mawr in 1925 to study geology and related sciences. She received her M.A. in geology in 1928 and was awarded an American–Scandinavian Foundation Fellowship. She took up the fellowship at the University of Oslo in September 1928 and under the guidance of V. M. Goldschmidt made a field and laboratory study of the metamorphic rocks of the Mt. Gausta region in the province of Telemark, southern Norway. For her thesis on this work she received her doctorate from Bryn Mawr in 1932. In September 1930 she was appointed an assistant in the Geology Department at Bryn Mawr and was successively promoted, eventually to full professor in 1945. During World War II she joined the Military Geology Unit of the U.S. Geological Survey in Washington, D.C., where her talents as geologist, photogrammetrist, and artist enabled her to produce terrain diagrams which were used to plan assault operations and were famous for their accuracy and clarity. She retired from Bryn Mawr College in 1966.
11. The nomination was repeated in 1930, 1931, 1932, 1933, 1934, and 1936, without success.
12. Eskola Archives, University of Helsinki.

7/Geochemistry in Göttingen: 1929–1935

1. W. A. Benjamin Inc., New York, 1965 (p. 363).
2. *Teknisk Ukeblad,* p. 124–125, 1936. The building is now part of the Physics Department, but a plaque on the outside wall records Goldschmidt's tenure. The Geochemical Institute moved to a new building on the outskirts of Göttingen in 1971, the address being appropriately Goldschmidtstrasse 1. It houses a collection of some 2500 documented rock and mineral samples analysed by Goldschmidt and his co–workers, together with the spectrographic plates.
3. Heide, Friedrich (1891–1973) was born in Dresden and was a student at the universities of Munich and Jena during the years 1911–1920, with an interval of military service during World War I. After graduation he was an assistant at the University of Jena until 1923, after which he moved to the University of Göttingen, first as assistant and later as docent in the Mineralogical Institute. After the retirement of Professor Mügge in 1928, he was in charge of the Mineralogical Institute until Goldschmidt took up the directorship in late 1929. During this time he supervised the construction and equipping of the new institute to Goldschmidt's specifications, and developed his interest in geochemical research. In 1930 he returned to Jena as Professor of Mineralogy and Director of the Mineralogical Institute, a position he occupied until his retirement in 1963. He is particularly noted for his research on meteorites, probably inspired by his association with Goldschmidt; his book *Kleine Meteoritenkunde,* first published in 1934, has gone through several editions and was translated into English by Edward Anders (a new version is in preparation by F. Wlotska and R. S. Clarke, Jr.).
4. Ernst, Theodor (1904–1983) was a student at Göttingen when the negotiations for Goldschmidt to accept the professorship began in 1927. In March 1929 he was appointed a teaching assistant in the institute, and worked closely with Goldschmidt in the lecture and laboratory instruction. He received his doctor's degree in petrology in 1936, and in 1937 was appointed docent in mineralogy and petrology. He remained at Göttingen until 1949 (except during World War II), when he was appointed Professor of Mineralogy and Geology at the University of Erlangen. He retired in 1972.
5. Gleditsch, Ellen (1879–1968), Norwegian chemist, was educated in Oslo and worked with Madame Curie in Paris from 1907 to 1912 and with Professor B. B. Boltwood at Yale University 1913–14, when she received an honorary D.Sc. from Smith College. She devoted her life to the chemistry of the radioactive elements.

In 1916 she was appointed docent in radiochemistry at the University of Oslo, a newly created position. During the following years she made many precise analyses of radioactive minerals and determined their age by the uranium–lead method. In 1917 she was elected to the Videnskaps–Akademi on the motion of Professor Heinrich Goldschmidt, the second woman so honored. In 1929 she succeeded Heinrich Goldschmidt as Professor of Inorganic Chemistry at the University of Oslo, the second woman professor in the university. In the 1940's she did some of the early work on the radioactivity of potassium and its significance as a heat source in the Earth. She retired in 1946 but continued her researches until her death. Throughout her life she was active in international affairs, serving on committees of the League of Nations and UNESCO. During both World Wars she worked for the relief of prisoners of war and refugees. Although V. M. Goldschmidt opposed her appointment to a professorship, he admired her greatly for her moral courage and her opposition to Naziism.

