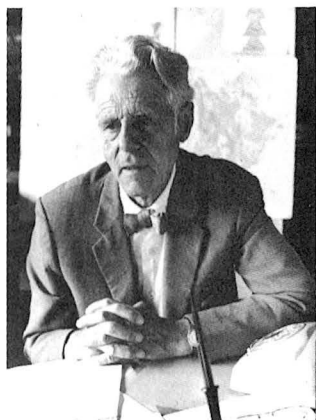


Memorial to Thomas F. W. Barth 1899—1971

KONRAD B. KRAUSKOPF

Department of Geology, Stanford University, Stanford, California 94305



Thomas Fredrik Weiby Barth, professor of mineralogy and director of the Mineralogisk-Geologisk Museum of the University of Oslo, died on the 3d of March 1971, in his 72d year. The Geological Society of America has lost a distinguished Honorary Fellow, and the world has lost an internationally-minded geologist of remarkably broad interests.

Tom Barth, son of a civil engineer, spent his boyhood in a small town in the far northern part of his country. In 1919 he entered the technical college in Trondheim with the intention of becoming a mining engineer, but a summer job at the Kongsberg silver mine after his first year brought him in contact with Carl Bugge, later Director of the Norwegian Geological Survey, who convinced him that his real interest lay in geology. Pursuing this new subject at the University of Oslo he was fortunate in finding teachers who inspired and challenged him, particularly W. C. Brøgger and V. M. Goldschmidt. For a brief period after his first degree he went with his new bride Randi (Thomassen) as scientific assistant to an agricultural college, but he was soon back at the university working with Goldschmidt in his epochal studies of crystal structure and the laws of distribution of the elements. Barth later referred to these early years of intensive concentration on a new and exciting field as the most stimulating period of his scientific life. Although most of the work was in the laboratory, his doctoral dissertation (1927) involved a field investigation of nepheline syenite pegmatites in northern Norway. Thus was established the happy pattern of field and laboratory study that he was to continue throughout his life.

The rich foreign experience that was to be so important to his career began with two happy years as research assistant to Professor K. H. Scheumann in Berlin and Leipzig, and continued with a Rockefeller Fellowship at Harvard in 1929. Here again he was most fortunate in his associates, for he was introduced to American mineralogic and petrologic ideas by such men as Charles Palache, Esper Larsen, and R. A. Daly. His good fortune continued the next year when he was invited to the Geophysical Laboratory in Washington, D.C., and made the acquaintance of A. L. Day, N. L. Bowen, and H. S. Washington. The latter in particular made a deep impression, as revealed by a later remark by Barth: "He taught me not only science and research, but also ethics, wisdom, and natural philosophy."

From this time on for many years Barth was torn between the attractions of well-equipped laboratories in America and his love for his native Norway. In 1936 he returned to Oslo and the next year became professor and director of the Mineralogisk Institutt; in 1939 he spent another year in Washington; then as war threatened to spread to all of Europe he came back to Oslo, landing only a few days before the German invasion. Through the years of the occupation he and his students managed to continue their scientific work under trying conditions, and also to engage in "illegal activities" for which several (Barth included) were confined for a period in a concentration camp.

After the war America beckoned once more, and the Barth family moved to Chicago. But the call of Norway ultimately proved stronger. In 1949 Barth returned again to Oslo, now as director of the Mineralogisk-Geologisk Museum, and from then on his visits abroad were limited to brief sojourns. In Oslo he faced difficult administrative problems, requiring much political effort to obtain the necessary funds for additional personnel and for bringing laboratory equipment up to date. These new activities were not all congenial, but Barth's talent as an administrator is shown by the steadily increasing reputation of the Museum and by the number of students and eminent scholars from many countries who have sought out its laboratories.

