
INTRODUCTION

Recognition of “geophysics”

The term for the physical investigation of the Earth was first defined by Fröbel in 1834.¹ He wrote:

One can say geophysics, if one means such conditions of the earth to which the various chapters of experimental physics correspond, thereby excluding geographical organization of organic nature as well as the geographical distribution of minerals.

He realized that at that time “much lies at hand to be designated by this name, indeed only the idea exists, and in addition I will possibly suppose, that a tendency lies in what is currently called geology to expand it to mean the theory of the Earth.”² In succeeding years, the fields of geomagnetism, seismology, geodesy, and meteorology were included under the term.

Initiation of geophysics in the USA

The work in experimental geophysics was initiated in the USA by Clarence King, appointed as the first director of the US Geological Survey (USGS) in 1879. His two-fold program involving the study of mining districts and the collection of mineral statistics was supplemented by geophysical and geochemical studies in support of mining geology.³ In 1880, Carl Barus, a physicist, was assigned to George F. Becker, a mining geologist with broad interests in physical and chemical problems, to make an experimental determination of the electrical currents around ore bodies. With Strouhal in 1885, he found a relation between electrical conductivity and the temperature of steels in different states of hardness, wrought iron, and cast iron, whose differences were being debated at the time.⁴

Emphasis on geological mapping

King resigned in 1881 and was replaced by John W. Powell, who emphasized geological mapping, and the experimental work in geophysics declined. Nevertheless, in 1884 the USGS moved into new headquarters and a physical laboratory as well as chemical laboratories were established. Following his

mathematical bent, Becker considered the fundamental shape of volcanic cones and the mechanical conditions for faulting. In addition, he developed ideas on how chemical energy would influence the succession of minerals in volcanic rocks. Eventually he became deeply involved in the study of strain, flow, and rupture in rocks.

Physics and chemistry terminated at USGS

In 1892 there was a major reduction in funding for the USGS, and the appropriations for physics and chemistry terminated. Becker was dismissed but reinstated in 1894 when Charles D. Walcott became director of the USGS to carry out reconnaissance geology of the gold areas in the southern Appalachians. In the meantime, Barus had studied the electromotive force of various thermocouples, the melting temperature of rocks, and the volume change on melting of diabase. In spite of his success he was dismissed. Although no longer regarded as important at the USGS, geophysics attracted the attention of universities.

Faculty positions at universities

In 1896 appointments to individual faculty positions in geophysics were made at two universities: Louis A. Bauer in geomagnetism at the University of Chicago, and Harry F. Reid in dynamic geology and seismology at Johns Hopkins University. The first university chair in geophysics in Germany was founded at the Institute of Geophysics in Göttingen in 1898; however, work there on geophysical problems began as early as 1756. Geophysics was clearly a discipline that could no longer be ignored.

Physics and chemistry re-established at USGS

In 1900 the Division of Physical and Chemical Research was re-established in the USGS under Becker's direction, but the experimental work was carried out by two new employees, Arthur L. Day, an American staff worker at the Physikalische-Technische [Reichs] Anstalt in Berlin, and E. T. Allen, a chemist. They determined the melting temperature of the principal rock-forming minerals, beginning with the plagioclase feldspars. This research was indeed critical to an understanding of the physical chemistry of rocks.

Education vs. research

While the new work was progressing, a new opportunity emerged. The wife of the director of the USGS, Mrs. Walcott, was active in a group in Washington whose aim was to start a national university in honor of George Washington.⁵ The Washington Memorial Institution was incorporated with Charles D.

Walcott as president of the Board of Trustees and Daniel C. Gilman as director. It was clear that substantial funding would be needed, so Walcott suggested that Gilman meet with Andrew Carnegie. The meeting in October 1901 included Mrs. Walcott, but they were unsuccessful in persuading Mr. Carnegie to support a national university. However, a plan for establishing a research institution in Washington was considered more appropriate. On November 16, 1901 Gilman and John S. Billings met with Carnegie and the emphasis was switched from education to research and postgraduate training.

Carnegie gift for research institution

Events moved quickly thereafter when Carnegie wrote to President Theodore Roosevelt on November 28, 1901 that he propose a gift to the nation. On December 2, 1901, Gilman, Billings, and Carnegie had lunch with President Roosevelt and a gift of \$10 million was announced for a scientific research institution in Washington along the lines of a memorandum prepared by Walcott. (Carnegie added \$2 million to the endowment in 1909 and an additional \$10 million in 1911.) That afternoon Carnegie met with Walcott⁶ at the New Willard Hotel⁷ that had just opened in 1901 on Pennsylvania Avenue in Washington, and told him of his wishes that his old friend Gilman, first president of Johns Hopkins University, be president of the new institution and that Walcott take an active part as secretary in conducting the institution in light of Gilman's advanced age (he was seventy years old). Walcott agreed, taking note, however, that his primary duty was as director of the USGS.

