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Rummaging through the attic; Or, A brief history of the geological sciences at Yale

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ABSTRACT

Commencing with the appointment of Benjamin Silliman as Professor of Chemistry and Natural History in 1802, the history of instruction and research in the geological sciences at Yale can be conveniently divided into seven generation-long stages. Each stage was characterized by a group of faculty members whose interests and personalities imparted a distinct flavor and character to the institution; as those faculty members left, retired, or died over a decade-long period of change, responsibility for geological studies passed to a new generation.

The first stage began with the appointment of Silliman; the second started in 1850 as Silliman's career drew to a close and J. D. Dana, his son-in-law, was appointed to the faculty, and brought the first Ph.D. degrees in the United States. The third stage commenced in 1880, and the fourth beginning in 1900, brought the first faculty appointments specifically for graduate instruction. The fifth and sixth stages saw the formative moves that welded different administrative units together, leading to today's Department of Geology and Geophysics. Stage seven, commencing in 1965, includes the present (1984), but holds the seeds of stage eight.

The increasing diversity of research activities in geology has led to a doubling of the number of geological faculty employed at Yale approximately every 50 years. The number of Ph.D's awarded has increased at a parallel rate. We suggest the size of the faculty will probably double again by the year 2035 and that production of Ph.D's will probably rise to a rate of 12 to 15 a year.

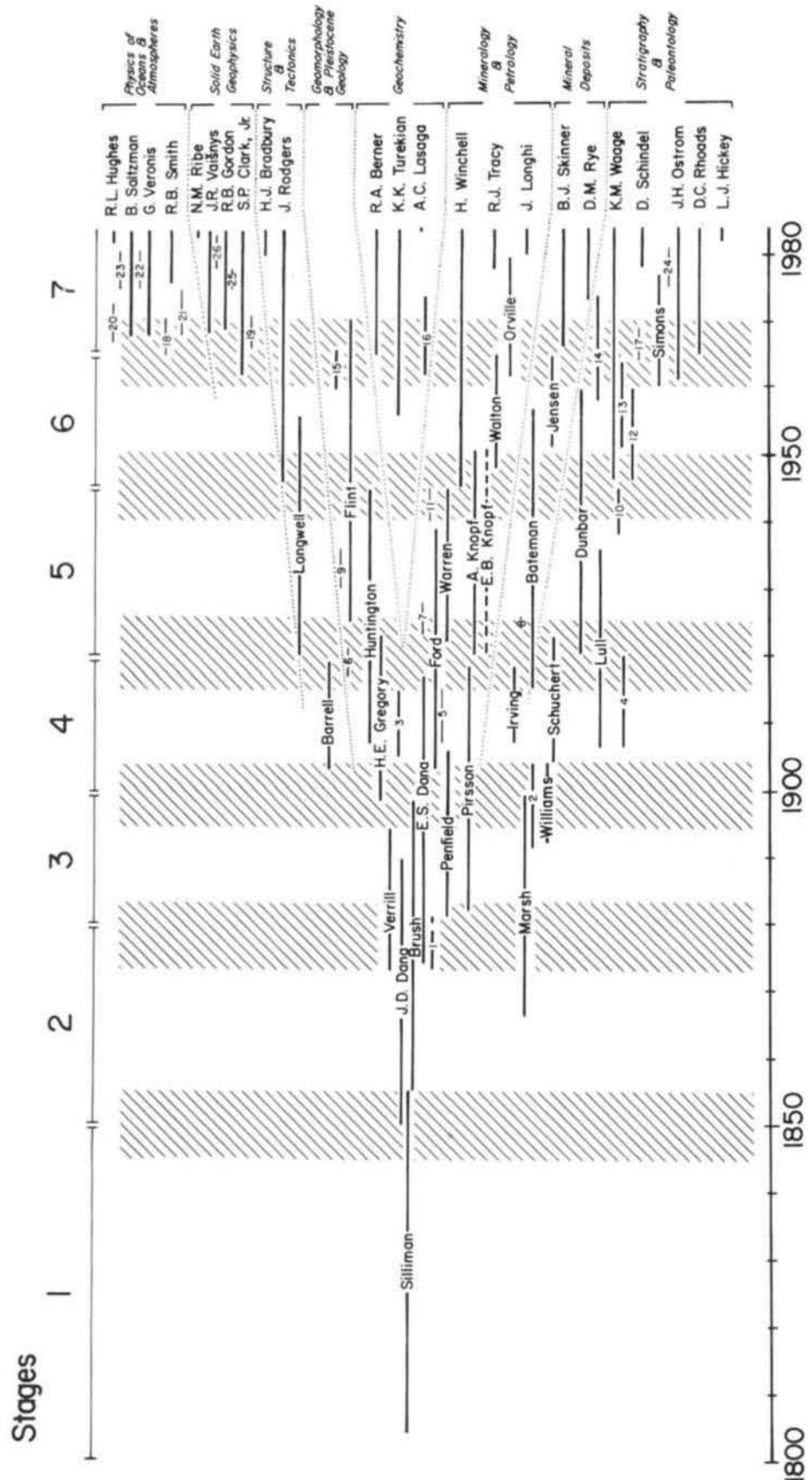


Figure 1. Sequence of faculty members teaching in the geological sciences at Yale. Distinct breaks in faculty appointments occur about 1850, 1880, 1900, 1920, 1945, and 1965. Names associated with heavy lines are mentioned in the text or are current members of the faculty. After 1900, instructorships are included only for those who progressed to higher rank. 1) G. W. Hawes; 2) C. E. Beecher; 3) Isaiah Bowman; 4) G. R. Wieland; 5) Freeman Ward; 6) J. P. Buwalda; 7) W. M. Agar; 8) K. C. Heald; 9) Helmut de Terra; 10) G. E. Lewis; 11) George Switzer; 12) J. T. Gregory; 13) J. E. Sanders; 14) A. L. McAlester; 15) A. L. Washburn; 16) R. L. Armstrong; 17) A. W. Crompton; 18) T. D. Foster; 19) N. L. Carter; 20) J.C.G. Walker; 21) H. T. Rossby; 22) M. E. Fiadeiro; 23) R. E. Hall; 24) D. R. Pilbeam; 25) Harve Waff; 26) Emile Okal. Designations of fields of study are matters of convenience and are open to question; for example, Rye and Skinner could equally well be listed under Geochemistry, Lasaga and Gordon under a new entry "Materials Science," and Saltzman and Turekian under Pleistocene Geology because of their work in paleoclimatology.

INTRODUCTION

Yale was one of the first institutions in the United States where geology was taught; the subject has been offered continuously since 1804, and as a separate discipline since 1812—the longest unbroken run, so far as we know, of any institution in the country. A study of the history of geology at Yale shows that any account must focus on the individuals who have worked at the institution—how they interacted and how their interests and activities changed the science and the institution. The story of the development of geology at Yale shows how individuals shape an institution, and could apply to dozens of other distinguished universities.

Geology was first taught at Yale in the first decade of the 19th century, but records show that even earlier there was research and teaching by Yale people in topics that would today be considered geology. In the 18th century, for example, it was a popular occupation for the mathematically inclined to calculate almanacs estimating the positions of the Moon and the planets and, especially, predicting the dates of eclipses. Today this would be called planetology, much of which is housed under the title of geology. Evidence of a marked interest in another aspect of planetology—meteors, fireballs, and comets—appears in a pamphlet prepared by Yale President Thomas Clap and published posthumously (Clap, 1781), which records his conclusion that fireballs are a class of comets that circle the Earth in highly eccentric orbits. Clap's conclusion was incorrect, but his enthusiasm for science and improvements in the teaching of mathematics were influential on the future of the sciences at Yale.

In 1801 President Timothy Dwight appointed a professor of mathematics and natural philosophy (physics)—the first of several faculty appointments that would place science on a secure and permanent footing at Yale. For his second appointment in 1802, he chose a recently graduated student who was then entering on a legal career; Dwight prevailed on him to abandon the law and become a teacher. The student, Benjamin Silliman (1779–1864), had never had a course in chemistry, mineralogy, or any other subject allied directly to geology, but he accepted Dwight's offer and, at the age of 23, was appointed Professor of "Chymistry" and Natural History. Silliman immediately set to work learning the subjects he was to teach by attending lectures in chemistry given by Professor James Woodhouse in the Medical School of the University of Pennsylvania. While in Philadelphia, he also attended lectures by Caspar Wistar on anatomy and surgery, took a private course in zoology given by Benjamin Barton, and made social contact with Joseph Priestley. Beyond some professional advice and assistance offered by Dr. John Maclean, Professor of Chemistry at Princeton, the Philadelphia experience was the only formal training in science that Silliman had when he presented his first course in chemistry to Yale College students in 1804–1805. The course consisted of 60 lectures, with mineralogy introduced at appropriate points. Silliman knew only too well that he was not really prepared for a career in either chemistry or natural history, so in 1805 he journeyed to England and Scotland where he spent a year inspecting mines, visiting various institutions, and studying in Edinburgh. While in Edinburgh, he became interested in the Vulcanist-Neptunist debate, which was then at its peak. He attended lectures by Dr. John Murray, an avowed Wernerian-Neptunist, and Dr. Thomas Hope, an avowed Huttonian-Vulcanist. Though more impressed by Murray, he struggled with the conflicting philosophies, remaining ". . . to a certain extent, a Huttonian, and abating that part of the rocks which the igneous theory reclaims as the production of fire, . . . as much of a Wernerian as ever" (Fisher, 1866, v. 1, p. 170). His earliest paper on the geology of New Haven (Silliman, 1810), written soon after his return from Scotland, makes interesting reading because it reflects the conflict in his mind and his attempts to resolve it. As he carried out this earliest geological investigation of the New Haven region, he was accompanied on horseback by interested local citizens, including Noah Webster, whom Silliman described as being "in the meridian of life" and "among the most zealous of my companions. . . ." (Fisher, 1866, v. 1, p. 216).

By the fall of 1806, Silliman was ready for a full-time teaching role. He was the founder of both the geological and chemical sciences at Yale, and more important for our story, one of the founding fathers of geology in North America.

Geological activities at Yale can be readily divided into seven stages: the first started about 1800 and covered the long career of Silliman and the early work of his distinguished student and son-in-law, James Dwight Dana (1813–1895). The second stage began about 1850, as Silliman's teaching career drew to a close. Two events of major importance marked the opening of this second stage. The first was the founding of a scientific school under the direction of Benjamin Silliman, Jr. and John Pitkin Norton; the other was the appointment of Dana to the faculty of Yale College. The third stage opened 30 years later, about 1880, by which time G. J. Brush had directed the Sheffield Scientific School to considerable prominence and the Peabody Museum of Natural History had been founded. Subsequent steps came in more-or-less generation-long gaps of 20 to 25 years. Each step began with a group of distinguished faculty members who were appointed over a period of about eight to ten years, and imparted to the institution a special flavor determined by their particular interests. As members of the group retired or died, responsibility passed to a new generation and a new pattern started to emerge. Distinct changes occurred about 1880, 1900, 1920, 1945, and 1965. It is now apparent that the Department of Geology and Geophysics has entered yet another stage of generational refurbishing in the 1980s; future histories will probably mark 1985 as the midpoint of the change. The dates of change are not exact—"about 1900" really means the time span from a few years before 1900 to a few years after 1900. An examination of Fig. 1 (adapted from an earlier diagram by Jensen, 1952) reveals that the seven steps are quite distinct.

STAGE 1: THE YEARS BEFORE 1850

When Benjamin Silliman started teaching chemistry at Yale, geology was not even a recognized discipline in most of the major academic institutions of Europe and North America. As illustrative material became available, Silliman expanded his classes in geology and mineralogy. His first course, initiated in 1807, was a private one based on early mineralogical acquisitions. In 1812, with the famous mineral collection of Colonel George Gibbs available for his use, he separated the geology and mineralogy lectures from his chemistry course and started a new course required of all Yale seniors (Narendra, 1979). By the time Silliman died in 1864, geology had risen to such prominence that 33 states had founded geological surveys (Merrill, 1920), and many geological topics—such as continental glaciation—captured the public imagination. The growth of the subject in North America was in no small measure aided by Silliman's elegant bearing (Fig. 2), powers of persuasion, and gifted teaching. But Silliman had acquired respectable scientific skills as well. His student, Amos Eaton, said, "Silliman . . . gives the true scientific dress to all the naked mineralogical subjects which are furnished to his hand" (Eaton, 1820, p. ix). Silliman was a founding officer, in 1819, of the first national organization for geologists, the American Geological Society, and he attracted to Yale many students and postgraduates who became leaders of the fledgling science. In 1818 Silliman founded the *American Journal of Science,* providing a publication outlet for scientists in all fields. That journal has been published at Yale, without a break, to the present day.

