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THOMAS SEWARD LOVERING

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A Biographical Memoir by

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Dr. Thomas S. Lovering.

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INNOVATIVE FIELD AND laboratory studies of the relations of hydrothermally altered wall-rocks to minable ore deposits were the principal scientific contributions of T. S. Lovering during an illustrious career that also included theoretical analysis, laboratory research, teaching, and administrative duties in the fields of economic geology and geochemistry. For more than forty years he was affiliated with the U.S. Geological Survey in detailed investigations of mining districts and mineralized terranes chiefly in Colorado and Utah. During the latter half or so of his USGS career, he often served as a U.S. delegate to mineral conferences throughout the world and as a minerals consultant to other federal civilian and military agencies. To many who knew him only casually from his penetrating questions and discussions at scientific meetings and symposia, he sometimes appeared brusque, argumentative, and perhaps egocentric. To his close associates and co-workers, however, he was invariably courteous, generous, and steadfast in his support and friendship. To him the search for scientific excellence was paramount and all else was secondary.

Tom, as he was known by his colleagues and a wide circle of both older and younger acquaintances, was born in St. Paul, Minnesota, on May 12, 1896. During World War I he trained as a Navy aviation cadet, but the armistice was signed before he was transferred to combat duty, and upon his discharge in 1919 he entered the Minnesota School of Mines. In 1922 he graduated with an E.M. degree and later in the same year enrolled in the graduate school of the University of Minnesota, where he received an M.S. degree in geology in 1923 and a Ph.D. in economic geology in 1924. While at Minnesota he was strongly influenced by Professors Frank F. Grout and John W. Gruner with whom he maintained an infrequent correspondence for many years.

Tom's first position after completing his doctorate was an instructorship in the Department of Geology at the University of Arizona. He remained at Arizona for only one academic year, accepting a position in 1925 with the U.S. Geological Survey to conduct studies of selected mining districts in the Colorado Front Range under the general supervision of B. S. Butler. In 1934 he gave up this full-time position with the USGS and became an associate professor of geology at the University of Michigan. During the following eight academic years, he also undertook many laboratory investigations and worked during the summer months for the USGS in Colorado, where he continued his studies of tungsten and base- and precious-metal mining districts and participated in regional mapping projects.

Upon the entry of the United States into World War II, Tom took a leave of absence from Michigan and rejoined the USGS on a full-time war service appointment to assist in the Strategic Minerals Program. His wartime activities included the completion of several detailed reports on mining districts in Colorado and the early phases of what became a long-range study of deeply concealed ore bodies and associated surficial alteration zones in the East Tintic mining district of central Utah.

At the end of World War II, Tom returned to the University of Michigan, where he resumed his professorship in the Department of Geology and Mineralogy for the 1946-47 academic year. By this time, however, his field research at East Tintic had reached a critical phase, and in 1947 he resigned from the faculty at Michigan and accepted a permanent assignment with the Mineral Deposits Branch of the USGS. He remained in this position until his retirement in 1966 at age seventy. During his retirement years he continued to pursue both academic and research activities for nearly two decades, including the authorship of a number of scientific papers, teaching, mineral deposits consulting activities, and worldwide travel. Within about a month of reaching his ninety-fifth birthday he succumbed to leukemia on April 9, 1991, at his residence in Santa Barbara, California.

Tom Lovering made significant contributions in several disciplines of geological science, including geologic mapping, ore deposits studies, geochemistry, and the thermodynamics and cooling rates of igneous intrusions. He is probably most widely remembered for his studies of the geochemistry of magmatic hydrothermal wall-rock alteration in the Boulder County tungsten and gold district in Colorado and the East Tintic mining district in Utah. These studies have helped clarify the general processes of ore deposition and in a number of instances have provided direct guides to the occurrence of concealed ore deposits.