The magnificent scheme

Early in December 1901, Walcott asked Becker to prepare quickly a statement for an independently endowed geophysical laboratory. Walcott's enthusiasm for such a laboratory may have stemmed from a talk given earlier that year by Arthur L. Day at the Philosophical Society of Washington on January 19, 1901. Walcott, as president, had heard Day's "account of the history, organization, and work of the Physikalische-Technische [Reichs] Anstalt of Berlin".⁸

On December 16, 1901, Becker delivered his outline for a geophysical laboratory to Walcott under the title "Concerning a Geophysical Laboratory." A handwritten draft with corrections and a typed version are preserved.⁹ The first paragraph of the typescript is as follows:

It is difficult to conceive of a more magnificent scheme than the founding of a generously endowed laboratory, devoted to researches into the physical and chemical conditions affecting the history of the globe. Very little work has been done in this direction for several reasons. As a rule physicists and chemists know too little of

geology to appreciate the applicability of these sciences to the elucidation of the history of the earth, while few geologists have the training in exact science which would fit them to undertake such researches independently. Again the investigations required are so laborious and expensive that no institution now in existence is in a position to undertake them, systematically, on an organized plan. The nearest approach to such work is that now going on in the division of Chemical and Physical Research of the Geological Survey, but there is little ground for hope of adequate appropriations from Congress for this purpose.

The two-page statement was presumably too brief in scientific substance for Walcott to use to persuade the Carnegie Institution of Washington (CIW) Board of Trustees, incorporated on January 4, 1902, for which he had been elected secretary, and a more detailed report was requested. Becker submitted the desired scientific program to Walcott on March 21, 1902.¹⁰ The program emphasized the need for experiments on the physical properties of rocks as they applied to “terrestrial density, upheaval and subsidence, and volcanism.” The principal projects were listed under (1) Mechanics, (2) High-temperature work, (3) Solutions and their relations, (4) Thermodynamics, and (5) Constitution of matter. The scientific program was published in 1903 with detailed plans for staff, building design, budget, and organization in an Appendix to the Report of the Advisory Committee on Geophysics.¹¹

Exceptional man vs. central laboratories

In accord with Carnegie’s wishes, the funds were to be used in “securing the exceptional man for the work for which he is intended, and supplying the necessary apparatus for experiments and research” (Letter from Carnegie to Donaldson, December 20, 1901). In contrast, the Executive Committee of the new Institution instituted the concept of small advisory committees to prepare reports on the needs of specific fields. The issue of individualism versus collectivism was clearly drawn. As Walcott explained to Carnegie, “individualism is the old view that one man can develop and carry forward any line of research, whereas collectivism embodies the modern idea of cooperation and community of effort.” In the years to follow, independent research departments developed in which teams of investigators tackled major scientific problems. R. S. Woodward, second president of CIW, described it as “a university in which there are no students.”¹²

Grants to individuals

Grants were given in 1903 to Frank D. Adams at McGill University (No. 4) to study the flow of rocks (Carrara marble, dolomites, and limestones) under pressure; and to C. R. Van Hise at the University of Wisconsin

(No. 71) to investigate the state of geophysical research in European institutions. In 1904 grants were given to George F. Becker of the USGS (No. 172) to study elasticity and plasticity on solids; to Arthur L. Day also in the USGS (No. 171) for the experimental investigation of mineral fusion and solution under pressure; to G. K. Gilbert (No. 126) for the preparation of plans to investigate the thermal gradient in a deep drill hole of at least 6000 feet depth; to Carlos de Mello (No. 170) for a bibliography on geophysics; as well as a continuation of the grant to F. D. Adams (No. 117) for studying the flow of rocks under pressure. The grants to Becker (No. 172) and Day at the USGS (No. 225); to F. D. Adams at McGill University (No. 227); and the bibliography for geophysics¹³ under F. B. Weeks (No. 170) were continued in 1905. These grants were clearly in accord with the wishes of Andrew Carnegie, who was supported by the Executive Committee, to discover and develop the exceptional man.