Silliman's effect on Yale as an institution was enormous. His leadership, forceful ideas, and organizational skills provided the momentum in the development of the physical sciences that led directly, albeit some years after his death, to Yale's becoming a university rather than a college.

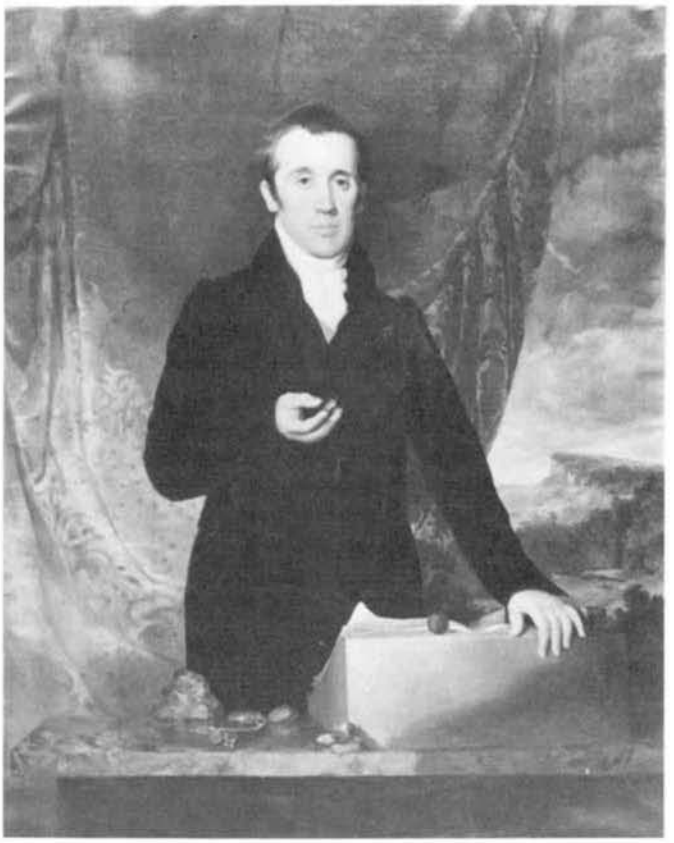


Figure 2. Benjamin Silliman. A portrait painted by Samuel F. B. Morse in 1825. (Courtesy, Yale Art Gallery).

STAGE 2: THE YEARS BETWEEN ABOUT 1850 AND ABOUT 1880

Two events mark the opening of stage 2. The first was the appointment, in 1850, of James Dwight Dana (Fig. 3) as Silliman's successor. Dana graduated from Yale College in 1833 and grew to great prominence during the next 20 years as a result of his scientific papers and contributions arising from his participation in the United States Exploring ("Wilkes") Expedition (1838–1842). Dana was also famous for his *System of Mineralogy,* first published in 1837, and his *Manual of Mineralogy,* which first appeared in 1848. By 1849, as Rossiter (1979) has observed, he was only 36 but had already accomplished far more than most geologists did in a lifetime. Aside from being one of the most distinguished geologists in North America, Dana was also Silliman's son-in-law. His appointment as the Silliman Professor of Natural History in 1850 (changed to Silliman Professor of Geology and Mineralogy in 1864) was necessary to keep him in New Haven rather than lose him to Harvard, and it is not hard to imagine the role Silliman might have played behind the scenes in order to bring about the newly endowed chair. Silliman continued to teach geology until Dana had completed his expedition reports and was ready to take over the lecturing role in 1856.

The second event that marked the opening of stage 2 was a result of Silliman's practice of accepting postgraduates for specialized instruction (for which no degree was given), a practice he started before 1820. His son, Benjamin Silliman, Jr., continued the practice by teaching applied chemistry to some of his father's special students, starting in 1842. This in turn led to the opening in 1847 of what was initially called the Yale School of Applied Chemistry, directed by the younger Silliman and John Pitkin Norton. The school received no financial assistance and little encouragement from Yale. Later named the Sheffield Scientific School after a wealthy benefactor, the institution developed into a successful technical college that awarded its own undergraduate degree for professional training in the applied sciences. In 1852 the new degree, the Bachelor of Philosophy (Ph.B.), was awarded to a group that contained members destined for greatness in geology. Perhaps the most distinguished was George Jarvis Brush (1831–1912; Fig. 4), Professor of Metallurgy from 1855 to 1871, then Professor of Mineralogy and Director of the Sheffield Scientific School. Another was William P. Blake (1826–1910), a prominent mining engineer, whose reports about Alaska are supposed to have had a considerable influence on U.S. Secretary of

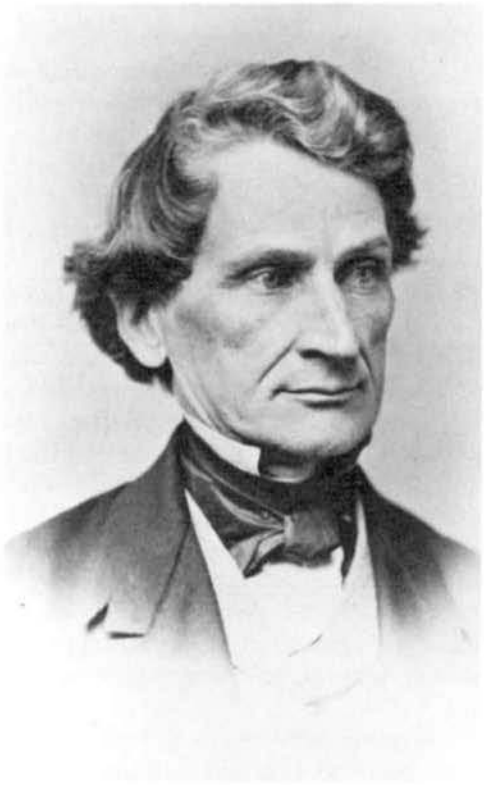


Figure 3. James Dwight Dana. A photograph from an album of a member of the class of 1865, Yale College.

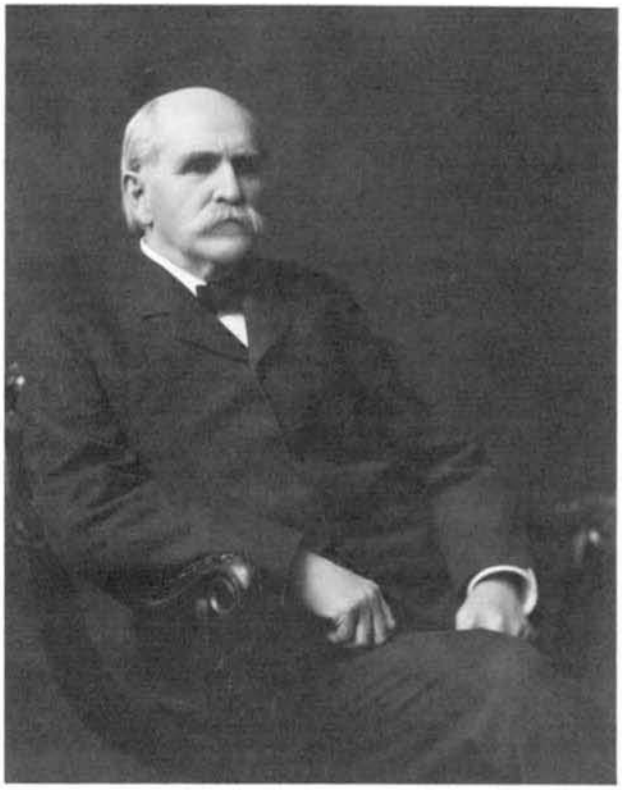


Figure 4. George Jarvis Brush. A photograph from the archives of the Peabody Museum.

State Seward when he considered the purchase of Alaska. Blake later became Professor of Geology and Director of the School of Mines at the University of Arizona. Yet another of the illustrious 1852 degree recipients was William H. Brewer (1828–1910), who worked on the California State Survey, was briefly Professor of Natural Science at the University of California, and then became Professor of Agriculture in the Sheffield Scientific School from 1864 to 1903.

When the School of Applied Chemistry was founded, it was administratively enclosed within a new "Department of Philosophy and the Arts," Yale's first formal graduate department. Master's degrees had been awarded on a somewhat casual basis since the first commencement in 1702, and degrees were also given for professional training in the Schools of Medicine, Law, and Divinity. The new Department, forerunner of today's Graduate School of Arts and Sciences, differed in that it awarded degrees for research. In 1861 the first three Ph.D. degrees in the country were awarded—one went to A. W. Wright (later a Professor of Chemistry and Molecular Physics at Yale), whose topic of research was the same as that of President Clap a century earlier—the velocity and direction of meteors entering the Earth's atmosphere. In 1863 J. Willard Gibbs (later Professor of Mathematical Physics at Yale) received his Ph.D. for a thesis on the form of teeth in spur gears. The thesis has not had any influence on geology or geologists, but Gibbs's later work in chemical thermodynamics has had a profound impact on most branches of geology. The first Ph.D. in geology was awarded to William North Rice in 1867 for a thesis discussing the Darwinian theory of the origin of species.

Among the many students attracted to Yale by its scientific atmosphere was Othniel Charles Marsh (1831–1899; Fig. 5), a member of the Massachusetts Peabody family, whose sons traditionally went to Harvard. Arriving in 1856, he was graduated from Yale College in 1860, did two years of graduate study in the Sheffield Scientific School, then went to Germany where, with the encouragement of the younger Silliman and J. D. Dana, he pursued his interests in vertebrate paleontology. Marsh managed to convince his wealthy uncle, George Peabody, to provide a gift of $150,000 to found a museum of natural history at Yale. The gift was awarded in 1866, the same year in which Marsh was appointed Professor of Paleontology, the first such professorship in America. The first building to house the Peabody Museum of Natural History was completed in 1876. Marsh had started his paleontological expeditions to the western states (Fig. 6) several years earlier—the first was in 1870—so by the time the museum was opened it housed not only collections of materials previously acquired by Yale, but a wealth of new material ready for study. Marsh's famous studies on extinct reptiles and other animals arose from this material, as did his work on toothed birds and the evolution of the horse, which particularly interested Darwin and

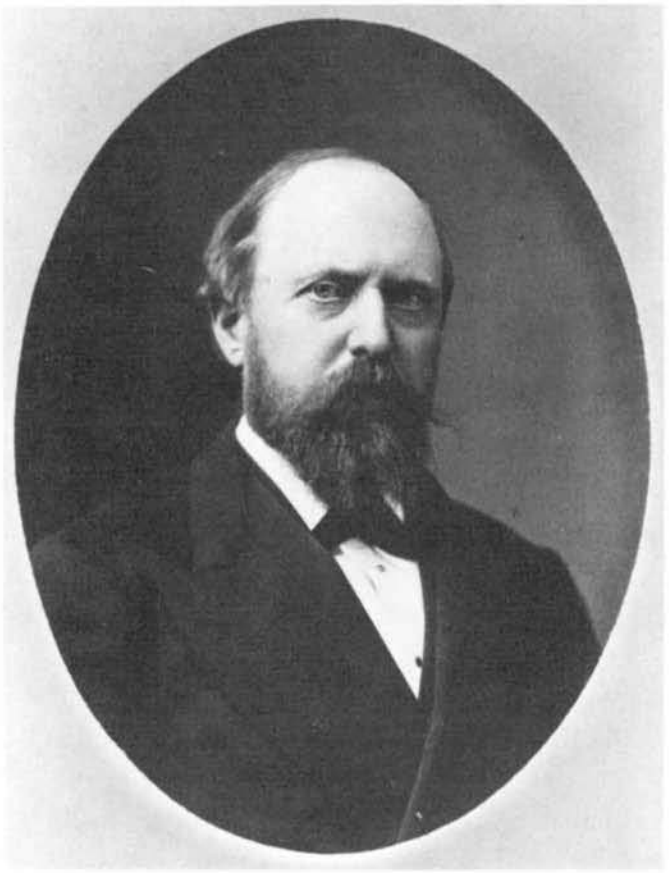


Figure 5. Othniel Charles Marsh. A photograph taken in 1872 by William Notman. From the archives of the Peabody Museum.

