The Remarkable Legacy of the Wisconsin School of Precambrian Geology

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ABSTRACT

R.D. Irving, C.R. Van Hise, C.K. Leath, and W.J. Mead formed a remarkable intellectual genealogy, which must be unique in the history of geology. By the 1920s, their Wisconsin School of Precambrian Geology had become so prominent that it attracted students from around the globe. Roland D. Irving (1847–88) was Wisconsin's first true geologist. He laid the groundwork for all subsequent investigations of the Precambrian rocks of the Lake Superior region of the United States and pioneered the application of microscopic petrography there. His protégé, Charles R. Van Hise (1857–1918), earned the first M.S. and Ph.D. degrees awarded by the University of Wisconsin. Upon Irving's premature death in 1888, Van Hise suddenly became both head of the Department of Geology and Mineralogy and chief of the U.S. Geological Survey (USGS) Lake Superior Division, which had been established at the university in 1882. Nine monographs and several bulletins emanated from the Division.

Charles K. Leith (1875–1956) was in turn a protégé of Van Hise; Leith became both head of the geology department and chief of the USGS Lake Superior Division after his mentor was named president of the university in 1903. In 1908, Leith appointed his own protégé, Warren J. Mead (1883–1960), to the faculty, for he recognized that Mead's quantitative and experimental talents could help to fulfill the dedication of the Wisconsin School to a sound physical and chemical understanding of rock deformation and metamorphism. Together they made widely available through textbooks important new principles of structural and metamorphic geology developed by the Lake Superior Division. During both world wars, Leith was adviser to the federal government on mineral economics, and in 1921 he authored a textbook about economic geology. Beginning in 1905, he carried on an active consulting career in addition to his other duties. Mead followed suit, and soon pioneered the new field of engineering geology.

Among many outstanding students of the early twentieth century Wisconsin School, two were of particular significance. Florence Bascom earned the M.S. in 1887 under Van Hise, the Ph.D. at The Johns Hopkins University in 1893, was elected to Fellowship in The Geological Society of America in 1894, and initiated an important geology program at Bryn Mawr College in 1895. In 1926, Englishman Gilbert Wilson earned the M.S. under Mead, and then received the Ph.D. from Imperial College in London in 1931. In 1939 he joined the Imperial faculty, where he inspired a postwar revolution in detailed structural analysis in Britain. The impact of Wilson and his students soon spread over Europe, and even reached back to Wisconsin, the spawning ground for that revolution.

INTRODUCTION

Few geologists have the choice that I face every morning, whether to walk to the university along Chamberlin (misspelled Chamberlain) Avenue or Van Hise Avenue. Madison, Wisconsin, may be the only city in North America with two parallel streets named after geologists. This circumstance reflects the equally unusual fact that our university has had two geologists serve as president, namely these same two individuals. Moreover, each has a campus building named for him, and my children attended Van Hise Middle School before it was renamed.

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Why should geology loom so large in Wisconsin history? The public prominence of Thomas C. Chamberlin and Charles R. Van Hise is due to their distinguished administrative roles as presidents of the university. Indeed, most present faculty members and local citizens who are familiar with these names have no idea that both were distinguished geologists first. By 1903, when Van Hise took the university helm, a so-called Wisconsin School of Precambrian Geology had already developed a considerable reputation. Chamberlin had first gained prominence as the skillful director of the later phases of the Second Wisconsin Geological Survey of 1873–79. The four-volume reports of the *Geology of Wisconsin* were as good as the best publications from any survey in the world at that time. Largely because of his success with the survey, Chamberlin was tapped for the university presidency in 1887. But success breeds success, and in 1892 he was lured away to organize a department of geology in the new University of Chicago. Although his geological interests were different from those of Van Hise, being chiefly in glacial geology, Chamberlin remained in close touch with his Wisconsin colleagues for many years and continued to act as an important catalyst for the science here. He even recruited Van Hise to present a course on structural geology at Chicago in alternate years from 1892 to 1902; Van Hise appears in photos of the University of Chicago geology faculty from that period. When Van Hise became president of the University of Wisconsin, Chamberlin then recruited Charles K. Leith to present the same course from 1905 to 1917.

During Chamberlin's presidency (1887–92), the University of Wisconsin underwent revolutionary changes, which were to give it international stature (Curti and Carstenson, 1949). Chamberlin championed curricular reforms to bring more science, to introduce concentration in a major field, and to introduce the seminar method of teaching; a Ph.D. program was also instituted with C.R. Van Hise receiving the first such degree in 1892 (Bailey, 1981). Chamberlin doubled the size of the faculty and laid the groundwork for an extension program. He also argued that the scholarship of the university should benefit the entire state. All of these innovations were strengthened by his successor, Charles K. Adams, and were culminated during Van Hise's tenure (1903–18). In 1904 a formal graduate school was founded and in 1907, a medical school. Also in 1907 the Extension Division was expanded to fulfill the famous Progressivist Wisconsin Idea that "the boundaries of the campus should be the boundaries of the state."

