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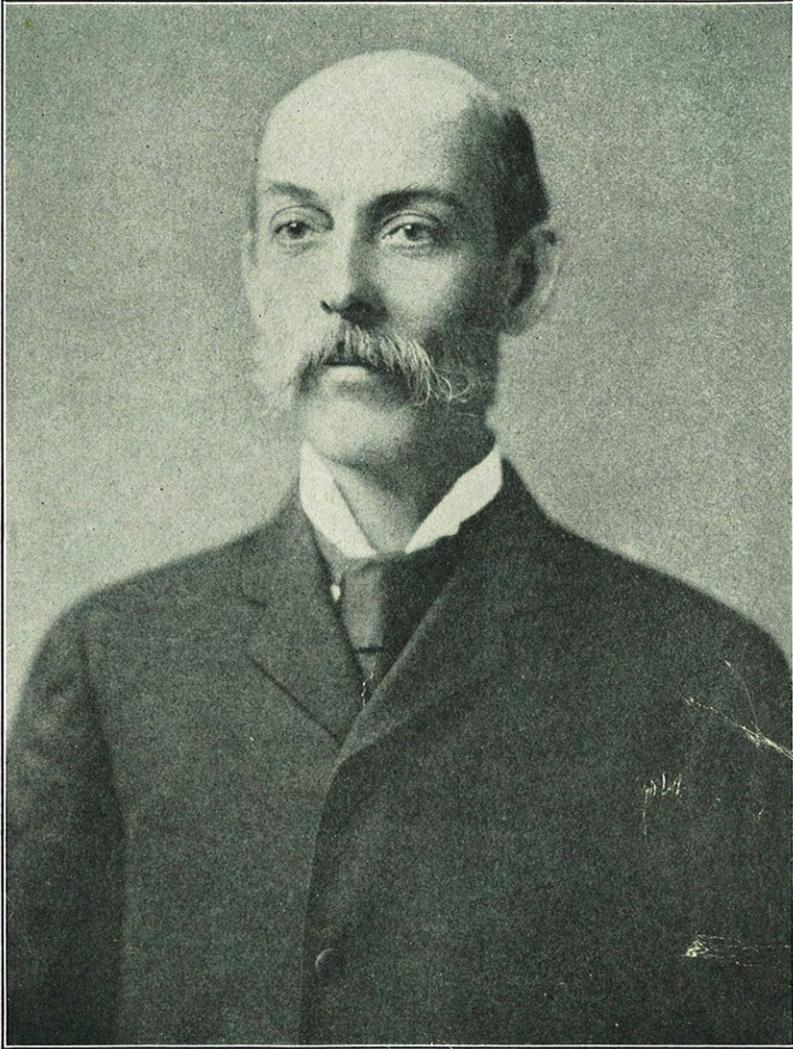
Volume XXI
SECOND MEMOIR

BIOGRAPHICAL MEMOIR GEORGE FERDINAND BECKER
1847-1919

BY

GEORGE P. MERRILL

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George F. Becker

GEORGE FERDINAND BECKER

By GEORGE P. MERRILL

Dr. George F. Becker was born in New York City, January 5, 1847. His father was Alexander Christian Becker, of a Danish family, settled in Archangel, Russia, where it is stated the head of the house (Samuel Becker) held for a time the office of Danish consul, holding his commission direct from the King of Denmark. Samuel Becker was a man of considerable wealth and given to lavish entertaining, but lost his property through absorption in science, particularly the new chemistry. On account of these financial troubles, Alexander Becker (the father of George F.) came to the United States and settled in New York. His first venture was in mercantile life, but finding this distasteful he studied medicine and entered upon the practice of his profession, but died when the subject of this sketch was 2 years of age.

"My mother's maiden name" writes Doctor Becker, "was Sarah Cary Tuckerman, a daughter of the Rev. Joseph Tuckerman known in Boston as a philanthropist and the first Minister-at-Large. He was a graduate of Harvard and an Overseer, and intimate friend of William Ellory Channing, Joseph Story and other prominent men of the day. The only scientific Tuckerman was my mother's first cousin, Edward, a member of this Academy [i. e., the National Academy of Sciences].

"Cambridge was selected as a residence by my parents with a view to the education of their two children Alexander Rudolph and myself. My mother's Cambridge friends were for the most part in the University set. Benjamin A. Gould was a very constant visitor. C. C. Fulton and Louis Agassiz married Mary Cary and Elizabeth Cary, first cousins of my mother. Charles Henry Davis, the founder of the Nautical Almanach and later Rear Admiral, was a frequent and welcome caller. Benjamin Peirce and Jeffries Wyman were likewise good neighbors. We knew Asa Gray more slightly but saw little of the Bonds. Longfellow, Lowell, Richard H. Dana, Holmes and Wolcott Gibbs and Charles Eliot Norton were valued acquaintances.

"Most of the scientific men took some little interest in me as a child but I owe most to Agassiz, Peirce and Wyman who seemed to like to encourage me in scientific curiosity.

"I was flying my kite in a field one day about 1856, when Peirce joined me to ask if I knew why it stayed up in the air. Of course I had no definite idea and he was at much pains to explain as much as I could understand of a distinctly difficult subject; he then and there excited an interest in my mind which has never yet wavered."

There is abundant evidence in the correspondence to which the present writer has had access that between mother and son there was early developed a strong bond of affection which was to continue throughout their entire lives.

It is told of George that when a boy of 4 years he quietly listened to his widowed mother all the evening as she read the history of the "Commonwealth of Massachusetts." After he had been tucked into bed, and sleep had come to him, his lonely mother was overcome with memories. Going to the child's bed, she knelt down; the little fellow must have felt her presence, for he reached out and touched her. "Oh, my child, who do you love?" said the mother. The sleepy little childish voice answered: "Anyone who will do good to the Commonwealth of Massachusetts."

In early youth Doctor Becker showed a decided taste for natural history and was of a studious and quiet nature, caring little for the talk and games of other boys.

"Games and sports interested me but little," he wrote, "and my mother had often to send me to the Delta, now occupied by Memorial Hall, to play with the other boys. I could play rounders and pre-Rugbian football decently well but I preferred gymnastics to these games because I could do them alone. The boys' talk did not interest me and I had sense enough to make no reference to natural history in their presence.

"Then (as ever since) the only society I cared for was such as I found mentally stimulating and the only pleasures for me were those involving some mental exertion. Chess I liked, but cards I found dull, the element of chance spoiling the fun.