Thomas Huxley (Schuchert and LeVene, 1940). Marsh's work marked the beginning of a new line of geological activities at Yale—vertebrate paleontology.

Another among the students who were attracted to Yale sciences during the period from 1850 to 1880 was Clarence King (1842–1901), who graduated from the Sheffield Scientific School in 1862. King's early geological activities were mainly in the West, and from 1867 to 1877 he was Director of the U.S. Geological Survey of the Fortieth Parallel, working in the area now embraced by the states of Nevada, Utah, and Colorado. His greatest scientific interest was probably the origin and geological history of the North American Cordillera, but more important for geology as a profession was his appointment, in 1879, as first Director of the newly founded U.S. Geological Survey. He was the first of many Yale geologists to join and serve that distinguished institution. King stressed the scientific as well as the practical side of geology, and the U.S. Geological Survey follows his tenets to the present day. The importance of the U.S. Geological Survey to the development of geology in both North America and the rest of the world can hardly be overestimated.

As the second stage drew toward its close in 1880, a change of major importance occurred within the complex institution called Yale. Some years earlier, J. D. Dana and others had become champions of the move toward making Yale a university rather than an undergraduate college with appendages in professional schools. However, there was continued resistance in the conservative administration to any plan which would place other units of the academic community on an equal footing with the College and its rigorous discipline of young male minds through the traditional memorization and recitation of classical subjects. Perhaps this regimentation had been necessary in earlier years when some of the students were really children and the faculty had to act *in loco parentis*; Benjamin Silliman, for example, was 13 when he entered Yale in 1792. But times had changed, and Harvard, under President Charles William Eliot, was directing the change. Eliot presented his ideas for a curriculum revision in his inaugural address in 1869; in the preparation of that address he was advised by G. J. Brush and Daniel Coit Gilman (B.A., 1852*), both officers of the Sheffield Scientific School (Morison, 1936). Gilman later became first president both of the University of California and of The Johns Hopkins University. Eliot set forth a plan whereby Harvard would become a university in which graduate degrees were to be offered in many departments and in which training and research in the sciences were to be given special emphasis. When Harvard made such a move, could Yale fail to react?

Eliot's plan temporarily led to a near-total abandonment of required courses for undergraduates at Harvard. Yale's curriculum reform began in the 1870s, when electives were allowed in Yale College for the first time. By 1887 an extensive elective system existed and Yale had officially become a university (Pierson, 1952).

STAGE 3: THE YEARS FROM ABOUT 1880 TO ABOUT 1900

By 1880, Yale's activities in the geological sciences were located in four administratively separate units—Yale College, the Sheffield Scientific School, the Graduate School, and the Peabody Museum. In the College, a general geology course was offered by J. D. Dana using his *Manual of Geology* (first edition in 1862) as a text. It is interesting to look at the exam Dana gave students in 1884 (Fig. 7). The questions have a decidedly modern ring to them and one wonders if students today could handle such an exam in two hours. It is especially interesting to see Question 4 concerning the sources of heat that cause geological changes. This was some years before the discovery of radioactivity, when questions such as the heat generated by gravitational compression were being widely debated. Dana obviously taught a course that was current.

In the Sheffield Scientific School, students followed one of several prescribed programs of study, the choice depending on their proposed profession. Basic geology was taught, oddly enough, by Addison Emery Verrill, Professor of Zoology (using Dana's textbook) and was required for most of the programs.

*Degrees are understood to be Yale degrees unless otherwise indicated.

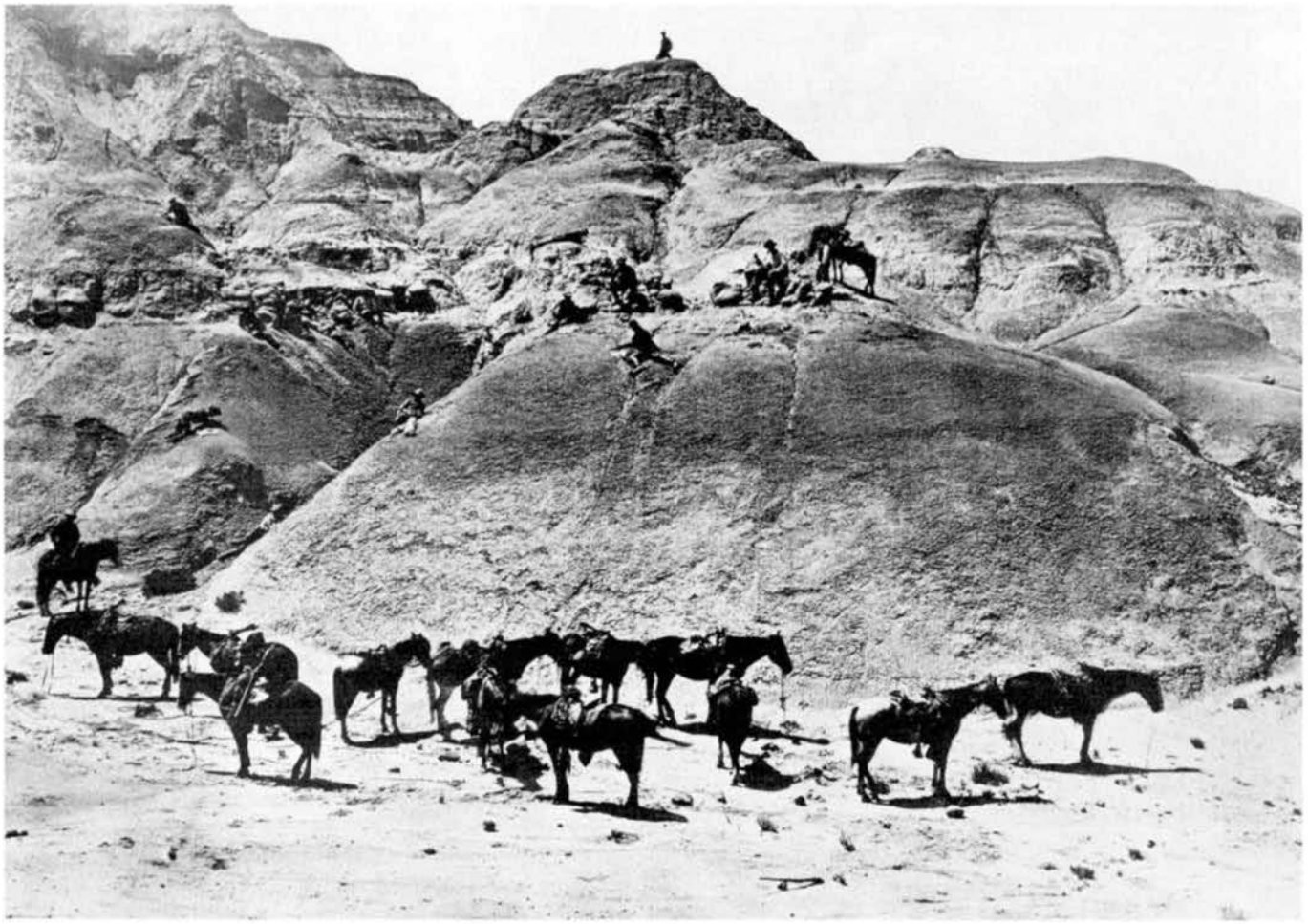


Figure 6. O. C. Marsh's 1873 student expedition to the West. Marsh can be seen sitting at the top of the small hill in the foreground, directly above the reclining figure looking for fossils on the side of the hill. Photograph by C. R. Savage. From the archives of the Peabody Museum.

More advanced instruction in geological topics was given by G. J. Brush and George W. Hawes. Much of the geological teaching on campus took place in the rooms of the Peabody Museum, where O. C. Marsh held sway as unofficial, but very real director. Marsh himself was what today we would call a research professor, and did almost no teaching. He was not paid a salary for most of his career, except for the last few years of his life when he needed money.

As the third stage opened, the winds of change were still blowing. In Yale College, geology became one of many electives, and in 1887, for the first time in 75 years, it was no longer a required subject for undergraduates. Dana, Marsh, and Brush were still active, but responsibility was passing to a new generation. J. D. Dana's son, Edward Salisbury Dana (1849–1935), was appointed Curator of Mineralogy in the Peabody Museum in 1874; in 1879 he became Assistant Professor of Natural Philosophy in Yale College, where he also taught mineralogy and crystallography, and in 1890 he was appointed Professor of Physics. Shortly thereafter Samuel Lewis Penfield (1856–1906) was appointed to the Sheffield Scientific School. Penfield had studied mineralogy with Brush and became his successor. With the two Danas, Brush, and Penfield, mineralogy at Yale was, for a few years, very strong and even pre-eminent in the country; it was in this period that E. S. Dana published the famous 6th edition of his father's *System of Mineralogy* (1892). Petrology, a subject considered in those days to be an offshoot of mineralogy, had been taught for some years in the Sheffield Scientific School by George W. Hawes (1848–1882; Ph.B., 1872), who left in 1880 to become Curator of the Geological Department of the U.S. National Museum. Hawes was succeeded by Louis Valentine Pirsson (1860–1919) who had studied chemistry at Yale (Ph.B., 1882), worked as an analytical chemist, and then had served as a field assistant to J. P. Iddings (Ph.B., 1877) and W. H. Weed of the U.S. Geological Survey in their work in the Yellowstone area. Pirsson (1918, p. 255) wrote of Hawes that he was "the earliest of the petrographers in this country." Pirsson himself could also lay claim to being one of the small group of people who developed petrology as a science in its own right. He is widely remembered

YALE COLLEGE.

1884.

DECEMBER EXAMINATION—SENIOR CLASS.

Geology.

TIME, 2 HOURS.

1. What are fragmental rocks and the sources of their materials?

2. The chemical constitution and organic sources of limestones.

3. The relation between the transporting power of rivers and their velocity; the geological effects of transportation.

4. Sources of the heat concerned in producing geological changes.

5. The distribution of the dry land of North America at the close of Archæan time; the mountains that then existed.

6. Evidence as to the time of elevation of the Rocky Mountains.

7. When appeared the first fishes; the first amphibians; the first mammals?

8. What are mountains of circumdenudation and how were they made?

9. Distribution of coal areas in North America; the age of the coal beds of the Rocky Mountains.

Figure 7. The examination of 1884 given to the class in introductory geology in Yale College by J. D. Dana. The numbers at the bottom of the page were written by the student who took the exam.

as the P of the CIPW system of normative calculations [Cross, Iddings, Pirsson, and H. S. Washington (B.A., 1886)]. In many respects, however, Pirsson reinforced the mineralogical strengths of Yale's geological activities so, as they neared the ends of their careers, J. D. Dana, a generalist, and O. C. Marsh, a paleontologist, were the two who gave breadth to the field. Fortunately, Pirsson became increasingly interested in some of the larger geological problems and in 1893 he was relieved of his teaching in mineralogy so he could take over the course of basic geology from Verrill (Cross, 1920). In 1915, Pirsson and Charles Schuchert published their course notes, which became the first in a long series of physical and historical geology texts authored by Yale geologists. The forefather of them all was Dana's *Manual of Geology*, used both at Yale and around the country for more than a generation. Verrill and Pirsson not only used Dana's text, they knew the man himself and taught the line of reasoning used in his book. In a sense, the many physical and historical geology texts from Yale faculty are one of the institution's major products.

The staff at Yale may have been small during the final years of the 19th century, but its prestige was high. Both J. D. Dana and Marsh were on the committee of the National Academy of Sciences that recommended the founding of the U.S. Geological Survey to Congress. Marsh was President of the Academy for 12 years (1883–1895), and Dana became the second President of the Geological Society of America, succeeding James Hall in 1889.

J. D. Dana stopped teaching in 1890 and a new cycle of change was underway. Unfortunately, the first steps were faltering. Henry Shaler Williams (1847–1918) was appointed in 1892 and succeeded Dana in 1894 as Silliman Professor of Geology in Yale College. After Williams graduated from the Sheffield Scientific School in 1868, he completed a Ph.D. (1871), taught briefly in Kentucky, and was then called to the chair of geology at Cornell, where he was responsible for the founding of the society of Sigma Xi. He became famous for his studies of the Devonian strata of the eastern United States and for his development of methods of stratigraphic correlation. He would seem to have been an ideal appointee, but unfortunately his few years at Yale were unhappy ones. Reportedly Williams was not as interesting a lecturer as Dana, and he suffered by comparison (Cleland, 1919). Problems caused by the assignment of faculty to different administrative units on campus also seemed to get in Williams's way, as later correspondence from H. E. Gregory to Williams suggests: ". . .it is certainly due to you that the agitation was started and that our faculty began to see clearly the danger of the relationship between the schools as they did" (Gregory, 1906, p. 148).