With the rapid expansion of agriculture and industrialization had come pleas all across the nation for more practical educational opportunities. In 1862 and again in 1890, Congress passed the Land Grant Acts, which provided federal aid to states in the form of grants of federal land, which could be sold or otherwise exploited to fund colleges that would emphasize education in agriculture, the mechanic arts (engineering), home economics, and ROTC. Then in 1887, the Hatch Act was passed, which created Agricultural Experiment Stations to stimulate agricultural research. Wisconsin responded promptly to these initiatives. Both developments helped foster the important new idea that research should be a handmaiden of education, which had been formalized first at The Johns Hopkins University in 1879 with the creation of a formal Graduate School on a German model. Most American geologists were right in step with the new initiative, for they had already been doing research through state or federal surveys or with the mining industry. The timing was perfect for Van Hise to be president, for he had been practicing this dual approach for 25 years, that is, ever since receiving his bachelor's degree!

WHY AT MADISON?

Against the background of a national impetus for educational innovation, we may ask why did a great School of Precambrian Geology develop at Wisconsin at the beginning of the twentieth century? To answer this question, we must investigate a remarkable intellectual genealogy and link that with the industrial expansion of the nation as well as the sweeping changes in higher education outlined above.

The arrival of Roland D. Irving in 1870 marked the real beginning of a geology program at the University of Wisconsin (fig. 1). A grandnephew of Washington Irving, he had been professionally trained at the Columbia University School of Mines in New York. He quickly gained prominence within the university as a faculty leader and outside the university as a research investigator (Curti and Carstenson, 1949). A new geological survey of the state commenced three years after he arrived, and he was recruited to participate in this investigation. Irving first studied the iron- and copper-bearing regions of northern Wiscon-

Figure 1. Roland D. Irving, the first professionally trained professor of geology and mineralogy at the University of Wisconsin (1870–88) and first chief of the U.S. Geological Survey Lake Superior Division (1882–88). This photograph dates from near the time of Irving's appointment to the federal survey in 1882.

Figure 2. Charles R. Van Hise, protégé of Roland D. Irving, professor of geology (1882–1903), second chief of the U.S. Geological Survey Lake Superior Division (1888–1903), and president of the University of Wisconsin (1903–18). This photograph shows Van Hise in 1905, early in his presidency.

sin; one result was the first recognition of a Lake Superior syncline. Next he investigated a large portion of central Wisconsin, including the Baraboo District. In 1883, his full study of the copper-bearing rocks (Keweenawan) was published by the USGS as Monograph 5. He also invoked the new technique of "microscopic lithology" (petrography) in this research and introduced it into the teaching program. Irving's initial appointment was in Mining and Metallurgy, but in 1878 a separate Department of Mineralogy and Geology was created with him as its professor. In 1880, his star student, Charles R. Van Hise, was appointed as instructor (fig. 2). Like Irving, Van Hise also worked part-time for the state geological survey, principally doing petrographic studies of Irving's samples (Bailey, 1981).

The states' rights tradition had discouraged the national government from sponsoring geological surveys within the original states, but there was no such restraint within the territories created by the 1787 Northwest Ordinance. Two surveys of the upper Mississippi Valley region led by D.D. Owen (1840, 1852) and the survey of Northern Michigan and northeastern Wisconsin led by J.W. Foster and J.D. Whitney (1850–51) had set the precedent. Lead deposits had motivated the Owen surveys, while the discoveries in northern Michigan of native copper in 1831 and iron ore in 1844 had spurred the Foster–Whitney survey. In 1880, soon after the Wisconsin state survey was completed, the USGS recruited both Chamberlin and Irving as special agents for the Tenth National Census, which was to include for the first time the gathering of statistical data on mineral resources under the direction of the USGS (Rabbitt, 1980, p. 25; Nelson, 1999, written communication). Chamberlin had been one of 13 state geologists who supported the efforts of Director King to extend the federal survey's activities into the states in order to prepare a geological map of the entire nation, and in 1881 Chamberlin was appointed chief of a new Glacial Division, a position he held for five years. Meanwhile, Irving proposed to the new USGS Director, J.W. Powell, that an integrated survey of the Precambrian rocks of the Lake Superior region, which would include petrographic studies, was now needed (Geschwind, 1994, p. 42). In 1882 the USGS adopted his suggestion, and established a Lake Superior or Precambrian Division to investigate the iron-bearing rocks, with Irving in charge of a new office located at the University of Wisconsin in Madison. Irving continued also to head the Department of Mineralogy and Geology, a balancing act hardly imaginable today.

As part of the USGS expansion, college professors were hired on temporary appointments to assist both field and laboratory efforts. Besides Chamberlin and Irving of Wisconsin, George W. Williams of The Johns Hopkins University was appointed to work with Irving during the summers of 1885 and 1886. His training in the new techniques of microscopic petrography under H. Rosenbusch at Heidelberg (Ph.D., 1882) made him a valuable asset. Evidence of the complex organizational relationships among university, state, and federal personnel is exemplified by Raphael Pumpelly, who was variously professor of mining engineering at Harvard, temporarily state geologist of Michigan (1869–71) and an assistant doing petrography for the second Wisconsin survey in 1877. In 1879 he joined the new USGS, and it was he who transmitted Irving's manuscript for USGS Monograph 5 (Irving, 1883) on the copper-bearing rocks to the Director for publication. In 1881 Pumpelly left the Survey to lead a Northern Transcontinental (railroad) Survey, but he returned to take charge of the Archean Division from 1884 to 1890. This new responsibility kept him in contact with the Lake Superior Division in Madison.

The new federal initiatives did not go unchallenged. For example, the seven prominent editors of *The American Geologist* presented a protest in their new journal in 1888. They professed "serious misgivings as to the result of the influence of the national geological survey in extending its operation into the settled states....especially into the states in which official geological surveys are in progress" (Calvin and others, 1888, p. 2–3). Their expressed fear was that such concentration of effort might cause a loss of public support of geological investigations at the state level, but could they also have harbored some sour grapes?