Besides the administrative load and besides his always continuing scientific work, Tom Barth somehow found time for energetic participation in international organizations—as president of the Commission on Geochemistry of the International Union of Pure and Applied Chemistry (1957-1960), as president of the Geochemical Society (1960-1961), and as president of the International Union of Geological Sciences (1964-1968). Honors came his way in great number—he was a member of the scientific academies of eleven countries and honorary member of nine professional societies; he received honorary doctoral degrees from the universities of Copenhagen, Nancy, Kiel, Liège, and Zürich; he was given the Reusch Medal of the Norwegian Geological Society, the Roebing Medal of the Mineralogical Society of America, the Eskola Medal of the Geological Society of Finland, and the Boricky Medal of Czechoslovakia. The Norwegian government gave him its highest award for civilian achievement, the Royal Order of St. Olav. He was widely sought, both in his country and abroad, as a lecturer, consultant, instructor for special courses, and leader of field trips. Even in the last months, when a liver ailment was sapping his strength, these activities continued. Almost to the time of his death he was working on plans for a field trip that he had expected to lead the following summer.

Tom Barth's scientific interests were exceptionally broad. X-ray study of crystal structure remained a favorite subject for research long after the initial stimulus of the early years with Goldschmidt. One notable result of this work, regarded by Barth himself as his most significant discovery, is contained in a paper on the distribution of iron and magnesium ions in the spinel structure of magnesioferrite, written with E. W. Posnjak in 1932. The demonstration that the symmetry of this mineral shown by x-rays requires that Mg^{2+} and half the Fe^{3+} ions be statistically distributed over a set of equivalent positions led to the general concept of order-disorder relations in minerals. Among the minerals that attracted Barth's early attention were the feldspars, and the structural relations within this complex group remained a focus of consuming interest

for more than 40 years. One result of the feldspar study was the suggestion that the distribution of sodium between plagioclase and potassium feldspar can serve as a measure of the temperature of crystallization of plutonic rocks.

A subject of at least equal interest was petrology, particularly the petrogenesis of granites, basalts, and high-grade metamorphic rocks. The early classical influence of Brøgger was strongly counteracted by the evidence for anatexis that he found in the Precambrian rocks of southern Norway and by a few weeks excursion in Finland in the company of J. J. Sederholm, so that Barth early in life became convinced of the paligenetic origin of much granite. This conviction was not shaken by his association with Bowen at the Geophysical Laboratory, but perhaps Bowen's influence can be traced in Barth's later thinking about the derivation of different kinds of basalt by crystal fractionation. Concern with the difficulty of handling complex petrographic relationships led to suggestions for better ways of presenting rock analyses and for extending the concept of the norm to metamorphic rocks.

Much of the petrology was based on Barth's own careful field investigations. In Norway the field studies ranged over the entire country, although his greatest effort was concentrated in the extreme southern part near Kristiansand. In later life he devoted much attention, as had so many of his countrymen, to the always fascinating rocks of the Oslo graben. During his sojourns in America, field work took him to many areas, from metamorphic rocks in New York to basalts in the Pribilof Islands. Also from his temporary base at the Geophysical Laboratory he undertook a field investigation of the volcanoes and hot springs of Iceland, a study which enabled him to confirm some of the general conclusions reached by Day, Allen, and Merwin from their pioneering work in Yellowstone Park. Iceland captured his interest not only for its geology but also for its people and culture, and the work resulted in a small popular book (in Norwegian), as well as many scientific papers and a lengthy monograph.

Together with the meticulous detail of the laboratory and field studies went broader speculations about earth history. Goldschmidt had noted the discrepancy between average amounts of sodium in sedimentary and igneous rocks, and had assumed that the difference could be explained by an increasing concentration of sodium in sea water; on this basis he could work out a figure for the total amount of erosion during geologic time, a figure that is still widely quoted. Barth took issue with his mentor, maintaining that the sodium deficiency in sediments could be explained by prior leaching of sodium salts from the material analyzed and that much so-called igneous rock has actually had a sedimentary history; hence, sodium in the ocean has probably reached a steady state, as have other ions, and the total amount of erosion is therefore much greater than Goldschmidt's estimate. The materials of the earth's crust, Barth insisted, are endlessly recycled from igneous to sedimentary to metamorphic forms and back again to igneous. This is hardly a startling conclusion in the light of plate tectonics, but it met with much skepticism when Barth first made the suggestion.

In addition to the more than 200 papers in his bibliography, Barth summed up much of his thinking in three well-known books. First was *Die Entstehung der Gesteine*

(1939), to which Barth contributed the section on igneous rocks. Then came *Theoretical Petrology*, first published in 1952 and revised in 1962. And finally near the end of his life appeared a slim volume entitled simply *Feldspars* (1969).