In 1904, Williams returned to Cornell. Only one other appointment was made before a great faculty expansion started at the turn of the century—that of Charles Emerson Beecher (1856–1904), appointed Assistant in Paleontology in the Peabody Museum in 1888. Beecher, an invertebrate paleontologist, had studied at the University of Michigan and worked in Albany with James Hall; after he came to Yale he completed a thesis on fossil sponges and was awarded a Ph.D. degree in 1889. This led to his appointment as a faculty member (Professor in 1897) in the Sheffield Scientific School, and he succeeded Marsh as unofficial director of the Peabody Museum. Beecher seems to have been the first senior faculty appointee to teach paleontology on a regular basis; unfortunately he died suddenly and unexpectedly in 1904, the same year in which Williams resigned. Marsh had died in 1899, so, as Yale entered its third century of instruction, it was rich with paleontological collections but devoid of faculty members to teach from them.

The number of students trained at Yale during the 20 years from 1880 to 1900 was not especially large, but those Yale graduates went on to play major roles in the development of science in the United States. One of the most significant was Arthur L. Day, who graduated from the Sheffield Scientific School in 1892 and then received his Ph.D. in physics from the

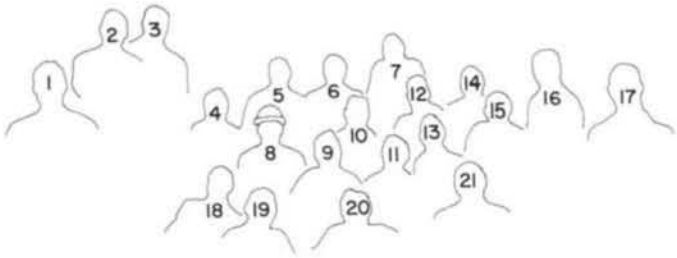


Figure 8. Faculty members and graduate students in front of the Peabody Museum of Natural History, 1911 (the names of faculty members are italicized): 1) Walter R. Barrows; 2) Charles W. Drysdale; 3) Alan M. Bateman; 4) *Richard S. Lull*; 5) *Herbert E. Gregory*; 6) *Freeman Ward*; 7) Donnel F. Hewett; 8) *Louis V. Pirsson*; 9) Henry G. Ferguson; 10) *Charles Schuchert*; 11) Ralph D. Crawford; 12) *William E. Ford*; 13) *Joseph Barrell*; 14) *Isaiah Bowman*; 15) *John D. Irving*; 16) Morley Wilson; 17) Charles C. Evans; 18) unidentified; 19) Kirk Bryan; 20) John J. O'Neill; 21) Bruce Rose.

Graduate School in 1894 for a thesis on "The seconds pendulum: determination for New Haven." Day gained experience in Germany and, on his return to the United States, became an assistant to G. F. Becker, the U.S. Geological Survey's Chief Physicist. The Geophysical Laboratory was born in the laboratories of the Survey, and from here Day was appointed as the first Director of the Geophysical Laboratory of the Carnegie Institution of Washington. Following Becker's intellectual lead, he started a tradition of careful and systematic measurements that have had an enormous impact on the geological sciences. In subsequent years, the Geophysical Laboratory became a working home for many Yale scientists, among them the remarkably productive J. F. Schairer [B.S., 1925; Ph.D. (Chemistry), 1928].

Three other graduate students of this era were destined to play major roles during the next stage of Yale's geological history. Two received their Ph.D.'s in 1899—Herbert Ernest Gregory and Charles Hyde Warren; the third, Joseph Barrell, received his degree in 1900.

STAGE 4: THE YEARS FROM ABOUT 1900 TO ABOUT 1920

The years from about 1900 to 1920 are among the most distinguished in the history of geology at Yale (Fig. 8). But they were also years of great tragedy and, at times, of turmoil.

In 1904, the geologists of the Sheffield Scientific School acquired a building of their own—Kirtland Hall—newly built of red New Haven Arkose. It was part of an expanding group of laboratories specifically built for the School. With the retirement of Brush in 1898, William Ebenezer Ford (1878–1939) was appointed Assistant in Mineralogy to S. L. Penfield. Ford had graduated from the Sheffield Scientific School in 1899, and,

while an Assistant, earned his Ph.D. in 1903 for a group of mineralogical studies. Penfield, a great analytical chemist and determinative mineralogist, died in 1906 at the age of 50. From 1903 onward Ford assumed teaching duties and advanced steadily in academic rank. He made a number of original contributions, but is best known for his revision of E. S. Dana's *Textbook of Mineralogy,* first published in 1877. J. D. Dana authored two mineralogical texts that have continued, through many editions and revisions, to the present day. They are the famous *System of Mineralogy,* and the *Manual of Mineralogy,* the latter now in its 19th edition under the authorship of C. S. Hurlbut, Jr., of Harvard and C. Klein, Jr., of New Mexico. But it was from the pages of the famous fourth edition of E. S. Dana's *Textbook,* published in 1932, that an entire generation of geologists learned mineralogy and crystallography. Popularly known, even today, as "Dana-Ford," its stature and reliability are such that the book is still kept in print by its publishers, John Wiley & Sons, and, as recently as 1980, sold as many as a thousand copies in a single year. While working on the revision, Ford maintained a reference file for all mineral species. When he died, the file passed to a former Yale student, Michael Fleischer [B.S., 1930; Ph.D. (Chemistry), 1933] who kept it current during his distinguished career at the U.S. Geological Survey, and used it for four editions of his very useful volume, *Glossary of Mineral Species,* the most recent dated 1983.

After the untimely death of Beecher in 1904, an unusual but inspired appointment was made in paleontology. Charles Schuchert (1858–1942) had left school at age 14 to enter his father's furniture business in Cincinnati. He was an amateur fossil collector who became so proficient in paleontology and such a recognized authority on brachiopods that, without formal training, he was appointed first by James Hall as his assistant, then by N. H. Winchell to the Minnesota Survey, and eventually as Assistant Curator under C. D. Walcott at the U.S. National Museum. In 1897 Schuchert published the *Synopsis of American Fossil Brachiopoda* and this, along with his other publications, led him to be invited in 1904 to be Professor of Paleontology and Historical Geology and Curator of the paleontological collections in the Peabody Museum. Schuchert was 46 at the time of his appointment, and local legend has it that the first lecture he gave before a Yale class was the first time he had ever attended an undergraduate college lecture. What a difference a new approach can make! While he attempted to improve the instruction of stratigraphy, Schuchert developed a way to plot the thickness and location of strata on base maps. Later he plotted the distributions of marine and nonmarine strata, which led to the development of the sophisticated paleogeographic maps for which he became famous. A firm opponent of Alfred Wegener's ideas of continental drift, Schuchert became the major geological spokesman against the concept at the famous symposium sponsored by the American Association of Petroleum Geologists in New York in 1926 (Schuchert, 1928). Schuchert, like Marsh, devoted his life to Yale and the Peabody Museum. Neither married, and each used his personal funds to enrich Yale's collections. Schuchert also acted as another of the unofficial directors of the Peabody Museum until his retirement, and on the occasion of his 80th birthday, in appreciation of his long service, he was bestowed with the title "Director Emeritus."

Marsh's successor as vertebrate paleontologist on the faculty was Richard Swann Lull (1867–1957). He brought a new outlook and new interests and quickly became a major figure on the campus. When G. G. Simpson prepared his memorial to Lull he wrote: "The names Marsh, Lull, and Yale are so strongly linked in the history of paleontology that it is almost a shock to recall that Marsh and Lull never met and that Lull was nearly 40 when he began his association with Yale" in 1906 (Simpson, 1958, p. 128). Lull studied zoology at Rutgers College, graduating in 1893, then joined the faculty of the Massachusetts Agricultural College (now the University of Massachusetts) in Amherst. Nearby Amherst College had a major collection of fossil footprints from the local Triassic redbeds; they drew Lull's attention and aroused his interest in vertebrate paleontology. He returned to studies under the direction of H. F. Osborn at the American Museum of Natural History and in 1903 he was awarded a Ph.D. by Columbia University. After three more years in Amherst, Lull came to Yale. He brought with him a love for research and a keen instinct for collecting, both strong Marsh attributes; and he also brought a love of teaching and a flair for innovation in museum exhibit design, neither of which had held much interest for Marsh. Lull taught a course on evolution to Yale undergraduates that was tremendously popular and year after year drew hundreds; "Lull's impressive bearing, his skilled delivery, and his complete command of the subject made each session unforgettable" (Simpson, 1958, p. 128). Outside of Yale, Lull became most famous for his widely read text, *Organic Evolution,* first published in 1917, for his extensive studies of horned dinosaurs, and for his classic volume, *Triassic Life of the Connecticut Valley* (1915) which was a pioneering study of paleoecology. Lull's career at Yale spans all of stage 4 and most of stage 5, because even though he retired in 1936, he remained active in his work in the Peabody Museum until he was nearly 80.

A fourth long-lived member of the faculty was Herbert Ernest Gregory (1869–1952). A member of Yale's class of 1896, Gregory completed his Ph.D. in 1899 and was immediately appointed Instructor in Physical Geography. In 1901 he was promoted to Assistant Professor, and in 1904 he succeeded H. S. Williams as the third Silliman Professor of Geology. Gregory's interests were varied—stratigraphy, structural geology, hydrology, and geomorphology—and in many respects he seems to have been more closely allied to the interests of J. D. Dana, the first Silliman Professor, than to those of H. S. Williams. With William Morris Davis of Harvard, Gregory founded the New England Intercollegiate Geological Conference, an annual field conference held in a different geographical and geological locality of New England each year. The 75th NEIGC took place in 1983. Gregory was also responsible for the founding of the Connecticut Geological and Natural History Survey in 1903. While returning from a trip to Australia and New Zealand, Gregory visited

Figure 9. Joseph Barrell. A photograph published originally in the *Bulletin of the Geological Society of America* (v. 34, 1923, Pl. 2).

Hawaii and found that the Bernice P. Bishop Museum in Honolulu was in need of both a new director and a major revitalization. Welcoming reaffirmation of the historic ties forged by Yale-educated missionaries in the early 1800s, the Yale Corporation and the Bishop Museum Trustees designed an arrangement whereby the Director of the Bishop Museum should also hold the rank of Professor at Yale. Gregory became Director of the Bishop Museum in 1920, and for a few years divided his time between New Haven and Honolulu, until he established his residence permanently in Hawaii. He continued to hold the Silliman Professorship until his retirement in 1936, but by then he had not taught at Yale for at least a decade.

Another paleontologist, who began his Yale association by collecting fossils in the West for Marsh, was George Reber Wieland (Ph.D., 1900). Lecturer in Paleobotany from 1906 to 1920, with nonteaching research appointments thereafter, Wieland is best known for his work on fossil cycadophytes, but he was also active and productive in the study of dinosaurs and fossil turtles (Nelson, 1977).

The careers of E. S. Dana, Ford, Lull, and Schuchert were all long and distinguished; they spanned the time from the end of the 19th century to the middle years of the 20th. It was these four men, together with Pirsson and Gregory, who carried forward the traditions and methods of their Yale forebears of the 19th century. It is fortunate that they were so long-lived and so active, because the careers of two other faculty members were sadly cut short—those of Joseph Barrell and J. D. Irving.

According to H. E. Gregory (1923), Joseph Barrell (1869–1919; Fig. 9) was the first person appointed to the geological faculty at Yale to carry out the program of organized graduate course work that had been authorized by the University in 1902. Prior to that time, graduate instruction had apparently been largely an extension of undergraduate instruction. From 1902 onward, the Ph.D. degree would not only entail completion of research and a satisfactory thesis, but, increasingly, formal courses as well. Barrell received a B.Sc. from Lehigh University in 1892 and a degree in mining (E.M.) in 1893. He then instructed in mining and metallurgy at Lehigh for four years and completed a geological study of the highlands of New Jersey, for which he received an M.Sc. in 1897. This prepared him to work with Pirsson, Penfield, and Beecher at Yale from 1898 to 1900, when he received a Ph.D. for a thesis on the geology of the Elkhorn District, Montana. He then returned to Lehigh for three more years. He was appointed Assistant Professor of Structural Geology at Yale in 1903 and Professor in 1908, a post he retained until his tragic early death from spinal meningitis in 1919.