Things were happening rapidly in the 1880s. Van Hise was granted one of the first two M.S. degrees given by the university in 1882, the basis for his degree being the research for the recent state survey. He was then promoted to assistant professor and was also appointed to a part-time post in the new Lake Superior Division. Irving put him in charge of field investigations of the Penokee–Gogebic Iron Range, which straddles the Wisconsin–Michigan border. The results of that work appeared in 1892 as USGS Monograph 19, co-authored by Irving and Van Hise. On the basis of this publication, Van Hise was granted the first Wisconsin Ph.D. degree ever awarded, also in 1892.

During the same period, Florence Bascom, daughter of university president John Bascom, studied geology under Irving and Van Hise. In 1887 she received the second M.S. degree ever in geology; it was granted for a petrographic study supervised by Van Hise of layered gabbros in the Penokee range around Mellen. After teaching in secondary schools for four years, Bascom applied to Johns Hopkins for further postgraduate study. Professor Williams, who had worked with Irving in Wisconsin while Bascom was studying for the M.S., acted as her adviser. Overcoming such obstacles to women as having to sit behind a screen during lectures, she received the Ph.D. in 1893 (Arnold, 1983). Bascom was the first woman geologist in the nation to earn that degree, and in 1894 became the second woman to be elected Fellow of The Geological Society of America. Because of her research promise, she was invited in 1895 to found a geology program at Bryn Mawr College in Pennsylvania, where she inspired many younger women to pursue careers in science. She continued to do outstanding research through a part-time appointment with the USGS.

In 1888 Irving died unexpectedly, and Van Hise suddenly inherited both the headship of the academic department and of the USGS Division. Chamberlin was now president of the university and Van Hise's classmate and friend, the Progressive politician Robert LaFollette, was governor. Geology thrived at Wisconsin. Directing a small army of geologists mapping all of the principal iron mining districts of Minnesota, Wisconsin, and Michigan was a formidable task, but one that Van Hise discharged with efficiency and imagination. An impressive series of detailed publications appeared over a 20-year period spanning the turn of the century. The most important of these are listed in table 1.

As a consequence of the massive effort of the Lake Superior Division, Van Hise became thoroughly familiar with the complex Precambrian geology of the entire region. For the federal survey, he also visited many other regions of the country where Precambrian rocks are exposed and consulted with the survey geologists working there. He always looked beyond the details of each district in search of a general synthesis, and in so doing, became a master exponent of multiple working hypotheses even before his colleague, Chamberlin, made that method of investigation famous. Van Hise became especially fascinated with the deformation and metamorphism that the old rocks displayed, and soon became a leading authority on the fundamentals of structural and metamorphic geology. This emphasis culminated in his most famous publications, "A Treatise on Metamorphism," a mere 1,285 pages long (Van Hise, 1904a), and a synthesis of all of the Lake Superior work, "Geology of the Lake Superior Region" (Van Hise and Leith, 1911). Through his own research and from his initial training in engineering and metallurgy, Van Hise came to appreciate more than most contemporaries that if geology was to advance from mere classification to the formulation of principles, its practitioners must become well grounded in basic mechanics and chemistry. He expressed this conviction emphatically in an address to an International Congress of Arts and Sciences at St. Louis in 1904, for which he was asked to address a daunting topic, "The Problems of Geology" (Van Hise, 1904b).

By the 1890s, Van Hise had recognized an urgent need for a much greater understanding of the behavior of minerals and rocks under conditions of pressure and temperature far beyond human experience. At the turn of the century, he was invited to join with T.C. Chamberlin and a few other visionaries to champion the establishment of a national laboratory to conduct experimental investigations on this geological frontier, and in 1906 was born the Geophysical Laboratory within the new Carnegie Institution of Washington (created in 1902). This laboratory would soon move the United States to the forefront of research on some of the most fundamental problems of earth science (Yochelson and Yoder, 1994). Coming very soon after he began his new career as president of his university, this was a fitting capstone to Van Hise's geological career and his state-of-the-art synthesis of structural and metamorphic geology.

THE VAN HISE–LEITH–MEAD DYNASTY

When Van Hise was called to the presidency in 1903, the publication history of the Lake Superior studies was at its midpoint (table 1), and there was still much to be done. Van Hise repeated his own inheritance from Irving 17 years prior by immediately promoting his most promising protégé, Charles K. Leith (fig. 3), to direct the Precambrian investigations, and, in 1905, also to chair the Department of Geology. Leith now supervised the completion of the publications about the iron ranges and also expanded the academic program in geology. It was remarkably fortuitous that Van Hise had such an able young colleague to whom he could pass his geological torch.