It is easy to recount the events of his busy life, to list honors that came his way, and to review his scientific achievements. Far more difficult is an attempt to picture the man himself—and for Tom Barth this is an all important side of the story. As a teacher he was inspiring, in the best sense of that over used word; as an administrator he was dedicated, patient, willing to listen to all viewpoints but tenacious in promoting the welfare of his institution; in the field he was the most genial of companions, able to shed briefly the worries of his official positions for the sheer joy of tramping through wild country. Fiercely loyal to his native Norway but at home in all countries, he gained wisdom from the extensive travel that served him well when he was called upon to lead international organizations beset by parochial national concerns. With all his honors and responsibilities he remained modest and unassuming almost to a fault, careless of personal comfort in a degree sometimes embarrassing to his companions. It was impossible for him to hold a grudge for long toward those who had injured him, even toward the Germans who had despoiled his country or toward Goldschmidt with whom in later years he had a serious falling out. Somewhere in his make-up was the impulse of an artist, evident in the sketches with which he decorated some of his papers and in the grace with which he traversed winter slopes on his beloved skis. When all this is said, something still is missing, just his simple friendliness, which has touched all who had the good fortune to visit Tom and Randi at their home, either their beautiful house in the hills above Oslo or one of their temporary residences in America.

He was a man great of heart and soul, a true world citizen of geology. He will be sorely missed in professional circles and even more in the minds of those who knew him well.

BIBLIOGRAPHY OF THOMAS F. W. BARTH

- 1925 On contact minerals from Pre-Cambrian limestones in southern Norway: *Norsk Geol. Tidsskr.* 8, p. 93-114.
- Die Kristallstruktur von Perowskit und Verwandten Verbindungen: *Norsk Geol. Tidsskr.* 8, p. 201-216.
- (with Goldschmidt, V. M., and Ulrich, F.) Geochemische Verteilungsgesetze der Elemente: IV. Zur Krystallstruktur der Oxyde der seltenen Erdmetalle: *Vid.-Akad. Skr. Mat.-Nat. Kl.* 5, p. 1-24.
- (with Goldschmidt, V. M., and Lunde, G.) Geochemische Verteilungsgesetze der Elemente: V. Isomorphie und Polymorphie der Sesquioxyde, die Lanthaniden-Kontraktion und ihre Konsequenzen: *Vid.-Akad. Skr. Mat.-Nat. Kl.* 7, p. 1-59.
- (with Lunde, G.) The effect of the lanthanide contraction on the cubic platinum metals: *Norsk Geol. Tidsskr.* 8, p. 220-223.
- (with Lunde, G.) X-ray investigations on the platinum metals, silver and gold: *Norsk Geol. Tidsskr.* 8, p. 258-269.
- (with Lunde, G.) Lattice constants of the cuprous and silver halides: *Norsk Geol. Tidsskr.* 8, p. 281-292.