"When I could not be at the Museum or in the woods and marshes I liked best to spend my time on the lounge in my mother's library with Audubon's text or Nuttall or Carpenter's animal physiology in my hands. I found them very stimulating to the imagination, as much so as Scott's novels, though these too I enjoyed."

Concerning his boyhood he also wrote:

It was a delight to me to roam alone about the woods especially those near Fresh Pond and the marshes not far away. Not a pool or a grove lacked inhabitants I knew something about. In fact, I believe I could recognize each New England bird and I was familiar with many of the reptiles. I knew not only the frogs and the toads but the spawn of most of the species and having heard so much of embryology from Agassiz it was delightful to follow the development of the translucent eggs from day to day, as well as to watch the fascinating transformation of the tadpoles.¹ I had a small shot gun which I generally carried on these expeditions but I rarely fired it excepting when some bird or rodent seemed to display characters to make him a candidate for admission to the museum. Sometimes, however, I would practice a bit at a mark to keep my hand in. One such day I was on the way home when a gentleman overtook me and seeing a museum alcoholic collecting case in my hands asked me what I had. I was tired and I didn't recognize my interlocutor so I merely replied the Latin names of my specimens, meaning to choke him off! But with these he was evidently familiar. He proceeded to ask me some questions I could answer, others much beyond me and then launched out into a most delightful 15 minutes disquisition suitable to my small capacity. I was ashamed, charmed and instructed as well I might be for it was no less than Jeffries Wyman who had thus honoured a little boy. I never met him afterwards without carrying away ideas and an improved sense of method.

Becker was fitted for college in Latin and Greek under the tutelage of Prof. Wm. B. Atkinson and was admitted to Harvard in 1864, only "with several partial conditions which did not trouble me. I was glad to be an undergraduate and was confident I could keep up with my class. I had no trouble in doing so excepting when colds and sore throats kept me out of the class room as they sometimes did for weeks together. Indeed, I had plenty of time for desultory study, looking up anything I did not understand and always finding that it led to something else I did not comprehend, which needed new search."

Concerning Agassiz and his teachings he wrote:

Very clearly impressed upon my memory is a passage from one of his lectures delivered about this time [probably 1859]. Substantially it is as follows though I cannot of course guarantee its literal accuracy. "As investigators we are necessarily open to new ideas whether they arise in our own minds or those of our colleagues. Yet it must not be supposed that this habit is sufficient to assure our receptivity without making a conscious effort to take broad views. Fundamental discoveries occur only at comparatively long intervals and they require a mental readjustment which is difficult, especially after youth is passed. Thus when Harvey made his great discovery of the cellular structure of tissues, the scientific life of all the anatomists over forty years old was arrested. Some accepted the truth but confessed themselves unable to revolutionize the conceptions which had been the basis of their work, others vainly contended against the truth."

Good precepts these but difficult to follow as the dear man himself soon exemplified. Not long afterwards the *Origin of Species* appeared and I well remember his next lecture to his class. He was almost overcome with pain, indignation and horror. This hypothesis, he told us, is a revival in a more insidious form of the thoroughly exploded heresy of Lamarck. He could not express to us the pain it gave him to see the great learning and ability of Charles Darwin applied to sophistical and almost blasphemous reasoning. The book could not but do vast harm and wrong though it is, let no one suppose it easy to refute, unsound. On the contrary the vast information and acute though misdirected arguments make a reply most difficult. The safest way would be not to read it at all. Fancy such an injunction addressed to that set of youths. After the lecture they adjourned to Putnam's room and I think I must have been invited to go along too, at any rate I went without receiving any rebuff. Of course it was an indignation meeting though nothing abusive was said of the master. It was a great day, a critical epoch in the lives of most of the young men present.

About the middle of his college course it would seem his interest in natural history had become considerably cooled, and—

I was somewhat adrift when a single lecture on mathematics opened my eyes to the fact that this is a science of great principles and ideas, not a mere jumble of tiresome computations and unrelated Chinese puzzles. That was a happy discovery to me. Chemistry too, attracted me though the instructions we received were distinctly

¹ Drawings, essays, and even poems on these various subjects, found among his papers and evidently prepared at about this time, are of quite exceptional merit and show a trend of mind little dreamed of by those who knew him only in his later years.

bad. In the senior year I took analytical and celestial mechanics under Benj. Peirce, with a single other classmate. Peirce went too fast but he was inspiring, and we were thus brought into contact with a really original thinker. I came out at graduation well up in my class—thanks to high marks in mathematics and English.

At the close of that year (i. e., senior) my mother offered to let me study in Germany after graduating at Harvard. I gratefully and eagerly accepted. In the winter of 1867-8 I had the benefit of intimate association with Dr. Herman Hagen the well known entomologist. He had just come from Koenigsburg accompanied by his wife to take a position in the Museum, and Agassiz, knowing of our plans to spend some years in Germany, persuaded my mother to take them in for the winter. They had the task of wintering themselves in a new country while I had more than plenty to learn from a German Savant. Hagen and I soon had a *lingua franca* in which we could converse and we spent many of our evenings in high debate upon an endless variety of topics. He was a somewhat eccentric but highminded scholar of enormous learning and the best standards. Diletantism and philistinism were to him anathema. His was just the companionship I needed and the opportunity was not thrown away. Though he was no better scholar than other of the men mentioned above, he had a greater effect upon me than they did because our intercourse was so constant and so familiar. My debt to Hagen is a great one. But for his instructions I should have been ill prepared to grasp the spirit of the German universities. By reason of his coaching I found myself at home in a very short time in German academic circles.

That Becker was a diligent student while in Germany is shown by the following translation of a certificate from the well-known chemist Bunsen:

TRANSLATION OF PROF. BUNSEN'S LETTER

It gives me especial pleasure to certify that Mr. G. F. Becker, Dr. Phil., from America has taken part in the practical chemical exercises in my laboratory with extraordinary zeal from Oct. 1868 to Nov. 1869; and has not only acquired a thorough knowledge of analytical chemistry, but also especial skill in the exercises of analytical work.

Inasmuch as I count Mr. Becker among my most active and most gifted pupils, I cannot suppress the wish that he may right soon find a sphere of action corresponding to his wishes and to his remarkable abilities.

Pride in his work and a determination to master its practical details led Becker to undertake while in Germany the somewhat unusual task of a puddler in the royal iron works. With what success he met is shown by the following:

CERTIFICATE AS PRACTICAL PUDDLER

It is herewith certified, that G. F. Becker of Boston has been at work in these works since Sept. 16 as puddler, and during this time has performed the severe labours of this branch of industry with extraordinary industry and most praiseworthy endurance.