How did such a coincidence come about? Leith had entered the university in 1892 at the age of 17. Having previously taken some business training, he answered a help-wanted advertisement for a secretary

Table 1. *Principal publications from the U.S. Geological Survey Lake Superior Division during the Irving–Van Hise–Leith era (1883–1935).*

USGS publication	Subject of report (Author[s] and year of publication)
Monograph 5	Copper-bearing rocks of Lake Superior (Irving, 1883)
Bulletin 62	Greenstone schists (Williams, 1890)
Bulletin 86	Pre-Cambrian correlations (Van Hise, 1892)
Monograph 19	The Penokee–Gogebic Range (Irving and Van Hise, 1892)
Annual Report	Principles of Pre-Cambrian geology (Van Hise, 1896)
Monograph 28	Marquette district, Michigan (Van Hise and others, 1897)
Monograph 36	Crystal Falls district, Michigan (Clements and others, 1899)
Monograph 43	Mesabi Range, Minnesota (Leith, 1903)
Monograph 45	Vermillion district, Minnesota (Clements, 1903)
Monograph 46	Menominee district, Michigan (Bayley, 1904)
Monograph 47	Treatise on metamorphism (Van Hise, 1904a)
Bulletin 239	Rock cleavage (Leith, 1905)
Monograph 52	Synthesis of the Lake Superior region (Van Hise and Leith, 1911)
Professional Paper 184	Pre-Cambrian of the Lake Superior region (Leith and others, 1935; update of Monograph 52)

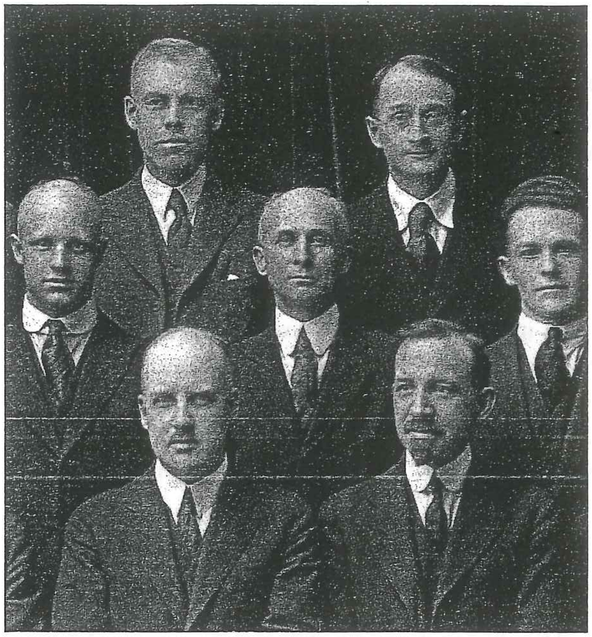

Figure 3. Part of the University of Wisconsin Department of Geology personnel for 1919–20. From left to right: Back row: C.K. Leith and E.F. Bean; middle row: H. Weeks (student; older brother of Lewis G. Weeks), W.H. Twenhofel, and A.D. Conover (student); front row: W.J. Mead and A.N. Winchell.

to Professor Van Hise, which job he hoped would finance his education. Leith soon became so fascinated by his employer's work that he chose to major in geology (McGrath, 1971). Van Hise recognized Leith's unusual ability, and immediately appointed him to the Lake Superior Division when he graduated. In 1901 Leith received the Ph.D. for a dissertation on rock cleavage, which was published as USGS Bulletin 239 (1905). There was a great and growing demand for expert consultants to the mining industry, especially for the man who had done the definitive study of the great Mesabi iron ores in Minnesota (USGS Monograph 43, 1903), which were then just beginning to be developed. So, in 1905, just two years after assuming direction of the division from his mentor, Leith changed his federal appointment to a per diem basis so that he could begin a long and lucrative consulting career.

During both world wars, Leith became much involved as an adviser to the federal government on strategic minerals, which led his career in an important new direction. Like most of his other work, even Leith's long involvement with the economic, strategic, and political aspects of minerals had a precedent in his mentor's career, for Van Hise had been an active participant in the earliest conservation movement championed by President Theodore Roosevelt. Van Hise's concern had been aroused early in his career by the impact upon him of the thoughtless decimation of the forests of the Lake Superior region and the resulting loss of soil by accelerated erosion. As a result, he became an outspoken leader in the movement at both state and federal levels. His vigorous challenge to corporate exploitation of forests and water embroiled him in political controversy, which brought questions of the propriety of such involvement by the president of the state university. In 1910 Van Hise published *The Conservation of Natural Resources of the United States,* the first general book on the subject. Leith's efforts in conservation took a somewhat different tack by emphasizing the importance of mineral resources in national and international affairs during both war and peace. His views were so influential that he was appointed as mineral adviser to the American Commission to negotiate peace, and in 1919 he accompanied Woodrow Wilson to the Versailles peace conference. In 1921 Leith published the textbook *Economic Aspects of Geology,* which not only treated all types of mineral resources and the geology of engineering construction, it also contained a novel section on the geopolitical implications of mineral resources, including a chapter titled "Geology and War." Ten years later he published a more popularly oriented book, *World Minerals and World Politics,* which stressed even more the importance of mineral resources in human affairs (Leith, 1931). He continued to write, speak, and advise on mineral resources during the remainder of his career, and he implemented a course at the university called Minerals as a Public Problem, which is still taught today.

In the years before World War I, industrialization was racing ahead, *laissez faire* capitalism was at its apogee, and the clamor from mining interests for his talents had made consulting irresistible to Leith. And why not, for he could have his cake and eat it, too. He could continue his university base and some research for the USGS as well as pursue private commercial ventures. Even Van Hise participated in some of those ventures in spite of his presidential duties. Capitalizing upon a friendship with Andrew Carnegie, Van Hise gained financial backing for mining exploration and speculation in Ontario from 1902 to 1907. Leith and, to a lesser extent, Van Hise, supervised a group numbering as many as 40, which was made up of geology graduate students and other assistants during the summer field season, mostly in Ontario. Included among the many workers were future state geologist W.O. Hotchkiss and future faculty members F.T. Thwaites and W.J. Mead. A later, even more ambitious Leith–Van Hise enterprise was an effort to develop a large, Mesabi-scale iron mine in Brazil (McGrath, 1971, chap. 6). Begun in 1911, this complex project finally collapsed during the 1940s when the Brazilian government adopted policies adverse to foreign investments. Although both men were circumspect about their commercial activities, especially their involvement with Carnegie, it is still amazing from a modern perspective how little fuss was made either by the press or the state government about both the university's president and a prominent department head being involved in such ventures (Vance, 1960).