Barrell's interests were eclectic, and he published major papers on such topics as isostasy, geologic time (he believed the earth to be at least 1.5 billion years old), the influence of climate on the nature of stratified rocks, the nature and relationship of marine and continental environments of deposition, volume changes during metamorphism, and the planetesimal hypothesis of the origin of planets. He was apparently an extraordinarily acute and demanding teacher of graduate students, but too demanding for most undergraduates. Among his peers and colleagues he seems to have been held in great affection but also in great awe; in Barrell's memorial, Gregory wrote (1923, p. 22) that "he possessed many attractive human traits, but his intellectual power was so obvious and so continuously displayed that 20 years of intimacy has left me an impression of a mind rather than of a man." Geologists often overlook Barrell because he died young and because his interests ranged so widely, but as G. L. Thompson (1964, p. 11) remarked, "many modern ideas are essentially his but since these ideas involved the basic fundamentals of geology, few people realize that Barrell was the originator."

The second important appointee primarily for graduate instruction was John Duer Irving (1874–1918), a petrologist and economic geologist who was appointed Professor of Geology and Mineralogy in the Sheffield Scientific School in 1907. Irving had studied at Columbia, where he received his Ph.D. in 1899. He was teaching at Lehigh University when a small group of people gathered in Washington, D.C. to form a not-for-profit membership corporation in order to publish a new journal, *Economic Geology*. Irving became its first editor, and when he moved to New Haven he brought the editorial responsibility with him. Though the journal has no formal connection with Yale, it has been housed and edited there ever since—after Irving, by A. M. Bateman and today by B. J. Skinner. In July 1917, having obtained a leave of absence from Yale, Irving left for France to serve

with the Eleventh Regiment of Engineers. He died a year later, a victim of influenza, while on duty at the Flanders front (Kemp, 1919).

Irving gave an inspired course, and some of his lecture notes remain. His successor, Bateman, continued to use many of the same notes. Eventually, the course grew into Bateman's famous volume, *Economic Mineral Deposits*, first published in 1942 by John Wiley & Sons. Bateman once pointed out to one of us (B.J.S.) how the structure of Irving's course could still be seen in parts of his book.

Mention must be made of the activities of three Yale faculty members who made important contributions to geology but who were not professional geologists. The first two were the geographers, Isaiah Bowman (Ph.D., 1909) and Ellsworth Huntington (Ph.D., 1909). Both were Harvard trained—Bowman as an undergraduate, Huntington as a graduate student. Both were strongly influenced by William Morris Davis, and both went on to make lasting contributions in geomorphology. Bowman was at Yale from 1905 to 1915, then became Director of the American Geographical Society (1915–1935) and eventually President of The Johns Hopkins University (1935–1948). While at Yale he wrote his most important scientific book—*Forest Physiography* (1911); the volume is really the first comprehensive account of landforms of the United States. Huntington's career at Yale was much longer than Bowman's. With the exception of a two-year gap from 1915 to 1917 while he was in military service, he was a member of the Yale faculty from 1907 to 1945, though from 1917 onward his position was that of Research Associate in Geography, and he did little teaching. An intrepid explorer and prolific writer, Huntington made contributions to knowledge about the geomorphology of the Near East, China, India, and Siberia, but he is most famous for his extensive studies of climatic changes and their influence on civilizations.

The third person who made important contributions to geology, though not a geologist, was Bertram Borden Boltwood (1870–1927) who graduated from the Sheffield Scientific School in 1892. Following studies in chemistry in Germany with Krüss and Ostwald, he received a Ph.D. in chemistry from Yale in 1897. In 1906 he joined the Yale faculty as Assistant Professor of Physics. After a year's leave (1909–10) when he worked in Manchester with Ernest Rutherford, he became Professor of Radiochemistry. Boltwood was both a superb chemical analyst and an accomplished physicist. Between 1900 and 1906, when he and the geologist J. H. Pratt (Ph.B., 1893; Ph.D., 1896) were working as consulting mining engineers and chemists, Boltwood became interested in radioactive minerals. When Rutherford and Soddy theorized in 1903 that a radioactive element disintegrates spontaneously, emitting energy and forming a new element that may in turn disintegrate, Boltwood found his life's work—identifying the daughter products. He published extensively and made many contributions—some with Rutherford, with whom he worked closely—but most important for geology was his demonstration (Boltwood, 1905) that lead is the end product of uranium decay. From this came his suggestion (Boltwood, 1907) that simple lead/uranium ratios in minerals should give an estimate of the time of crystallization of the mineral. Radiometric dating was born; one of the specimens he analyzed was a uraninite crystal from a pegmatite near Glastonbury, Connecticut, for which he estimated an age of 410 million years. Boltwood was not aware that two isotopes of uranium were present and that two different daughter products were included; fortuitously, the errors involved compensated each other and the date he calculated is surprisingly close to the age we would assign today (265 m.y.).

STAGE 5: THE YEARS FROM ABOUT 1920 TO ABOUT 1945

At the beginning of stage 5, a university-wide administrative reorganization occurred and the present-day departments of study were formed. Unification of all the geology faculty of the three schools—Yale College, the Sheffield Scientific School, and the Graduate School—created a geology department that was a distinct budgetary unit with the power to govern its own faculty appointments, responsible to a central university administration. Charles Schuchert was named the first Chairman of the new Department of Geology in 1920.

The Peabody Museum building was demolished in 1917 to provide space for a new Yale dormitory complex, the Harkness Quadrangle. Almost immediately thereafter the United States entered World War I, and construction of the promised new museum building was not begun until 1923. In his annual report as Geology Chairman in 1921, Schuchert spoke for all the anguished curators whose collections were inaccessible: "The paleontologists, with the grand collections in their charge scattered in nine different and strange places, find that their effectiveness in teaching and in extension work is almost nil. The geologists of Yale College are also in temporary quarters, and since 1917 the various members of the Department have been housed in four different buildings. The natural history museums of our country are growing with leaps and bounds, but dear old Peabody Museum is boxed up and the Lord (and the University Corporation) alone know when we shall be allowed to emerge. A more depressing state of affairs no department at Yale was ever subjected to, and all this is being observed by the spirit eyes of Benjamin Silliman, James D. Dana, Othniel C. Marsh, and George J. Brush!" (Schuchert, 1921, p. 180). At long last, under Lull as first official Director, the Museum and its new displays were finished. Eight scientific societies—one of them the Geological Society of America—held their annual meetings in New Haven in December 1925, and 800 of their members attended the dedication of the new building.

In this stage, long-lived Lull, Ford, Schuchert, and E. S. Dana were still present and active; Schuchert and Dana also assumed important roles in university affairs. But increasingly prominent was a faculty who trained some of today's most distinguished geologists. The new faculty members were A. M. Bateman, C. R. Longwell, C. O. Dunbar, A. Knopf, C. H. Warren, and R. F. Flint. With the exceptions of Flint and Knopf, each of

these appointees had received all or a major portion of his professional education at Yale. It would seem that Yale found it difficult to look beyond its own graduates when new appointments were to be made.

The first appointment of the new era actually occurred before 1920. Alan Mara Bateman (1889–1971) was a Canadian who graduated from Queen's University and had already gained a good deal of field experience when he arrived at Yale in 1910 to study with Irving. During the summers of 1911 and 1912 he worked for the Geological Survey of Canada on the Fraser River, British Columbia, and from this work came his thesis on the "Geology and ore deposits of the Bridge River district, British Columbia," for which he received a Ph.D. in 1913. Bateman was then invited to join the famous Secondary Enrichment Investigation inspired by L. C. Graton, then at the U.S. Geological Survey, which included members of academia, industry, and the Geophysical Laboratory. The work continued for a number of years and led to many important papers—especially concerning the deposits at Kennecott, Alaska (White, 1974). In 1915 Bateman was appointed Instructor in Geology; when Irving left for military training in 1916, Bateman was appointed Assistant Professor. He continued to work at Yale until his death, rising through the ranks and finally becoming the Silliman Professor of Geology in 1941.

Following Bateman's appointment and the deaths of Pirsson, Irving, and Barrell, there were three appointments in 1920: Longwell, Dunbar, and Knopf. Chester Ray Longwell (1887–1975) entered Yale as a graduate student in 1915 but service in the U.S. Army interrupted his studies, and he did not complete his thesis on the geology of the Muddy Mountains of Nevada until 1920. He was appointed to the Yale faculty in the same year and advanced steadily, becoming Professor in 1929. Longwell's main interest continued to be western geology, especially the western overthrust belt which his thesis did much to define. He was an excellent teacher and such major figures in the geological world as W. W. Rubey and James Gilluly were among the graduate students he influenced. He was also an excellent teacher of undergraduates and taught elementary physical geology at Yale. Following Pirsson's death he inherited the physical geology portion of the Pirsson and Schuchert *Textbook* (1929), which eventually became the famous Longwell, Knopf, and Flint version of *Physical Geology* (1948).

The second appointee of 1920 was Carl Owen Dunbar (1891–1979; Fig. 10), successor to Beecher and Schuchert. Dunbar studied geology at Kansas where he came under the strong influence of W. H. Twenhofel (B.A., 1908; Ph.D., 1912), who was a great admirer of Schuchert and encouraged Dunbar to do graduate work under him. Dunbar received his Ph.D. in 1917, after which he did a year of postgraduate study with Schuchert and then spent two years as an instructor at the University of Minnesota. In 1920 he returned as Assistant Professor of Historical Geology and Assistant Curator of Invertebrate Paleontology, becoming Professor of Paleontology and Stratigraphy in 1930. Dunbar's broad professional interests centered on the fusuline foraminifera and their use in stratigraphic correlation. As a

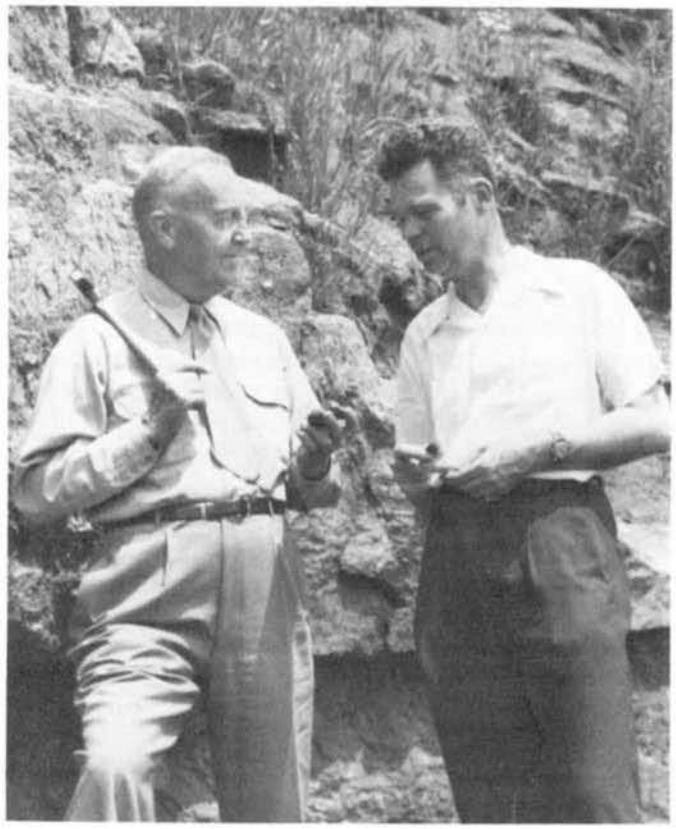


Figure 10. Carl O. Dunbar and John Rodgers. A photograph taken in 1956. (Courtesy of K. M. Waage).

teacher he was demanding and meticulous and had a great influence on the students he came in contact with—especially the graduate students. He also was an important textbook writer. He collaborated first with Schuchert in revision of the historical side of the *Textbook of Geology* (Schuchert and Dunbar, 1933), which he later rewrote as the highly influential *Historical Geology* (1949). He then revised this book again with K. M. Waage (1969). Perhaps even more influential at the graduate level was the book Dunbar co-authored with John Rodgers in 1957, *Principles of Stratigraphy,* a classic text that grew out of a jointly taught course. As Director of the Peabody Museum he initiated the construction of the museum's first dioramas. Probably the best known exhibit produced during his directorship is the 110 foot-long Pulitzer Prize-winning mural, "The Age of Reptiles," painted by Rudolph Zallinger.