Advisory Committee report

The Advisory Committee on Geophysics for CIW consisted of three geologists, T. C. Chamberlin (University of Chicago), C. R. Van Hise (University of Wisconsin), C. D. Walcott (USGS), and three physicists, R. S. Woodward (Columbia University), C. Barus (Brown University), and A. A. Michelson (University of Chicago) (Figure 1.1).¹⁴ The Advisory Committee chaired by Woodward submitted a list on September 23, 1902 (also published in the first *Year Book*), of sixteen specific problems involving the broader scope of geophysics – as viewed today, encompassing the atmosphere, oceans, and lithosphere – and explicitly including geochemistry. Suggestions for specific research projects and support had been obtained by letter from Lord Kelvin, E. Suess, F. Becke, O. Kohlrausch, J. H. van't Hoff, G. H. Darwin, and W. Nernst. Their list of specific problems (abbreviated here) included:

- heat transfer in the atmosphere
- determination of gases in magmas, rocks, and meteorites
- function of the ocean as a reservoir of atmospheric constituents
- physical chemistry of natural solutions as related to ore deposits
- alteration and recrystallization of minerals under varying conditions
- heat of formation of natural compounds
- deformation of rocks
- effect of pressure on the melting of minerals, including volatiles
- thermal conductivity of rocks
- elastic constants of rocks under varying conditions
- sources of internal heat on Earth
- relationship of heat distribution to deformation and volcanism
- tidal deformation

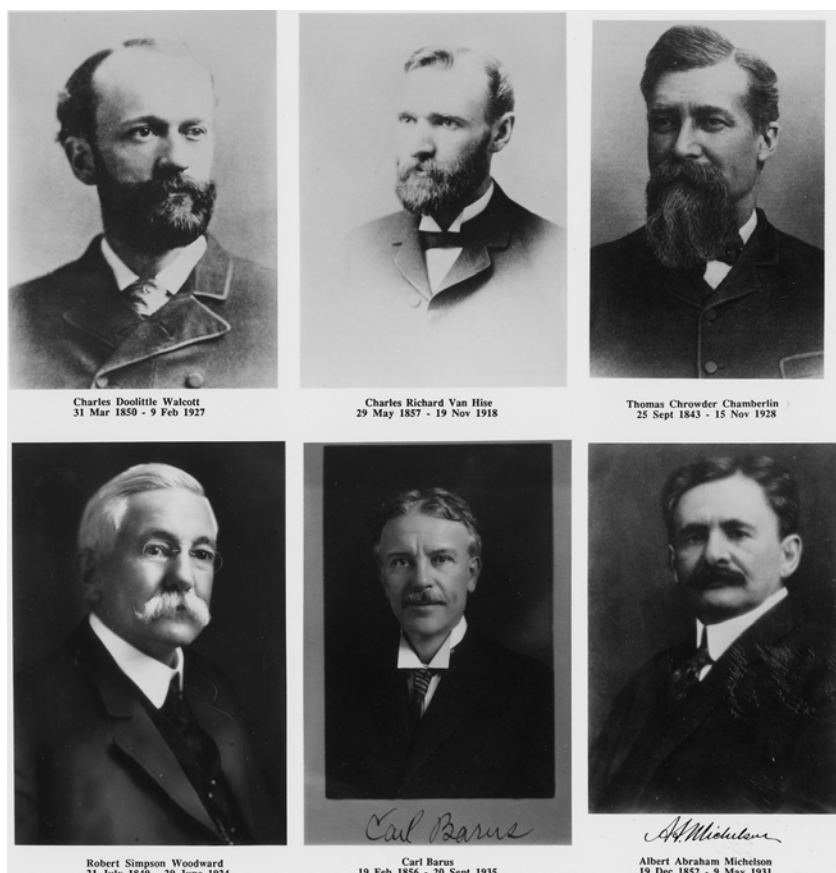


Figure 1.1 Members of the Joint Advisory Committee on Geophysics. (Top) Geologists: Charles Doolittle Walcott, Charles Richard Van Hise, and Thomas Chowder Chamberlin. (Bottom) Physicists: Robert Simpson Woodward (Chairman), Carl Barus, and Albert Abraham Michelson. From E. L. Yochelson and H. S. Yoder, Jr., “Founding the Geophysical Laboratory, 1901–1905,” *Geol. Soc. Am. Bull.* 106 (1994), 341. By permission of the National Academy of Sciences and the US Geological Survey.

- Moon–Earth tidal relationship
- density and mass distribution in the Earth
- gravity in oceans and continents.

Because “the trustees were not prepared to act” (*CIW Year Book*, 1904, p. xxxv), further study of the subject of geophysical research, especially in Europe, was assigned to Van Hise. On the basis of those discussions he laid out a four-part program considered by geologists as “most pressing” that included the relation of liquid and solid rocks, minerals and rocks from

aqueous solutions, deformation of rocks, and physical constants of rocks.¹⁵ In addition, the opportunity to systematize the seismological investigations of the world was recognized. These areas were backed up with a detailed and definitive outline of experiments for the investigation of igneous and metamorphic rocks prepared by eight petrologists in the interest of promoting the “Science of Petrology.”