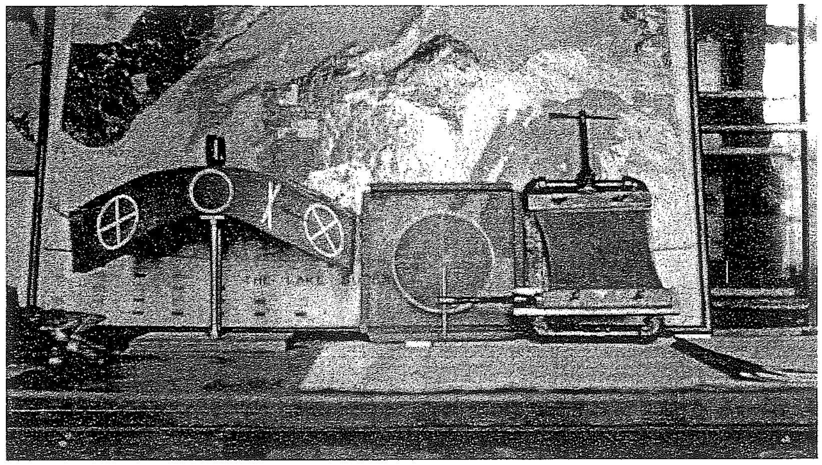

Figure 4. "Mead's Toy Shop": Some of the apparatus built by W.J. Mead to illustrate the fundamental mechanics of rock deformation (from Rettger and Emmons, 1921, p. 218).

During mineral explorations in Ontario in the summer of 1902, some student fieldworkers conceived the idea of an annual yearbook or scrapbook named the *Outcrop* (Deming, 1926). Leith (ca. 1938) reported that it began as a kind of newspaper with a social column and a miscellaneous column concocted to relieve the boredom of rainy, tent-bound days. It soon developed, however, into an ambitious, liberally illustrated record of both the serious and diverting activities of the entire Department of Geology with special emphasis upon summer field work. The Geology Club's *Outcrop* was produced by elected student co-editors almost every year from 1902 through 1957. These elaborate volumes, which now reside in the University of Wisconsin Archives, are historical treasure troves of information about the department not to be found in official histories. Especially interesting are letters from alumni about their experiences exploring for minerals or petroleum in far-flung corners of the Earth. Beginning in 1924, a short extract was published in multiple copies under the title, *The Outcrop–Printed Version,* which contained lists of faculty and students, the addresses of alumni, and a few brief notes about departmental activities such as visiting speakers. Beginning in 1970, an Alumni Newsletter replaced the scrapbook format as a medium for recording annual events in the department; the name *Outcrop* was resurrected, however, as the title for an occasionally published alumni directory.

Continuing the Wisconsin intellectual genealogy, Leith appointed his own most promising student, Warren J. Mead, as instructor in 1908 and assistant professor two years later (fig. 3). Leith saw that Mead's special talent for experimental and quantitative approaches to geological problems would provide a fine complement to his own field approaches (Bailey, 1981). Mead built ingenious apparatus for investigating and teaching the deformation and metamorphism of rocks (fig. 4). Like Leith, he soon was in demand for consulting. Through the urging of Van Hise, Mead was asked in 1915 to investigate severe landslide problems, which were hampering the excavation of the Panama Canal. This experience led him to become a pioneer in engineering geology; he soon created what was probably the first course in this subject. In 1934, Wisconsin lost Mead to MIT.

In the first 15 years of his leadership, Leith quadrupled the size of the geology faculty, thus broaden-

Figure 5. Group photo from the Lake Superior field trip of May 1926. W.J. Mead is second from the left at the back (with brimmed hat); Gilbert Wilson is at the right front. Others from left to right are: Back row: W.A. Seaman (professor at Michigan Institute of Technology), Mead, K. Fowler, E. Hahn. Middle row: C.H. Stockwell, W.F. Brown, J.M. Hansell; front row: W.P. "Texas" Rand, H.S. Bostock, and Wilson. Bostock and Stockwell had distinguished careers with the Geological Survey of Canada. Katharine Fowler received the Ph.D. from Columbia University, pursued a lifelong career in geology, and married Harvard structural geologist Marland P. Billings. In 1999 she received (posthumously) the first Wisconsin Department of Geology and Geophysics Distinguished Alumnus Award. Emily Hahn practiced engineering and geology for only four years before turning to journalism. In 1976 the university awarded her an honorary degree for her distinction as a writer and a champion of women's rights to pursue their own careers.

