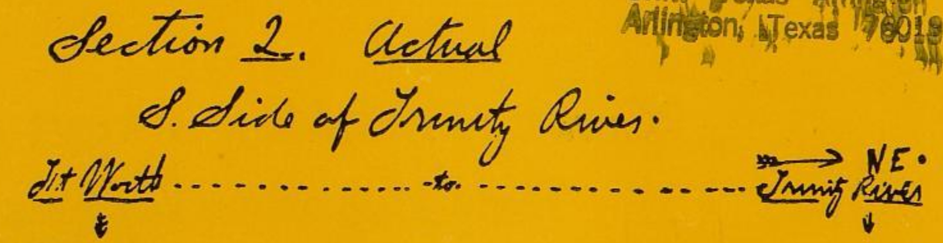
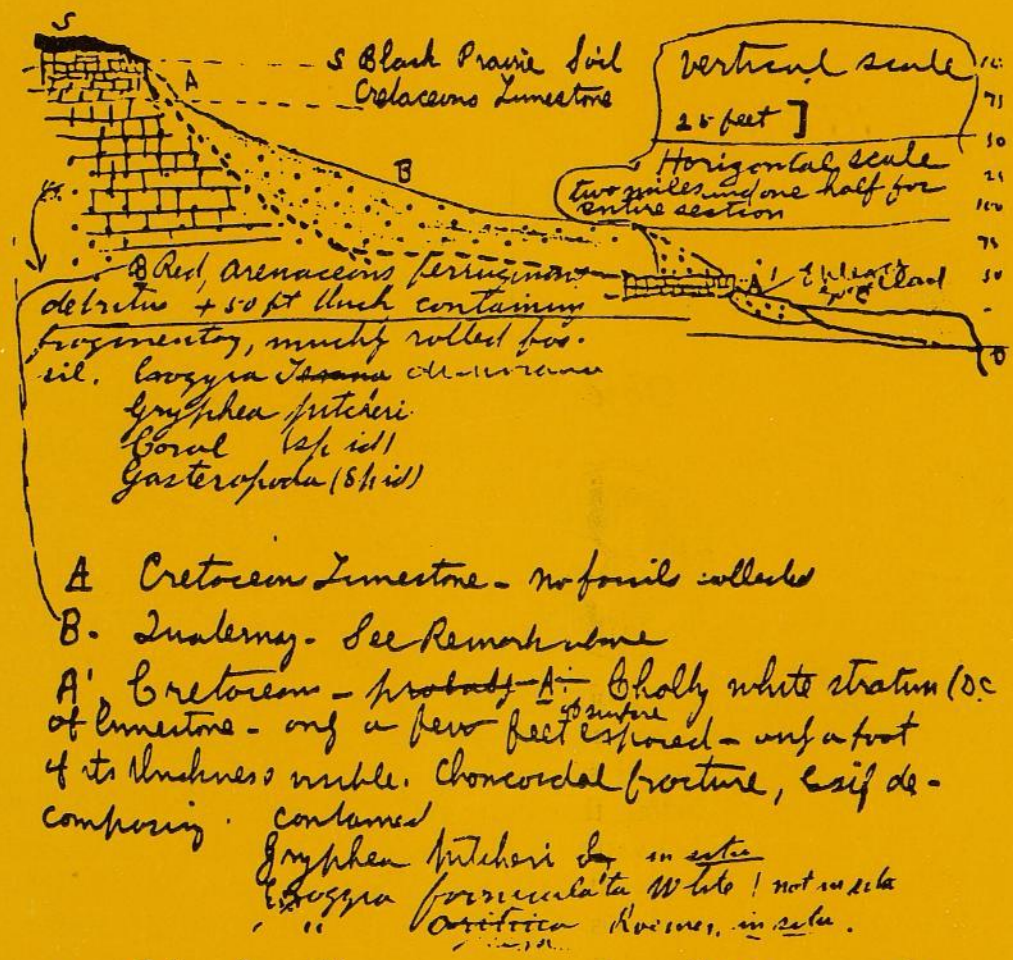


BAYLOR GEOLOGICAL STUDIES



FALL 1976

Bulletin No. 31

The Significance of Robert Thomas Hill's Contribution to the Knowledge of Central Texas Geology

PAUL NOBLE DOLLIVER

"Creative thinking is more important than elaborate equipment--"

Frank Carney, Ph.D.
Professor of Geology
Baylor University
1929-1934

Objectives of Geological Training at Baylor

The training of a geologist in a university covers but a few years; his education continues throughout his active life. The purposes of training geologists at Baylor University are to provide a sound basis of understanding and to foster a truly geological point of view, both of which are essential for continued professional growth. The staff considers geology to be unique among sciences since it is primarily a field science. All geologic research including that done in laboratories must be firmly supported by field observations. The student is encouraged to develop an inquiring objective attitude and to examine critically all geological concepts and principles. The development of a mature and professional attitude toward geology and geological research is a principal concern of the department.

The Baylor University Press
Waco, Texas

BAYLOR GEOLOGICAL STUDIES

BULLETIN NO. 31

The Significance of Robert Thomas Hill's Contribution to the Knowledge of Central Texas Geology

Paul Noble Dolliver

BAYLOR UNIVERSITY
Department of Geology
Waco, Texas
Fall, 1976

Baylor Geological Studies

The Baylor Geological Studies Bulletin is published semi-annually, Spring and Fall, by the Department of Geology at Baylor University. The Bulletin is specifically dedicated to the dissemination of geologic knowledge for the benefit of the people of Texas. The publication is designed to present the results of both pure and applied research which will ultimately be important in the economic and cultural growth of the State.

ISSN 0005-7266

Additional copies of this bulletin can be obtained from the Department of Geology, Baylor University, Waco, Texas 76703. $1.05 postpaid.

CONTENTS

ILLUSTRATIONS

The Significance of Robert Thomas Hill's Contribution to the Knowledge of Central Texas Geology

Paul Noble Dolliver

ABSTRACT

Robert T. Hill's observations and conclusions regarding the geology of Central Texas are frequently recognized for their remarkable durability and validity in light of subsequent investigations. Hill's geological contribution, as seen through his participation in government science, his work, and the works that preceded him, illustrates the unique combination of factors that determined the ultimate success of his endeavor. These factors, considered in terms of the man, his methodology, and the region he chose to study, suggest that the stature of Hill's work was the product of his being the first competent geologist to examine and describe Central Texas in sufficient detail and with sufficient tools to define its chief geological features.

INTRODUCTION*

Most students of Texas geology are familiar with Robert Thomas Hill's contribution to the geological knowledge of Central Texas. Hill's work is frequently cited as the basis for most subsequent investigations, an enduring foundation whose durability and validity have been sustained by more extensive and detailed inquiry. This work is an attempt to explain the remarkable durability and validity of Hill's basic geological conclusions regarding Central Texas by isolating and analyzing those significant factors that determined the unique stature of his contribution.

ACKNOWLEDGMENTS

The writer wishes to express appreciation to Professor Stanley W. Campbell, Department of History, and Professor O. T. Hayward, Department of Geology, Baylor University, for their constant guidance in the preparation of this study. For assistance in the acquisition of source materials the writer is indebted to: Mr. James G. Stephens, Head Librarian, Science and Engineering Library, Southern Methodist University; Dr. Chester V. Kielman, Librarian-Archivist, Barker Texas History Center, University of Texas; Mr. Bob Tissing, Assistant Librarian, Barker Texas History Center; the staff of the Field Records Division, U. S. Geological Survey Library, Denver, Colorado; and the staff of Moody Memorial Library, Baylor University. Special thanks are also extended to Mr. Kent Keeth, Librarian, Texas Collection, Baylor University, for his helpful comments and criticisms; to Mr. Don Little for assistance in field work; to Mr. Chris Hayward for assistance with photography; and to those students and faculty of the Geology Department, Baylor University, who made it all worthwhile.

Special appreciation is due Dr. Claude Albritton, Southern Methodist University, for his careful review of the manuscript before publication.

*A thesis submitted in partial fulfillment of the requirements for the B.S. degree in Geology, Baylor University, 1975.

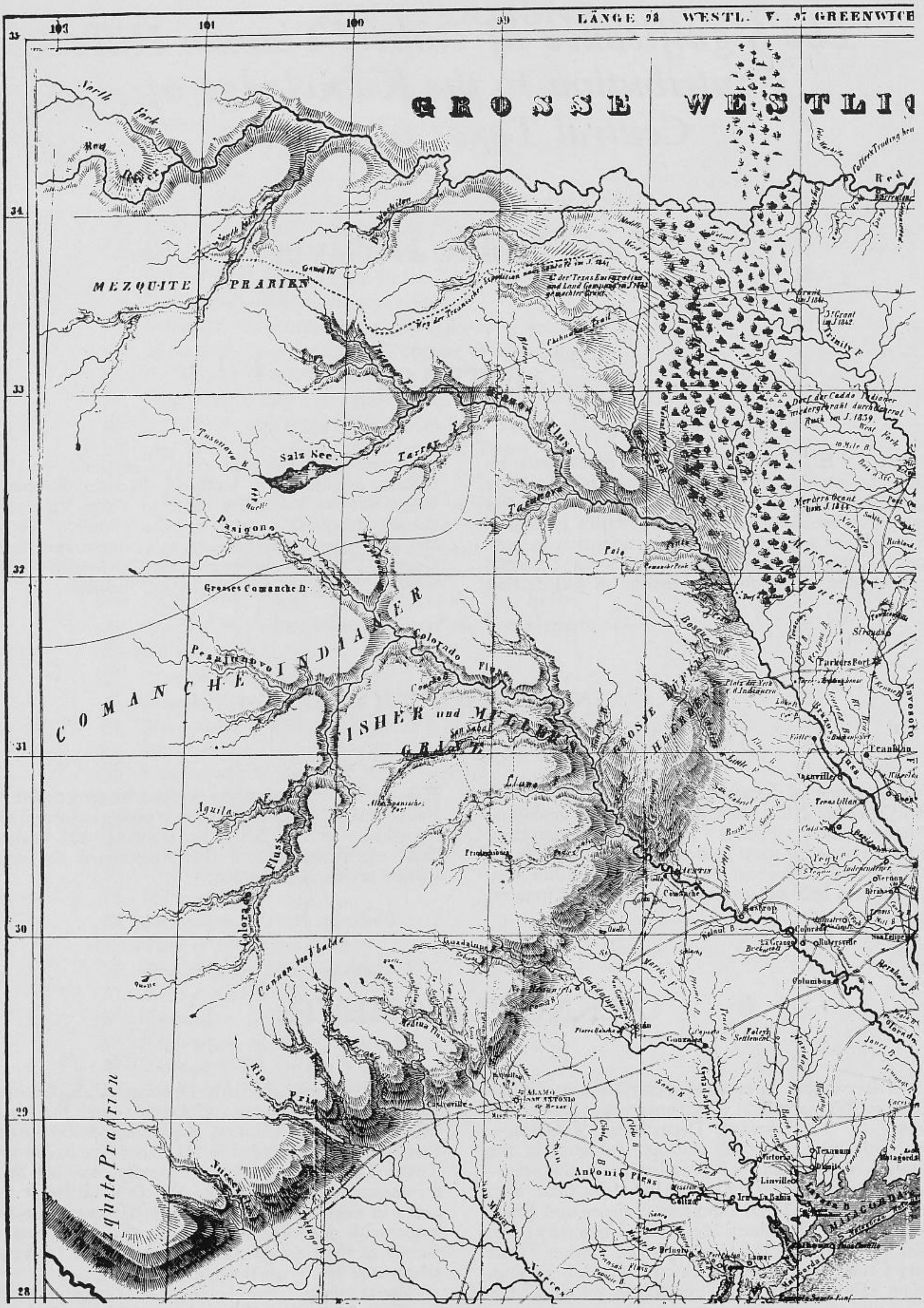


Fig. 1. A portion of Roemer's map of Texas showing his delineation of the eastern border of the Cretaceous. Roemer, 1852.

HILL AT CORNELL

In the spring of 1882 twenty-three year old Robert Thomas Hill boarded a train bound for Ithaca, New York. He carried with him a trunkful of fossils, the product of years of wandering through the country surrounding the frontier town of Comanche, Texas. Here the lonely sensitive boy had nurtured an interest in geology, and an ambition to pursue that interest through formal training. His letters of inquiry had led to correspondence with Andrew D. White, president of Cornell University. Subsequently, arrangements were made for Hill to attend this institution where "any person might find instruction in any study" (Miller, 1964, p. 249).

Hill's arrival in Ithaca marked his introduction into the realm of academia, dominated by a scholastic aristocracy. This eastern intellectual community, engaged in the noble quest for knowledge (a sharp contrast to the crudities of frontier existence), fired the enthusiasm of the young man from Comanche (Hill, 1931a). Hill began in earnest studies designed to supplement his meager education and, after several months' training in some fourteen subjects, he was admitted to Cornell (Vaughan, 1944, p. 148).