- (with Lunde, G.) Contributions to the study of the structure of mixed crystals: *Norsk Geol. Tidsskr.* 8, p. 293-301.
- 1926 The structure of synthetic, metamict, and recrystallized fergusonite: *Norsk Geol. Tidsskr.* 9, p. 23-36.
- Die kristallographische Beziehung zwischen Helvin und Sodalit: *Norsk Geol. Tidsskr.* 9, p. 40-42.
- Die reguläre Kristallart von Kupferglanz: *Centralb. f. Min. etc. A.*, p. 284-286.
- Sagvandite, a magnesite-bearing igneous rock: *Norsk Geol. Tidsskr.* 9, p. 271-303.
- 1927 (with Lunde, G.) Über das Mineral Villiaumit: *Centralb. f. Min. etc. A.*, p. 57-66.
- Über die Gitterdimensionen des Zinkoxyds und das Achsenverhältnis des Zinkits: *Norsk Geol. Tidsskr.* 9, p. 317-319.
- Über kali- und wasserhaltige Skapolithe: *Centralb. f. Min. etc. A.*, p. 82-88.
- (with Lunde, G.) Der Unterschied der Gitterkonstanten von Steinsalz und von chemisch reinem Natriumchlorid: *Zeit. f. physik. Chem.* 126, p. 417-424.
- Note on the symmetry of orthoclase: *Norsk Geol. Tidsskr.* 9, p. 398-400.
- Die Pegmatitgänge der kaledonischen Intrusivgesteine im Seiland-Gebiete: *Vid.-Akad. Skr. Mat.-Nat. Kl.* 8, 123 p.
- 1928 Kalk- und Skarngesteine im Urgebirge bei Kristiansand: *Neues Jahrb. f. Min. etc. B. B.* 57 A, p. 1069-1108.
- V. M. Goldschmidt's Kristallochemie und ihre Bedeutung für die technische Stoffkunde: *Metallwirtschaft* 6, p. 173-177.
- Om erupsjonsprovinser: *Naturen* 52, p. 110-122.
- Ein neuer Zwilling bei triklinem Feldspat, Aklin B: *Zeit. f. Krist.* 68, p. 473-475.
- Zur Genese der Pegmatite im Urgebirge: I. Die Geologie und Petrographie der granitischen Pegmatite im südlichsten Norwegen: *Neues Jahrb. f. Min. etc. B. B.* 58 A, p. 385-432.
- Zur Genesis der Pegmatite im Urgebirge: II. Ein syntektischer Gesteinkomplex aus dem südlichsten Norwegen: *Chemie der Erde* 4, p. 95-136.
- Die Lage des "rhombischen Schnittes" bei sauren Plagioklasen: *Zeit. f. Krist.* 68, p. 616-618.
- 1929 Die Symmetri der Kalifeldspäte: *Fortschritte d. Min. Krist. und Petr.* 13, p. 185-189.
- Die Temperatur der Anaxis des Urgebirges im südlichsten Norwegen: *Centralb. f. Min. etc. A.*, p. 120-127.
- Über den monoklinen Natronfeldspat: *Zeit. f. Krist.* 69, p. 476-481.
- Über die Sagvandite und ihre Entstehung durch Syntexe von Dolomitgesteinen: *Min. Petr. Mitt.* 40, p. 221-234.
- 1930 (with Daly, R. A.) Dolerites associated with the Karroo system, South Africa: *Geol. Mag.* 67, p. 97-110.
- (with Berman, H.) Neue optische Daten wenig bekannter Minerale (Die Einbettungsmethode): *Chemie der Erde* 5, p. 21-42.
- Optical properties of mixed crystals: *Am. Jour. Sci.* 19, p. 135-146.
- Pacificite, an anemousite basalt: *Wash. Acad. Sci. Jour.* 20, p. 60-68.
- Mineralogy of the Adirondack feldspars: *Am. Mineralogist* 15, p. 129-143.
- Oprinnelsen til den Midt-Atlantiske Rygg: *Naturen* 54, p. 361-366.
- 1931 Crystallization of pyroxenes from basalts: *Am. Mineralogist* 16, p. 195-208.
- Mineralogical petrography of Pacific lavas: Pt. I, Minerals: *Am. Jour. Sci.* 21, p. 377-405.
- Mineralogical petrography of Pacific lavas: Pt. II, Rocks: *Am. Jour. Sci.* 21, p. 491-530.
- (with Posnjak, E.) The spinel structure: An example of variate atom equipoints: *Wash. Acad. Sci. Jour.* 21, p. 255-258.
- Pyroxen von Hiva Oa, Marquesas-Inseln und die Formel titanhaltiger Augite: *Geophys. Lab. Carnegie Inst. of Washington*, 758, p. 217-224.
- Proposed change in calculation of norms of rocks: *Min. Petr. Mitt.* 42, p. 1-7.
- Permanent changes in the optical orientation of feldspars exposed to heat: *Norsk Geol. Tidsskr.* 12, p. 57-72.