6. Hassel, Odd (1897–1981) was born in Oslo, the son of a physician. He entered the university in 1915 and took his first degree in chemistry in 1920. He then did research in Germany for some years, receiving a doctor's degree from the University of Berlin in 1924. Returning to Norway in 1925, he was appointed docent in physical chemistry and electrochemistry at the University of Oslo, and worked closely with Goldschmidt on crystal structure problems. Goldschmidt nominated him for the chemistry professorship in 1929, and when the faculty rejected this nomination Goldschmidt resigned and left Oslo for Göttingen. In 1934 Hassel was appointed to a newly established professorship in physical chemistry, which he held until his retirement in 1964. During World War II he was imprisoned for his anti–Nazi activities. He was a lifelong friend of Goldschmidt and gave his memorial address to the Videnskaps–Akademi on November 14, 1947 (see Appendix A). In 1969 he shared the Nobel Prize in Chemistry with the British chemist Derek Barton "for their contributions to the development of the concept of conformation and its application to chemistry". Hassel's activities during World War II are extensively documented in Arnold Kramish's book *The Griffin* (New York, 1986).
7. The house still stands; it has been converted into apartments.
8. *Nature,* vol. 159, p. 701, 1947.
9. Peters, Clemens was born in 1902 in Münster, Germany, and studied chemistry at the universities of Münster and Wurzburg, receiving his doctorate from Wurzburg in 1930. He then joined Goldschmidt's institute at Göttingen, where together with Mannkopff he developed the methods of quantitative determination of minor and trace elements by optical spectrography.

During the following years he was co–author with Goldschmidt on eight publications on the geochemistry of specific elements. In 1934 he joined the Badische Analin–und Sodafabrik in Ludwigshafen as a structural chemist and X–ray crystallographer, remaining there until his retirement in 1967.

10. Mannkopff, Reinhold (1894–1978) began his university studies in Freiburg, but they were interrupted by service in World War I. After the war he completed his studies at the University of Göttingen, receiving his doctor's degree in physics in 1926. In 1929 he joined Goldschmidt's institute, firstly as scientific assistant and later as docent. For geochemical problems he worked out spectral analytical methods, by developing high–dispersion prism spectrographs in the workshop of the institute. The physics of the carbon arc was the subject of his further research. He served in World War II, and after the war returned to the Göttingen institute.
11. Berman, Harry (1902–1944) was born in Boston, but his family moved to Johnstown, Pennsylvania in 1909, where he received his elementary and high school education. He then attended Carnegie Institute of Technology with interest in mathematics and engineering, but for financial reasons was forced to abandon college work at the end of one year. In 1922 he became an assistant in the mineralogy section of the Smithsonian Institution in Washington, D.C., where he acquired his intense and lasting interest in minerals. In 1924 he moved to Harvard University as assistant to Charles Palache, Professor of Mineralogy and Director of the Mineralogical Museum. Over a period of several years he completed college requirements, eventually receiving his Ph.D. degree in 1936. During the academic year 1932–33 he was awarded a scholarship for foreign travel, which he utilized in studying with J. D. Bernal in Cambridge, England, and with Goldschmidt in Göttingen. After his return to the United States he established an X–ray crystallographic laboratory in the Mineralogical Museum at Harvard. Goldschmidt admired Berman as "a very clever mineralogist," but took great umbrage when Berman published "Constitution and classification of the natural silicates" (*Am. Mineral.*, vol. 22, pp. 342–408, 1937), evidently because he failed to give what Goldschmidt considered was adequate reference to the Oslo school. During World War II Berman was active in the manufacture of quartz crystal oscillators and was killed in an airplane crash in Scotland while on a mission to Great Britain.
12. Minami, Eiiti (1899–1977) graduated in chemistry from the University of Tokyo in March, 1923. After graduation he was appointed lecturer in the Mineralogy Department, where he taught mineralogical chemistry until 1938, except for the period from

May 1933 to July 1935 which he spent as a visiting researcher with Goldschmidt in Göttingen. While there he investigated the selenium and rare earth concentrations in Japanese and European shales. His results on the abundance and distribution of the rare earth elements remained the basic data on these elements for almost 30 years; they were confirmed and extended in the 1960's by the work of Professor L. A. Haskin and his coworkers at the University of Wisconsin. Shortly after his return to Japan he was appointed Professor of Analytical Chemistry in the University of Tokyo, where he remained until retiring in March 1960, because of the age requirements of the university.