When Lovering undertook his alteration studies in Boulder, Colorado, in the 1930s, it was generally believed that the altered selvages of the tungsten- and gold-bearing ore shoots were created by wall-rock reactions with a single hydrothermal solution that concurrently deposited the ore and gangue minerals. Tom was able to show, however, that the wide outer zone of strongly argillized (clay-mineral rich) wall rock gives way abruptly near the ore shoots to a zone of sericitic alteration, which indicated a change from early strong acid solutions to near neutral solutions. These neutral solutions were then followed in turn by weakly alkaline fluids from which the gold, tungsten, and associated gangue minerals were deposited.

To further refine his hypothesis of the widely differing compositions of wall-rock altering solutions as compared to ore depositing solutions, Lovering undertook a detailed study of Utah's East Tintic mining district in the early 1940s. In this district hydrothermal wall-rock alteration zones adjacent to and above large replacement ore bodies are greatly more extensive than the relatively narrow selvages bordering the Boulder County veins. In addition, some well-defined geologic events, including minor faulting and igneous intrusions and eruptions, could be used to establish the relative timing of surges of the various altering solutions. The early results of his studies in East Tintic were published in 1949 as *Monograph I* by the Society of Economic Geologists. In this report he describes five distinct and separable periods of movement of magmatic hydrothermal fluids:

> First, an early district-wide flooding by neutral, magnesium-rich reducing solutions that dolomitized limestone wall-rocks and locally propylitized the basal parts of the earliest erupted lavas.
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> Second, after a period of intrusion of minor bodies of monzonite and quartz-monzonite and the eruption of lavas, localized invasions of hot acidic solutions that severely leached and sanded the underlying limestones and hydrothermal dolomites, and strongly argillized the border areas of the minor intrusive plugs and the adjacent and nearby lavas. These argillized zones were comparable in many respects to the argillized envelopes of the Boulder County tungsten- and gold-ore shoots.
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> Third, a multiple late-barren stage following closely in time on the mid-barren argillizing stage that is characterized in part by extensive silicification of carbonate rocks at depth and minor silicification of areas of lava and porphyry. Shortly following the silicifying solutions there was extensive

flooding of near-neutral, sulfur-rich solutions that converted iron oxide minerals in the intrusive rocks, lavas, and some of the sedimentary rocks to cubic pyrite.

Fourth, closely following the silicifying and pyritizing solutions, potassium-rich fluids moved along many of the channel-ways and conduits used by the preceding jasperoidizing solutions, converting some of the early-formed clay minerals to adularia, sericite, and illite. In most places minor clear quartz, pyritohedral pyrite, and sparse barite were deposited at this time.

Fifth, a change in composition of the potassium-rich solutions at the source with the abrupt and increasing appearance of ore ions in the hydrothermal solutions, eventually leading to the abundant precipitation of sulfide, sulfantimonide, sulfarsenide, and other ore minerals that replace part of the early-formed jasperoid, sanded dolomite, and other fresh and altered rocks. Fluid inclusions entrapped within these ore and gangue minerals indicate that they were deposited from near neutral, saline solutions at temperatures ranging from 150°-300°C.

For Lovering the selection of the East Tintic mining district for his most definitive studies of hydrothermal wall-rock alteration was highly fortuitous, inasmuch as relatively few major mining districts elsewhere in the world show such a distinct sequential series of hydrothermal events leading to ore deposition. Many other large districts are greatly complicated, in fact, by overprints of repetitive stages of solution activity, continued igneous emplacement, and similar geologic events.

Tom Lovering also was a lifelong advocate of detailed geologic mapping, and he often expressed his personal observation that theoretical and experimental studies were valid only when closely linked with meticulous field examinations and demonstrable physical relations. His geologic and alteration maps of the East Tintic district, published in 1960 as U.S. Geological Survey Mineral Investigations Field Studies Map MF-230, for example, were widely used by private mining and exploration groups in the district, leading to the discovery and development of two major new mines and the delineation of several other prospective zones that may be worthy of development.