During the 1880's Cornell University experienced growth and change that was representative of the dramatic developments occurring throughout the academic world. The considerable private endowments that had initially enabled reform-minded educators of the 1870's to escape the strictures of sectarianism and paternalism (Hofstadter, 1963, p. 275) now provided funds for libraries, laboratories, and fellowships that attracted more and better students and teachers. Academicians like Andrew White directed this growth along the lines of the German University, emphasizing scientific specialization and research (Herbst, 1965, p. 19). The effort reflected the demands of an increasingly complex and specialized society, a society whose broad influence produced the academic freedom and research tradition necessary for individual and creative scientific investigations.

Hill's geological training at Cornell was characterized by a high degree of flexibility that facilitated individual research. Formal course offerings were subordinated to the "objective method" of exciting the student's interest in a subject to the degree that he would independently pursue that interest further (Hill, 1931b, p. 33). Professor Henry Shaler Williams implemented this method during the years of Hill's residency. Williams took advantage of the rich field of Devonian strata surrounding Ithaca by placing primary emphasis on the study of paleontology. This study was intended to combine instruction, exploration, and original research (Bishop, 1962, p. 245).

There had been a paleontologist in the geology department almost since Cornell's founding; consequently, a fine collection of local fossils had been assembled (Hewett, 1905, vol. 2, p. 241). This collection was utilized as a primary means of instruction, as indicated by this excerpt from the Cornell *Register* for 1874.

> The early training of all geological students consists in the personal, critical examination of specimens, the student being required to find out everything for himself, without the consultation of books. On entering the laboratory, one or more good specimens are placed before him, the difference between *seeing* and *observing* is explained, and he is directed to observe, as carefully as possible, all their characters, and record in drawing and writing, in a suitable book, his observations just as he makes them. . . . Having carefully observed several specimens of more or less nearly related forms, he is then required to compare these with one another, and determine what characters are common to all, or what distinguish each. Only after he has completed his work for himself is he allowed to consult authorities, and, by comparing his own work with that of a master, test the accuracy of his own results. (Bishop, 1962, p. 172)

Professor Williams instituted elaborate paleontological surveys extending from Ohio in the West to the Catskill Mountains in the East as a means of encouraging exploration and original research (Hewett, 1905, vol. 2, p. 234). His particular interest in the development of precise methods of fossil study and the utilization of these methods in age determinations gave direction to the student surveys and ultimately resulted in the publication of the Devonian correlation papers for the United States Geological Survey (Ibid. p. 239-40). R. T. Hill, in addition to being a conspicuous contributor to this research effort, was encouraged by Williams to compile the material on Texas geology that he would use in writing his Bachelor's Thesis (Wrather, 1941, p. 2223).

It was in connection with his interest in Texas geology and his excellence as a student that Hill's name came to the attention of Major John Wesley Powell, then director of the recently organized U. S. Geological Survey. He invited Hill to Washington for an interview and thereafter offered him a position with the survey (Alexander, 1973, p. 25). Having finished the research and most of the writing of his thesis, Hill arranged to leave school a year early and graduate the following year (Ibid. p. 26). He accepted Powell's offer and joined the Survey in June, 1885 as Assistant Paleontologist in the Division of Mesozoic Invertebrate Paleontology, under the direction of Dr. Charles Abiathar White (Ibid. p. 27).

The instruction at Cornell was significant to Hill's geological training in that it fulfilled what was then considered one of the paramount purposes of liberal education, the development of the "judgement and reasoning powers" (Williams, 1893, p. 40). Research was seen as a valuable extension of classroom instruction, designed to inculcate upon the student the "spirit of the investigator" (originality and independence of view) and develop his powers of "observing accurately, recording correctly, comparing, grouping and inferring justly, and expressing cogently the results of these mental operations" (Ibid.). Exercises in fossil identification, field surveys, and the researching and writing of a thesis reflecting original investigation and thought were all means toward this end.

The geology department at Cornell had been severely chastised for the paucity of classroom instruction (Bishop, 1962, p. 239). But even such leading institutions as Harvard, where a good deal of geology was taught in the classroom, produced students that were incapable of defining the geology of an unknown region (Fairbanks and Berkey, 1952, p. 109-10). In light of this fact, Hill was probably better qualified than most to serve the U. S. Geological Survey. But although he was praised as a mature, perceptive, and industrious student (Alexander, 1973, p. 24)—and would receive Special Distinction in Geology at the 1887 commencement at Cornell (Hewett, 1905, vol. 3, p. 388)—he was as yet unprepared to pursue independent field investigation with the sophistication that characterized the research efforts of the U. S. Geological Survey.

HILL AND GOVERNMENT SCIENCE

The very existence of the U. S. Geological Survey was indicative of the expanding influence of science in nineteenth century America, an influence expressed in the trend toward national centralization, institutional organization, and specialization. The Survey's establishment was an attempt to rectify administrative chaos in Washington and a duplication of Hayden, King, and Powell's efforts in the field (Miller, 1964, p. 137). In addition, it affirmed that systematic scientific investigation was indeed a necessary and legitimate function of the national government (Leighton, 1951, p. 574).

The consolidation of the western surveys under a single national agency was only one manifestation of the institutional organization and diversification taking place within the realm of geological science. The move from Cornell to Washington placed Robert Hill in the midst of American scientific society. Washington was one of a number of cities whose concentration of colleges, libraries, and museums lured scholars and provided the nucleus for the development of scientific societies (Bruce, 1972, p. 78). These societies, in addition to stimulating research and facilitating scholastic interchange (Curti, 1964, p. 571), reflected the diversification and specialization of interest needed to keep pace with the flood of new scientific facts.

Hill began frequenting the Cosmos Club soon after his arrival in Washington. The club was a gathering place for great intellects of several disciplines; it served also as the meeting hall of scientific societies; and it was here that Hill delivered his first scientific paper on the geography and geology of the Cross Timbers of Texas (Hill, 1937). He reveled in the "coterie of great scientists" who lived in what he termed the "Periclean Age of science" (Hill, undated a). But while the scientific life of the capital was a stimulating intellectual challenge, it was also a source of bitter disillusionment for the young geologist from Cornell.

The passion for facts and the ambitious research endeavors that characterized the "new breed" of scientist were accompanied by a fierce competitiveness in the quest for knowledge, a competitiveness that nurtured secrecy, suspicion, and outright denunciation. Intense rivalries developed, especially among geologists (Dana vs. Hall, Cope vs. Marsh), that received nationwide public attention and tended to discredit the Geological Survey and unify opposition forces (Darrah, 1951, p. 339). Less than a year after his joining the Survey, Hill too became embroiled in a professional dispute that had a profound influence on his professional career.

During the summer of 1886 Hill made an excursion with his superior, Dr. C. A. White, over a section from Elmo to Millsap, Texas. White asked Hill for a brief table of the stratigraphic sequence and formation names to use in a paper of his, guaranteeing that Hill would receive full credit. When his article was published the next year Hill was not given credit. Hill's protestations that he had published first and that White had given him insufficient credit in his article were met by demands by White that Hill be discharged from the Survey and his notebooks be turned over to White—Major Powell decided in Hill's favor (Vaughan, 1944, p. 150). Hill was by nature highly sensitive to the opinions of others, to the point of being defensive toward the very slightest rebuke, or what he interpreted to be a rebuke. This experience with White awakened him to the bitter realities of competition within the scientific community and instilled in him a pervasive distrust of professional colleagues that often precipitated senseless rivalries and constituted a detraction from his productive energies (Hill, 1931b).

The mere fact that R. T. Hill was a member of the U. S. Geological Survey had far more important implications regarding his professional career than the pernicious effects of personal encounters with White and others. The Geological Survey (as opposed to, say, academic institutions) virtually controlled the science of geology in the United States during the latter part of the nineteenth century. Such control was possible because it had the advantage of a dual organization, exercising the power of a government agency and enjoying the freedom of a scientific society (Manning, 1967, p. 216).

The Survey's power as a government agency was the product of ample federal funding and the administrative freedom given Powell in utilizing those funds; its freedom is attributable not only to his power, but also to the favorable research conditions it provided its members. Powell's first assertion in defense of the Survey's dominance of American geology was that one national survey was more efficient than many state surveys and that the "plant for geological investigation was too expensive for private agencies" (Dupree, 1957, p. 226). The special problems of frontier life caused self-sufficient research expeditions to be prohibitively expensive; only heavily subsidized or extremely wealthy scientists could hope to publish elaborate illustrated publications, and the great mass of field observations and laboratory results almost precluded the individual scientist's success without the cooperative support of specialized talent. Powell's utilization of Survey funds to build up a highly competent and specialized scientific staff, to provide favorable research conditions (free from economic burdens), and to supply a ready means of publishing results established the U. S. Geological Survey as the government's most productive research agency during the nineteenth century (Manning, 1967, p. 216). Robert T. Hill's membership in this agency is a vital key to his success as a geologist and the significance of his scientific contributions.

The historical significance of Hill's contributions can be measured by the degree to which he reflected or satisfied the goals of government science (specifically, the U. S. Geological Survey) regarding both scientific and economic development. Practitioners of science under government auspices encountered the question of whether their research efforts should be pursued in the interest of pure science or of practicality and utility. John Wesley Powell approached this dilemma with the "optimism of discovery"—the faith that science in the service of mankind was a great and profitable ambition—and with a proclivity for order and organization (Darrah, 1951, p. 354). He saw the Geological Survey's purpose as being one of a great fact-finding agency, and thus emphasized the discovery and classification of new materials and the publication of results (Herbst, 1965, p. 38). He attempted to place this great fact-finding or research effort within the context of the government's role of promoting the welfare of the people by "providing for investigations in those fields most vitally affecting the great industries in which the people engage" (Dupree, 1957, p. 226).

In reality, what Powell did was to provide Survey members with the means and justification of pursuing either pure or practical research. Such a practical design as the completion of a national map to guide land classification and settlement was considered no more valid or important as a research endeavor than the pursuit of paleontologic research. The generous appropriations to the Division of Paleontology were evidence of this (Ibid. p. 213). Powell asserted that the Survey's concentration in areas of theoretical as well as economic interest stimulated private or local (state) research by virtue of the fact that the possession of knowledge was not exclusive, that individual gains by discovery were gains for all men (Ibid. p. 227). The significance of this view lay in the fact that while it was often fiercely contradicted by members of Congress, state legislators, and informed citizens, it did succeed in providing Survey scientists with a means of pursuing theoretical as well as practical work. But, while Hill and others were able to take advantage of this boon to theoretical investigation, they were often called upon to justify the Survey's research efforts by informing the public of the utility of their work.

Hill's function in this capacity was realized early in his career. In 1887 Powell sent him to Austin to lobby for the passage of legislation to establish a Texas state geological survey, a task which involved writing newspaper articles, circulating petitions, and delivering lectures and speeches (Hill, 1931b, p. 28). Whether Hill's efforts contributed much to the ultimate approval of the bill is questionable. The same grating personality that would later tend to offset his scientific accomplishments provoked opposition to the proposed survey on the grounds that it was advocated by a dude (*Galveston Daily News,* 1887, p. 5). But the fact that he sought popular support by attempting to clarify the geologist's role in society and dispel the myth of Texas' vast mineral reserves is significant.

It was not until the last third of the nineteenth century that the profession of geologist became clearly recognized and that professional standards were developed for that vocation (Mather, 1959, p. 1108). Thus most citizens were naturally vague in their understanding of the geologist's function in society. In Texas, where fundamentalism still resisted the challenge of Darwinian science, attitudes toward geology transcended vagueness to the point of hostility and contempt (Stanley-Brown, 1932, p. 81). But while Hill often encountered the sentiment that "a geologist and a raving maniac are the same thing," he noticed that even the most intractable farmer was receptive to information on his soils and advice as to the best place to bore wells (Fairbanks and Berkey, 1952, p. 111).

In accordance with his efforts to advise citizens of the practical applications of geology, Hill attempted to dispel the popular belief in the great mineral wealth of Texas. Observers since William Kennedy had reported rich deposits of iron ore, coal, lignite, and copper (Ferguson, 1969, p. 35). Anton Roessler's small scale geologic maps of Texas, the first of their kind, contained copious symbols of mineral localities, but failed to indicate the economic futility of attempting to work these deposits (Young, 1965, p. 37). Hill frequently encountered landowners who were sure of little more than that their property had a gold mine (Fairbanks and Berkey, 1952, p. 111).

The bill authorizing the establishment of the third Texas Geological Survey was passed May 12, 1888, and upon Hill's recommendation Edward T. Dumble was appointed chief geologist of the Survey (Vaughan, 1944, p. 157). The essence of Hill's attempts to inform the public of the folly of their misconceptions and of the utility of geological science were articulately expressed in the purposes of the Dumble Survey:

1. A search for ores, minerals, oils, coals, clays, and other minerals possessing a commercial value, and the determination of the question, whenever possible, whether they exist in sufficient quantities and under suitable conditions and surroundings to make it reasonably certain that it will be profitable to work them.