The trial charges, which Mr. Becker made, before leaving, without assistance, gave a most excellent result, and furnished the proof of the practical thoroughness as well as of the intelligent grasp, of the whole puddling process on the part of the aforementioned gentleman.

He also took means to instruct himself with zeal and success in furnace construction, as far as the customs here present anything peculiar or unusual—put a helping hand in the building, repair and preservation of the furnaces, and made himself acquainted with the whole working of the shop.

Konigshütte, Nov. 1, 1870.

THE DIRECTOR,
RICHTER.

(Signed)

During the Franco-Prussian war, Doctor Becker served as a correspondent for the New York Herald, being attached to the Crown Prince's staff, but says of himself that he was not very successful. He was present at the battle of Woerth and the siege of Strassburg, and was once captured by the French and held prisoner for a few hours. Even at this time he foresaw the coming of the great war, though anticipating its date. He wrote, "I bet a bottle of the best champagne that Germany will be at war with Europe within 10 years."

Returning to America, Doctor Becker was employed during 1872-73 as a construction engineer by steel works at Joliet, Ill. While here he invented, but did not patent, an improved puddling process which is stated to have been in use both in Joliet and Youngstown, Ohio, up to within the last five years (i. e., about 1918). Shortly after this he went to California, partly, it is said, on account of his health, though it seems probable that the field seemed most inviting to one of his profession. Here during 1875-1893 he was instructor in mining and metallurgy in the State university. Among his pupils was the now well-known mining engineer, John Hays Hammond. While here he fell under the influence of Clarence King, who was then engaged upon the survey of the fortieth parallel. In 1879, when King became director of the consolidated geological surveys, Becker was among the first to receive appointment, and it is here that his scientific career as a physicist and geologist may well be said to have begun.

Soon after his appointment Doctor Becker made a reconnaissance of the San Francisco, Utah, Eureka, Nevada, and Bodin, Calif., mining districts, with a view to laying out the work rather than of completing the examination of any single district. Owing to a change in the plans of the director, Becker personally undertook the study of the mines of the region, though at a later date (1884) those of Eureka were examined and reported upon by Mr. J. S. Curtis, acting as his assistant.

Early in 1880 Becker was instructed by the director of the survey to take, in addition to his survey duties, the office of a special agent of the Tenth Census (this without extra remuneration) and to assist in the compilation of statistics and technical information as to the precious metal industries of the country. The district assigned included Idaho, Utah, Arizona, and the country to the west of them. To S. F. Emmons was assigned the area of the Rocky Mountains. This investigation extended throughout the census year.

The results of this work were published as Volume XIII of the census reports, entitled "Statistics and Technology of the Precious Metals," by Geo. F. Becker and S. F. Emmons. It contained chapters on the geology of the Western States and Territories, statistics of production, and a very large amount of information on most of the important features of hydraulic mining, deep mining, quartz milling, etc., with brief but adequate discussions. This report, so far as statistics of production are concerned, is now out of date, but the technical information for the most part retains its value.

Becker here took occasion to discuss the four ore belts of the Pacific slopes and thought to show that each coincides with a well-marked zone along which relative upheaval has occurred. This fact by itself he thought demonstrated that a relation existed between the great movements which interest geologists and the accumulation of ore deposits which form the basis of the mining industry.

In March of 1880 Becker had been also instructed on the part of the survey to make a reexamination of the Comstock lode. Messrs. F. von Richtofen, Clarence King, and J. A. Church had each written reports upon the extraordinary deposit, but many features of the occurrence were not satisfactorily elucidated. The importance of the occurrence and the fine opportunity for study seemed to justify a fresh and more elaborate investigation.

The work, which was carried on at the same time with the census investigation, was completed in two years, the report forming Monograph III (1882) of the survey series. Besides full descriptions of the ore bodies and their occurrence, it contained a discussion of the rocks, showing that the lava propylite, supposed to be the chief rock of the district, consisted in reality of better-known eruptives in a peculiar state of decomposition. This, at the time, was an important petrographic discovery, and particularly so in view of the work of Zirkel on the rocks of the fortieth parallel survey. Examination of supposed propylites from all the other regions from which geologists had collected them in the United States showed that they were all of a character similar to that of the Comstock. Trachyte was shown to be absent, contrary to previously expressed opinions. The heat of the lode was shown to be due to hot water, rising along the vein from great depths, and deriving its heat from a source not less than 5 miles from the surface. The complex "distributed faults" or "step faults" of the locality were elucidated, and it was shown on mechanical principles how such were formed. Suggestions were given as to the most probable position of undetected ore bodies.

While many of the ideas put forward in this report have been the subject of controversy, it may safely be said to mark a new era in geological investigations in America. No previous investigations, by any survey, had been undertaken on so broad a basis. No known and available means of investigation were left untouched and untried. That Becker fully realized the possibilities of the opportunity offered is shown by the selection of assistants, among whom were the physicists, Carl Barus and William Hallock, and the then young and rising petrologist, J. P. Iddings. The appearance of this monograph placed Becker in the front rank among American geological investigators.

Doctor Becker's next field of investigation comprised, under the administration of J. W. Powell,² a study of the quicksilver deposits of the Pacific coast. This proved a somewhat prolonged investigation and for its satisfactory completion necessitated a study of the deposits of similar nature in Italy and Spain. Though under governmental authority, he was obliged to carry on this portion of the work at his own expense. The results of these studies appeared in 1888, as Monograph XIII of the survey series, under the caption of "Geology of the Quicksilver Deposits of the Pacific Slope."

In this report it was shown that all of the ores were deposited in preexisting openings and not by substitution. Where these openings were fissures the deposits were veins. Contrary to the generally received belief, veins of quicksilver ores, it was shown, are very common and were filled from solutions, not by sublimation, the material being deposited as black amorphous sulphide and subsequently converted into cinnabar. In connection with the deposits a new class of veins was proposed, called "chambered veins." It was shown that not only cinnabar but gold and the sulphides of iron, copper, and antimony and zinc dissolve in solutions of sodium carbonate charged with hydrogen sulphide, such as occur in great abundance as spring waters in volcanic regions. The report contained a digest of the descriptions of all the important or interesting quicksilver ore deposits of the world.

In the same volume it was shown for the first time that the Cretaceous and Tertiary formations in this part of California were continuous in life and sedimentation. Attention was also called to a great and hitherto unnoticed upheaval in the Coast Ranges, at the beginning of the Cretaceous period. Becker thought to show further that in some cases serpentine resulted from the action of mineralized solutions on sandstones.