The Committee of Eight

The report submitted on October 10, 1903, by a Committee of Eight provided even greater detail for the initial program of research for the proposed geophysical laboratory. The Committee consisted of Whitman Cross (USGS), Joseph P. Iddings (University of Chicago), Louis V. Pirsson (Yale), and Henry S. Washington (Private Laboratory), the group now famous for the *CIPW* system¹⁶ of rock classification, published in 1902 (Figure 1.2a). Other members were Frank D. Adams (McGill University), James F. Kemp (Columbia), Alfred C. Lane (Michigan State Geological Survey), and John E. Wolff (Harvard) (Figure 1.2b).¹⁷ It was indeed a distinguished group: four of these petrologists became members of the National Academy of Sciences, and one became a foreign associate. Their suggestions for geophysical research, outlined in some detail, are tabulated in brief in Table 1.1.

There appears to be no written record of who organized the committee or how the group was assembled. (It may be presumed that their suggestions resulted from discussions held in Washington when at least six of the Committee of Eight met at the Washington Meeting of the Geological Society of America between December 30, 1902 and January 2, 1903. Neither Pirsson nor Wolff was registered, but Wolff is listed as having given a paper on 2 January.) The emphasis on physics espoused by Becker and the CIW Advisory Committee on Geophysics thereby evolved toward physical chemistry as promoted by Van Hise and the Committee of Eight.

Generating support for a laboratory

Walcott was the principal advocate for an independent research laboratory with the strong backing of the Advisory Committee and the Committee of Eight. Additional support was gained through letters from outstanding scientists abroad and a resolution was engineered by S. F. Emmons at the International Congress of Geologists in Vienna in 1903. Extended discourses on critical problems and geological issues were arranged by Walcott and were given by Van Hise and Becker at the International Congress of Arts and Science of 1904, held in St. Louis. Personal meetings with Carnegie, however, did not appear to advance the concept of a research laboratory.

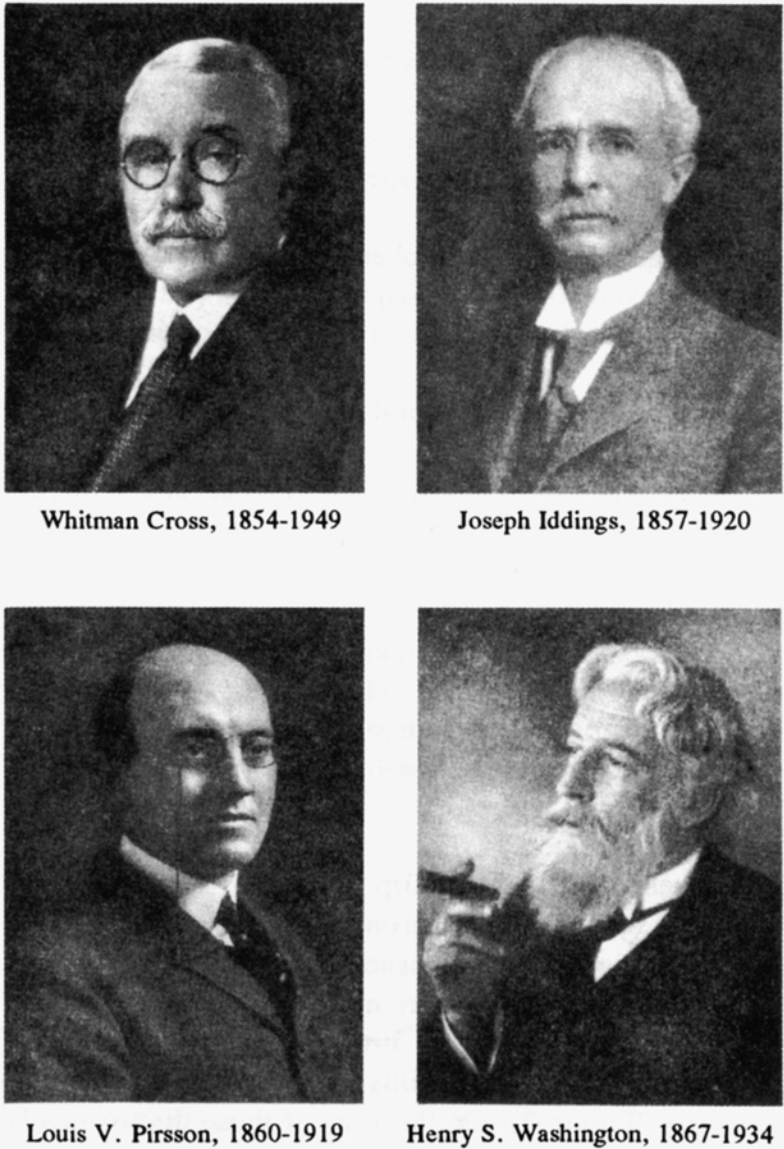
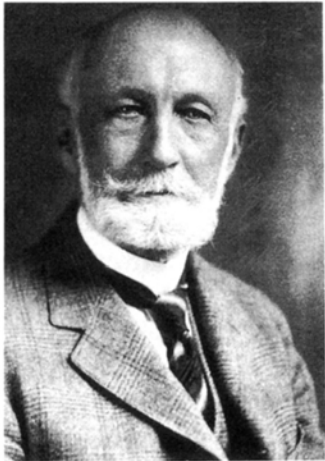