2. An investigation of the geological formation and the topography of the country with a view to determining the probability of obtaining artesian water and the feasibility of irrigating from such wells as from streams, shallow wells, or tanks where necessary.

3. The determination of the adaptability of soils to certain crops, and how their fertility can be increased by the use of minerals closest at hand.

4. The search for and development of useful articles as not yet fully known. (Dumble, 1889, p. 9).

Though local scientists like Jacob Boll, George Stolley, and E. T. Dumble had pushed for a state geological survey in the late 1870's and early 1880's, J. W. Powell was responsible for initiating the campaign that ultimately resulted in the creation of the third Texas Geological Survey (Ferguson, 1969, p. 81). The success of his endeavor extended the research interests of the U.S. Geological Survey into Texas. Whether this new research activity stimulated or inhibited local activity is subject to debate. Powell, of course, regarded it as a stimulus, but many state geologists complained of the lack of cooperation on the part of the national survey and its ignorance of the state survey's needs (Branner, 1890, p. 298). Hill's role in this dilemma would become clearer; the imperatives instigated by Powell and established by Hill's efforts to generate popular support for the Dumble survey guided his subsequent geologic work in Central Texas.

PREVIOUS INVESTIGATIONS

Robert T. Hill's first publication, "The Present Condition of Knowledge of the Geology of Texas" (Hill, 1887a), was a resumé of previous geological investigations in Texas, something he regarded as essential to the intelligent study of the state and eminently practical in terms of its usefulness to future investigators, whose scientific determinations would promote profitable economic development (Ibid. p. 89). From this exhaustive literature survey he was able to make the following perceptive observations, observations that would guide his subsequent research efforts:

1) There is no accurate knowledge of the essential topographic features of Texas upon which geologic work can be based.
2) The geologic work has been fragmentary, unconnected, uncorrelated, and unsystematic throughout. It has been mostly descriptive paleontology instead of stratigraphic work.
3) There has been very little accurate stratigraphic work recorded.
4) Most of the literature deals with broad generalities rather than with specific description. (Ibid. p. 88)

Hill attributed this "fragmentary and unsatisfactory" state of geological knowledge to some very tangible factors: hostile Indians, the Civil War, and abortive attempts at a state survey (Ibid. p. 7). An analysis of the major developments in the evolution of the geological knowledge of Central Texas prior to Hill's work reveals yet another limiting factor, governed to some extent by the factors he cites, but more significant in the implications it has regarding Hill's later contributions; that factor is methodology.

William Goetzman stated the following thesis in his book, *Exploration and Empire*: "... explorers, as they go out into the unknown, are 'programmed' by the knowledge, values, and objectives of the civilized centers from which they depart. They are alert to discover evidence of the things they have been sent to find" (Goetzman, 1966, p. 199). Similarly, the early investigators of frontier Texas geology were limited by their programming, or more precisely, by their methodology.

Dr. Ferdinand Roemer, the distinguished German geologist and paleontologist, arrived in Texas in December, 1845, to make a study of its suitability for German immigration. His observations between December, 1845, and April, 1847, were contained in four publications, constituting what Hill considered the most valuable contributions to the geological knowledge of Texas (Hill, 1887a, p. 15). On the basis of observations made during his travels, Roemer differentiated three physiographic regions: 1) the lowland along the coast; 2) the hill country or "undulating region," which he characterized as widespread open prairies with narrow forest strips limited to the river banks; and 3) the highland, consisting of a tableland of concordant summits incised by valleys and ravines (Roemer, 1852, p. 1). In addition, his observations of the Cretaceous strata from San Antonio to as far north as Torrey's Trading-house (Waco) allowed him to delineate the eastern border of the Texas Cretaceous (Fig. 1) and postulate its great westward extent (Hill, 1887a, p. 72).

Roemer lamented the fact that the most interesting geology commenced "where civilization ceases and the wilderness begins" (San Antonio de Bexar, New Braunfels, and Austin were "Western Texas" frontier settlements at the time) (Roemer, 1846, p. 358). Such physical limitations confined his studies to more accessible regions. Consequently, the majority of his deductions concerning the Texas Cretaceous were made from features observed in the vicinity of New Braunfels. The nature of these deductions elucidates the additional limitations imposed by Roemer's methodology.

The rather abrupt transition from Roemer's hill country to the highland in the region of New Braunfels was the prime focus of his observations of the Texas Cretaceous (Roemer, 1852, p. 1). He noted that the fauna of the plateau limestones near New Braunfels indicated a lower geologic horizon than the adjacent lower lying strata and postulated that such an inversion of the stratigraphic sequence with respect to the topography could have been the result of faulting (Ibid. p. 19). This hypothesis, he added, might also explain the sudden steep elevation of the highland and the conspicuous lithologic change from the "siliceous, chalky strata" of the highlands to the "less firm white limestone and marls" at the foot of the highlands (Roemer, 1849, p. 379). To this point, Roemer's methodology—his means of conceptualizing the problem and suggesting a solution based on careful analysis of a variety of criteria—was in accord with the methods of modern field investigation. His great errors, ones that would confound Texas geologists for the next thirty years, arose out of his attempts to formulate conclusions from too little evidence and within the context of erroneous presuppositions.

Roemer asserted that the faulting was in all likelihood a very local and isolated feature and that the age difference between the Cretaceous highlands and lowlands would prove to be negligible once more extensive stratigraphic comparisons were made (Roemer, 1852, p. 19). This contention, though unsupported by cited evidence, far outweighed his more valid deductions in the eyes of subsequent investigators. In fact, with the exception of Jacob Boll, a widely travelled naturalist of Texas (Boll, 1879, p. 380), and Jules Marcou (whose geological contributions will be discussed shortly), geologic researchers in Texas, up to and including Hill, almost totally neglected Roemer's observation of faulting near New Braunfels. This neglect probably resulted from translation difficulties (Ferguson, 1969, p. 34); but more significantly, it reflected the willingness of Roemer's successors to accept his judgments unquestioningly.

Roemer's minimization of the significance of the faulting near New Braunfels was only one indication of the unsuitability of his methodology to the explication of the unique geological circumstances present in Central Texas. While the faulting was the key to understanding Central Texas geology, the abundance of paleontological evidence available to Roemer could have provided a compelling indication of its true nature had his observations not been biased by European bases for analogy and interpretation. Because of the relative horizontality of the strata and absence of deeply incised valleys Roemer saw no opportunity to date the Cretaceous formations on the basis of lithologic criteria (Roemer, 1852, p. 19). His only recourse was to examine their organic inclusions. In the process, he described one hundred eighteen Cretaceous species, fifty-eight of them for the first time (Hill, 1887a, p. 72). While admitting that there were distinct lithologic and paleontologic dissimilarities between the Texas Cretaceous and the Cretaceous of the rest of North America and Europe, Roemer asserted that certain analogies did exist (Roemer, 1848, p. 24). He assumed the Cretaceous strata of Texas, despite their peculiarity, to be contemporaneous with those in New Jersey; and tracing the former across the Atlantic to southern Europe and the latter to Cretaceous strata in northwestern Germany, he postulated their faunal differences to be a product of climate, not time (Ibid. p. 25). Such a conclusion was made on the selective correlation of a few "characteristic forms" (to the exclusion of several anomalous forms) and in the absence of any stratigraphic correlations (". . . despite its considerable thickness, there appears to be no way to subdivide the Cretaceous of Texas on the basis of lithologic and paleontologic criteria") (Ibid p. 24). This assertion was in accord with prevailing geologic thought, which accepted as valid the concept of geological formations and isothermal lines of worldwide extent. Roemer was following procedures well established by Maclure, Eaton, Hall, and other American geologists in attempting to define the relative ages of North American strata from more precisely known European stratigraphic sequences; his methodology compelled him to date the Texas Cretaceous as the equivalent of the Chalk or Chalk Marl of southern Europe (Fig. 2) (Roemer, 1848, p. 24).

Scientists would later accord Ferdinand Roemer the title "Father of the Geology of Texas." Indeed, his work in Central Texas was a pioneering effort. Against severe limitations resulting from poor transportation and hostile Indians, he succeeded in collecting a wealth

Maestrichtian	Chalk	Upper Cretaceous
Senonian		
Turonian	Chalk Marl	
Cenomanian		
Albian	Green Sands	Lower Cretaceous
Aptian		
Rhodanian		
Urgonian	Wealden	
Neocomian		
Valengian		

Fig. 2. Table of periods in the Cretaceous "Epoch." *Adapted from* Agassiz, 1886, p. 173.

of paleontologic data. He utilized this data in conjunction with other geologic observations to postulate the extent of the Texas Cretaceous, to differentiate its character with respect to broadly defined topographic regions, and to determine its absolute age and relationship to European equivalents. Subsequent investigators operating under similar physical and methodological restraints generally accepted this outline as a point of departure rather than as a subject of contention, much to the detriment of their sincere efforts.

In February, 1858, an act of the Texas legislature authorized the state's first geological and agricultural survey. Later that same year Dr. Benjamin F. Shumard was appointed to the position of State Geologist. His most noteworthy effort in this capacity was the construction of a section of the Texas Cretaceous observed along a line extending from Austin to the Red River in Grayson County. Though this section, published in 1860, was accepted until the 1880's by most students of Texas geology, it contained a number of errors, the nature of which provides some indication of the inadequacy of Shumard's attempts to define the geology of Central Texas.

Hill noted that while B. F. Shumard's writings exhibited much labor they were "deficient in stratigraphy and are mostly of a paleontologic character" (Hill, 1887a, p. 76). The fact is, Shumard was recognized by his peers as an able paleontologist, not a stratigrapher (Ferguson, 1969, p. 57). His published section was not so much the result of accurate, systematic field investigation as it was a consequence of his efforts to synchronize various described sections. He had arranged his brother's (G. G. Shumard) observations on the Red River, Dr. Riddell's work with the First Geological Survey in Central Texas (McLennan, Coryell, and Bosque Counties, primarily), and his own and Dr. Roemer's observations near Austin to make up his section. Unfortunately, those investigations conducted north of the Brazos River, where the Balcones faulting grades into simple monoclinal folding, failed to note that the plateau limestones of Roemer's highland dipped beneath the chalky Upper Cretaceous limestones to the east (Ibid.). Shumard thus saw little reason to doubt, at least on the basis of the information used to compile his section, that the Comanche Peak and Edwards limestone of the highlands were the youngest of a normal succession of horizontal Cretaceous strata.

What most dramatically illustrates the deficiency of Shumard's methodology is the fact that despite his previous experience and an abundance of paleontological evidence, he failed to recognize the existence of an extensive Lower Cretaceous marine fauna in the limestone of the highlands west of the Balcones fault zone. Operating under the same methodological handicap that restricted Roemer, Shumard sought to adapt the Upper Cretaceous section of Iowa and Nebraska, described by Hayden and Meek some years earlier, to the definition of the Texas Cretaceous. He had, in fact, first studied Cretaceous fauna in this portion of the Great Plains; it was only later, in describing fossils collected by his brother, G. G. Shumard, on Marcy's expedition to explore the Red River, that he had his first opportunity to study the Cretaceous fauna of Texas (Marcy, 1854, p. 158). But despite his later assertions that he was unable to correlate Comanche Peak fossils with any in the Upper Cretaceous Nebraska section (Shumard, 1859, p. 585), Shumard's predilection for the fossil identifications and stratigraphic interpretations of his fellow paleontologist, Ferdinand Roemer, overshadowed any discrepancies he may have encountered.* Widespread belief in the veracity of Shumard's "topsy-turvy" section (as Hill called it) was sustained for over two decades by his reputation as an able paleontologist, the unprecedented scale of his endeavor, and the demonstrable accuracy of his correlation of the true Texas Upper Cretaceous with that of the other Gulf states (Shumard, 1861, p. 188-205).

Shumard's Cretaceous section was not entirely without its critics, the most competent of these being the European-trained geologist, Jules Marcou. Marcou had accompanied Lieutenant A. W. Whipple's thirty-fifth parallel survey, one of several surveys conducted in 1852 and 1853 to determine the most suitable route for a transcontinental railroad. The party traversed the extreme northwestern portion of Texas, roughly along the line of the Canadian River, where Marcou identified several fossils as Neocomian (Lower Cretaceous) in age (Marcou, 1855, p. 127). This age determination constituted the first well substantiated recognition of the Lower Cretaceous in North America (Stanton, 1897, p. 583). Its significance was furthered by the fact that Marcou extended this age designation to include the bluffs near Austin and New Braunfels and the hills around Fredericksburg, all of which Roemer had asserted were Upper Cretaceous. He also had the opportunity to examine samples collected near Denison, Texas, where G. G. Shumard had made his observations only a year before, affirming that these too were Lower Cretaceous in age (Marcou, 1854, p. 25).