Tom was particularly proud also of his contributions to the geologic map of Colorado, which was published in 1935 in collaboration with W. S. Burbank, E. N. Goddard, and E. B. Eckel, and his geologic maps of the Colorado Front Range and the Front Range mineral belt that accompany U.S. Geological Survey Professional Paper 223, published in 1950 with Eddie Goddard.

As an exception to his long-standing rule to avoid administrative and supervisory positions if at all possible, Tom agreed in 1954 to become chief of the USGS Section of Geochemical Exploration. In large part this reflected his deeply held interest in the refinement and continued development of new mineral exploration techniques. On stepping down from this position in 1958, Tom served until his retirement as a senior research scientist within the Geologic Division, continuing his studies of the geochemistry of hydrothermal wall-rock alteration, innovative techniques of geochemical exploration, and worldwide mineral resource evaluation.

During his lifetime Tom received many honors, including election to the National Academy of Sciences, the Distinguished Service Medal of the U.S. Department of the Interior, the Penrose Medal of the Society of Economic Geologists, the Jackling Medal of the American Institute of Mining and Metallurgical Engineers, and the Achievement Award Gold Medal of the University of Minnesota. He was an active member and supporter of numerous scientific and engineering societies, some of which include the American Association for the Advancement of Science; the American Geophysical Union; the American Association of Mining, Metallurgical, and Petroleum Engineers; the American Association of Petroleum Geologists; the Clay Minerals Society; the Geochemical Society; the Geological Society of

America; the Society of Economic Geologists; and, a particular favorite of his, the Colorado Scientific Society.

For approximately ten years after his retirement from the USGS Tom maintained a residence near the USGS regional headquarters in Lakewood, Colorado, but spent many winters in Tucson, Arizona, where he later accepted a research professorship in economic geology at the University of Arizona. During this time he also taught special courses in economic geology at the University of Texas, University of Utah, and other academic institutions. In 1976 he moved from Lakewood to Santa Barbara, California, where he became a research associate at the University of California, Santa Barbara. As with his other postretirement academic activities, this affiliation allowed Lovering to interact with bright students and an outstanding faculty in the academic and research environment that he so greatly enjoyed.

Throughout the greater part of his years as a student and as a professional geologist Tom enjoyed the love, support, and companionship of his wife, Corinne. He married Alexina Corrine Gray on October 11, 1919, shortly after his discharge from the Naval Aviation Corps. She was no stranger to the rigors of geologic fieldwork and cheerfully accepted the discomforts of wilderness camping in the Colorado Rockies, spartan lodgings in declining mining camps, and less than palatial accommodations in a wide variety of motels and hotels in small towns throughout the west. Corrine died on August 27, 1969. Finding his life lonely and incomplete in many ways without a close companion, Tom later married Mildred Stewart, with whom he shared many common interests, especially extensive land and sea travel throughout the world. Millie also preceded him in death on March 13, 1983.

Tom is survived by one son, Tom G. Lovering; a daughter-in-law, Dorothy; and two grandchildren, David and Karen.

SELECTED BIBLIOGRAPHY

1923

The leaching of iron protores; solution and precipitation of silica in cold water. *Econ. Geol.* 18:523-40.

1927

Organic precipitation of metallic copper. *U.S. Geol. Surv. Bull.* 795:45-52.

1928

Geology of the Moffat Tunnel, Colorado. *Am. Inst. Min. Metall. (Engl. Trans.)* 18:337-46.

1929

The New World or Cooke City mining district, Montana. *U.S. Geol. Surv. Bull.* 811:1-87.

The Rawlins, Shirley, and Seminoe iron ore deposits, Carbon County, Wyoming. *U.S. Geol. Surv. Bull.* 811:203-35.

1932

Field evidence to distinguish overthrusting from underthrusting. *J. Geol.* 40:651-63.

1933

With J. H. Johnson. Meaning of unconformities in the stratigraphy of central Colorado. *Am. Assoc. Pet. Geol. Bull.* 17:353-74.