The third appointee of 1920 was Adolph Knopf (1882–1966). Knopf, a petrologist, was successor to Pirsson. All of his training was at the University of California at Berkeley where he was strongly influenced by the teaching of Andrew Lawson. Knopf received a B.S. in Mining Geology in 1904 and throughout his life made important contributions to economic geology. First and foremost, however, he was a petrologist and field geologist. In 1905 he started working with the U.S. Geological Survey and spent six field seasons in Alaska, during which time (1909) he completed his Ph.D. thesis. Between 1910 and

1920 Knopf worked with Waldemar Lindgren, F. L. Ransome, L. C. Graton, W. H. Emmons, J. B. Umpleby, and others as they studied the ore districts of the western United States; he published a number of papers and contributed to many others. One has to wonder how the arrival of such an accomplished economic geologist on the scene at Yale must have seemed to the already appointed A. M. Bateman. By 1920, salaries at the U.S.G.S. were so low compared to those at universities that Graton left for Harvard, Lindgren for M.I.T., Emmons for Minnesota, and Knopf for Yale (Coleman, 1968). Knopf, like Barrell, was a scientist with eclectic interests and a demanding mind. He challenged students mightily and is remembered by them as an inspiring teacher. From Boltwood he developed an interest in radiometric methods of measuring geologic time and while he did not, unfortunately, seize the opportunity to start making such measurements at Yale, he played a major role in bringing geologic insight to the measurements made so enthusiastically by those in the laboratory.

Shortly before Knopf joined the faculty, his wife Agnes died during the influenza epidemic of 1918, leaving him with three children. In 1920, he married Eleanora Bliss (1883–1974), a distinguished Bryn Mawr geologist then working at the U.S. Geological Survey. Unfortunately, neither the geology faculty nor the Yale University administration was ever bold enough or sensitive enough to appoint Mrs. Knopf to the faculty or to allow her to teach, though she worked in her husband's office. A long generation of students remembers with affection and gratitude her intellectual stimulation and advice (Rodgers, 1977). She became the leading structural petrologist in the country and was an active, productive scientist until her death in 1974.

Two other appointees of this stage were C. H. Warren and R. F. Flint. Charles Hyde Warren (1876–1950) graduated from the Sheffield Scientific School in 1896, and received a Ph.D. in mineralogy under the direction of Penfield in 1899. He also spent a summer in the field in Yellowstone with Iddings, as Pirsson had done. After a short term as Instructor in Mineralogy at Yale he moved to M.I.T. and advanced to Professor of Mineralogy in 1912. At the retirement in 1922 of Russell M. Chittenden, Brush's successor as Director of the Sheffield Scientific School, Warren was recalled to replace him. His title was changed from Director to Dean and he was simultaneously appointed Sterling Professor of Geology. Warren was an able and fair administrator—he not only served as Dean but also as Chairman of the Department of Geology from 1923 to 1938. Most of Warren's activities were taken up in administration so he did little teaching and little research. His administrative leadership was vitally important, however, and to his credit can be recorded the final solution of the difficulties caused by the continued maintenance of two different undergraduate schools within the university, and the inevitable duplication of course offerings, among other things. Under his guidance, the Sheffield Scientific School ceased to exist except as a legal title to cover administration of the School's endowment funds.

The last member of the famous group of faculty of stage 5 to be appointed was Richard Foster Flint (1902–1976). Like Knopf, Flint brought new blood and ideas to Yale, for he had received all of his education at the University of Chicago (B.S., 1922; Ph.D., 1925). He joined the Yale faculty the year he received his Ph.D. and became both a masterful teacher and the most distinguished glacial geologist of his age—indeed, he was widely and affectionately known as the "Pope of the Pleistocene." Flint joined with Longwell and Knopf as an author of *Physical Geology,* then published subsequent editions with different coauthors until the time of his death.

To those who were privileged to get to know him, Flint was a warm and responsive friend, but unfortunately he found it difficult to lower a barrier of reserve and to most people he came across as autocratic and forbidding. This did little to endear him to the geological community of North America, so in spite of his scientific status he received few honors in his homeland, but a great many honors from abroad. He was also the losing protagonist in a long-continued debate over the origin of the channeled scablands. Flint ridiculed J Harlen Bretz's suggestion that the unique topography resulted from a catastrophic flood and he was overly dogmatic in his rejection of the idea.

A faculty member appointed to the Department of Zoology during stage 5, G. Evelyn Hutchinson, must also be mentioned. Hutchinson was educated at Cambridge University and worked in South Africa prior to his appointment to the faculty in 1928. From the moment he arrived at Yale he started to influence geology and geologists through his many contributions in biogeochemistry and limnology. Indeed, Hutchinson can be considered the first geochemist appointed at Yale. In 1946, as stage 6 opened, a second geochemist was appointed to the faculty, this time in the Department of Astronomy. Rupert Wildt, who had studied with V. M. Goldschmidt, is more correctly called a cosmochemist, and like Hutchinson he was so eminent in his field that when the new journal *Geochimica et Cosmochimica Acta* was founded in 1951 (American editor, F. E. Ingerson, Ph.D., 1934), the names of Wildt and Hutchinson appeared among the distinguished members of the Editorial Advisory Board.

Institutions are sometimes blessed by a flux of students who for a time catalyze each other's interests and stimulate each other to heights of great achievement. A necessary ingredient for success is that the students have the right temperaments, but even more essential is that they have an outstanding faculty with whom to interact (Rubey, 1974; Gilluly, 1977). All these conditions were met at Yale during the period 1920 to 1945 (Figs. 11 and 12). It was a period when the Graduate School at Yale flowered under the leadership of Dean Wilbur L. Cross and Yale President James Rowland Angell, a period during which, according to the respected historian of Yale, George Pierson (1955), there was a revival of scholarship among Yale undergraduates.

The list of Yale students of this time who went on to gain distinction in geology reads like an honor roll for the profession. Among the geology Ph.D.'s were Henry G. Ferguson (1924), Donnel F. Hewett (1924), Thomas B. Nolan (1924), James Gilluly (1926), George Gaylord Simpson (1926), J. B. Stone (1926),

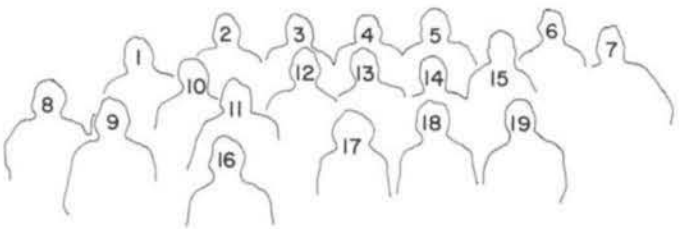


Figure 11. Faculty members and graduate students in front of Kirtland Hall, ca. 1922 (the names of faculty members are italicized): 1) unidentified; 2) William W. Rubey; 3) Joseph E. Hare (?); 4) James Gilluly; 5) Thomas B. Nolan; 6) unidentified; 7) unidentified; 8) Ludlow Weeks; 9) Carle H. Dane; 10) *Ellsworth Huntington*; 11) *Alan M. Bateman*; 12) *Chester R. Longwell*; 13) *Adolph Knopf*; 14) Waldo S. Glock; 15) *Carl O. Dunbar*; 16) unidentified; 17) J. Doris Dart; 18) *Charles Schuchert*; 19) *Richard S. Lull.*

Wilmot H. Bradley (1927), Carl Tolman (1927), G. Arthur Cooper (1929), Philip B. King (1929), Aaron C. Waters (1930), A. K. Miller (1930), Carle H. Dane (1932), Norman D. Newell (1933), M. N. Bramlette (1936), Paul D. Krynine (1936), Yang Tsun-Yi (1939), Preston E. Cloud (1940), A. L. Washburn (1942), and John Rodgers (1944). Joining this remarkable group were W. W. Rubey, who did not complete his Ph.D. requirements, but who was later awarded an honorary degree (D.Sc., 1960), Harry H. Hess (B.S., 1927) who was also awarded an honorary degree (D.Sc., 1969), and Ralph E. Grim (B.A., 1924). Including those who taught and those who studied, the extraordinary Yale group from this period has been awarded 13 Penrose medals to date; they are (in order of receipt) Schuchert, Simpson, Gilluly, Knopf, Rubey, Hewett, King, Hess, Bradley, Cloud, Rodgers, Waters, and Cooper. Two others, A. L. Day and M. E. Wilson, have also been awarded the medal, which was first presented in 1927. No fewer than nine of the same group have served as President of the Geological Society of America; they are, in order of appointment, Schuchert, Knopf, Gilluly, Longwell, Rubey, Nolan (when he was also Director of the U.S. Geological Survey), Hess, Bradley, and Rodgers. In addition, J. D. Dana, Arnold Hague, A. L. Day, George S. Hume, Peter T. Flawn, and Paul A. Bailly, recipients of Yale degrees in other periods, have also served as president.

STAGE 6: THE YEARS FROM ABOUT 1945 TO ABOUT 1965

The faculty appointed around 1920 continued essentially unchanged through the 1930s and to the end of World War II in

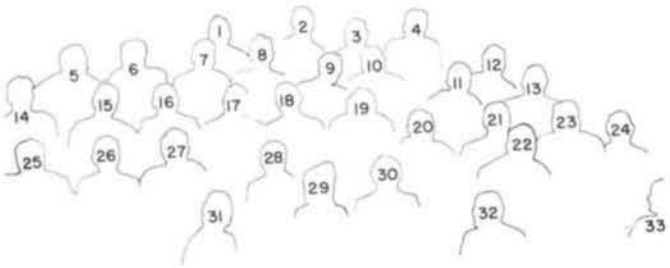
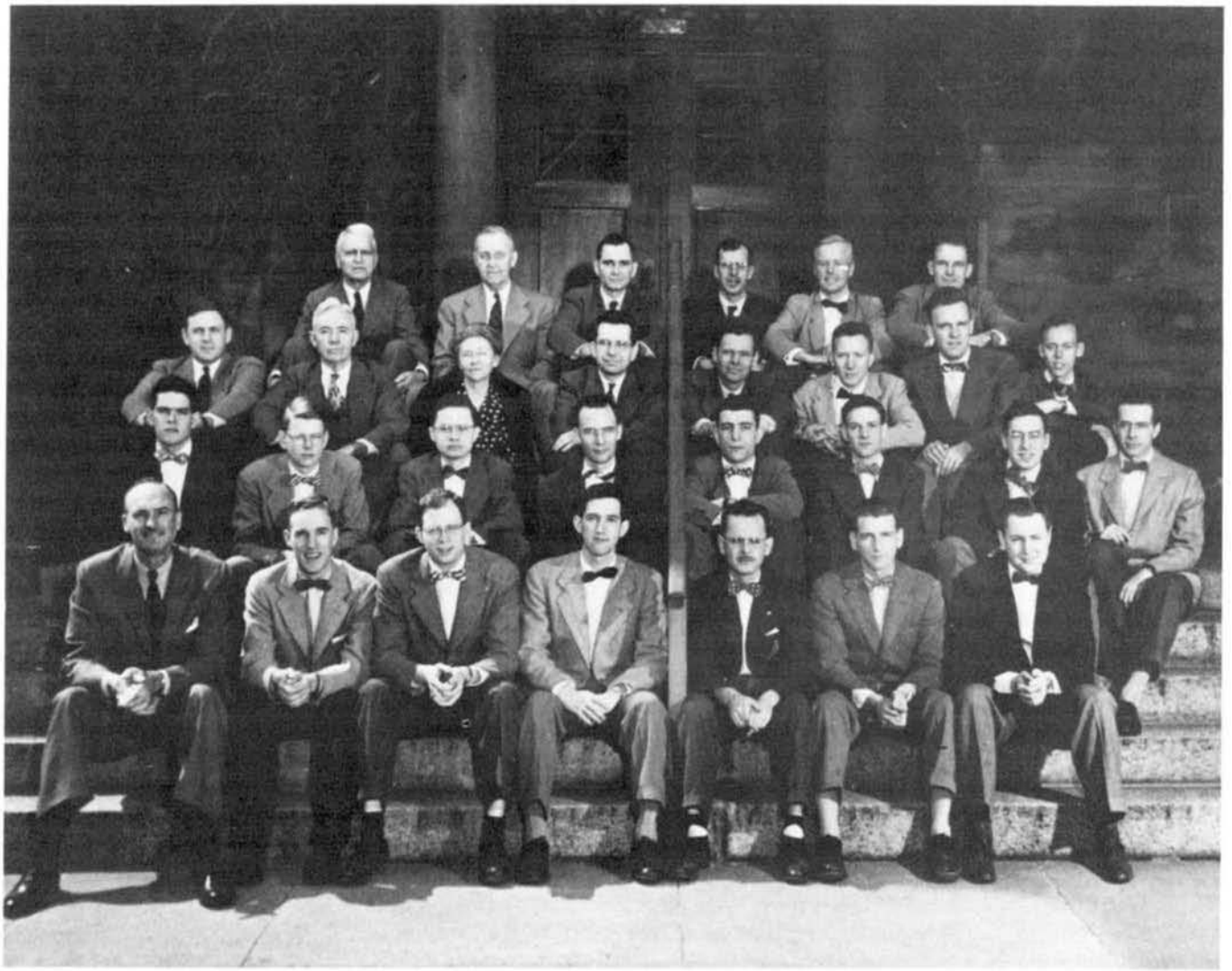