Figure 1.2a Members of the Committee of Eight who also participated in the formation of the *CIPW* system of rock classification. *Source:* H. S. Yoder, Jr., “Development and promotion of the initial scientific program for the Geophysical Laboratory.” In G. A. Good (ed.), *The Earth, the Heavens and the Carnegie Institution of Washington* (American Geophysical Union, 1994), p. 24. By permission of the American Geophysical Union.



Alfred Church Lane, 1863-1948



James Furman Kemp, 1859-1926



Frank Dawson Adams, 1859-1942



John Eliot Wolff, 1857-1940

Figure 1.2b The remaining four members of the Committee of Eight. By permission of the American Geophysical Union. *Source:* As Figure 1.2a.

Late in 1904, Woodward, Chairman of the Advisory Committee on Geophysics, was elected president of CIW, and the next step seemed inevitable. At the meeting of the Trustees on December 12, 1905, Woodward and Walcott persuaded them to establish the Geophysical Laboratory.¹⁸ Carnegie was not pleased and quickly wrote to express his opinion (Figure 1.3). He was clearly opposed both to extracting “exceptional men” from their own environment

Table 1.1 *Geophysical investigations suggested by CIW Committee of Eight, 1903.*

Igneous rocks	Metamorphic rocks
1. Physical properties	1. Physical properties
2. Mutual solution of minerals	2. Thermal properties
3. Diffusion in liquids and solids	3. Rock-water interaction
4. Crystallization from liquids	4. Hydrothermal mineral solubility
A. Liquidus of simple systems	5. Chemical reactions and crystallization
Rates of crystallization	6. Hydration and dehydration
B. Gas solubility in magmas	7. Crystal growth
Hydrous mineral stability	8. Solution of stressed crystals
Crystal size, habit, texture	9. Rock deformation
5. Chemical analysis	10. Development of foliation
6. Thermal properties of minerals	11. Effects of stress on composition
	12. Origin of graphite in metamorphic rocks

Source: *CIW Year Book* 2 (1903), 195–201.

and especially to erecting buildings. Nevertheless, the decision was in the hands of the Board of Trustees, not the donor of the endowment.

Obviously, Woodward and Walcott were so sure of the outcome that major decisions had been made well in advance of the December 1905 vote. What skillful politicians they were! A letter dated October 25, 1905 shows the letterhead already prepared (Figure 1.4) – well in advance of the vote – in the same script used today. It is also apparent that the appointment of A. L. Day, then assistant to Becker at the Survey, as the first director had been made, and yet the old address of the USGS was retained. This simple letter has quite a story behind it,¹⁹ especially in regard to the apparent bypassing of Becker as director, presumably because of his rigid stance on his proposed budget considered excessive by Walcott. Becker has been referred to erroneously as the director by Williams,²⁰ and in recent editions of the *Encyclopaedia Britannica* (e.g. 1977, vol. 1, p. 981) as the first director of the Geophysical Laboratory. Becker, age 58, was a geologist with a strong physics background, whereas Day, age 36, was a physicist with essentially no geological background. The official appointment of Day as director was made several months into 1906; however, Day had been receiving from CIW a small “honorarium” from April 1, 1904 and a “salary” from April 1905, so the appointment was not unexpected. The work of Day, Allen, and Iddings on the plagioclase feldspars was published by CIW in 1905²¹ with the consent of Walcott, CIW secretary and director of the USGS, in recognition of the support from CIW. It was considered to be the first publication of the Geophysical Laboratory, with an extensive introduction written by G. F. Becker!