Professor Marcou's remarkable discovery prompted him not only to conclude that the Cretaceous of Texas increased in age as one proceeded from east to west, but that Roemer's generalizations and Shumard's Cretaceous section were unquestionably wrong. He credited Roemer with having observed that the plateau limestones were older although topographically higher, but noted that the German paleontologist had erroneously considered the entire section to be Upper Cretaceous in age. With regard to Shumard's work, he made several more penetrating criticisms:

1. Confusion of topographic and stratigraphic elevations.
2. Negligible use of stratigraphic and paleontologic evidence.
3. Ignorance of European time equivalents of certain key Cretaceous fossils (especially the Neocomian).
4. Misrepresentation and misidentification of fossils.
5. Fossils listed independent of stratigraphic subdivisions. (Marcou, 1862, p. 90-93)

This critical appraisal of his contemporary's work illustrates the fact that although Marcou was similarly inhibited by the necessity of defining North American geologic features in terms of European equivalents, he did not succumb to the methodological pitfall of misinterpreting or ignoring data because it was not suggestive of either the European model or previous interpretations. Marcou possessed an advantage in that he was able to evaluate these previous interpretations in the light of evidence that he had personally collected. In other words, his conclusions were based on field observations, something—as Hill noted—that none of his critics could claim (Hill, 1887a, p. 26).

Jules Marcou's significant discoveries, if not accepted on the basis of their supportive evidence, should have at least stimulated thoughtful inquiry into the validity of his interpretations; instead, they were largely disregarded. The reasons were many. The European geologist had embroiled himself in personal disputes with American scientists, who subsequently sought in earnest to discredit his findings, pointing in particular to his careless dating of certain exposures in New Mexico (Stanton, 1897, p. 584). Convinced of the validity of Roemer's interpretations, and reassured by the knowledge that investigation of other regions of the United States had revealed no Lower Cretaceous strata comparable to those purported to exist in Texas, scientific opinion found Marcou's discoveries unacceptable.

*Actually, some of his last discoveries (Shumard, 1861, p. 188-205) would have necessitated a substantial revision of his section, perhaps to include a Lower Cretaceous sequence; unfortunately, he died before attempting such a revision.

METHODOLOGY

The exploration of the American West revealed to the geologist vast "new bonanzas of specimens, formations, and natural phenomena to describe and classify" (Bruce, 1972, p. 69) and ushered in an intensely exploratory phase of geological investigation—the "Heroic Age" of American geology. This period was aptly characterized by a deep commitment to accurate systematic field work and meticulous observation, its great advances often being credited to geologists' devotion to these ideals (Hartzell, 1896, p. 276). And while there was none of the extensive philosophical and methodological discussion that occupied the geological profession during the first half of the nineteenth century (Kitts, 1973, p. 261), there were concerted and successful efforts to standardize and systematize the pre-existing methodology to accommodate the new wealth of geologic data.

The greatest and most fundamental of Hill's contributions to the knowledge of Central Texas geology were made in the field of stratigraphic paleontology, and much of his success can be attributed to his mastery of the precepts of this discipline as advanced by John Wesley Powell and vigorously exercised by numerous U.S. Geological Survey and state survey geologists (Fig. 3). One of Powell's goals as director of the U.S. Geological Survey was to define clearly the most important principles of stratigraphic paleontology in the hope of facilitating more systematic and efficient research by American geologists. Before the 1880's there were no standardized criteria for the definition of stratigraphic units other than systems (Moore, 1941, p. 186). Used to delineate a group of deposits characterized by distinctive fauna and bounded by unconformities or horizons of pronounced lithologic change, these systems appeared to

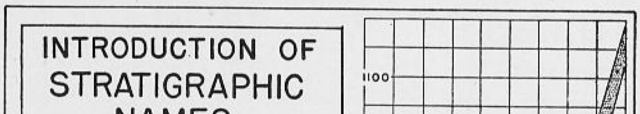


Fig. 3. A graph showing numbers of stratigraphic names introduced in North America during five-year periods from 1826-1935. Although it does not measure progress in stratigraphic research (as many of the names introduced probably reflect ignorance more than knowledge), it is still an accurate indication of the degree of activity in this field. Note the activity between 1886 and 1895. Moore, 1941, p. 196.

define natural rock units, especially in the region where each was first differentiated (Ibid. p. 185). What followed were attempts by geologists (as we have seen) to utilize these "type" systems in defining stratigraphic units elsewhere. By the 1880's, however, it was an accepted fact that stratigraphic columns in many parts of the world failed to match one another very closely; in fact, many investigators were highly skeptical of assertions that widely separated strata of similar paleontologic character were necessarily deposited contemporaneously (Ibid.). This realization may explain why the European tendency to place primary emphasis on paleontologic rather than lithologic criteria was not generally adopted by American geologists.

In Europe, most stratigraphic divisions were based on time intervals differentiated by the presence or absence of certain characteristic fossils, whereas in America, under the emphasis of Powell, classification was chiefly on the basis of lithology:

> The classification involved in a cartographic system designed for general use should be objective rather than theoretic; it should be based upon rock masses in their observed and readily observable relations rather than upon time intervals contemplated in historic geology, or even upon the organic remains contemplated in biotic geology; it should be petrographic rather than chronologic or paleontologic.
>
> . . . While the minor geologic divisions must have a natural basis, those of greater magnitude may be somewhat differently defined. The structural geologic unit is the 'formation'. It is defined primarily by petrography and secondarily by paleontology; and, in thoroughly studied regions, is generally found to constitute a genetic unit. (Quote by John Wesley Powell *in* Moore, 1941, p. 187.)

Despite this strong emphasis on the importance of lithologic criteria, it should be noted that paleontologic work was still essential to accurate stratigraphic work, thus the term "stratigraphic paleontology." But Hill recognized, as did most reconaissance geologists of his generation, that the usefulness of paleontologic data was not measured merely in terms of increased numbers of fossils available for correlation purposes, but in the more exact definition of those fossils with respect to a precisely determined stratigraphic sequence (Ibid. p. 202). Herein lies one of Hill's great advantages over his distinguished predecessors. Roemer, Shumard, and Marcou, though able paleontologists, were unsuited to the task of making accurate stratigraphic determinations; their methodology limited the value of their paleontologic observations.

American geologists also began to diverge from their European colleagues on the rules of stratigraphic nomenclature. Since James Hall's survey work in New York, American geologists demonstrated a tendency to apply geographic names to stratigraphic units (Ibid. p. 186). By the late 1880's, Powell's emphasis on this convention, like his emphasis on lithologic criteria for defining stratigraphic units, reflected the consensus of American geologic thought. The essential principles of stratigraphic classification and nomenclature were standardized approximately as they exist today (Ibid. p. 216). The success of Hill's effort in contrast to previous investigators, and more specifically, the remarkable durability of his stratigraphic column of the Texas Cretaceous, can be partially attributed to this fact.

Perhaps the most vital aspect of any methodology is the characterization of those intellectual qualities that are considered essential to an individual's success in that discipline—for all other mental procedures are merely manifestations of the refinement of those basic qualities. Geologists of the late nineteenth century were armed with minimal "aids to the normal faculties of observation" (Williams, 1893, p. 44). Because of this, and because they saw themselves "faced with the task of reconstructing events that happened on a vast scale and in the remote past from the partial remains of the products of those events," a premium was placed on the capacity to observe and reason (Bradley, 1963, p. 15). Observation was actually an intrinsic part of reasoning, and reasoning itself was the geologist's most valuable tool. As Bradley defined it: The geologist must reason analogically because all reasoning depends on analogy and the power to recognize it; "he must use inductive reasoning to reconstruct a whole from the parts," and he must use imagination, the capacity to visualize "in three dimensions and with perspective," to visualize processes "as they may have operated with time" (Ibid. p. 15-16).

These idealized qualities were given profound meaning in Hill's time by T. C. Chamberlain's concept of the multiple working hypothesis, the most significant methodological revelation in the science of geology during the latter half of the nineteenth century. Chamberlain very succinctly stated that in the process of geologic investigation the investigator must avoid the danger of being constrained, or "ruled," by a particular idea or hypothesis by becoming "the parent of a family of hypotheses . . . bringing into view every rational explanation of the phenomenon in hand and developing every tenable hypothesis relative to its nature. . . ." (Chamberlain, 1897, p. 843). Many of the most revolutionary and significant geological discoveries of the period can be credited to the deliberate or subconscious application of this principle.

Robert T. Hill came to Cornell with a maturing and perceptive mind. Here he was infused with an appreciation for originality and independence of view and supplied with the rudiments of precise observation and valid reasoning. Previous informal acquaintance with Central Texas geology from his residence there guided Hill's studies toward a complete and perceptive familiarity with previous investigations of the region, and gained him entrance into one of the nation's centers of scientific activity. In Washington he was stimulated and challenged by the great scientists of the age and was instilled with their fierce competitive and often destructive drive. As a member of a powerful and productive government agency with adequate physical and methodological means for research, he acquired a methodological framework and an awareness, conscious or not, of the intellectual requisites or qualities necessary to operate effectively within this framework. Equipped with this body of knowledge, procedures, and objectives, R. T. Hill advanced into the "unknown" frontier of Texas geology.

HILL'S CONTRIBUTION TO THE KNOWLEDGE OF CENTRAL TEXAS GEOLOGY

Robert T. Hill's systematic study of the geology of Central Texas began with a three month field assignment by Major Powell, Director of the U. S. Geological Survey. He spent most of the autumn of 1886 in the vicinity of Dallas-Fort Worth and Austin, visiting localities, measuring sections, recording observations, and collecting and identifying fossil and rock specimens (Appendix). Before the end of the year he had completed two papers, published in the prestigious *American Journal of Science* during 1887: "The Topography and Geology of the Cross Timbers and Surrounding Regions in Northern Texas" and "The Texas Section of the American Cretaceous." Together they constitute the first and most revolutionary of Hill's scientific contributions and the beginnings of his work on three features of Texas geology "which he continued to study until complete presentation": Texas physiography, Texas artesian waters, and Texas Cretaceous geology (Hill, 1931c).

In the process of reviewing the condition of geological knowledge of Texas, Hill (1887a) had included his own classification of the general topography of the state (Fig. 4), noting that each of the regions delineated had a "well marked individuality, although the boundaries between them cannot always be closely defined" (Hill, 1887a, p. 52). He hazarded such a definition in "Topography and Geology of the Cross Timbers," with his first physiographic map of Texas (Fig. 5). The map, with an expanded reiteration of his first attempt at topographic classification, introduced an extended description of the Cross Timbers (through which a stratigraphic section had been made) and presaged subsequent contributions that would culminate in a physiographic atlas of the Texas region.

A similar indication of the direction Hill's studies would take was provided by his brief mention of the occurrence of artesian waters beneath the Black and Grand Prairies at Fort Worth and Dallas. Their presence was again noted shortly afterward in a newspaper article in which Hill cited the lack of geographic maps giving accurate elevations and detailed information of strata as the chief obstacles to determining accurately the locality and productivity of artesian wells (Hill, 1887d). The intimation was that Hill's contribution to the knowledge of Texas' groundwater resources would increase as his knowledge of Texas geology grew—and so it did.

Director John Wesley Powell, in the *Annual Report* of the U.S. Geological Survey for 1886-1887, announced that "one of the most important events of the year in systematic geology was the discovery by Dr. [Charles A.] White and Mr. [Robert T.] Hill of a great series of Cretaceous strata in the State of Texas underlying the rocks hitherto regarded as the base of the American

Kennedy, 1841.	Ferd. von Roemer, 1848.	R. H. Loughridge, 1884.	Classification used in this work.	
The level region.	The level region (niedriges, flaches Land).	Southern and coast prairies. Gray silt and pine lands. Sea marsh. Oak, hickory, and pine region. Brazos delta and other alluvial lands.	(1) The coastal plain. Pine lands. Pine, oak, and hickory lands. Prairies of East Texas. Coast alluvium. Southwestern prairies.	Continuation of salient topographic features of coast plain of Louisiana, Arkansas, Mississippi, Alabama, &c.
Rolling or undulating region.	Hill land, or rolling or undulating region (sanftwelliges Hügelland).		(2) Black prairie region.	Continuation of black prairie regions of same States, except Louisiana.
Mountainous region.	Highlands (das zum Theil felsige Hochland).	Central black prairie region. Cross timbers. Sand hills and metamorphic lands of Central Texas. Northwestern red loam prairies and timber lands. Gypsum prairie region.	(3) Central or denuded region. Cross timbers. Coal Measures. Grand prairie. Butte districts. Hamilton County prairie. Granite region. Gypsum lands. Red prairies.	Peculiar to Central Texas and southern part of Indian Territory. Terminates west of San Antonio before reaching Rio Grande.
	Steppen-Lande.	Llano Estacado (table lands and sand hills).	(4) Plateau or Staked Plains region.	Southern continuation of Great Plains at eastern foot of Rocky Mountains, British America to Southern Texas.
		Plains with granitic mountains and probably "sand" desert of Rio Grande.	(5) Mountainous or trans-Pecos region. West of Pecos River and Lower Rio Grande, between Eagle Pass and Laredo.	Southeastward deflection and continuation of mountain region of New Mexico.