- 1931 Feltspat III: Forekomster i Iveland og Vegusdal i Aust-Agder og i flere herreder i Vest-Agder: Norges Geol. Undersøkelse 128B, p. 111-151.
- (with Posnjak, E.) A new type of crystal fine-structure: Lithium ferrite ($\text{Li}_2\text{O}\cdot\text{Fe}_2\text{O}_3$): Phys. Review 38, p. 2234-2239.
- 1932 (with Posnjak, E.) Silicate structures of the cristobalite type: I. The crystal structure of α -carnegieite (NaAlSiO_4): Zeit. f. Krist. 81, p. 135-141.
- (with Posnjak, E.) Silicate structures of the cristobalite type: II. The crystal structure of $\text{Na}_2\text{CaSiO}_4$: Zeit. f. Krist. 81, p. 370-375.
- (with Posnjak, E.) Silicate structures of the cristobalite type: III. Structural relationship of high-cristobalite, α -carnegieite, and $\text{Na}_2\text{CaSiO}_4$: Zeit. f. Krist. 81, p. 376-385.
- The cristobalite structures: I. High-cristobalite: Am. Jour. Sci. 23, p. 350-356.
- The cristobalite structures: II. Low-cristobalite: Am. Jour. Sci. 24, p. 97-110.
- (with Posnjak, E.) Spinel structures: With and without variate atom equipoints: Zeit. f. Krist. 82, p. 325-341.
- The chemical composition of noselite and h  uyne: Am. Mineralogist 17, p. 466-471.
- The structures of the minerals of the sodalite family: Zeit. f. Krist. 83, p. 405-414.
- Molekular rotasjon: Naturen 56, p. 367-374.
- 1933 (with Ksanda, C. J.) Crystallographic data on mellite: Am. Mineralogist 18, p. 8-13.
- (with Tunell, G.) The space-lattice and optical orientation of chalcanthite ($\text{CuSO}_4\cdot 5\text{H}_2\text{O}$): An illustration of the use of the Weissenberg x-ray goniometer in the triclinic system: Am. Mineralogist 18, p. 187-194.
- Zur Hauynformel (Fine Erwiderung): Centralb. f. Min. etc. A, p. 291-304.
- 1934 Polymorphic phenomena and crystal structure: Am. Jour. Sci. 27, p. 273-286.
- Temperaturen i lava- og magmamasser, samt et nytt geologisk termometer: Naturen 58, p. 187-192.
- (with Posnjak, E.) The crystal structure of ilmenite: Zeit. f. Krist. 88, p. 265-270.
- (with Posnjak, E.) Notes on some structures of the ilmenite type: Zeit. f. Krist. 88, p. 271-280.
- (with Balk, R.) Chloritoid from Dutchess County, New York: Am. Mineralogist 19, p. 345-350.
- (with Donnay, J.D.H., and Tunell, G.) Various modes of attack in crystallographic investigation: Am. Mineralogist 19, p. 437-458.
- 1935 Non-silicates with cristobalite-like structure: Jour. Chem. Physics 3, p. 323-325.
- (with Ksanda, C. J.) Note on the structure of dickite and other clay minerals: Am. Mineralogist 20, p. 631-637.
- Vestige of a Pleistocene thermal activity in Iceland: Am. Geophys. Union Trans. 16, p. 284-288.
- 1936 The large Pre-Cambrian intrusive bodies in the southern part of Norway: Report 16th Int. Geol. Congress, Washington, 1933, p. 297-309.
- Structural and petrologic studies in Dutchess County, New York: Pt. II: Petrology and metamorphism of the Paleozoic rocks: Geol. Soc. America Bull. 47, p. 775-850.
- The crystallization process of basalt (A supplement and a reply): Am. Jour. Sci. 231, p. 321-351.
- Thermal activity in Iceland: Norsk Geol. Tidsskr. 16, p. 288-291.
- 1937 Volcanic ash from Vatnaj  kull (a modern formation of sideromelane): Norsk Geol. Tidsskr. 17, p. 31-38.
- Crystallographic studies in the vivianite group: Am. Mineralogist 22, p. 325-341.
- 1938 Feldspar equilibria and their implication: I. Norsk Geol. Tidsskr. 17, p. 177-190.
- Progressive metamorphism of sparagmite rocks of southern Norway: Norsk Geol. Tidsskr. 18, p. 54-65.
- (with Greig, J. W.) The system, $\text{Na}_2\text{O}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ (nephelite, carnegieite)- $\text{Na}_2\text{O}\cdot\text{Al}_2\text{O}_3\cdot 6\text{SiO}_2$ (albite): Am. Jour. Sci. 35-A, p. 93-112.