13. Strock, Lester William (1906–1982) was born of Pennsylvania Dutch parents in Chambersburg, Pennsylvania. He received his Ph.D. in chemistry from the University of Pennsylvania in 1931. He specialized in crystal chemistry, and in May 1933 arrived in Göttingen as a post–graduate guest researcher. He had been attracted to Göttingen by Goldschmidt's earlier work on crystal structures, but rapidly adapted to the new developments in geochemical research. He remained at Göttingen until November 1935, during which time he published on the geochemistry of selenium and lithium. He then spent some time in London writing a small book *Spectrum Analysis with the Carbon Arc Cathode Layer* (Adam Hilger, London, 1936) which described the technique used so successfully in Goldschmidt's institute. He rejoined Goldschmidt in Oslo from May 1937 to December 1938. From January 1939 until the early 1950's he served as research radiographer for the Saratoga Springs Commission of the N.Y. State Conservation Department. In 1951 he joined the Sylvania Electric Products Co. and worked for this firm until his retirement in 1971, investigating the crystal chemistry of compounds used in the lighting industry.
14. Witte, Helmut, born 1909, studied at the universities of Braunschweig, Munich, and Göttingen. He completed his studies in Goldschmidt's institute and received his doctor's degree with a thesis on spectral physics in 1933. After graduation he was appointed a scientific assistant in the institute, doing research on the distribution of trace elements in black shales. He worked in industry from 1939 to 1943, when he was called to the Technical University in Darmstadt, first as docent and from 1954 Professor of Physical Chemistry.
15. Noll, Walter (1907–1987) was born in Jena, and studied at the universities of Jena and Heidelberg, graduating from Jena in 1930 with a thesis on the sorption of potassium on clay minerals. In April 1930 he joined Goldschmidt's institute at Göttingen, where he investigated the synthesis of clay minerals and the geochem-

istry of strontium. From November 1932 to April 1937 he was scientific assistant in the Mineralogisch–Geologisches Institut of the Technische Hochschule in Hannover. He then joined IG–Farbenindustrie as a silicate chemist. In 1950 he was appointed docent in crystal chemistry at the University of Cologne and was promoted to professor in 1958.

16. Engelhardt, Wolf von, was born 1910 in Dorpat, Estonia, studied at the universities of Halle, Berlin, and Göttingen, and graduated from Goldschmidt's institute in 1935 with a thesis on the geochemistry of barium. He was then appointed assistant to Professor C. W. Correns at the Mineralogical Institute of the University of Rostock. After World War II he directed the geological work of the petroleum company Gewerkschaft Elwerath in Hannover. In 1957 he was appointed Professor of Mineralogy and Petrology in the University of Tübingen, a position he held until his retirement in 1978. He is noted for his researches on sedimentary petrology, on the investigation of the Ries astrobleme, and for his work on the mineralogy and petrology of the lunar rocks.
17. For a biography see: *Science and Russian Culture in an Age of Revolutions: V. I. Vernadsky and his Scientific School, 1863–1945,* by K. E. Bailes. Indiana University Press, Bloomington, Indiana, 1990.
18. The Vernadsky–Goldschmidt correspondence is in the Vernadsky papers at the Columbia University Library in New York.
19. Letter to Professor Denis Shaw, McMaster University, Hamilton, Ontario, February 6, 1973.
20. Laves, Fritz Henning (1906–1978) was born in Hanover, Germany. He studied at the universities of Innsbrück and Göttingen, and received his doctorate in crystallography from the Swiss Institute of Technology in Zürich in 1929. After graduation he joined Goldschmidt in Göttingen as assistant and docent. He was obviously a favorite of Goldschmidt, who permitted him to smoke in the laboratory, a unique privilege. During this time he studied the structure of intermetallic compounds, a major advance in the understanding of alloys. At Göttingen he was never promoted beyond docent, since the Nazi regime suspected him, a principled man, of protecting Jews (in 1933 he tried to muster the Faculty of Science at Göttingen in support of Goldschmidt). During World War II, through the influence of Paul Rosbaud, he was assigned to a group under Reichsmarschal Göring to develop an alloy "stronger than steel and lighter than air". After the war he was one of the German scientists transferred to the United States, and he joined the University of Chicago in 1948, working with Professor Julian Goldsmith on order–disorder in the feldspar minerals. In 1954 he returned to Zürich as the successor to Paul