Fig. 4. The progressive classification of the topographic features of Texas, including Hill's first attempt at such a classification. Hill, 1887a, p. 53.

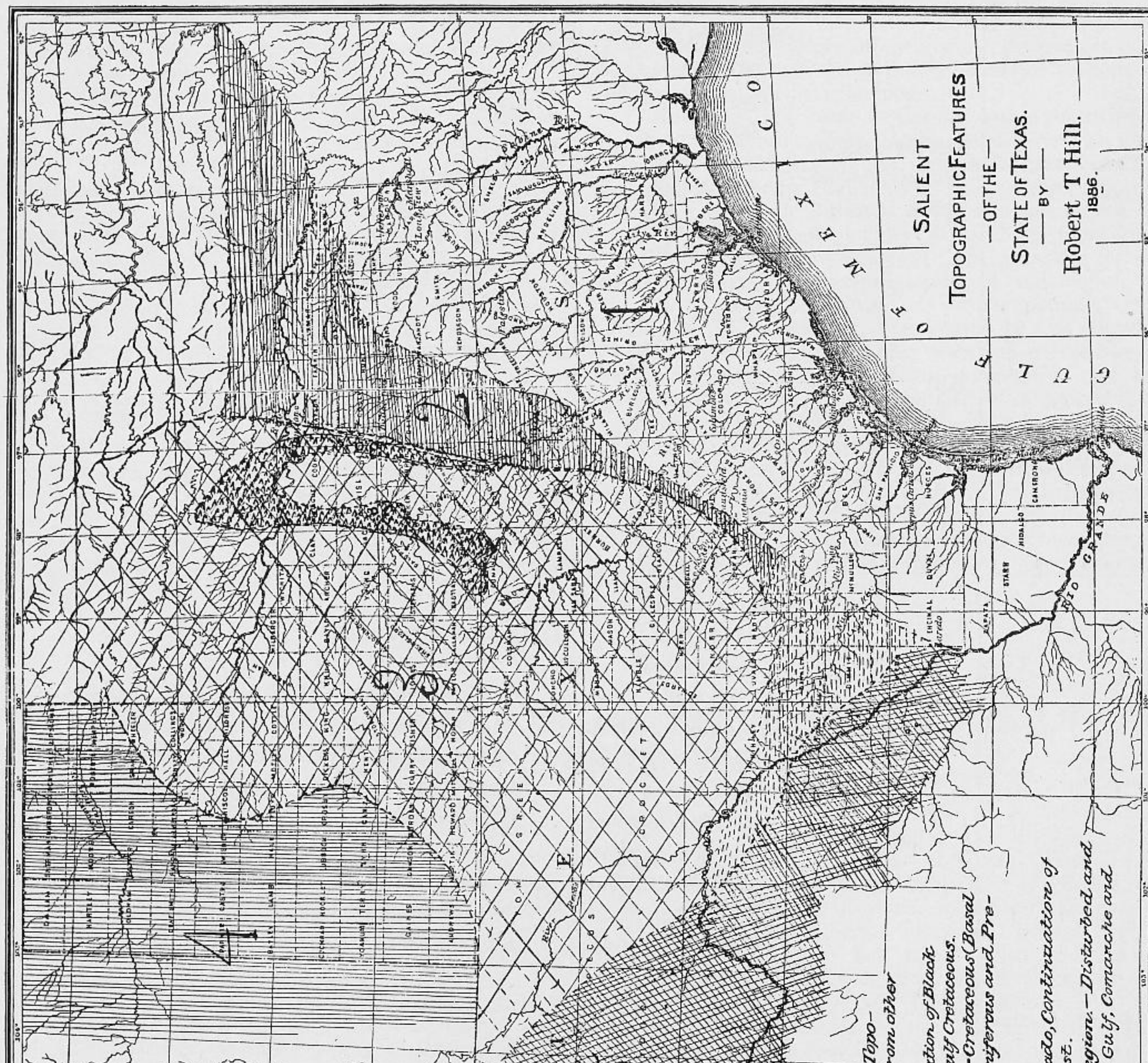
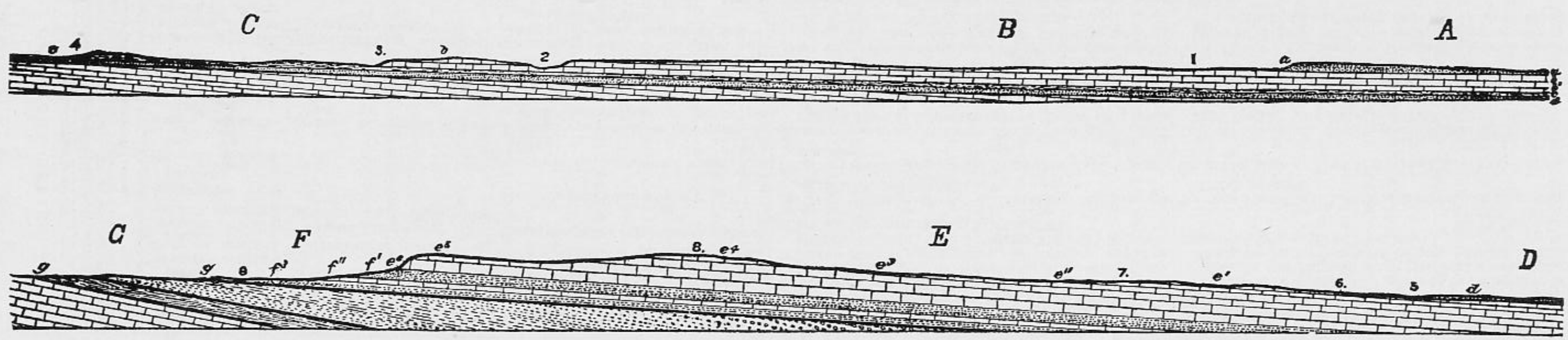


Fig. 5. Hill's first physiographic map of Texas. Hill, 1887b.



GEOLOGIC SECTION ALONG THE LINE OF THE TEXAS AND PACIFIC RAILWAY, FROM ELMO, KAUFMAN COUNTY, TO MILLSAP, PARKER COUNTY.

1. Terrel; 2. Dallas; 3. Eagle Ford; 4. Arlington; 5. Handley; 6. Fort Worth; 7. Ben Brook; 8. Weatherford; 9. Millsap.

A. Coast Plain—Marine Tertiary. B. Black Waxy Prairie—Riply and Rotten Limestone, of Gulf Series. C. Eagle Ford Shales, and accompanying prairies. D. Lower Cross Timbers—Timber Creek Group ("Dakota sandstone?" of Shumard). E. Grand Prairie Region—Comanche (Texas) Division of the Cretaceous. e', e'', e^3, Washita, or upper, division; e^4, e^5, e^6, Lower, or Fredricksburg (Comanche Peak) division. F and G. Upper Cross Timbers—f', f'', f^3, Dinosaur Sands; g, g, Carboniferous Coal-measures. Faunal horizons—e^8, Toxaster elegans Fauna; e'', Horizon of Gryphæa Pitcheri (var. Dilatata) with Ostrea carinata; e^3, Gryphæa Pitcheri, var. Fornicula (Exogyra forniculata; e^4, Ammonites vespertinus; e^5, Hippurites (Caprina) Limestone; e^6, Comanche Peak Fauna, including horizon of Gryphæa Pitcheri with Ostrea Matheroniana.

Fig. 6. Hill's first detailed profile section of the Texas Cretaceous. Hill, 1887b, p. 296.

Geologic Section of the Cretaceous Strati of the State of Texas, as seen along the Line of the Texas Pacific Railroad, from Elmo, Kaufman County, to Millsap, Parker County, and, with local Variations of thickness, as it occurs throughout the State. Based upon personal Observation. By Robert T. Hill. *

Series	Division	Position.	History and Synonymy.	Stratigraphy.	Paleontology.	Occurrence along Texas Pacific R.R.
		BASAL TERTIARIES.				Van Zandt Co. west to Elmo.
GULF SERIES.	Upper Cretaceous.	NAVARRO BEDS.	Ripley Group of Shumard, 1861. (3) (2) Loughridge, 1884. (4) Included by Rœmer in Kreidebildungen am Fusse des Hochlandes. (5)	Marls, clays, and limestones, of varying hardness, and in beds of limited extent. Mostly concealed by the prairie soil.	"I have been able to recognize the following species common to the Tippah (Miss.) and Navarro (Texas) beds: Nautilus Dekayi, Baculites Tippaensis, B. Spillmani, Purpurea cancellaria, Rapa supraplicata, Strombus densatus, Ficus subdensatus, Pleurotoma Ripleyana, Pholadomya Tippana, P. elegantula, P. chy-ardium Spillmani, Legumen elliptica, Siliquaria biplicata, Pecten simplicus, P. Burlingtonensis, and Exogyra costata."—B. F. Shumard, Proc. Bost. Soc. Nat. Hist., 1861.	Elmo and Terrell. Terrell to concealed point fifteen miles west of Dallas.
GULF SERIES.	Upper Cretaceous.	Exogyra ponderosa Marl.				Narrows southward towards Rio Grande. This and all the succeeding members are exposed along north and south lines from Denison to beyond New Braunpels, and can be transected by going from east to west. They thicken southward.
GULF SERIES.	Upper Cretaceous.	DALLAS LIMESTONE.	"Austin" Limestone of Shumard, 1860. Wrongly placed by him in series. Part of Rœmer's Kreide. am Fusse des Hochlandes.	Soft magnesian limestone, earthy fracture, fine texture, highly foraminiferous. Blue upon fresh exposure, but decomposing and bleaching shortly after. Agrees, in main, with the same formation as described in other Gulf States.	Inoceramus biformis, Gryphæa vesicularis, Exogyra costata, Ostrea anomiaformis, Arca vulgaris, Radiolites Austinensis, Nautilus Dekayi, Baculites anceps, Helicoceras, Ammonites, Cassidulus æquorus, Hemiaster parasutus.—B. F. Shumard, Aug., 1860. Most of Rœmer's species from the Cretaceous at the foot of the highlands are from the Austin Limestone and the upper (Ripley) beds.	From above point east of Dallas to Eagle Ford, seven miles west of Dallas.
GULF SERIES.	Middle Cretaceous.	Zone of Ostrea bellaplicata.	Part of "Lower Cretaceous" of Shumard, 1860.	Conformable with above by position and faunal continuity. No line of demarkation yet made between the above groups.	Dr. Shumard's list includes forms of the over and underlying beds.—R. T. H. Ostrea bellaplicata Shum.	Escarpment, two miles south of Eagle Ford, and along north and south line to Denison.
GULF SERIES.	Middle Cretaceous.	EAGLE FORD SHALES.	"Arenaceous Group" and "Fish Bed" of Dr. Shumard's "Lower Cretaceous," 1860. Kreide. am Fusse des Hochlandes. Rœmer.	Argillaceous shales, varying from blue at top to yellow in middle, and to blue again at base, but with marked faunal zones.	Corax, Lamna, Otodus, and other vertebrates in the upper half. Only zone of Inoceramus problematicus, Ostrea con- gesta, and various undetermined Ammonitidæ. Blue shales at base are barren.	Along face of escarpment and underlying prairie from Eagle Ford to seven miles west. Also at Denison.
GULF SERIES.	Middle Cretaceous.	TIMBER CREEK GROUP.		Coarse-grained, friable, ferruginous sands, alternating with thin seams of yellow clays. Lignitic.	Ostreidæ, lignites, etc.	Lower Cross Timbers, from point few miles east of Arlington to eight miles west. Thins out to south.
				PLANE OF UNCON	FORMITY BY EROSION.	
COMANCHE SERIES.	Lower Cretaceous. Upper or Washita Division.	Upper Denison Fauna.	"Lower Cretaceous." (1)	Thin alternations of limestone, sandstones, and shales.	Ostrea crenulimargo, Turritella Marnochii, Nucula, Corbula, etc.	Missing at Fort Worth, having been eroded away previous to deposition of above group.
COMANCHE SERIES.	Lower Cretaceous. Upper or Washita Division.	Cidaris hemigranosus. Toxaster elegans. Exogyra arietina.	"Washita Limestone." (1) " " "Indurated Blue Marl." (1)	Alternating bands of firm yellow limestones and calcareous marls, growing thicker downward. The "blue marl" is the same material.	Many species of off-shore fauna, mostly undescribed, in upper bed. Many forms from below. Ananchytes ovatus, Lima Wacoensis, Ammonites Swallovii, Janira occidentalis, J. Texana, Gryphæa sinuata, Marcou; Ostrea Marshii, Marcou; G. Pitcheri bed accompanied by O. carinata.	This upper portion of the Texas Cretaceous occupies a narrow area from Fort Washita to San Antonio; is especially well exposed along Missouri Pacific R.R. Nearly the entire series can be found in a short distance from the city of Fort Worth.
COMANCHE SERIES.	Lower Cretaceous. Upper or Washita Division.	Gryphæa Pitcheri (with O. carinata).	"Washita Limestone." (1) Jurassic and Neocomian of Marcou.	Loose bedded or cemented Gryphæas.		
COMANCHE SERIES.	Lower Cretaceous. Upper or Washita Division.	Ammonites vespertinus.		Harder, chalky limestone.	A. vespertinus, formerly A. Texanus. Ancyloceras annulatus, Inoceramus.	Between Fort Worth and Weatherford, forming base of high prairies.
COMANCHE SERIES.	Lower Cretaceous. Upper or Washita Division.	Exogyra forniculata.		Ferruginous, calcareous marls, limited.	The forniculate and naviate varieties of G. Pitcheri abundant.	Six miles west of Fort Worth, south of Ben Brook, etc.
COMANCHE SERIES.	Lower Cretaceous. Lower or Fredericksburg Div.	Ammonites acutocarinatus.	Upward extension of next two.	Upward continuation of Comanche Peak features from groups below.	Ammonites acutocarinatus, Shum., and all of Shumard's typical Comanche Peak fauna in greater abundance.	Top of this group first exposed in bed of Trinity, Fort Worth. Highest summit Ben Brook Station.
COMANCHE SERIES.	Lower Cretaceous. Lower or Fredericksburg Div.	Hippurites Limestone.	"Caprina Limestone." (1)	Hardest limestone of series. Flints. Chalk.	"Comanche Peak" fauna, with Hippurites Texanus; Caprina, Requienia, etc.	Traces on buttes S. of Weatherford; typical at Comanche Peak.
COMANCHE SERIES.	Lower Cretaceous. Lower or Fredericksburg Div.	Comanche Pk. fau. Gryphæa Pitcheri (with O. Math.)	"Fredricksburg" of Rœmer. "Comanche Peak Group."	Crumbling chalky at top; thin hard bands at base, and great bed of Gryphæa Pitcheri.	Over fifty species have been described which belong here. See Shumard's section. The Gryphæa bed No. 2, with O. Matheroniana, is part.	Well displayed in vicinity of Weatherford, from which point to Millsap, ten miles west, the remainder of this section is regularly exposed in descending series.
COMANCHE SERIES.	Lower Cretaceous. Lower or Fredericksburg Div.	Requienia Texana.	"Caprotina Limestone." (1)	Firmer bands of limestone. Fossiliferous.	Culmination of Requienia Texana; Panopæa and many bivalve casts.	
COMANCHE SERIES.		DINOSAUR SAND.	Upper Cross Timber. (1)	Pure, uncemented pack sands.	Vertebrate remains only, Dinosauridæ, Chelonidæ, etc.	Upper Cross Timbers, few miles west of Weatherford, to Millsap Station; Sand Hills of Staked Plains.
		CARBONIFEROUS.				Millsap Station.