- Radium and the petrology of certain granites of Finland: *Am. Jour. Sci.* 35-A, p. 231-245.
- 1939 Varmer kilder og vulkanisme på Island: *Naturen* 63, p. 11-27.
- Norske mineraler av beidellit-gruppen: *Norsk Geol. Tidsskr.* 19, p. 300-310.
- Geomorphology of Vest-Agder l'jord-land: *Norsk Geografisk Tidsskr.* 7, p. 291-304.
- Eruptivgesteine, in Barth, T.F.W., Correns, C. W., and Eskola, P., eds., *Die Entstehung der Gesteine, ein Lehrbuch der Petrogenese* (reprint, 1960): Berlin, Julius Springer, p. 1-115.
- 1940 Notes on igneous and palingenic rocks from the Antarctic Archipelago. A contribution to the petrology of circum-Pacific rock types: *Sci. results, Norwegian Antarctic Expedition, 1927-1928: Proc. Sixth Pacific Sci. Congress 1939*, 2, p. 747-754.
- Pristine and contaminated rock magma and thermal water: *Bull. Volcanol., ser. 2*, 6, p. 81-87.
- Geysir in Iceland: *Am. Jour. Sci.* 238, p. 381-407.
- 1941 Geysirer og geysirteorier: *Naturen* 65, p. 193-209.
- Litt om Sørlandets anorthositer: *Norsk Geol. Tidsskr.* 21, p. 186-191.
- Lavas of Gough Island: *Sci. results, Norwegian Antarctic Expedition, 1927-1928: Det Norske Videnskaps-akademi i Oslo*, 20, 20 p.
- Island: Oslo, Johan Grundt Tanum, p. 1-135.
- 1942 Craters and fissure eruptions at Myvatn in Iceland: *Norsk Geografisk Tidsskr.* 9, p. 58-81.
- Some unusual ground-water phenomena in Iceland: *Norsk Geografisk Tidsskr.* 9, p. 158-172.
- 1943 Ild og vann på Island: *Naturen* 67, p. 33-42.
- Lamprofyrer av to forskjellige aldre i kystmigmatiten vest for Kristiansand: *Norsk Geol. Tidsskr.* 23, p. 175-185.
- 1944 (with Kvalheim, A.) Christensenite, a solid solution of nepheline in tridymite: *Sci. results, Norwegian Antarctic Expedition, 1927-1928: Det Norske Videnskaps-Akademi i Oslo* 22, 9 p.
- 1945 Studies on the igneous rock complex of the Oslo region. II. Systematic petrography of the plutonic rocks: *Vid.-Akad. Skr. Mat.-Nat. Kl.* 1944, 9, p. 1-144.
- Geological map of the western Sørland: *Norsk Geol. Tidsskr.* 25, p. 1-9.
- Oslofeltets eruptivbergarter og deres innbyrdes slektskap: *Med. Dansk Geol. Forening* 10, p. 636-641.
- (with Bruun, B.) Studies on the igneous rock complex of the Oslo region. IV. Fluorine in the Oslo petrographic province: *Vid.-Akad. Skr. Mat.-Nat. Kl.* 8, p. 1-12.
- Studies on the igneous rock complex of the Oslo region. V. F'alkenstenite, a new zeolite in variolite from Horten, and the surface conditions during the effusion of the oldest Permian lavas: *Vid.-Akad. Skr. Mat.-Nat. Kl.* 8, p. 13-22.
- 1947 (with Oftedahl, Chr.) High-temperature plagioclase in the Oslo igneous rocks: *Am. Geophys. Union Trans.* 28, p. 102-104.
- Geysers of Iceland: *Am. Geophys. Union Trans.* 28, p. 882-887.
- The nickeliferous Iveland-Evje amphibolite and its relation: *Norges Geol. Undersøkelse* 168a, 71 p.
- The Birkeland granite, a case of petroblastesis: *C. R. Soc. Geol. Finlande* 20, p. 173-182.
- On the geochemical cycle of fluorine: *Jour. Geology* 55, p. 420-426.
- 1948 The distribution of oxygen in the lithosphere: *Jour. Geology* 56, p. 41-49.
- Oxygen in rocks: A basis for petrographic calculations: *Jour. Geology* 56, p. 50-60.
- Recent contributions to the granite problem: *Jour. Geology* 56, p. 235-240.
- 1949 Frequency distribution of the minerals in two petrographic provinces: *Jour. Geology* 57, p. 55-61.
- (with Bloss, F. D.) Observations on some Yellowstone geysers: *Geol. Soc. America Bull.* 60, p. 861-886.
- Oxygen in rocks: A basis for petrographic calculations. A supplement and a reply: *Jour. Geology* 57, p. 425-427.