Niggli as Professor of Mineralogy, where he remained until retirement.
21. See Appendix A.
22. Richard probably refers to Richard Wagner, composer of Parsifal and other operas.
23. *Geol. Fören. Förh.*, vol. 56, p. 385–427, 1934.
24. *Teknisk Ukeblad*, No. 11, p. 6–7, 1936.
25. Letter to Denis Shaw, August 12, 1972. Actually, Hitler came to power not as the result of a putsch in March 1933, but through the election of January 30, 1933.
26. Letter, May 6, 1933, in the archives of the University of Göttingen.
27. Letter, February 2, 1935, in the archives of the University of Göttingen.

8/Oslo: 1935–1942

1. The house is still in use (1991).
2. Saeland, Sem (1874–1940), Norwegian physicist, Rector, University of Oslo, 1927–36.
3. Schetelig, Jakob Grubbe Cock (1875–1935), the son of a ship owner, entered the University of Oslo in 1893. During his student years he was an assistant to Fridtjof Nansen, working up the oceanographic results of the "Fram" North Polar expedition (1893–96). In 1905 he was appointed a scientific assistant to Professor Brøgger, and later senior curator at the Geological Museum. In 1917 he succeeded Brøgger as Professor of Mineralogy and Petrology and Director of the Museum. His first mineralogical publication, in 1911, described the new mineral thortveitite, $Sc_2Si_2O_7$, the first mineral containing the rare element scandium as a major component. In the following years he published many papers on rare minerals in Norwegian pegmatites. After Goldschmidt's move to Göttingen in 1929 he took over direction of the Raw Materials Laboratory. He died in 1935 after a lengthy illness.
4. Archives, Geological Museum, Oslo.
5. Holtedahl, Olaf (1885–1975), Norwegian geologist, received doctorate from University of Oslo 1913, Professor of Geology and Director of the Geologisk-Paleontologisk Institut, 1920–56. Geologist on expeditions to Svalbard 1914–17, Novaya Zemlya 1921, Antarctica 1927–28; author of "Geology of Norway" (1960).
6. Bugge, Arne, brother of Carl Bugge; geologist, Geological Survey of Norway, 1921–52.
7. Bugge, Carl (1881–1968), geologist, Director of the Geological Survey of Norway, 1921–51.

8. *J. Chem. Soc (London)*, p. 655–673, 1937.
9. *Gerlands Beitr. Geophy.*, vol. 15, p. 38, 1926.
10. *Travaux du congres jubilaire Mendeleev II.* Acad. Sci. U.R.S.S., p. 387, 1937.
11. *Fra Fysikkens Verden*, vol. 3, p. 179, 1942.
12. Harwood, Henry Francis, Professor of Chemistry, Imperial College of Science & Technology, London.
13. Holmes, Arthur (1890–1965), English geologist, Professor of Geology, University of Durham, 1924–43, Edinburgh, 1943–65.
14. *Geochemische Verteilungsgesetze der Elemente*, IX, p. 34, 1938.
15. This correspondence is from the Palache papers, Mineralogical Museum, Harvard University.
16. *Am. Mineral.*, vol. 30, p. 126, 1945.
17. Kvalheim, Aslak, born 1911, was educated as a chemical engineer and joined the Raw Materials Laboratory on October 1, 1937. He was responsible for the laboratory operations and became Goldschmidt's closest collaborator. After the latter's departure in 1942, he was appointed Director of the Raw Materials Laboratory, filling that position until Goldschmidt's return in June 1946 and after his death in 1947. He was an expert in quantitative spectral analysis, and published extensively on that theme and on the utilization of Norwegian mineral resources. In 1941 he was co–author with Goldschmidt of a monograph on trace elements in meteorites, which unfortunately on account of the war was never published.
18. See Appendix A.
19. Not quite true—his mother's urn is porphyrite.
20. Archives, Geological Museum, Oslo.
21. *Norske Videnskaps–Akademi i Oslo Årbok* 1940, p. 29–41.
22. Seip, Didrik Arup (1884–1963), Professor of Linguistics, University of Oslo, 1916–1945. University Rector 1937–45, but dismissed by the German administration in September 1941, arrested by the Gestapo and imprisoned in Grini concentration camp outside Oslo; transferred to the Sachsenhausen concentration camp outside Berlin in April 1942; as a result of protests from Swedish and Finnish academic authorities he was released in December 1942, but held in civil internment in Germany until April 1945.
23. Hoel, Adolf (1879–1963), geologist and polar scientist, Professor of Polar Geography, University of Oslo, 1940. In the 1930's he became a prominent member of Quisling's Nasjonal Samling. After Seip's dismissal Hoel was appointed Prorector and in 1943 Rector of the University of Oslo. After the German defeat in 1945 he was dismissed from the university and prosecuted for his actions during the war.
24. Letter to B. Mason, September 29, 1990.