Figure 12. Faculty members and graduate students in front of Kirtland Hall, 1938 (the names of faculty members are italicized): 1) *Alan M. Bateman*; 2) *Richard F. Flint*; 3) *Carl O. Dunbar*; 4) *Charles Schuchert*; 5) J. David Love; 6) *G. Edward Lewis*; 7) *Adolph Knopf*; 8) *Chester R. Longwell*; 9) *Eleanora B. Knopf*; 10) J. Danvers Bateman; 11) Wendell G. Sanford; 12) *William E. Ford*; 13) Joseph P. Jennings; 14) Esa Hyyppä; 15) Chauncey D. Holmes; 16) Hugh H. Beach; 17) Preston E. Cloud; 18) John C. McCarthy; 19) William A. Rice; 20) Allen J. Turner; 21) John S. Shelton; 22) Earl M. Irving; 23) S. Warren Hobbs; 24) Shu Chen; 25) A. Lincoln Washburn; 26) Yang Tsun-Yi; 27) John Rodgers; 28) Gladys M. Galston; 29) Mrs. Lewis; 30) Jean M. Berdan; 31) Mrs. Washburn; 32) Mrs. Hyyppä; 33) Mrs. Shelton.

1945. E. S. Dana died in 1935, breaking the last direct link that went back through his father to his grandfather, Benjamin Silliman. Schuchert died in 1942, at the ripe old age of 84; Ford died in 1939, before retirement; and Huntington died in 1947. Lull retired from teaching duties in 1936, but continued to be active in research. Gregory retired from the Silliman professorship of geology in 1936 and was succeeded in the chair by Knopf, who was, in turn, succeeded by Bateman and then in 1962 by a student of this era, John Rodgers (Fig. 10). There have only been six Silliman Professors from 1850 to the present day. Four additional endowed professorships in geology have been established in this century. C. H. Warren retired in 1945 so by the end of the war there was a small senior faculty—Longwell, Dunbar, Flint, Bateman, and Knopf. New appointments were needed, not only to maintain faculty strength, but also to handle the anticipated increases in teaching loads as military personnel returned to catch up on delayed educations (Fig. 13).

Following Ford's death, George Switzer joined the faculty as mineralogist, but he was quickly called to the Smithsonian Institution and his place was taken in 1945 by Horace Winchell, son of A. N. Winchell, grandson of N. H. Winchell. He had studied as an undergraduate at the University of Wisconsin and completed a Ph.D. at Harvard. Just prior to Knopf's retirement in 1951, Matt S. Walton was appointed as a petrologist, and started a program of study on the petrology of the igneous and metamorphic rocks of the Adirondacks. In vertebrate paleontology, Lull



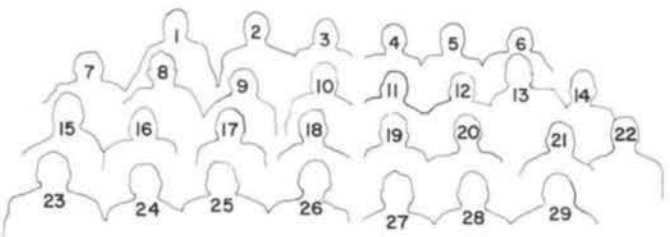


Figure 13. Faculty members and graduate students in front of Kirtland Hall, 1950 (the names of faculty members are italicized): 1) *Adolph Knopf*; 2) *Carl O. Dunbar*; 3) *Karl M. Waage*; 4) *Joseph T. Gregory*; 5) Heikki G. Ignatius; 6) William H. Hays; 7) Dwight R. Crandell; 8) *Chester R. Longwell*; 9) *Eleanora B. Knopf*; 10) *Horace Winchell*; 11) *John Rodgers*; 12) John Imbrie; 13) Walter W. Wheeler; 14) Charles P. Thornton; 15) Spencer S. Shannon, Jr.; 16) Colin W. Stearn; 17) George White; 18) E. R. Ward Neale; 19) John E. Sanders; 20) E. Carl Halstead; 21) J. Thomas Dutro, Jr.; 22) Sanborn Partridge; 23) *Richard F. Flint*; 24) Charles H. Smith; 25) John A. Elson; 26) James W. Clarke; 27) Grant M. Wright; 28) Henry W. Coulter; 29) Richard V. Dietrich.

was succeeded by G. Edward Lewis (Ph.D., 1937), who left for the U.S. Geological Survey in 1945, then in 1946 by Joseph T. Gregory.

Karl M. Waage, a recent Princeton Ph.D. (1946), was appointed in invertebrate paleontology and stratigraphy. John Rodgers (Ph.D., 1944) was appointed in sedimentary geology in 1946, but was then asked to switch to structural geology in anticipation of Longwell's retirement. In 1951, Mead LeRoy Jensen received his Ph.D. from M.I.T. and was appointed in economic geology. At Yale he quickly organized a laboratory for measuring sulfur isotope ratios, starting what later became a strong trend toward geochemistry. John E. Sanders, who received his Ph.D. in 1953 for a thesis on "Geology of the Pressmen's Home Area, Hawkins County, Tennessee," was appointed Assistant Professor in 1956. Also in 1956 Karl K. Turekian was appointed Assistant Professor in the field of geochemistry. Before

the beginning of the next stage in 1965, J. T. Gregory, Walton, Jensen, and Sanders had all departed, and several new appointments had been made. Vertebrate paleontology became very strong with three new men: Elwyn L. Simons, John H. Ostrom, and Alfred W. Crompton. A. Lee McAlester was appointed in invertebrate paleontology, Sydney P. Clark, Jr., in geophysics, and Philip M. Orville, in petrology. In effect, the careers of these people belong with the next stage, but all were appointed prior to 1965.

The biggest change during the stage from 1945 to 1965, however, was the erection of a new building. Since 1904, most of the geologists (except for those who had offices in the Peabody Museum) had been housed in Kirtland Hall. The building was two long blocks away from the new Peabody Museum as well as from the buildings that housed the Departments of Chemistry, Physics, and Zoology. Having outgrown the long-occupied quarters, the Department of Geology needed to move. Through a generous gift from C. Mahlon Kline (Ph.B., 1901), an expanded science complex was created on the north end of the Yale campus, where the Peabody Museum and the existing chemistry, physics, astronomy, and biology facilities already were situated. Three new Kline buildings were erected, one each for biology, chemistry, and geology. In 1963, the Department of Geology moved into its new quarters adjacent to the Peabody Museum. Soon after the move a diversification of activities and an expansion of the faculty took place.

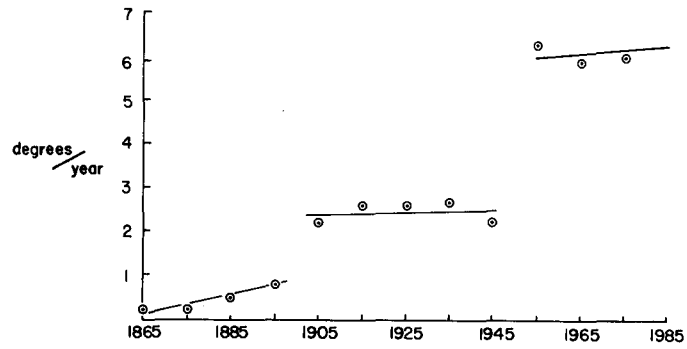


Figure 14. Numbers of Ph.D. degrees awarded in geology at Yale each year averaged over decade intervals. Each decade is plotted at the midpoint of the interval. Prior to the turn of the century, fewer than 10 students received degrees in each decade; the succeeding 45 years, to the end of World War II, saw an average of 25 students per decade; during the third period, from 1950 to the present, about 60 students graduated each decade, giving averages per year of less than 1, 2.5, and 6, respectively.

STAGE 7: FROM ABOUT 1965 TO THE PRESENT

Bateman retired in 1957 but remained active as Editor of *Economic Geology*, the position he had held since 1919, until a very few years before his death in 1971. Flint also retired in 1970, and died in 1976; his colleague and close friend, A. Lincoln Washburn (Ph.D., 1942), who had been appointed Professor in 1960, relinquished all teaching duties in 1966 to become a Senior Research Associate. In 1970 Washburn left for the University of Washington. With the departure of Flint and Washburn, the 75 years of studies in the areas of classical geomorphology and glaciology came to an end, although the closely related area of Pleistocene studies continues today through research in climatology, hydrology, and marine geochemistry.

Geochemistry, which had grown strongly under the guidance of Turekian, started to occupy more attention. Richard L. Armstrong (Ph.D., 1964) began a radiometric dating laboratory soon after his appointment as Assistant Professor in 1964. Minze L. Stuiver came from Holland in 1959 to operate the Yale Radiocarbon Laboratory, a project initiated and strongly supported by Flint, but left for the University of Washington in 1969.

The most important change that has occurred during the current stage, however, is an expansion of the Department to become the Department of Geology and Geophysics (1968), and the appointment of a geophysics faculty. Appointments have been made in two areas: (1) the physics of oceans and atmospheres, begun with the appointment of Theodore D. Foster (who subsequently left) and then led by George Veronis (1966) and Barry Saltzman (1968), and (2) solid earth geophysics, led by S. P. Clark, Jr. (1962). There have been a number of subsequent appointments in both areas.

GRADUATE DEGREES IN GEOLOGY FROM YALE

We have mentioned some of the students who were at Yale and the roles they played later in life as faculty members in the development of the science. A complete accounting of all Yale students who have made important contributions to geology is beyond the scope of this paper. A total of 351 people had received Ph.D.'s in geology by December 1984. The first was awarded in 1867 to William North Rice, but completion of degrees was sporadic for many years, and until the beginning of the 20th century Yale averaged fewer than one degree per year. Starting about 1900, a noticeable increase in the production rate occurred (Fig. 14); the award rate rose to about 2.5 degrees per year and remained at that level until the end of World War II. The rise actually started in 1903, and coincided with the first appointments made specifically for graduate instruction. Starting about 1950, another distinct jump occurred, to an average award rate of 6 degrees per year— a rate maintained to the present day. This second jump was apparently generated by the increased size of the graduate student body as returned servicemen swelled its ranks after World War II, and by the maintenance of the increased student-body size by an inflow of government funds supporting the research carried out by the students.

DEGREES HELD BY YALE FACULTY

During the first century of geological instruction the instructors were, by and large, educated at Yale. This is not surprising, considering the small number of institutions where geologists

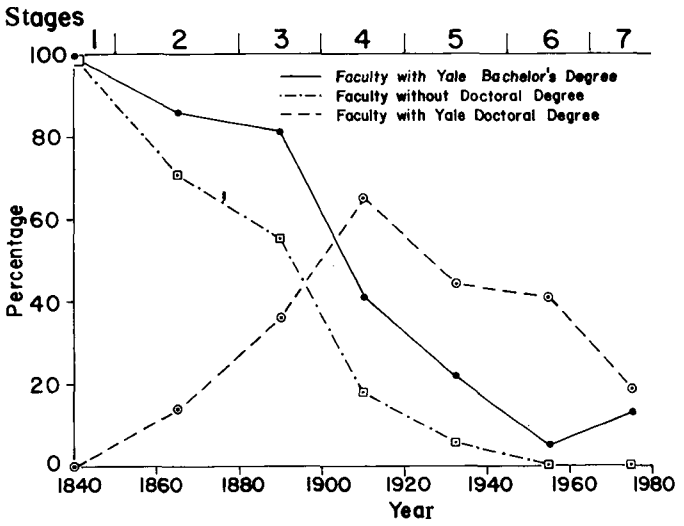


Figure 15. The percentage of Yale geology faculty members educated at Yale was very high during the early stages but has declined steadily as has the percentage of the faculty without doctoral degrees.

were trained; as the number of institutions increased, the percentage of faculty appointees who held Yale bachelor's degrees decreased. The fraction of the faculty educated at Yale has declined steadily throughout the twentieth century and appears to have bottomed out at about 10 percent (Fig. 15; Table 1).