ing the specialties represented (detailed in Bailey, 1981). Some of the more notable additions were A.N. Winchell in mineralogy and petrology (1908), F.T. Thwaites as museum curator (1911) and later lecturer in geomorphology and glacial geology (1928), and W.H. Twenhofel in sedimentation and paleontology (1916), to mention only three who remained on the faculty for many years. But it was the Leith–Mead partnership that originally put the Wisconsin department on the map. Leith's textbooks, *Structural Geology* (1913, 1923) and the Leith and Mead *Metamorphic Geology* (1915) publicized the pioneering concepts of Van Hise and disseminated widely the wealth of insights gained from the Precambrian studies in the Lake Superior region during the preceding three decades. In recognition of the stature of Wisconsin's pioneer geologists, the National Academy of Sciences inducted Van Hise to Fellowship in 1902, Chamberlin in 1903, Leith in 1920, and Mead in 1939. By 1910 the department's reputation had grown so much that students were applying from all over the United States and Canada. In 1927 Francis J. Pettijohn considered only Wisconsin, Berkeley, Chicago, and Yale for his pursuit of the Ph.D. (Berkeley won; Pettijohn, 1984, p. 99). Throughout the 1920s, graduate students and postdoctoral scholars were coming to Madison from Europe, China, and Japan—the boundaries of the campus had expanded over the entire globe!

GILBERT WILSON AND MODERN STRUCTURAL GEOLOGY

The most impressive measure of the global reputation of the Wisconsin School of Geology is provided by the career of a young Englishman named Gilbert Wilson, who came to study at Madison in 1925–26. He grew up in the English Lake District, but had crossed the Atlantic in 1920 to study mining engineering and geology at McGill University in Montreal, where he graduated in 1925. While there, he heard of the Wisconsin reputation, and decided to come here for postgraduate study. Wilson immersed himself in the Precambrian geology of Leith, Mead, and Winchell, studying structural and metamorphic geology, petrography, and ore deposits, and participated in field trips to the Lake Superior region (fig. 5). In 1926 he was awarded the M.S. for a thesis titled "The Pre-Cambrian Trendlines," which was supervised by Mead. Curiously, his mentor, who had already supervised several M.S. and at least two Ph.D. degrees, was himself awarded the Ph.D. rather tardily in the same year. Those were indeed different times when a professor could oversee Ph.D. candidates before receiving the Ph.D. degree himself, and also could carry on an extensive consulting career while retaining a full academic position.

After Wisconsin, Wilson worked in mining geology in Russia, Yugoslavia, Canada, and Africa. In 1931 he took the Ph.D. at Imperial College in London and then was a lecturer at Reading University and University College, London, before joining the Imperial faculty in 1939. Wilson principally taught structural geology and field mapping at Imperial. He was a dedicated teacher and had an exceptional talent for illustrating complex, three-dimensional features with lucid drawings (fig. 6). Building upon the principles that he had learned from Leith and Mead at Wisconsin, he proceeded to refine and expand the analysis of deformed rocks. He single-handedly invented structural geology as a subdiscipline in British universities, where it had been largely ignored; stratigraphy and paleontology together with mineralogy and petrology had dominated for years (Ramsay and Cosgrove, 1987). Wilson himself wrote the following acknowledgment of his debt to Wisconsin (in Wilson and Cosgrove, 1982):

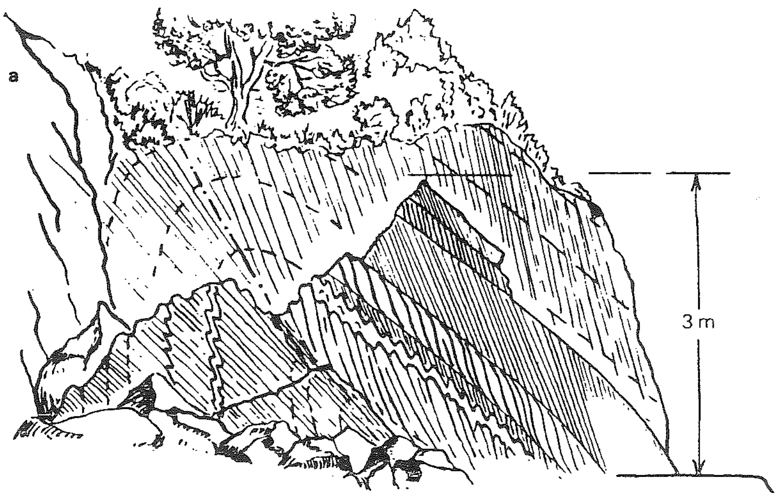

Figure 6. *Drawing by Gilbert Wilson of a medium-scale overturned anticline in Devon, southwestern England, showing the geometric relationship of slaty cleavage and small parasitic folds to the limbs and axial plane of the larger fold. It was such fundamentals of structural geology as this that Wilson had first learned at Wisconsin from Leith and Mead, and which he later refined and elaborated in Great Britain (first published in Wilson, 1961; reprinted in Wilson and Cosgrove, 1982).*

> *The foundations of much that I have written were laid in the lectures on structural geology by Professors C.K. Leith and W.J. Mead at the University of Wisconsin many years ago. The principles which they expound run through the whole of this work, in places disguised in modern jargon, elsewhere modified by more recent advances in knowledge, but it was they who instilled in me the importance of minor structures in the elucidation of the major structures in the field.*

What was it that so inspired young Gilbert Wilson at Wisconsin? It was that Van Hise, Leith, and Mead applied basic mechanics to explain the deformation of rocks in terms of maximum and minimum stress, directions of compression, shear, and extension, and the concept of the strain ellipsoid, that important device for the understanding of ductile deformation. The origin of slaty cleavage, schistosity, elongation of pebbles, and the like were emphasized, as was the value of such sedimentary features as cross bedding, graded bedding, and symmetrical ripple marks for determining original "way up" in overturned strata. Most specifically, however, as noted in his acknowledgment, Wilson was impressed with the ability to apply mechanical theory to the inference of obscure, large-scale structures from a systematic study of the geometric relationships of small-scale features like parasitic or drag folds and cleavage (fig. 6).