This series is one of unbroken sedimentation and faunal continuity from base to top. Subdivisions are temporarily designated by horizons of prominent fossils. Many species continue throughout the entire series.

(1) Trans. St. Louis Acad. of Science, Aug., '60. (2) Trans. St. Louis Acad. of Science, Aug., '61. (3) Proc. Bost. Soc. Nat. Hist., vol. viii, '61. (4) Tenth Census Rep. on Cotton Production, '84, p. 18. (5) Kreidebildungen von Texas, '52.

December 23, 1886.

Fig. 7. Hill's first geologic column of the Texas Cretaceous. Hill, 1887b, p. 298-299.

Cretaceous and corresponding in many aspects with the Lower Cretaceous of Europe" (Powell, 1889, p. 82). This terse official pronouncement, though incorrect in a couple of its assertions, heralded Robert T. Hill's rise to prominence in the geological community. Actually, Hill alone "rediscovered" the Lower Cretaceous sequence that Marcou had first noted. And by introducing it in the first detailed profile section and accurate geologic column of the Texas Cretaceous (Figs. 6 and 7) he confirmed its existence more unequivocally than Marcou had been able to do with his record of paleontologic and lithologic anomalies. White's role in the discovery had been as witness to the evidence upon which Hill had based his conclusions (Alexander, 1973, p. 28). White used this evidence in a subsequent publication (White, 1887), precipitating the first of Hill's many personal feuds.

The revolutionary concept that there were two great Cretaceous series in Texas instead of one had occurred to Hill while he was compiling material for his Bachelor's thesis at Cornell (Hill, 1931b, p. 17). In pursuit of this idea he studied localities "which might throw light upon the theory that he had conceived. . . ." (Hill, undated b). Confirmation of the theory came not only in the form of a cross section and stratigraphic column showing the sequence and nomenclature of Cretaceous strata in Texas, and in a careful cataloguing of paleontologic horizons, but in the assertion that a profound "non-conformity" had indeed been the source of previous confusion.

In an article written in 1884 (Cope, 1880), Professor E. D. Cope discussed his observations of Cretaceous strata in the vicinity of San Antonio. He noted the same prominent escarpment that Roemer had delineated over thirty years before and, assuming Marcou to be correct in dating the limestone of the highlands as older than that of the adjacent lowlands, he identified the fault that could have caused such pronounced displacement. Cope gave no name to it, and apparently the fact that he published such an astonishing observation (one that Roemer had at least inferred) in a zoological paper obscured it from the attention of geologists (Sellards and Baker, 1934, p. 51). It was not until three years later that Hill quoted the article and, on the basis of studies in the Austin area, made the unfortunate choice of naming the structural feature the "Austin-New Braunfels non-conformity" (Hill, 1887c). Despite this misnomer (which would be changed to "Balcones fault zone" a year later), Hill deserves credit for having discovered the peculiar relation of stratigraphy to topography that misled both Roemer and Shumard in their efforts to define the sequence of Cretaceous strata in Texas (Fig. 8).

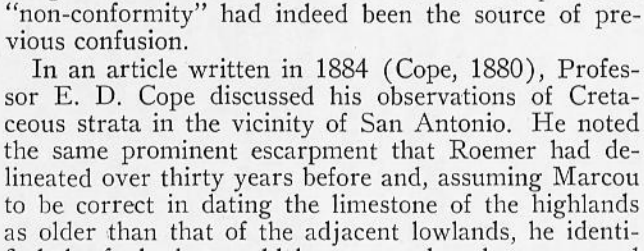


Fig. 8. Hill's illustrations of the relationship of stratigraphy to topography along the "Austin-New Braunfels non-conformity" and the nature of Roemer's misinterpretation of it. Hill, 1887c, p. 292-293.

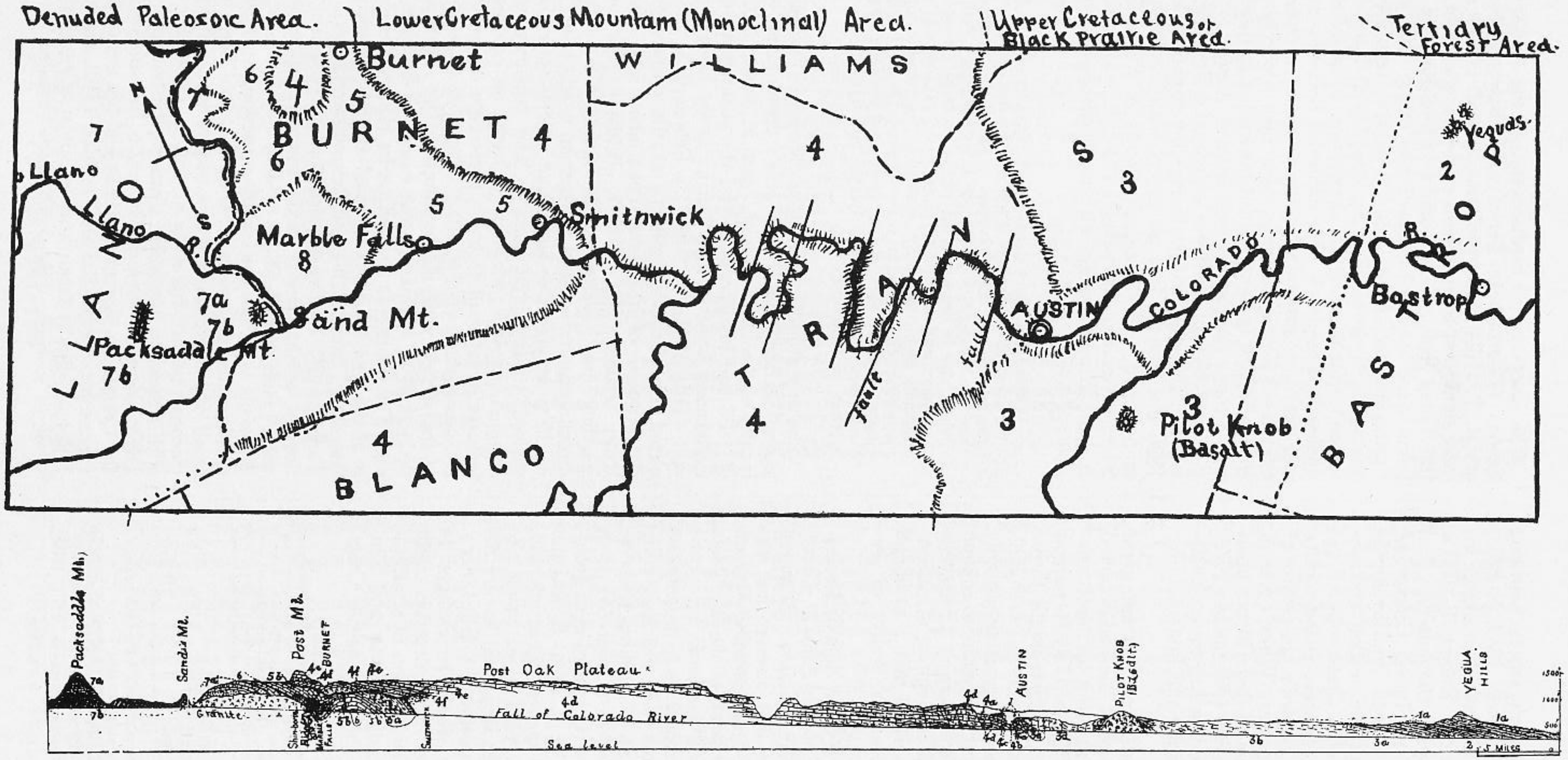
The discovery, or re-discovery, of the Lower Cretaceous (Comanchean Series) and Balcones faulting are R. T. Hill's most revolutionary and, in this sense, most significant contributions to the knowledge of Central Texas geology. It should be added that one revelation went hand-in-hand with the other. Hill's first Cretaceous section was made in an area relatively unaffected by Balcones faulting (the Dallas-Fort Worth region), thus assuring his observation of an essentially undisturbed sequence. The nature of Balcones faulting and previous errors in interpreting the succession of Cretaceous strata in Texas were thus probably much clearer to Hill as he continued his studies farther south in the more complex geology around Austin.

The time spent in Austin lobbying for the State Survey and his brief reconnaissance investigations late in 1886 disclosed to Hill an exceptionally well exposed sequence of rocks along the bluffs of the Colorado River, extending for several miles on either side of Austin. His infatuation with the section was irrepressible:

> Within this short distance the river has worn through the crust of Cretaceous sediments that formed the floor of the plains and now traverses nearly every terrane from the late Quaternary to the earliest Cambrian. Perhaps no where else in the world can be seen a more comprehensive geologic section, a better illustration of sedimentary and igneous rocks, and their relation to topographic form and economic conditions or other geologic features dependent upon structure than in that portion of the Colorado which traverses the counties of Burnet and Travis. . . . (Hill, 1889a, p. 288) (Fig. 9)

The opportunity to study in detail this "superb geological section" came with Hill's appointment to the faculty of the University of Texas at Austin in the fall of 1888 and his assumption of the position of head of Cretaceous work for the Texas Survey early the next year (Hill, 1931b, p. 39). By February he had completed a preliminary attempt at the description and classification of the formations along the Colorado River section (Hill, 1889a). While it contained no startling new revelations, the article did outline the direction future work on the section would take. Within the next year five successive articles introduced or revised stratigraphic names. The tendency was to abandon previous designations based on paleontologic features in favor of Powell's preference for geographical nomenclature (Fig. 10). Progressive refinements of the section were also accompanied by more detailed deductions of the nature and extent of Balcones faulting. The effort was spurred on by Hill's determination to make this the most detailed Cretaceous section in America. Toward this end he assigned Messrs. J. A. Taff and N. F. Drake, also members of the Texas Survey, to the precise study and correlation of individual fault blocks (Ibid. p. 44).