At the close of the census investigation, Mr. J. S. Curtis, who had been one of Becker's assistants in that inquiry, joined the survey and was directed by him to study the Eureka mines. Mr. Curtis's volume, Silver Lead Deposits of Eureka, Nevada, Monograph VII, 1884, of the survey series, was well received by those interested in mining.

The above completes the list of Doctor Becker's monographic studies, but by no means closes or limits the period of his activity. In fact, they were but the beginning. While finishing the writing and attending to the publication of the report on quicksilver, he elaborated a plan to be carried out by his assistants, Messrs. H. W. Turner and W. Lindgren. It was intended that this investigation should cover the west slope of the Sierras for the entire length marked by frequent or important gold mines. The plan included four memoirs on the lithology, descriptive geology, mining geology, and systematic geology of the region. He proposed that the mapping and the descriptive memoir should be done by assistants under his supervision, while his own attention was to be given to the investigation of the questions arising in the work, such as the nature and origin of the structure, the character and effect of the glaciation, the origin and history of the ore deposits, the relation of the eruptive rocks to one another, and the like.

This investigation was never completed as planned. About 7,600 square miles were mapped and much preliminary work was accomplished in areas of which the topographic basis has been only lately completed.

Commenting upon this, Doctor Becker wrote:

It might seem more expedient to have begun this work with the ore deposits, but a little consideration shows that this would have involved loss of time and labour. If one were to begin with the gold bearing gravels, questions which would arise immediately are: What is the source of the pebbles? What are the relation of the channels to one another and to the present drainage system? What is the age of the deposits? These questions can be solved only by a study of the general geology of the country. If one were to begin with the quartz veins more numerous problems of a similar character would compel a return to a preliminary study of the geological history of the region.

Becker's personal studies of the gold belt led to seemingly definite solutions of a number of questions. Some of his conclusions were as follows: There is strong evidence of a post-

² King resigned on Mar. 11, 1881, and Powell was appointed to his position three days later. Doctor Becker's position on the survey does not seem to have been affected by the change.

Triassic upheaval in the Sierra probably identical with a disturbance which has been recognized in British Columbia. Two sets of earlier Cretaceous beds (divisions of the Shasta group) are contemporaneous or continuous. Authentic information not previously published shows that California was inhabited by men in the Neolithic stage of development, before the main glaciation of the Sierra. The glacial period of the Sierra probably began and ended much later than that of northeastern America. The deep canyons of the modern rivers of the Sierra were due to the protecting action of the glaciers on the higher part of the range.

A large portion of the Sierra, he thought, was affected by systematically disposed fissures or joints. A study of their peculiarities showed to him that this network of divisions was produced by a pressure acting on the range downward from the south-southwest. This pressure, he thought, could be accounted for by the weight of the sediments in the great valley of California, provided that the earth is a solid, highly viscous mass, but not if the interior is fluid.

The fissure systems, he argued, controlled to a large extent the emission of eruptive rocks. They affected the modeling of the country and also indirectly explained the formation of the canyons, among them the Yosemite Valley and the great domes of that region.

During the winter of 1892 Doctor Becker made his first systematic studies of the deforming effects of great pressures. This he regarded as essential to a comprehension of the structure (announced later) and showing that relative elevation must attend the formation of slate. The theory, to him, accounted for the distribution and spacing of fissures or cracks when the action is slow. In the same connection he accounted for the columnar structure of many lavas and gave a simple proof of the fact that the pebbles in auriferous river channels and other watercourses "shingle upstream."

A reconnaissance of the gold fields of southern Alaska by Becker in 1895 afforded incidentally material for an interesting theoretical discussion of vulcanism and the shape of volcanic cones, in which it was shown that such tend to approach definite geometrical form almost exactly coinciding with that of Fujisan, Japan, but that steeper shapes will not form on a large scale by ejection from a central vent.

In 1896, under the auspices of an English company, Doctor Becker visited the Wittwaterstrand of South Africa for the purpose of studying the gold fields. Aside from whatever report he may have made to the company, his observations found their way into print in the Eighteenth Annual Report of the United States Geological Survey (1896-97) and the *Zeitschrift für Geologie Praktique*, besides less technical accounts in the *National Geographic Magazine* and the *London Economist*. In all these publications Doctor Becker held the ground of the marine origin of the gold-bearing gravels and the alluvial origin of the gold itself, in opposition to De Launay and others, who thought it precipitated from a saturated solution of gold and pyrite in sea water. He noted that "in the pre-Tertiary rocks only those gravels remain which were protected by superjacent beds and allowed to indurate. River gravels, as such, could escape dispersion only when during subsidence they were immediately covered by fresh deposits, without undergoing any notable wave action." Hence the extreme rarity of pre-Tertiary river gravels. Such an origin—i. e., as marine, rather than as river gravels—he felt furnished a strong reason for the belief of their prolonged productiveness.

It was while employed in this work that Doctor Becker became conversant in some detail with matters relating to the Jameson raid and the Boer war and led to the preparation of an article on "The revolt of the Uitlanders," published in the *National Geographic Magazine* of that year. In this he set forth in a dispassionate and impartial way the prevailing conditions as they appeared to an outsider, and through his personal influence with President Krueger he is said to have been instrumental in bringing about an amicable settlement of certain difficulties that threatened to lead to international complications.

The most original, outstanding, and valuable of Doctor Becker's work was not, however, along the lines of descriptive geology. His interests lay largely in the more abstruse chemico-physical problems and concerning which he had almost from the start taken advanced grounds, not merely in relation to the problems to be solved, but, as well, to the methods of their solution. Along these lines he was a pioneer, and it was not too much to claim that the present

Geophysical Laboratory is the outgrowth of his work more than that of any one man.³ His published shorter papers showed an ever-increasing tendency to delve into physical and chemical problems and theories and to devise methods for their solution. This is evident in his *Finite Homogeneous Strain, Flow, and Rupture of Rocks* (1893), *Rock Differentiation* (1896-97), *Experiments on Schistosity and Slaty Cleavage* (1904), *Torsional Theory of Joints* (1913), and numerous other papers.

Concerning the paper of 1893 Day remarks:

In this we recognize a splendid attempt to define and formulate in precise terms, some of the relations in the science of rock mechanics. This was a magnificent task of pioneer quality and of extraordinary difficulty, but was not immediately fruitful because clothed in somewhat abstruse form.