We must ask which of these structural concepts was original with the Wisconsin School. Given the centuries of quarrying of slate in Europe, it would be surprising if slaty cleavage had not attracted the early attention of geologists. Indeed, by the 1830s, cleavage was recognized by none other than Adam Sedgwick as distinct from bedding and that it was best developed in finer lithologies (Sedgwick, 1835). Several different origins were proposed, which included mechanical, chemical, electrical, and magnetic causes. During the 1840s, the distortion of fossils in slates was recognized and quantified, and this was taken by many as proof that cleavage must be of mechanical origin due to compression perpendicular to the cleavage planes (Sharpe, 1849). This inference seemed to be strengthened by the microscopic examination of slates by Sorby (1853) and compression experiments both by him and by Tyndall (1856). Many workers had noted that cleavage is remarkably consistent in its strike, tending to parallel the regional axis of elevation more closely than the local strike of bedding. Most workers thought the dip of cleavage planes varied so greatly in amount and direction that they failed to recognize any further pattern, but H.D. Rogers had observed in the Appalachian Mountains as early as 1849 that "the cleavage dip is parallel to the average dip of the anticlinal and synclinal axis planes" (Rogers, 1856, p. 447). He noted such deviations from his generalization as a fanlike arrangement at fold crests and a tendency for a sigmoidal shape across beds of contrasting lithology (that is, refraction). Rogers also suggested that "foliation is parallel or approximately so to the cleavage" and that these two phenomena were closely akin, having "originated at the same time and from one and the same cause" (p. 452). He rejected a mechanical origin, however, in favor of his own variation of Sedgwick's early idea of molecular crystallizing forces ever resident in mineral matter, which have only to await the quickening influence of heat to awaken them (paraphrased from Rogers, p. 465 and 471). By the 1880s, however, the mechanical origin of cleavage under compression was fully accepted, and the strain ellipsoid was being invoked for its analysis (Harker, 1885). Debate now centered upon whether cleavage formed entirely after the folding of bedding or overlapped with that folding.

On the basis of pioneering microscopic studies, Sorby (1853) had argued that cleavage was produced during compression primarily by the rotation of platy minerals into a preferred orientation. In reviewing the subject in 1896, Van Hise (p. 633–668) concluded that the parallel development of new minerals was more important than flattening and rotation of earlier minerals. He also noted that elongate minerals tend to align in cleavage planes with their long axes parallel to the dip of those planes (that is, lineation). Leith, in his Ph.D. dissertation (1905) and textbook (1912), accorded with Van Hise and such earlier authors as Sorby (1853), Heim (1878), and Harker (1885) in distinguishing two types of cleavage, which Leith supported with a wealth of new microscopic data. He named them *flow cleavage,* having fine mineral grains oriented within the planes by rotation and recrystallization during rock flowage, and *fracture cleavage,* being a very closely spaced jointing or fissility lacking any parallel arrangement of mineral grains; relative degree of plasticity (or ductility) was considered the controlling genetic factor that differentiated them. Although both types had similar geometric relations to other structures and to each other, even grading into one another, flow cleavage was considered to be more pervasive (or penetrative). Like Rogers and others before, the Wisconsin workers envisioned a continuum of increasing dynamic metamorphism from slaty cleavage to schistosity and, in some cases, even to a gneissic texture.

The recognition that slaty cleavage and so-called drag or parasitic folds bear a systematic geometric relationship to larger structures was the principal contribution of the American geologists working in the Lake Superior region between 1880 and 1910. The complex Precambrian rocks of the Lake Superior region are so obscured by glacial deposits and vegetation that the early geologists were forced to learn how to use small-scale features visible in scattered outcrops in order to infer the large-scale structures, which were generally not visible, but which they knew must hold the key to an overall understanding of the region. Their applications in structural geology were taught routinely at Wisconsin by the turn of the century and were made available to a wide audience through Leith's textbook in 1913.

It is difficult to trace to specific individuals the first recognition of each clue, but it is clear that these insights did emerge from the Lake Superior Division based at Madison. For example, hearsay gave former State Geologist William O. Hotchkiss credit for first recognizing the value of cross-bedding and graded bedding for determining the upward-facing direction in vertical or overturned strata. After much investigation of this elusive rumor, I finally found confirmation in his field notes and correspondence from the Florence District in June 1910 (Hotchkiss Notebook No. 1, June 21, 1910, p. 4, on file at the Wisconsin Geological and Natural History Survey and letter to C.R. Van Hise, June 26, 1910, in the C.K. Leith archive, Correspondence Box 37, at the Steenbock Library, University of Wisconsin–Madison). More details about the tangled history of these criteria are presented in another article (Dott, 2001).