Fossils were the chief guide to making such detailed stratigraphic determinations, as they had been to Hill in all of his previous reconnaissance work in the Cretaceous. In fact, his early attempt to categorize fossils with respect to particular stratigraphic horizons (Hill, 1887c) was an essential factor in his subdivision of the Cretaceous system of Texas and his unravelling of the complexities of Balcones faulting (Hill, undated c). Hill had actually begun such an effort at categorization while at Cornell. His thesis work revealed to him a



Geologic Section and Profile of Central Texas revealed by the Colorado River.

1, Quaternary Terraces of Colorado below its emergence from the plateau and cañon area (4); 1a Quaternary littoral deposits; 2, Marine Tertiary; 3, Upper Cretaceous of undulating Black Prairie area; 4, Lower Cretaceous of "Hard Lime Rock," "Mountain" or plateau area; 5, Carboniferous shales and limestones; 6, Silurian; 7a Potsdam; 7b, Llano; 8, Granite. Basalt at Pilot Knob.

Fig. 9. Hill's first illustration of the Colorado River section showing the relation of stratigraphy to "topographic form." Hill, 1889a, p. 293.

Progressive Development of Knowledge of the Texas Cretaceous.

(Numbers and parentheses by R. T. Hill.)

Dr Ferdinand Roemer, 1846.	Dr B. F. Shumard's Section of 1860.	Professor Jules Marcou, 1861.	Robert T. Hill, 1886–'93.
Made no section or nomenclature, but mentions in the sequences given what are known to be the following beds: *Cretaceous of the Highlands.* 6. } Chalk marls and limestones of 5. } Fredericksburg (Caprina and Comanche Peak). 4. Limestone flags with *Exogyra texana* (Walnut beds). 2. Chalks with *Orbitulina texana* and *Natica prægrandis* (Glen Rose). 10. Yellow clays with *Exogyra arietina.* 9. White limestone with *O. carinata* (Washita or Fort Worth). 6. Dolomitic limestone with *Requienia texana* (Caprina). 6. Yellow limestone with Caprina (Caprina). *Cretaceous at Foot of Highlands.* 15. Yellow marls with *E. ponderosa.* 14. White limestone (with Austin chalk fauna). 13. Beds with fish teeth (Eagle Ford).	*Upper Cretaceous (mostly Lower).* 6. Caprina limestone. 4. } Comanche Peak group. 5. } 14. Austin limestone. 13. Fish bed. 10. Indurated blue marl (*E arietina*). 9. Washita limestone. 12. Blue marl. 2. Caprotina limestone. *Lower Cretaceous (all Upper).* 12. Arenaceous group. 13. Fish bed. 13. Marly clay or Red River group. To which may be added later discoveries of— 16. Ripley. 12. Dakota.	(Criticism of Shumard's section, and rearrangement.) *Senonian (Upper Cretaceous).* 14. Austin limestone. Fish bed in sandstone. 13. Blue marl with *I. problematicus.* *Middle Cretaceous, or Greensand and Turonian.* 13. Marly clay or Red River group. 6. Caprina limestone. 4. } Comanche Peak group. 5. } Superior part with *E. texana.* 10. *Exogyra arietina* marl. *Lower Cretaceous, or Aptien and Neocomian.* 9. Washita limestone, comprising superior part of Comanche Peak group with *G. pitcheri.* 2. Caprotina limestone.	*Upper Cretaceous.* Glauconitic division: 18. Washington........ } Montana division. 17. Brownstown........ } 16. White Cliffs........ } 15. *Exogyra ponderosa* (Taylor) marls........ } Colorado division: 14. Austin chalk. 13. Eagle Ford shales. Dakota division: 12. Lower Cross Timber sands. *Lower Cretaceous.* Washita division: At Austin. At Denison. 11. Shoal Creek limestone. 10. { *E. arietina* beds........ Denison beds. { Main street. Paw Paw. North Denison. Marietta. 9. Fort Worth limestones. Preston beds. { 8 Duck Creek chalk. 7. Kiamitia clays. Fredericksburg division: 6. Caprina limestone; 6*b*. Austin marble; 6*a*. Flags. 5. Comanche peak chalk. 4. Walnut clays (*Exogyra texana* beds). Trinity division: 3. Paluxy sands. 2. Glen Rose beds. 1. Trinity sands.

Fig. 10. Chart by Hill showing the progressive development of knowledge of the Texas Cretaceous. Note the gradual change in nomenclature from paleontologic to geographic designations. Hill, 1894, p. 317.

ANNOTATED CHECK LIST.

The first figure following the author's name refers to the full title of the original publication given in the bibliography at the end of the check list. The second figure gives the page of the original publication. The last figures are those of the year of publication. The capital letters refer to the formation and horizon. Species no longer considered valid, owing to previous description, are italicized. Comments are by the compiler. An * indicates that the species has not been figured. The localities are usually those given by the author of the species.

PROTOZOA.

Although the cretaceous rocks of Texas are mostly of foraminiferal origin, including innumerable microscopic species now being studied in the geological laboratory of the survey, none of them have been recorded except the following conspicuous microscopic forms:

NODOSARIA TEXANA, Con., 2, 159, 1857. W. Between El Paso and Frontera.
Occurs also in vicinity of Fort Worth, 700 miles east of original locality.

ORBITULITES (TINOPORUS) TEXANUS, Roem. 1, 392, 1849; 2, 86, 1852. F. Between New Braunfels and Fredricksburg.
This form composes the mass of a well defined chalk horizon south of the Brazos, as seen in the bluffs of the Colorado near the mouth of Bull Creek.

TEXTULARIA, sp. ind., Hill 3. A. Austin chalk.

GLOBIGERINA, sp. ind., Hill 3. A.

COELENTERATA. ANTHOZOA.

TROCHOCYATHUS (TURBINOLIA) TEXANUS, Con. 2, 144, 1857. W. Between El Paso and Frontera.

CLADOPHYLLIA FURCIFERA, Roem. 4, 1888. H. Barton Creek, [two miles] west of Austin.

ISASTREA DISCOIDEA, White. Geol. Mag. 1888, p. 662. N. "Navarro beds."
Have found what is probably this species in the shales at Eagle Ford.

COELOSMILIA AMERICANA, Roemer 4, 1888. H. Barton creek, west of Austin.

PARASMILIA AUSTINENSIS, Roemer 4, 1888. H. Barton creek, west of Austin.

PLEUROCORA COALESCENS, Roemer 4, 1888. H. Barton creek, west of Austin.

PLEUROCORA TEXANA, Roemer 4, 1888. H. Barton creek, west of Austin.

ASTROCOENIA GUADALUPAE, Roemer 1, 391, 1849; 2, 187, 1852. V.? Hills north of New Braunfels.

ECHINODERMATA.

OPHIODERMA, sp. nov., Hill 2, 1887. W. Fossil creek, six miles north of Fort Worth.

Fig. 11. The first page of Hill's annotated check list of Cretaceous fossils. Note that localities and stratigraphic horizons have been given. Hill, 1889b, p. 1.

profusion of paleontologic descriptions, most of them unaccompanied by identification of either the geographic locality or the stratigraphic horizon from which the fossils had been collected. Such a dearth of essential information prompted the compilation of a rudimentary checklist of Cretaceous fossils, which was eventually published as a field guide for Texas State Survey personnel (Fig. 11) (Hill, 1889b). Both Hill's "Preliminary Annotated Check List" (Hill, 1889b) and "Check List" (Hill, 1889c) were presented within the context of a refined Colorado River section—an indirect but positive assertion of their utility in future stratigraphic determinations.

The public utility of scientific investigations (as mentioned earlier) was a paramount concern of most scientists of the late nineteenth century. Generally insecure in their financial base, they were subject to the caprice of private benefactors and/or the political whims of legislators. In either case, the demonstration of the utility of a project was often essential to its support. It was for this reason that E. T. Dumble, the State Geologist, felt compelled to make the following observation regarding Hill's checklist:

> . . . the working out and preparation by the National Survey of such purely scientific matters as is contained herein . . . is absolutely necessary to the proper prosecution of the work of the State Survey in the discovery and description of the economic materials contained within the (Cretaceous) system, yet lacks that direct interest to the people of the State that obtains in the economics themselves. (Letter of Transmittal to Hon. L. L. Foster, Commissioner of Agriculture, Insurance, Statistics, and History, Austin, Texas, from E. T. Dumble, State Geologist *in* Dumble, 1889.)

The utilitarian character of many of Hill's later contributions to Texas geology are also defined within the context of this cooperation between the research interests of the U. S. Geological Survey and the more purely practical concerns of the State Survey.

Shortly after completing his Cretaceous checklist Hill submitted "Events in North American Cretaceous History Illustrated in the Arkansas-Texas Division of the Southwestern Region of the United States" for publication in the *American Journal of Science*. The article, a discussion of cycles of sedimentation, changing land areas, and marine transgressions and regressions in the southwestern United States (defined by Hill as lying "south of the Uinta and Ozark uplifts and between the Sierras on the west and the great Atlantic timber belt on the east") (Hill, 1889d, p. 282), was prompted by his conviction that "the two Cretaceous series were now becoming sufficiently defined to begin the interpretation of the geologic history and paleogeography which they recorded" (Hill, 1931c, p. 14). Thus the article demonstrates not only Hill's grasp of the regional implications of his paleontologic and stratigraphic studies, but the extent to which his reconnaissance investigations had progressed.

In February, 1890, after a protracted struggle with university authorities that stemmed largely from his informal and innovative teaching methods, R. T. Hill resigned his position as Assistant Professor of Geology (Alexander, 1973, p. 42-48). With supplementary support from the U.S. Geological Survey, he devoted his energies entirely to the Texas Survey, pursuing reconnaissance studies in North Texas and completing "A Brief Description of the Cretaceous Rocks of Texas and their Economic Value" for the Survey's *First Annual Report*. The paper, an amalgam of pure research and economic investigation, summarized the details of the Cretaceous System (gathered largely from work on the Colorado River section), including the first attempt to differentiate and correlate various blocks of the Balcones fault zone at Austin (Fig. 12). Within the outline provided by this summation, Hill discussed the economic importance of the Texas Cretaceous, thereby fulfilling the professed aims of the State Survey and intimating, by association, the inherent utility of even his most "purely scientific" studies.

Hill's tenure as geologist in charge of Cretaceous investigation for the Texas Survey proved to be nearly as short-lived as his service with the University. A quarrel erupted between Hill and Dumble, stemming from "undue strictures" upon his work (in the form of a paper, by another Survey geologist, that disagreed with Hill's geological conclusions on two minor points) and aggravated by insufficient and, Hill thought, misdelegated funds (Ibid. p. 52). A short time later Hill resigned from the State Survey and made plans to leave Texas. Meanwhile, "Classification and Origin of the Chief Geographic Features of the Texas Region," an-

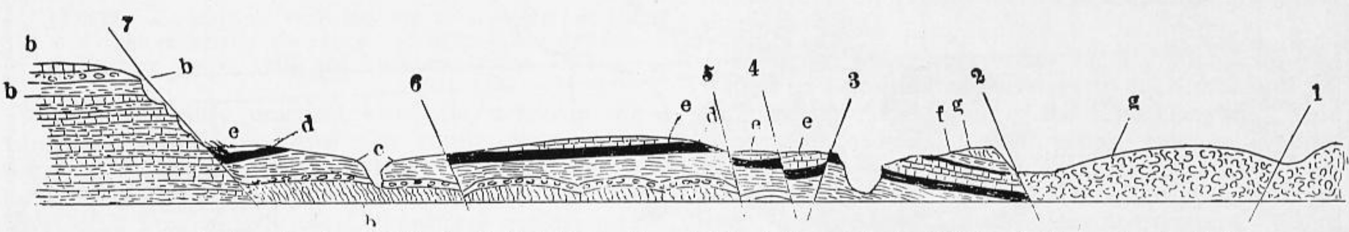


FIG. 5.—Cross section from Waller Creek, East Austin, through Mount Bonnell to the Bull Creek plateau, showing faults.

g. Austin chalk.
f. Sixth Ward (Eagle Ford) clays.
e. Shoal Creek limestone.
d. Exogyra Arietina clays.
c. Washita limestones.
b. Caprina limestone and flint beds.
a. Alternating, or magnesian, beds.

1. Waller Creek fault in chalk.
2. Sixth Ward fault.
3. Shoal Creek and Twenty-fourth Street fault.
4. Slaughter house and Bonnell road fault.
5. Sieder's Spring fault.
6. Half mile west of railroad.
7. Mormon Spring, or Mount Bonnell, fault.

Fig. 12. Hill's first attempt to differentiate and correlate various fault blocks of the Balcones fault zone at Austin. Hill, 1890a, p. 135.