In his discussion of rock differentiation an attempt was made for the first time in America to apply physiochemical laws along the experimental lines of Van't Hoff and others. The conclusions reached can be made clear by quoting his own abstract.⁴

All known processes by which the segregation or differentiation of a fluid magma could take place involve molecular flow. This is demonstrably an excessively slow process excepting for distances not exceeding a few centimeters. Soret's method of segregation, even if it were not too slow, seems inapplicable because it involves a temperature unaccountably decreasing with depth. The normal variation of temperature, an increase with distance from the surface, would be fatal to such segregation. The least objectionable method of segregation would be the separation of a magma into immiscible fractions; but this seems to involve a superheated, very fluid magma, while the law of fusion and the distribution of phenocrysts in rocks indicate that magmas prior to eruption are not superheated to any considerable extent and are very viscous.

The homogeneity of vast subterranean masses called for by the hypothesis of differentiation is unproved and improbable. The differences between well-defined rock types are more probably due to original and persistent heterogeneity in the composition of the globe. Hypogeal fusion and eruption tend rather to mingling than to segregation, and transitional rock varieties are not improbably mere fortuitous mixtures of the diverse primitive relatively small masses of which the lithoid shell of the earth was built up.

This paper was subjected to a critical review, with only partial agreement by C. F. Tolman, in the *Journal of Geology* for May-June, 1897.

In the paper on schistosity and slaty cleavage published in 1896 and already referred to, Becker took issue with the general idea to the effect that a secondary cleavage may be induced under pressure, but argued that "deformation of a solid, homogeneous, viscous, isotropic, not infinitely brittle, mass will develop structure in it on not less than one surface nor on more than four surfaces simultaneously." This he thought to show both mathematically and by experiment. In summing up his results he stated:

In view of the evidence merely outlined above, it appears to me utterly impossible to deny that solid flow does as a matter of fact induce a true cleavage which is parallel to the lines of relative tangential motion or gliding, this cleavage not necessarily being accompanied by any actual ruptures however microscopic.

Again in his paper on *Current Theories of Slaty Cleavage* (1907), which was largely controversial, Becker referred to the prevalent ideas as found in the literature, and then he stated his own views as follows:

Like Tyndall and Daubrée, I consider a parallel arrangement of flattened grains unessential to cleavage. Rupture takes place on planes of maximum slide or maximum tangential strain. Rupture is a gradual process and cohesion is impaired through flow before it is destroyed. Impaired cohesion in my theory is cleavage. Cleavage develops most perfectly when the stress tending to produce it is persistent in direction, because viscous resistance is then small. In a rotational strain there are two sets of mathematical planes on which maximum slide takes place and both sets are parallel to the axis of rotation. They make with the greatest axis of the strain ellipsoid angles given by

$$\tan = \frac{B}{(ABC) \frac{1}{3}}$$

A being the greatest axis, *B* the least and *C* the axis of rotation. The planes of maximum slide contain the circular sections of the ellipsoid only in a limiting case. During the progress of strain these mathematical planes sweep through wedges of the mass, but the two sets of planes sweep at different rates, one set having a relative angular velocity from, say, 20 to an infinite number of times as great as the other. On the planes which sweep rapidly viscosity reinforces rigidity, there is no time for considerable flow to take place, and unless actual rupture

³ See his *Project for a Geophysical Laboratory and construction of a geophysical laboratory*. Year Book, Carnegie Institution, 1902 and 1904.
⁴ *Amer. Jour. Sci.*, vol. III, 1897, p. 40.

occurs, so that joints form, the effect will be small. On the other set of planes viscosity is small, the mass has time to yield by flow, cohesion is weakened and cleavage results. In a word, the theory is that slaty cleavage is due to solid flow attendant upon rotational strains. So much of the energy of the system as is not potentialized is dissipated on the plane of maximum slide, and this may or may not lead to the alteration of mineral constituents, e. g., the transformation of feldspar into biotite.

In his paper on the Age of the Earth (1910), Becker pointed out the probable errors in the methods previously employed, with particular reference to the works of Kelvin, Darwin, Joly, and F. W. Clarke. He thought also to show that "radioactive minerals cannot have the great age attributed to them. Only something like a tenth of the heat emitted by the earth can be ascribed to radioactivity plus all other exothermic chemical transformations, the remaining nine-tenths of the heat being due to compression." Barrell, in a more recent paper (1917), subjected this conclusion to severe criticism, but as to which of the two credit is to be given for nearest approach to actual facts it is as yet impossible to say. Although not so shown in his correspondence, Doctor Becker was greatly interested in Chamberlin's planetesimal hypothesis, though by no means in agreement therewith.

In accordance with an arrangement made with the War Department, Doctor Becker, under orders of July 8, 1898, visited the Philippines for the purpose of investigating and reporting on the mineral resources of these islands. He sailed from San Francisco on the transport *Pueblo* July 15, under General Otis. After reaching Manila, he devoted some time to the preparation of a brief paper entitled "Memorandum on the Mineral Resources of the Philippine Islands," compiled from various unpublished records and published memoirs available in Manila, and from verbal information furnished by mining men, capitalists, and others. This memorandum was published in Part VI of the Nineteenth Annual Report of the United States Geological Survey.

In September of that year, Doctor Becker spent some days in field work on the island of Corregidor and about Mariveles. On his return to Manila he prepared, at General Otis's request, a memorandum on the agricultural resources of the archipelago. Shortly afterwards, finding it impracticable on account of the native rebellion to pursue further his geologic investigations, he attached himself to the Bureau of Military Information, Eighth Army Corps, under Major Bell. In this position he rendered valuable service, translating from the Manila newspapers articles of importance or interest to the Government and the military authorities, and endeavoring to enlighten public opinion in the islands by published articles correcting Spanish misrepresentations and setting forth the real conditions in the United States so far as those conditions were likely to become of importance to the Philippines.

Doctor Becker's own account of his services, as given in a report to Major Bell, are worthy of reproduction in full.

MANILA, P. I., March 1, 1899.

SIR: Pursuant to your verbal request, I submit the following report of work done by me in connection with the Information Bureau of the 8th Army Corps, during the three months just passed, viz: December, January and February.

I made voluntary tender of my services to you at the beginning of December, because the military situation made geological field work impracticable and I was unwilling to occupy the position of United States Geologist, in Charge, without rendering any services to the Government.