- 1949 (with Rosenquist, T.) Thermodynamic relations of immiscibility and crystallization of molten silicates: *Am. Jour. Sci.* 247, p. 316-323.
- 1950 Intrusion relations of bathoite from southern Norway: *Am. Mineralogist* 35, p. 622-628.
- 1951 The feldspar geologic thermometers: *Neues Jahrb. f. Min. Abh.* 82, p. 143-154.
- Sub-solidus diagram of pyroxenes from common mafic magmas: *Norsk Geol. Tidsskr.* 29, p. 218-221.
- 1952 The differentiation of a composite aplite from the Pribilof Islands, Alaska: *Am. Jour. Sci., Bowen Volume*, p. 27-36.
- Orogeny and geochemistry: *Schweiz. Min. Petr. Mitt.* 32, p. 354-360.
- 1953 The layered gabbro series at Seiland, northern Norway: *Norges Geol. Undersøkelse* 184, p. 191-200.
- (with Byers, F. M., Jr.) Volcanic activity on Akun and Akutan Islands: *Proc. Seventh Pacific Science Congress* 2, p. 382-397.
- 1954 Studies on the igneous rock complex of the Oslo region. XIV. Provenance of the Oslo magmas: *Vid.-Akad. Skr. Mat.-Nat. Kl.* 4, p. 1-20.
- New types of cristobalite-like structures. III. *Congress Union International Cristallographie, Paris*, 20 p.
- (with Fleischer, M.) Geochemical research: *Geochim. et Cosmochim. Acta* 6, p. 132-151.
- 1955 Presentation of rock analyses: *Jour. Geology* 63, p. 348-363.
- 1956 Studies in gneiss and granite. I & II: *Vid.-Akad. Skr. Mat.-Nat. Kl.* 1, p. 1-35.
- *Température de formation de certains granites Précambriens de Norvège Méridionale: Colloque International de Pétrographie, Nancy*, p. 119-129.
- Geology and petrology of the Pribilof Islands, Alaska: *U.S. Geol. Survey Bull.* 1028-F, p. 101-157.
- 1957 Temperature relations of the mineral facies of metamorphic rocks: *Jour. Madras Univ. B.* 27, p. 37-48.
- 1959 Principles of classification and norm calculations of metamorphic rocks: *Jour. Geology* 67, p. 135-152.
- *Geologisk termometri: Finland, Geologi* 8, p. 85-95.
- The interrelations of the structural variants of the potash feldspars: *Zeit. f. Krist.* 112, p. 263-274.
- The diffusive transformation sanidine-microcline: *Madrid, Estudios Geológicos* 15, p. 31-38.
- 1960 The Bowen reaction series and the development of different magma types: *Indian Mineralogist* 1, p. 24-28.
- (with Dons, J. A.) Precambrian of southern Norway, in O. Holtedahl, *Geology of Norway: Norges Geol. Undersøkelse* 208, p. 6-67.
- (with Bugge, J.A.W.) Precambrian gneisses and granites of the Skagerak coastal area, south Norway: *Guide to excursion no. A8, XXI International Geol. Congress, Norden: Norges Geol. Undersøkelse* 212f, p. 1-35.
- 1961 Abundance of the elements, areal averages and geochemical cycles: *Geochim. et Cosmochim. Acta* 23, p. 1-8.
- Garnet-sillimanite and garnet-spinel bands in the layered gabbro series in Seiland, north Norway: *Bull. Geol. Inst. Uppsala* 40, p. 17-24.
- Präzision der Mineralfazies durch Feldspatanalysen: *Neues Jahrb. f. Min. Abh.* 96, p. 217-220.
- Composition and evolution of magma in the southern Mid-Atlantic Ridge: *Fiziko-khimicheskiye problemy formirovaniya gorykh porod i rud: Akademiya Nauk SSSR*, p. 31-55.
- The feldspar lattices as solvents of foreign ions: *Madrid, Inst. "Lucas Mallada," Fasc.* 8, p. 3-8.
- Ideas on the interrelation between igneous and sedimentary rocks: *C. R. Soc. Geol. Finlande* 33, p. 321-326.