During the first stage of geology at Yale, up to the year 1850, the sole faculty member, Benjamin Silliman, did not hold a doctoral degree. During the second stage, 1850 to 1880, the American Ph.D. degree was introduced and the first holders of doctoral degrees were appointed to the faculty. As shown in Figure 15, the percentage of faculty members not holding earned doctoral degrees dropped steadily and reached zero during stage 6. There was a marked preference for Yale doctoral degrees through stage 4, when 65 percent of the total faculty had Yale doctorates while an additional 18 percent lacked doctorates. From the fourth stage onward, the number of faculty members holding Yale doctorates has declined steadily. With the retirement of John Rodgers in June 1985, Yale geology will be in an unusual situation, at least temporarily—for the first time in more than a century, it will have only one faculty member with a Yale doctorate.

WOMEN GEOLOGISTS AT YALE

Yale's record of awards of Ph.D. degrees in geology to women is unimpressive. Women were admitted for graduate studies at Yale as early as 1892, but it was not until 1903 that the first woman geologist, Mignon Talbot, enrolled to work in paleontology with Beecher. Talbot received a Ph.D. in 1904—near record time—and spent her professional career teaching geology at Mt. Holyoke College. The second woman to receive a Ph.D., in 1908, was Ruth Sawyer Harvey (Jones), who completed a thesis on the "Drainage and glaciation in the central Housatonic basin" of Connecticut, under the direction of H. E. Gregory. This was the first Yale thesis that specifically focused on the question of glaciation. For a few years Miss Harvey taught physical geography at the Philadelphia High School for Girls, but, apart from preparing her thesis for publication (Harvey, 1920), she seems to have done no further professional work after her marriage in 1917.

The third woman to receive a Ph.D. was Gladys Mary Wrigley, in 1917, who wrote on the "Roads and towns of the Central Andes" under the guidance of Bowman. Wrigley's work was done at a time when geography was administratively considered one of the "geological sciences" and the geological profession can only claim her on the basis of an institutional technicality. Wrigley later worked with Bowman in New York where she became editor of the *Geographical Review.*

Not a single Ph.D. degree in geology from Yale was awarded to a woman for the next 32 years. These were the years when Eleanora Bliss Knopf carried out her studies at a desk in her husband's room, and when photographs taken of department members (Figs. 11 and 12) included Mrs. Knopf and occasionally wives of graduate students or visitors, but only a very few female graduate students, and none who completed the requirements for a doctoral degree. We can offer no explanation for this lamentable hiatus. Following World War II, the situation started to change, albeit rather slowly. Jean Milton Berdan, daughter of a famous Yale professor, received her Ph.D. for a thesis on the "Brachiopoda and Ostracoda of the Manlius Group of New York State" in 1949, and Elizabeth Jean Lowry (Long) completed a thesis on the "Geology of part of the Roan Mountain Quadrangle, Tennessee" in 1951. Then another hiatus occurred, until 1968, when Rosemary Jacobson Vidale was awarded a Ph.D. for her thesis on "Calc-silicate bands and metasomatism in a chemical gradient." Following Rosemary Vidale, 12 more women have received Ph.D.'s in geology (for a total of 15 since 1949) and the number of women students enrolled has risen to a point where an award rate of 1.5 to 2 per year was reached by 1983. It is interesting—and sad—to note, however, that despite 182 years of geology at Yale, no woman has yet been appointed to the regular teaching faculty in the discipline. This situation will surely change during the next step of Yale's geology history, because women students now play an increasingly important role in the Department.

Women were first admitted as undergraduates at Yale in 1969. The first major to graduate from the Department of Geology and Geophysics was Margaret B. Coon, in 1974. The following year there were three women graduates and the number has risen to a point where eight women graduated in 1983 and six in 1984. From 1974 to 1984, the Department graduated 168 majors in all, of whom 58 were women.

CLOSING REMARKS

The history of teaching and research in the geological and geophysical sciences at Yale is one that records a slow, steady

TABLE 1. SOURCES OF UNDERGRADUATE AND DOCTORAL DEGREES OF THE YALE GEOLOGY FACULTY
(Members are listed by order of their appointments to the faculty.)

Stage	Name	Bachelor's degree	Doctoral degree	Date of Appointment
1	B. Silliman	Yale	---	1802
2	J.D. Dana	Yale	---	1850
	G.J. Brush	Yale	---	1855
	O.C. Marsh	Yale	---	1866
	A.E. Verrill	Harvard	---	?1873
	G.W. Hawes	Yale	Heidelberg	1873
	E.S. Dana	Yale	Yale	1874
3	S.L. Penfield	Yale	---	1881
	L.V. Pirsson	Yale	---	1882
	C.E. Beecher	Michigan	Yale	1891
	H.S. Williams	Yale	Yale	1892
	H.E. Gregory	Yale	Yale	1898
4	J. Barrell	Lehigh	Yale	1903
	W.E. Ford	Yale	Yale	1903
	C. Schuchert	---	---	1904
	I. Bowman	Harvard	Yale	1905
	R.S. Lull	Rutgers	Columbia	1906
	G.R. Wieland	Penn. State	Yale	1906
	F. Ward	Yale	Yale	1907
	E. Huntington	Beloit	Yale	1907
	J.D. Irving	Columbia	Columbia	1907
	A.M. Bateman	Queen's (Ont.)	Yale	1915
	J.P. Buwalda	California (Berkeley)	California (Berkeley)	1917
5	A. Knopf	California (Berkeley)	California (Berkeley)	1920
	E.B. Knopf	Bryn Mawr	Bryn Mawr	---
	C.R. Longwell	Missouri	Yale	1920
	C.O. Dunbar	Kansas	Yale	1920
	C.H. Warren	Yale	Yale	1922
	W.M. Agar	Princeton	Princeton	1923
	K.C. Heald	Colorado College	Pittsburgh	1924
	R.F. Flint	Chicago	Chicago	1925
	H. de Terra		Munich	1930
	G.E. Lewis	Yale	Yale	1938
	G. Switzer	California	Harvard	1940
6	H. Winchell	Wisconsin	Harvard	1945
	J. Rodgers	Cornell	Yale	1946
	K.M. Waage	Princeton	Princeton	1946
	J.T. Gregory	California	California	1946
	M.S. Walton	Chicago	Columbia	1948
	J.E. Sanders	Wesleyan (Ohio)	Yale	1951
	M.L. Jensen	Utah	M.I.T.	1951
	K.K. Turekian	Wheaton College (Illinois)	Columbia	1956
	A.L. McAlester	Southern Methodist	Yale	1958
	A.L. Washburn	Dartmouth	Yale	1960
	E.L. Simons	Rice	Princeton, Oxford	1960
	J.H. Ostrom	Union College	Columbia	1961
	P.M. Orville	Cal. Tech.	Yale	1962
	R.L. Armstrong	Yale	Yale	1962
	S.P. Clark, Jr.	Harvard	Harvard	1962
	A.W. Crompton	Stellenbosch	Stellenbosch, Cambridge	1964
7	D.C. Rhoads	Cornell (Iowa)	Chicago	1965
	R.A. Berner	Michigan	Harvard	1965
	T.D. Foster	Brown	California	1965
	N.L. Carter	Pomona	California (L.A.)	1966
	B.J. Skinner	Adelaide	Harvard	1966
	J.C.G. Walker	Yale	Columbia	1967
	J.R. Vaišnys	Yale	California (Berkeley)	1967
	G. Veronis	Lafayette	Brown	1968
	B. Saltzman	City College (N.Y.)	M.I.T.	1968
	H.T. Rossby	Royal Inst. Technol. (Sweden)	M.I.T.	1968
	R.B. Gordon	Yale	Yale	1968
	D.M. Rye	Occidental	Minnesota	1973
	M.E. Fiadeiro	Lisbon	California (San Diego)	1975
	R.E. Hall	Cal. Tech.	California (San Diego)	1975
	H.S. Waff	William and Mary	Oregon	1975
	D.R. Pilbeam	Cambridge	Yale	1975
	R.B. Smith	Rensselaer	Johns Hopkins	1976
	R.J. Tracy	Amherst	Massachusetts	1978
	D. Schindel	Michigan	Harvard	1978
	E.A. Okal	Paris	Cal. Tech.	1978
	J. Longhi	Notre Dame	Harvard	1980
	H.J. Bradbury	Liverpool	Liverpool	1980
	R.L. Hughes	Melbourne	Cambridge	1982
	L.J. Hickey	Villanova	Princeton	1982
	N.M. Ribe	Yale	Chicago	1983
	A.C. Lasaga	Princeton	Harvard	1984

expansion covering almost two centuries. Starting in 1802 with one man, Benjamin Silliman, the teaching faculty has grown to a total of 22 full-time members in 1984, corresponding to approximately a doubling in the size of the faculty every 50 years. While no one can predict the future with certainty, we believe there are several reasons to expect that the faculty size may increase still further in the future. One reason for such an expectation comes from the broadening involvement of geologists—perhaps we might better say earth scientists—in many aspects of society and the economy. As Paul Bailly (1984) pointed out in his presidential address before the Geological Society of America, in medium-sized and large countries, there is a strong correlation between the Gross National Product (GNP) of a country and the number of geologists employed. For every $50 million of GNP, in 1980 U.S. dollars, one geologist is employed. Bailly also pointed out that in economically developed countries, among which the United States certainly belongs, there is approximately one geologist employed for every 7,000 people. Because both the GNP and the population are expected to grow over the next 50 years, the number of geologists employed will presumably grow too, and it is not unreasonable to conclude that Yale's involvement in that growth will require additions to the faculty. Numbers of students will presumably increase too, so that the production rate of Ph.D's could increase to a level of 12 to 15 a year, while undergraduate majors might increase from today's figure of about 15 to as many as 30 to 35 a year.

A second reason for expecting that growth patterns of the past will continue in the future is the growing diversity of geological activities. During the first stages of the history of geology at Yale, the principal activity of geologists was a descriptive natural history of the Earth. During the century from about 1880 to 1980, geology developed, as Bailly (1984) remarked, "into a body of scientific disciplines with explanatory power and nascent predictive power." In a very real sense, we are now poised on the threshold of a new era in geology when large-scale testing of predictions will occur as a result of major investigative programs. Planetary studies, ocean-floor drilling, global geodynamic studies, and other large programs have already exposed geologists to ways of working and thinking that could barely have been imagined a generation or two ago. New, possibly larger and possibly even more exciting programs have already been spawned. Examples are the U.S.S.R.'s Deep Drilling Program, the Continental Scientific Drilling Program in the United States, Canada's Lithoprobe, and the U.S.'s COCORP programs of deep, crustal seismic sampling. No doubt other such exciting ventures lie ahead, and they will inevitably stimulate the field. Such programs provide a guarantee that the rate of development of the geological sciences will continue to increase and to diversify in the future. Surely the geological and geophysical activities at Yale will also continue to grow and diversify in the future.

ACKNOWLEDGMENT

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BIBLIOGRAPHIC NOTE

The brief nature of this overview of Yale geology has precluded detailed reference to, and discussion of, the large body of relevant manuscript material in the Yale University Archives. This material includes the papers of Benjamin Silliman, the two Danas, Brush, Marsh, Schuchert, Huntington, and other faculty members. Constant sources of reference were the three volumes of the *Historical Register of Yale University* (1939, 1952, 1969), which contain official records of faculty appointments. Sarjeant (1980) greatly simplified the task of finding obituaries where contemporary observations were recorded, particularly in regard to the reasons for the appointment of our faculty members, the effectiveness of their teaching, and the degree of influence they had on their colleagues as well as on their students.

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