The first duties assigned me in the Bureau under your direction were to keep watch on the Philippine newspaper, "La Independencia," controlled by Mr. Antinio Luna, and to make translation of articles which seemed of importance or interest to the Military Governor. Another similar newspaper, the "Republica Filipina," controlled by Mr. Paterno, was afterwards included in this commission, and a variety of written and printed documents were submitted to me for translation. Your files contain copies of these translations. The following is a list of the more important of them. "America and Ourselves" a leader in the *Independencia* of Dec. 2, 1898, "Let us Wait" a leader in the *Independencia* of Dec. 3rd. "Philippino Yearnings for Spain" being extracts from the *Independencia* of Dec. 10th, threatening extracts from the *Independencia* of Dec. 19th. Passages from *Republica Filipina* of Dec. 25th complaining of the delay by the United States in announcing its policy. "Let there be Confidence" a conciliatory leader in the *Independencia* of Dec. 26th. Interview with Malolos Cabinet, Buencamino spokesman (a letter to Mr. Rickards, dated December 27th).

Primo de Rivera on the Paterno negotiation, (extracts from a memorial of the ex-captain General to the Spanish Senate in August last with some explanations and comments. Handed in December 31.) Primo de Rivera on ecclesiastical reform. (This from the same memorial as the last. Comments were added. Handed

in Jan. 1, 1899.) Letter of Buencamino to Republica Filipina, January 1, being a reply to a letter of mine. Manifesto by Aguinaldo January 5th. Second Manifesto by Aguinaldo January 5th. "Aguinaldo pleading with his brother Philipinos," a rare pamphlet by Emilio Aguinaldo, issued in December 1898 and immediately withdrawn. The translation is accompanied by an analysis. After January 4th, the Philippino newspapers removed from Manila and became openly hostile to the United States. It then ceased to be a matter of importance to keep track of their sentiments or expressions.

In December 1898 it appeared to be desirable to try influencing public opinion among the Natives by published statements correcting Spanish misrepresentations and setting forth soberly the real conditions in the United States so far as they are likely to become important to the Philipinos. In order to give such explanations more weight, it was expedient that they should be signed by a responsible person, and, if possible, by someone not in the military service. As I fulfilled these conditions, the task was assigned to me and several articles were written. All of them were carefully scrutinized by the Chief of the Bureau of Information, and by him submitted to higher authority, but I alone assumed responsibility for them to the public, in order that the Military Government might not be committed in any way by these utterances. Nothing was added by my superiors to these essays, but some sentences were struck out as impolitic. The articles were translated into intelligible Spanish under my supervision, and were published both in that language in the Philippino papers and in English in the Manila Times. The following thus appeared: "The Future of the Philippines" printed in Independencia, December 10, and replied to in the same issue. This appeared in the Manila Times on December 7th. "Treatment of North American Indians," Republica and Times Dec. 17. "Territorial Government in the United States," Republica and Times of December 23. "Free Education in the United States," Independencia of Dec. 24, and Times of Dec. 27th. Letter to the Republica on the delay by the United States in announcing its policy, Dec. 28. A further paper on "Religious American and the Catholic" was prepared, and the Republica promised to print it, but failed to do so. At the suggestion of a General Officer and with your consent, I also wrote an unsigned editorial for the Manila Times entitled "An Important Step." It appeared on Tuesday, Feb. 21.

During the month of January, at your instance, I took up the matter of the reestablishment of the Cedula Personal, gathering arguments for and against its reestablishment on any basis and opinions concerning the most expedient fees for such a personal certificate. It was found that the inhabitants of Manila wished for a Cedula and (although there was some opposition on this point) that it would be best to make only one class, putting the fee very low. I wrote an argument on the general question and directed especially to the desirability of making the Cedula compulsory on all men, in Manila, excepting U. S. soldiers, between the ages of 18 and 60, leaving it optional for women. General Otis was at first disinclined to the compulsory feature but yielded to my representations. I have the satisfaction of believing that the compulsory cedula will be an important aid in the preservation of order under American control in this Archipelago.

I also undertook an examination of the matter of licenses which, however, was interrupted by the outbreak of the Insurrection.

In addition to the matters detailed above, many others have fallen to my share which are not important enough for special mention, such as deciphering telegrams, procuring secret agents, examining into rumours, collecting information, seeing to the printing and posting of the Military Governor's proclamation and making myself generally useful in the Bureau so far as my lack of military education permitted. You have also done me the honor to consult me on most of the matters in which you have been engaged.

When the Insurrection broke out it became impossible for me to sever my connection with the Bureau without loss of self respect. Inclination drew me in the same direction as loyalty and I have accompanied you on most of your strictly military duties as well as upon quests for information. Without specific instructions I have understood that, in the field as in the office I was to be constantly on hand, in readiness to undertake any message or commission you might see fit to entrust to me, and to render without orders any service within my capacities which circumstances clearly called for, if only by example. It has not always been easy to draw the line between officiousness and negligence, but you have been kind enough to give me reason to believe that I have not erred grossly in either direction. Your own official reports more than sufficiently cover such services as I have found an opportunity of performing at the front.

I cannot close this report without referring to the pleasure it has afforded me to assist, in a variety of extremely interesting matters and in some thrilling situations, an officer so ingeniously and intelligently devoted to his duty, who is as intent on correcting abuses and ameliorating the lot of the wretched as he is strenuous in the quest for military information and fearlessly aggressive on the field of battle.

How well his services were appreciated is shown by the following extract, re George F. Becker, from official report of Maj. J. F. Bell, in charge of the Office of Military Information of the Department of the Pacific, to Maj. Gen. Arthur MacArthur, commanding Second Division, Eighth Army Corps, under date of February 11, 1899, on the fight at Caloccan of February 10:

I have reserved for the end of this letter, mention of the exceedingly gallant and courageous conduct of Professor George F. Becker, U. S. Geologist, because in accordance with his idea of his duty he insisted on accompanying me into this fight and remained with the Company, much of the time mounted, throughout the entire

engagement. He was as cool and collected as if he were pursuing geological investigations in his study, encouraged the men behind whom he was standing and rendered other valuable services which required him to pass mounted immediately in rear of the entire line. I am sorry that, not being a soldier, he cannot receive the reward which his courage and gallantry has entitled him to.

The view he took of his duty referred to above, arose from the fact that for sometime before this war he volunteered to assist me in the Information Bureau and the instincts of a courageous gentleman have prevented his abandonment of his self imposed task of following me wherever I go now that the expected war with the Insurgents has come about and sometimes calls me, in the line of my duty, into dangerous situations.

In justice to him however I should add that long prior to any certainty of hostilities he made me promise that if hostilities did occur I would permit him to accompany me wherever my duty called me. He has accompanied me, pursuant to his own desire, on every reconnoissance I have made and frequently against my judgment as to what was best for him.

Very respectfully,

Sgd. J. F. BELL,
Major of Engineers.

After the outbreak of hostilities, upon invitation of General McArthur, to whose staff Major Bell was transferred, Doctor Becker accompanied the latter to the front and participated in a number of military reconnoissances and engagements, rendering service that has been favorably reported to the War Department.