25. Suess, Hans Eduard, was born in Vienna on December 16, 1909, the son of Franz Eduard (1867–1941) and the grandson of Eduard Suess (1831–1914), both distinguished geologists who held professorships at the University of Vienna. He received his doctorate in chemistry at the University of Vienna in 1935, and was a research associate and later professor at the University of Hamburg until 1949, when he emigrated to the United States. During World War II he twice visited Goldschmidt in Oslo. He was intrigued by Goldschmidt's data on the abundances of the elements, especially the high abundances at neutron numbers 50 and 82 (later called "magic numbers"). In 1947, he published a joint paper with his colleague Hans Jensen *Zur Deutung der Goldschmidt'schen Haufigkeitsverteilung der Elemente* (The interpretation of Goldschmidt's abundance distribution of the elements) in *Naturwissenschaften,* vol. 34, p. 131. This led to the formulation of theories of nuclear structure and the origin of the elements, which resulted in the award of Nobel Prizes to Maria Goppert Meyer, Eugene Wigner, and Hans Jensen in 1963, and to William Fowler in 1983. Together with Harold Urey, Suess published a revision of Goldschmidt's abundance table in 1956. Since 1955 he has been Professor of Chemistry (now Emeritus) at the University of California, San Diego. In 1974, he received the Goldschmidt Medal, the highest award of The Geochemical Society.
26. *Applied Geochemistry,* vol. 3, p. 385, 1988.
27. See Appendix A.
28. *Applied Geochemistry,* vol. 3, p. 387, 1988.
29. Letter dated November 24, 1946; p. 63 in Adolf Hoel's book *Universitetet under okkupasjon* (Oslo, 1978).

9/Last Days—Sweden, Great Britain, Norway: 1942–1947

1. Backlund, Helge Gotrik (1878–1958), born in Estonia, educated in St. Petersburg, assistant in the Mineralogical–Geological Museum, 1902–17. Professor of Geology, Åbo Akademi, Finland, 1918–24; Uppsala University, 1924–43. He did extensive field work in Siberia, Svalbard, and Greenland.
2. Regulation 18B, effective in Britain during World War II, provided for the internment without trial of persons considered dangerous to the war effort. Sir Oswald Mosley was the leader of the British Union of Fascists.
3. *Quart. J. Geol. Soc. London,* vol. 100, p. xlv, 1945.
4. Solberg, Halvor Skappel (1895–1974), Norwegian meteorologist; Professor, University of Oslo, 1930–64.

5. Hylleraas, Egil Andersen (1898–1965), Norwegian physicist; Professor, University of Oslo, 1937–65.
6. Jensens and Lorentzens are large grocery stores in Oslo.

10/Epilogue

1. "I am aware that the new journal will, at the beginning, have to fight its way through the maze of scientific literature, but I have no doubt that the journal will soon be established and become a very valuable contribution to the development of geochemistry and cosmochemistry. I am deeply sorry that the late Professor V. M. Goldschmidt, who was an old friend of mine, is with us no longer. I have discussed the idea of such a journal with him many times after the war, and he certainly would have given every possible support to it." Letter, P. Rosbaud to F. E. Wickman, August 12, 1949.
2. The publisher was right and I was wrong. The book went through four editions and sold more than 50,000 copies in the American edition; it has been translated into German, Russian, Spanish, Portuguese, Japanese, and Malay.
3. Letter to Professor Denis Shaw, August 12, 1972. (in Russian, translated by Dr. J. Dostal, St. Mary's University, Halifax, Canada).
4. Letter to Professor Denis Shaw, June 19, 1973.
5. Letter to Professor A. A. Levinson, January 8, 1988.