1934

Geology and ore deposits of the Breckinridge mining district, Colorado. *U.S. Geol. Surv. Prof. Pap.* 176.

1935

Geology and ore deposits of the Montezuma quadrangle, Colorado. *U.S. Geol. Surv. Prof. Pap.* 178.

Theory of heat conduction as applied to geological problems. *Geol. Soc. Am. Bull.* 46:87-100.

With W. S. Burbank, E. N. Goddard, and E. B. Eckel. Geologic map of Colorado. *U.S. Geol. Surv.* Scale 1:500,000.

1936

Heat conduction in dissimilar rocks and the use of thermal models. *Geol. Soc. Am. Bull.* 47:87-100.

1938

With E. N. Goddard. Laramide igneous sequence and differentiation in the Front Range, Colorado. *Geol. Soc. Am. Bull.* 49:35-68.

1941

The origin of the tungsten ores of Boulder County, Colorado. *Econ. Geol.* 36:229-79.

1943

Minerals in World Affairs. New York: Prentice-Hall.

1947

Sericite-kaolin alteration as a guide to ore. In Report of the Committee on Research on Ore Deposits of the Society of Economic Geologists. *Econ. Geol.* 42:534-35.

1948

With V. P. Sokoloff and H. T. Morris. Heavy metals in altered rocks over blind ore bodies, East Tintic district, Utah. *Econ. Geol.* 43:384-99.

1949

With others. Rock alteration as a guide to ore—East Tintic district, Utah. *Econ. Geol. Monograph I.*

1950

With E. N. Goddard. Geology and ore deposits of the Front Range, Colorado. *U.S. Geol. Surv. Prof. Pap.* 223.

The geochemistry of argillic and related types of alteration. *Colo. Sch. Mines Q.* 45:231-60.

1953

With O. L. Tweto. Geology and ore deposits of the Boulder county tungsten district, Colorado. *U.S. Geol. Surv. Prof. Pap.* 245.

1954

Safeguarding our mineral-dependent economy. *Geol. Soc. Am. Bull.* 64:101-25.

1955

Temperatures in and near intrusions. In *Economic Geology, 50th Annual Volume, Part 1,* ed. A. M. Bateman, pp. 249-81.

1958

Current developments in geochemical exploration. *Pakistan J. Sci.* 10:28-33.

1959

Significance of accumulator plants in rock weathering. *Geol. Soc. Am. Bull.* 70:781-800.

1960

With A. O. Shepard. Hydrothermal alteration zones caused by halogen acid solutions, East Tintic district, Utah. *Am. J. Sci. Bradley Vol.* 258-A:215-29.

With others. Geologic and alteration maps of the East Tintic district, Utah. *U.S. Geol. Surv. Min. Invest. Field Studies Map* MF-230, two sheets, Scale 1:9600.

1961

Sulfide ores formed from sulfide-deficient solutions. *Econ. Geol.* 56:68-99.

1963

Epigenetic, diplogenetic, syngenetic, and lithogenic deposits. *Econ. Geol.* 58:315-31.

1965

With H. T. Morris. Underground temperatures and heat flow in the East Tintic district, Utah. *U.S. Geol. Surv. Prof. Pap.* 504 F:F1-F28.

1967

With C. Engel. Translocation of silica and other elements into *Equisetum* and other grasses. *U.S. Geol. Surv. Prof. Pap.* 594 B:B1-B16.

1969

The origin of hydrothermal and low-temperature dolomite. *Econ. Geol.* 64:743-54.

1978

With O. L. Tweto and T. G. Lovering. Ore deposits of the Gilman district, Eagle County, Colorado. *U.S. Geol. Surv. Prof. Pap.* 1017.

1979

With H. T. Morris. General geology and mines of the East Tintic mining district, Utah and Juab Counties, Utah. *U.S. Geol. Surv. Prof. Pap.* 1024.