In May he made a journey to the island of Negros and endeavored to examine the deposits of tertiary lignite there, but the hostility of the natives prevented extended investigations.

While here he met with an adventure which gave him reputation quite unsought and along lines little expected. It seemed that he wished to examine a coal deposit near San Carlos, and for safety's sake was given an escort of a noncommissioned officer and 16 men. Notwithstanding this they were attacked by a considerable body of natives. The rest of the story is told in a clipping from the newspaper Freedom of September 29 of that year:

The men saw three lines of skirmishers surrounding the plantation. Guns were grabbed, orders given, and they were soon out and ready to meet the enemy; now here is where the "Old Professor" as the boys called him [Becker] shone. Emerging from the owner's house in his shirt sleeves, with a little popgun, a 32-caliber revolver, which he had borrowed from one of the boys, he took his position as commander on the right, accompanied by four comrades.

There was a hot fight for a time. Finally the rebels closed in on the right. The five men protecting that position awaited the charge calmly. When the insurrectos were within about 10 yards a volley rang out, and four blacks dropped. But one kept coming, and straight for the professor. Up went his little popgun and never a tremor in his arm. He fired and missed. The black was now almost upon him. Again he fired and this time he caught his man in the right arm shattering it, and causing him to drop the murderous looking bolo. A volley rang out and the black dropped at the professor's feet. When it was all over 12 dead insurrectos were counted.

"Well it's the first time I ever fired a pistol at a human being, boys, but I had to do it, and I did it."⁵

Incidental to this it should be stated that Doctor Becker was twice "cited" for bravery in the field during his stay in the islands.

On December 26, 1902, President Roosevelt called upon the National Academy of Sciences for a report on the desirability of instituting scientific explorations of the Philippine Islands and on the scope to such an undertaking, expressing his hope that such a plan might be adopted by Congress.

A committee of the academy, consisting of Messrs. G. F. Becker, W. G. Brewer, C. Hart Merriam, F. W. Putnam, and R. S. Woodward, representing Harvard, Yale, Columbia, the Department of Agriculture, and the Geological Survey, was appointed on January 14 following. Becker was elected secretary and under conditions usually prevailing may be assumed to have done his full share of the work.

The committee was unanimous in the opinion that scientific explorations of the Philippines were most desirable, both for the good of science and for the benefit of the inhabitants of the islands, and so reported on February 7, 1903.

On March 9 following, the President constituted a board of scientific surveys of the islands, consisting of Mr. C. D. Walcott, chairman, and Messrs. F. V. Coville, Barton Evermann,

⁵ "A day or two since a half tipsy soldier called on Bell to speak about the reconnoissance at Gaudalupe of February 20, and 'to shake the hand of a brave man.' Then he added, 'Say, Major, who was that old man [Doctor Becker] along with you?' and when he had heard, remarked 'Well he was a crackerjack, too.'"

W. H. Holmes, C. H. Merriam, Gifford Pinchot, and O. H. Tittmann, selected from the Government bureaus to consider the cost and other features of the plan proposed by the National Academy. The board made a report in harmony with the plan of the academy. It estimated the total expense for the first of the 10 years (including an item of \$250,000 for the purchase of three small vessels) at \$761,950. It also submitted the draft of a bill to provide for these surveys and memoranda as to their administrative conduct.

For reasons which it is not necessary here to discuss, even were they known, these recommendations were never carried out.

Doctor Becker was also a member of the committee of the National Academy of Sciences appointed in 1915 by President Wilson to consider and report upon the possibility of controlling the slides in the Panama Canal, which then threatened seriously to interfere with its usefulness, but was unable on account of ill health to visit the canal and participate in its deliberations. He had, however, been over the ground in 1913 in company with Geologist D. F. MacDonald, and rendered important service in the preparation of the final report.

With all his close attention to details in matters of science, Doctor Becker was by no means oblivious to the duties of citizenship. This appears in his correspondence relative to the Philippines, already referred to, and in numerous letters I find in his files. While not obtrusive in his manner, it would seem that he was by no means diffident. Convinced of the soundness of his own opinion or views on any subject, he did not hesitate to make them known wherever he felt they might be useful. The following letters are of interest and self-explanatory:

NEWBURY, N. H., *Sept. 26, 1901.*

MY DEAR BECKER: I thank you for your kind letter of the 21st and the speech you made at New York. Roosevelt's hard task would be easy if all men would give him the wise and reasonable consideration which you express in this speech.

As for myself, I can only thank you for what you say. Nothing can bring me back to where I stood last June. But I must "fight my course" being chained to the stake.

Yours faithfully,

(Signed) JOHN HAY.

MARCH 4, 1905.

DEAR MR. PRESIDENT: I do not feel able to allow this day to go by without expressing my congratulations on your past administration and cordial good wishes for that which begins to-day. You have justified the predictions which were made by some of your friends, including myself, at the time of Mr. McKinley's death, and have earned the confidence which the nation has lately expressed in you.

May nature continue to smile upon you and may the country continue to sustain you in raising the standard of national life.

Very respectfully, your obedient servant,

(Signed) GEORGE F. BECKER

Nov. 15, 1912.

DEAR DARWIN: ———— has informed me of your illness, bad news which at once recalled the details of many pleasant hours I owe to you.

Illness and suffering sometimes make a body lonely; and that is why I write to say how much I wish I could cheer you now as you cheered me when I lay ill at McKinney Hughes house. You have a host of willing friends who hope all good things for you and know that you have deserved them. May our wishes be efficacious.

Pray do not dream of answering this greeting or of asking any one to do so. I sympathize too keenly with Lady Darwin and your children to burden them with needless letters.

Most cordially yours,

(Signed) G. F. BECKER.

So. Lee, July 16, 1915.

Doctor OTIS SMITH.

DEAR DOCTOR SMITH: I have read your Greek & B K address with pleasure and I think it ought to do good.

There is an argument for public spirit on the part of university men which I have never heard emphasized. Perhaps you might like to use it in some future address. University education is to a large extent gratuitous; for the undergraduates at Harvard or the Johns Hopkins do not pay fees covering more than a fraction of the expenses of their education. Men who seek or use their university training solely for their personal service are almstakers. Only by public service can educated men repay the debt they incur and thus fulfil the designs of the founders.

Cordially yours,

(Signed) GEORGE F. BECKER.