Wilson himself refined and expanded the Wisconsin concepts to elaborate such things as lineations and the mechanics of thrust faulting. In so doing, he became the postwar master of small-scale structural analysis (see Wilson, 1961; Wilson and Cosgrove, 1982). Recapitulating his own intellectual ancestry, Wilson influenced a number of brilliant students, who themselves carried on the Wilsonian revolution in the detailed structural analysis that had its roots here in Wisconsin. One of Wilson's protégés was John G. Ramsay, whose publications are well known today in structural circles (for example, Ramsay and Huber, 1983). Ramsay pioneered especially the quantitative analysis of strain in ductilely deformed rocks as exemplified in the Scottish Highlands and the Helvetic nappes of the Swiss Alps. He succeeded Wilson at Imperial College, but later moved to the Geologisches Institut in Zurich. Another Wilson protégé was M.R.W. Johnson, who joined the faculty of the University of Edinburgh. One of Johnson's students was I.W.D. Dalziel, who joined the Wisconsin faculty from 1963 to 1966, thus closing the genealogical circle begun with Wilson's 1925–26 studies at Madison. To underscore the coincidence, Dalziel co-authored the *Geology of the Baraboo District* (Dalziel and Dott, 1970), which brought a modernized structural analysis back to one of the classic areas where it had been spawned nearly 100 years earlier and where Gilbert Wilson himself must have been instructed nearly half a century before.

CONCLUSIONS

The prominence of geology in the early history of Wisconsin was a consequence of the presence of important metallic ores and of a few exceptionally talented geologists just as American industrialization began to accelerate. But why did an unusually reputable School of Precambrian Geology develop here rather than, say, in Minnesota or Michigan? The explanation seems to be that the outstanding results of the Second Wisconsin Geological Survey of 1873–79 caught national attention and immediately increased the stature of Irving and Chamberlin. Moreover, both men had established connections with the USGS during the Tenth Census, and the Survey chose Irving as the most promising candidate to direct a thorough investigation of the iron-bearing Precambrian rocks of the Lake Superior region.

The establishment of the federal Lake Superior Division office at Madison in 1882 provided the opportunity for Irving and his protégé, Van Hise to launch an ambitious, well supported, and sustained research program. With an army of geologists at their command, they were able to launch a 30-year integrated investigation of all key areas of Precambrian rocks on the American side of Lake Superior. This was big science long before the Era of Big Science! Both men were of exceptional ability, and in Van Hise's protégé, Leith, comparable intellectual and organizational skills were recognized early, thus assuring the smooth passage of the torch from Van Hise when he assumed the presidency of the university in 1903. Both Van Hise and Leith left most of the details of the region to their geological foot soldiers and concentrated their own attentions upon the structural and metamorphic aspects of Precambrian rocks. They developed fundamental concepts that were to provide the foundations for the subsequent development of both subdisciplines throughout the twentieth century.

Because of the notoriety of the government publications on the iron districts, which emanated from the Precambrian Division at Madison, and more topical publications on structural and metamorphic geology, the Wisconsin department had achieved an enviable reputation already by 1910. The addition to the faculty of Leith's protégé, Mead, completed one of the most remarkable intellectual genealogies in the history of geology (fig. 7). Mead's special quantitative and experimental talents helped the reputation continue to grow and to attract students from abroad. Through Gilbert Wilson, Wisconsin structural concepts were carried across the Atlantic to be spread even farther like ripples on a pond as, in turn, Wilson's own intellectual children and grandchildren have propagated them all around the globe.

Intellectual dynasties, like political ones, tend to stagnate eventually. During the 1920s, Leith became more and more distracted with his commercial consulting and governmental advising activities; significantly, 1920 was the last year that he taught full time. Nonetheless, he continued to hold the reins of the department firmly, making practically all decisions without consultation with other faculty members. He also attempted to have his son, Andrew, appointed as his successor as department head, but this blatant nepotism was thwarted by a faculty coup in 1934 when C.K. was out of town (Bailey, 1981). He continued to hold his faculty position until mandatory retirement in 1945, however, even though he resided in Washington, D.C., most of the time. As a consequence, his specialties of structural and metamorphic geology languished while other specialties, such as sedimentary geology, forged ahead. It was not until the 1960s that Leith's specialties finally began to recover.

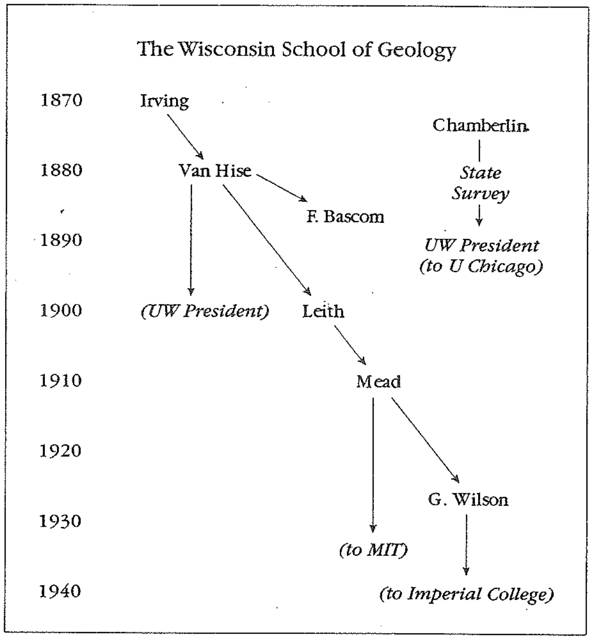

Figure 7. A genealogical chart for the Wisconsin School of Precambrian Geology from 1870 to 1940. Besides the faculty succession from Irving to Mead, two unique graduate students, Florence Bascom and Gilbert Wilson, are shown. T.C. Chamberlin, although not directly linked to the Precambrian School, was nonetheless an important catalyst for the development of geology at the University of Wisconsin, even after he departed to the University of Chicago.

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