- 1962 Idei o vzaimootnoshenii etc: *Geokhimiya* 4, p. 296-299 (in Russian).
 — Die Menge der Kontinentalsedimente und ihre Beziehung zu den Eruptivgesteinen: *Neues Jahrb. f. Min. Mh.* 1962, p. 59-67.
 — A final proposal for calculating the mesonorm of metamorphic rocks: *Jour. Geology* 70, p. 497-498.
 — Feldspar solid solutions: *Chemic der Erde* 22, p. 31-40.
 — The feldspar geologic thermometers: *Norsk Geol. Tidsskr.* 42, Feldspar volume, p. 330-339.
 — (with Almann, R., and Hellner, E.) Comments on comments on the two-feldspar geothermometer: *Norsk Geol. Tidsskr.* 42, Feldspar volume, p. 346-348.
 — Theoretical petrology, a textbook on the origin and the evolution of rocks (2d ed., 1962): New York, John Wiley & Sons, p. 1-416.
 — Measurements of paleotemperatures in granitoid rocks: *Chteniya im. V. I. Vernadskogo, IV. Akademiya Nauk SSSR*, p. 3-20.
- 1963 The composition of nepheline: *Schweiz. Min. Petr. Mitt.* 43, p. 153-164.
 — On pyroxene molecules in the CIPW norm: *Geol. Mag.* 100, p. 280-281.
 — Contributions to the mineralogy of Norway. Vesuvianite from Kristiansand, other occurrences in Norway, the general formula of vesuvianite: *Norsk Geol. Tidsskr.* 43, p. 457-472.
 — (with Reitan, P. H.) The Precambrian of Norway, in Rankama, K., ed., *The Precambrian (The geologic systems)*: New York, John Wiley & Sons, Inc., v. 1, p. 27-80.
- 1965 (with Thoresen, Kari) The attitude of the rhombic section in triclinic feldspars: *Norsk Geol. Tidsskr.* 45, p. 83-96.
 — On the constitution of the alkali feldspars: *Tschermaks Min. Petr. Mitt.* 10, p. 14-33.
 — Relations between optical orientation and structural state in the system of potassium feldspar: *Indian Mineralogist* 6, p. 40-47.
- 1966 Aspects of the crystallization of quartzo-feldspathic plutonic rocks: *Tschermaks Min. Petr. Mitt.* 11, p. 209-222.
 — (with Ramberg, I. B.) Eocambrian volcanism in southern Norway: *Norsk Geol. Tidsskr.* 46, p. 219-236.
 — (with Ramberg, I. B.) The Fen circular complex, in Tuttle, O. F., and Gittins, J., eds., *Carbonatites*: New York, Interscience Publ., p. 225-257.
- 1967 (with Smithson, S. B.) The Precambrian Holum granite, south Norway: *Norsk Geol. Tidsskr.* 47, p. 21-55.
 — Structure and volume relations of the alkali feldspar mixed crystals: *Schweiz. Min. Petr. Mitt.* 47, p. 121-127.
- 1968 Petrology of continental rocks: *Bull. Geol. Soc. Finland* 40, p. 3-9.
 — The geochemical evolution of continental rocks—A model, in Ahrens, L. H., ed., *Origin and distribution of the elements*: Oxford, England, and New York, Pergamon Press, p. 587-597.
- 1969 Exsolved feldspars-perthite, peristerite, Schiller feldspar: *Instituto de Investigaciones Geológicas, Diputación Provincial de Barcelona* 23, p. 9-14.
 — Granulite facies rocks of the Precambrian of south Norway, particularly around Arendal: *Sci. de la Terre* 14, p. 359-369.
 — Feldspars: London, Wiley-Interscience, p. 1-261.
- 1970 Deep-seated volcanism along the major Precambrian breccia in south Norway. II. Svarten at Ny Hellesund: *Norsk Geol. Tidsskr.* 50, p. 253-256.
 — The geological metabolism of the continents: *Scientia*, p. 1-11.