A striking feature of Doctor Becker's career was his versatility, which he seems ever to have cultivated, rather than held in check. An interesting illustration of this is afforded in a paper (lecture) prepared by him in 1904, entitled: "How small an Army we need." The purport of the paper can not here be further elucidated than to state that a copy of the same being sent Brig. Gen. J. F. Bell, then at Fort Leavenworth, Kans., received the following indorsement:

INFANTRY AND CAVALRY SCHOOL AND STAFF COLLEGE,
OFFICE OF THE COMMANDANT,
Fort Leavenworth, Kansas, Sept. 17, 1904.

DR. GEORGE F. BECKER,
Washington, D. C.

MY DEAR DOCTOR: I have received the article entitled: "How small an Army we need," which you have kindly sent me for criticism. I not only have no criticism to make, but am astonished that a man who has never been a professional soldier could have written so soundly on the subject you have selected. I have submitted this article to many of my assistants on duty with this college, and it meets with the hearty concurrence of all of them. We find the matter of which it treats so clearly and cogently set forth that we would be greatly gratified to see it published in some form or periodical where it could reach the masses of our non-professional fellow citizens. You have not even made any technical error in the statements of fact or deductions. We only hope that there is a respectable percentage of our fellow countrymen who may be able to see this matter in the same light that you do.

Hoping you may continue your studies and efforts on behalf of the country in this line, believe me,

Truly and sincerely yours,

(Signed) J. F. BELL,
*Brigadier-General, U. S. Army,
Commandant.*

It is difficult to write of the purely personal side of Doctor Becker, since few of those who were associated with him and knew him at all intimately are now living. That he was of more than ordinary affectionate nature both as boy and man is evident from his correspondence; this is particularly conspicuous in his letters to his mother. Few but his most intimate friends could see in this seemingly unemotional man, absorbed in problems of science, one whose daily letters to wife and mother were concluded in language of the tenderest endearment.

"I owe him a debt," writes his one time assistant, H. W. Turner, "for his rigid requirements of exact notes on all geological matters . . . In camp we found Dr. Becker always a good sport and an interesting companion."

"In thought and manner," writes Doctor Day, "Dr. Becker was a true pioneer, absolutely fearless, impatient of limitations, quick to get at the heart of the problem, direct and vigorous in its prosecution, and with an untiring spirit even under the strain of protracted illness which clouded the closing years of his life." And again, "Like most pioneer thinkers, Dr. Becker was by necessity the master of several fields of scientific research. He possessed an excellent working knowledge of mathematics, physics, chemistry, and geology, and used all these with the greatest freedom and effectiveness throughout all his work. With the possible exception of Gilbert, there is no man of his time in the Washington geological work who possessed greater versatility in discussion or such breadth of view." And still again, in a personal note to the present writer he says: "I cherish Dr. Becker's memory as that of one of the finest men, one of the soundest scientists, and one of the best friends I ever knew."

Highly commendatory is the following extract from a letter written by General Bell to Mrs. Becker—the mother—under date of February 21, 1901:

Your son and I were strongly drawn toward each other, because we lived here together at a time of great distress, and we found our ideas accorded respecting the propriety and impropriety of matters in general. We easily became indignant at abuses committed by Americans and worked hard together for the credit of our land and nation. His strong conviction and determination was a support to me in many cases of doubt and uncertainty. His companionship on the battle-field was inspiring. Bravery is expected in a soldier. He gets no credit from having it, but great discredit if he has it not, but bravery is not expected from those whose business is other than fighting. They have nothing to gain and all to lose from being killed; whereas a soldier may gain undying fame by losing his life on the field of battle. Therefore, when a man takes his life in his own hands, as your son did, inspired solely by an interest in his nation, and the manly instinct antagonistic to cowardice, he is deserving of credit indeed. No bond of affection is so strong as that which is created by the sharing of mutual dangers. I think our satisfaction might have been more complete had we had your strong intellect and sympathy to aid us at a time when much hardship and suffering was visible on every side.

The most prominent characteristic of Doctor Becker, as viewed by the writer, was his persistent aggressive attitude toward geophysical problems and the establishment of a laboratory for the experimental work essential to their solution. This was the one dominant feature of his career and one which was ultimately crowned with success by the establishment of the Carnegie Geophysical Laboratory. That he was thoroughly in earnest in this is shown—if further evidence is needed—in his last will and testament, by which his entire residual estate is to pass to the Smithsonian Institution to be applied to “the advancement of geophysics.”

His thoughtfulness and willingness to assist in matters covering a wide field was little realized by the majority of his acquaintances. It was at his suggestion that there was established in 1909, by the National Academy of Sciences, a medal to be conferred from time to time upon men “who can not be classed as eminent scientists, but who are eminent in the application of science to the public welfare.” His article in the *National Geographic Magazine*, “Revolt of the Uitlanders,” was a model of unprejudiced plain speaking and unquestionably did much toward clarifying the public mind on a subject concerning which it was at best poorly informed. His remark in that connection that “no man of ordinary virtue who does not identify himself with the country in which he lives, to whom that country is not a ‘home’ will use his official power . . . for the best interests of the community from which he longs to be gone” is worthy of repetition.

Becker took an ardent and decided stand in the Great War; and though there is found little on the subject in his correspondence, it is known that he was thoroughly American in thought and action.

Doctor Becker enjoyed a wide range of acquaintances both among the scientific fraternity in America and abroad and what is commonly spoken of as “society,” particularly that of the higher circles of political life, and around his hospitable table there gathered not only members of the congressional delegations, but the Cabinet, Supreme Court, and foreign legations as well.

Doctor Becker received the degree of Ph.D. (*summa cum laude*) from the University of Heidelberg in 1869, being, it is said, the first foreign student to attain this distinction, and was graduated with high honors from the Royal Academy of Mines of Berlin in 1871. He was an original fellow of the Geological Society of America and was president of the same in 1914. He was a member of the National Academy of Sciences, the Washington Academy of Sciences, the Geological Society of Washington, the American Institute of Mining Engineers, and an honorary member of the Geological Society of South Africa. With the exception of the two years 1892–1894, when the position was abolished for lack of appropriations, Doctor Becker held in the United States Geological Survey, for the entire period from 1880 until his death, the position of “geologist in charge.”

He represented the Government in different geological congresses and in the Radioactivity Congress in Brussels of 1910.

Doctor Becker was thrice married. First to Sarah M. Barnes, from whom he was legally separated in 1879, and on June 17 of the same year to Alice Theodora Watson, who died early in the year following. On February 11, 1902, he was married to Florence Serpell Deakins, who survives him. During the later years of his life he suffered severely from asthma and its complications, but retained active interest in his work until the last. He died at his home in Washington, April 20, 1919, at the age of 72 years.

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