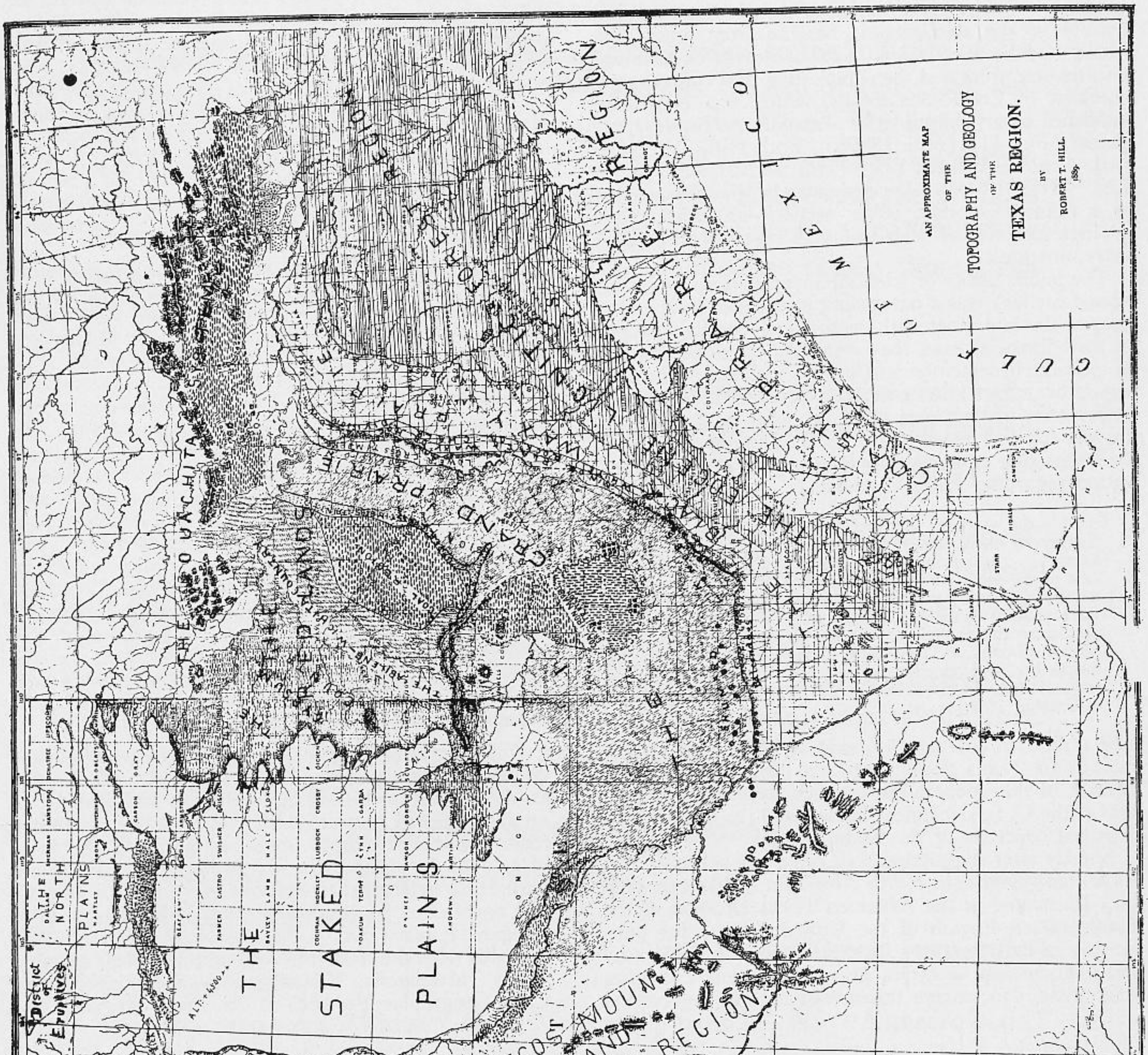


Fig. 13. Another of Hill's progressive attempts to characterize the physiographic provinces of Texas. Hill, 1890b.

other of his progressive attempts to classify the physiographic features of Texas was published in *American Geologist*. Like "Events in North American Cretaceous History," it illustrates the breadth of his familiarity with the physiography and geology of the region (Fig. 13); in addition, Hill's awareness of the close relationship of the two is implicitly conveyed (although in retrospect he assumed a more explicit statement) (Hill, 1931c, p. 15).

Hill returned to Washington in the fall of 1890 and was assigned by Powell to the investigation of ground water under the auspices of a temporary organization of the Department of Agriculture, informatively titled "The Artesian and Underflow Investigation between the 97th Meridian and the Rocky Mountains." Its establishment was part of an attempt by Powell's congressional opponents (most of them from drought-ridden western states) to limit his power as Survey Director (Sterling, 1940, p. 422). Their effort was made in the face of overwhelming evidence collected during the early years of the Survey that demonstrated the very limited value of artesian waters in arid lands (Darrah, 1951, p. 310).

Such inauspicious circumstances detracted only indirectly from Hill's work with the Artesian Inquiry. The position provided him with an opportunity to extend his field studies of the Cretaceous into western Texas, eastern New Mexico, and Indian Territory, the ultimate object being the submission of the report, "On the Occurrence of Artesian and Other Underground Waters in Texas, Eastern New Mexico, and Indian Territory, West of the Ninety-seventh Meridian," on the groundwater resources of the region. For years afterward, Hill lamented the fact that deficiencies in editing and printing (which he attributed to the short-lived agency's insufficient "editorial organization") had opened the work to petty criticisms that detracted from an otherwise valuable contribution (Hill, 1931b, p. 59). He was undoubtedly correct in this view. In examining the occurrence of ground water over such a vast region (Hill, always reluctant to accept artificial boundaries, extended his study east of the 97th meridian to include much of East Texas) (Alexander, 1973, p. 59), Hill felt it was essential to consider:

(1) The geography of the region.

(2) The simple laws of the occurrence and distribution of underground water.

(3) The composition, variation and arrangement of the rocks underlying the region and affecting the distribution of water. (Hill and Vaughan, 1898, p. 201)

Such an eminently practical viewpoint not only divorced his efforts from the taint of pretensions surrounding the Artesian Inquiry, but afforded an opportunity to expand and intensify his studies of the Texas Cretaceous (particularly the Comanchean Series) and Texas physiography.

The first results of this stimulus were contained in "The Comanche Series of the Texas-Arkansas Region," representing the culmination of Hill's reconnaissance work on the Comanche Series, approximately as it would appear in his superlative monograph of the Texas Cretaceous (the 21st *Annual Report*). He even anticipated the unique scope of the 21st *Annual Report* by extending the assumption of the intimate relationship of geology to topography conveyed in previous physiographic works to the point of considering the Comanche Series in terms of "separate and distinct terranes" (Fig. 14) (Hill, 1891, p. 504).

DEFINITION OF THE TERRANES.

CONSTITUTION OF THE COMANCHE SERIES.

C. The Washita, or Indian Territory Division.
- 11. The Denison Beds.
- 10. The Fort Worth Limestone.
- 9. The Duck Creek Chalk.
- 8. The Kiamitia Clays or *Schloenbachia* Beds.

B. The Fredericksburg or Comanche Peak Division.
- 7. The Goodland Limestone.
- 6. The *Caprina* Limestone.
- 5. The Comanche Peak Chalk.
- 4. The *Gryphæa* Rock and Walnut Clays.
- 3. The Paluxy Sands.

A. The Trinity Division.
- 2. The Glen Rose or alternating beds.
- 1. The Trinity or Basal Sands.

Fig. 14. Chart of the "separate and distinct terranes" that Hill delineated on the basis of stratigraphic and paleontologic data. "Central Texas," he remarked, ". . . is so extensive that deductions as to its subdivisions have required much time; and although I have been constantly studying it for many years, not until now have I felt justified in dividing it into well-defined terranes." Hill, 1891, p. 504.

Shortly after the appearance of "On the Occurrence of Artesian and Other Underground Waters," Hill completed "The Geologic Evolution of the Non-mountainous Topography of the Texas Region; an Introduction to the Study of the Great Plains," published in *American Geologist*. This article was very similar to his previous paleogeographic works (Hill, 1889d and Hill, 1890b) both in substance and implication. The differences were those of regional scope and detail, arising from field work for the Artesian Inquiry. Taking into account areas peripheral to the Southwest (Mexico, the Rocky Mountains, the West Indies), Hill placed in a time sequence features such as the Balcones fault zone and Texas' rivers, features more subtly indicative of their evolution than near-horizontal successions of strata.

His work with the Artesian Inquiry done, Hill was shifted to a position as secretary to the Committee on Irrigation of Arid Lands of the 52nd Congress. This sinecure provided him with ample time to lay the groundwork for his final publications concerning Central Texas geology. He was simultaneously able to keep "an ear close to the sessions of Congress," where the precarious fate of the U.S. Geological Survey was being discussed (Hill, undated d). Friends of the Survey prevailed, and in October, 1893, Hill returned to its ranks, first as executive officer and later as one of its four principal geologists. Major Powell gave him free rein in continuing his geological work in Texas to the point of its summation. Hill termed these years encompassing five field seasons "the happy days of my life," alternating between the "delightful scientific, literary

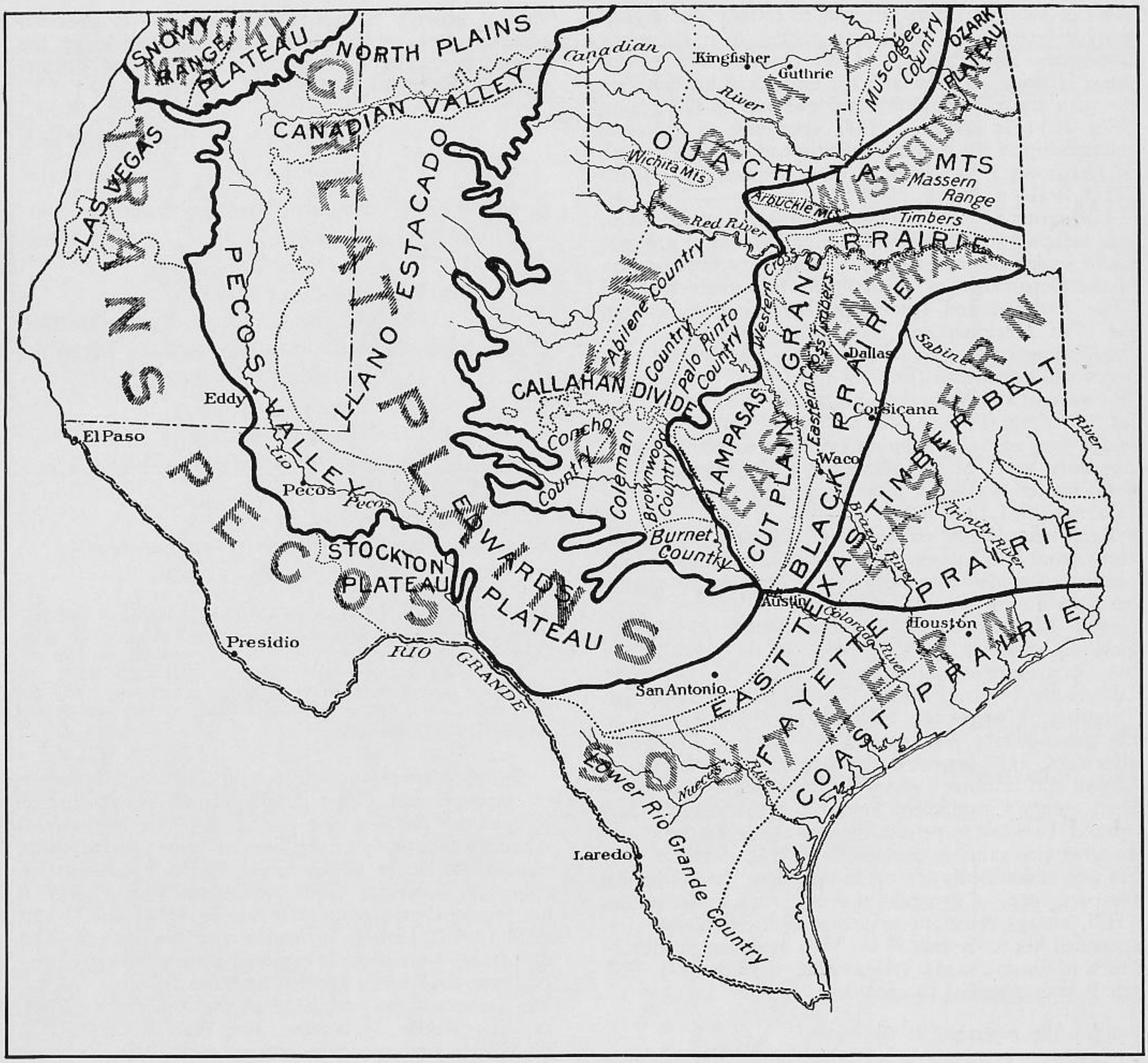


Fig. 15. Hill's final classification of the physiographic provinces of Texas. Hill, 1900, p. 1.

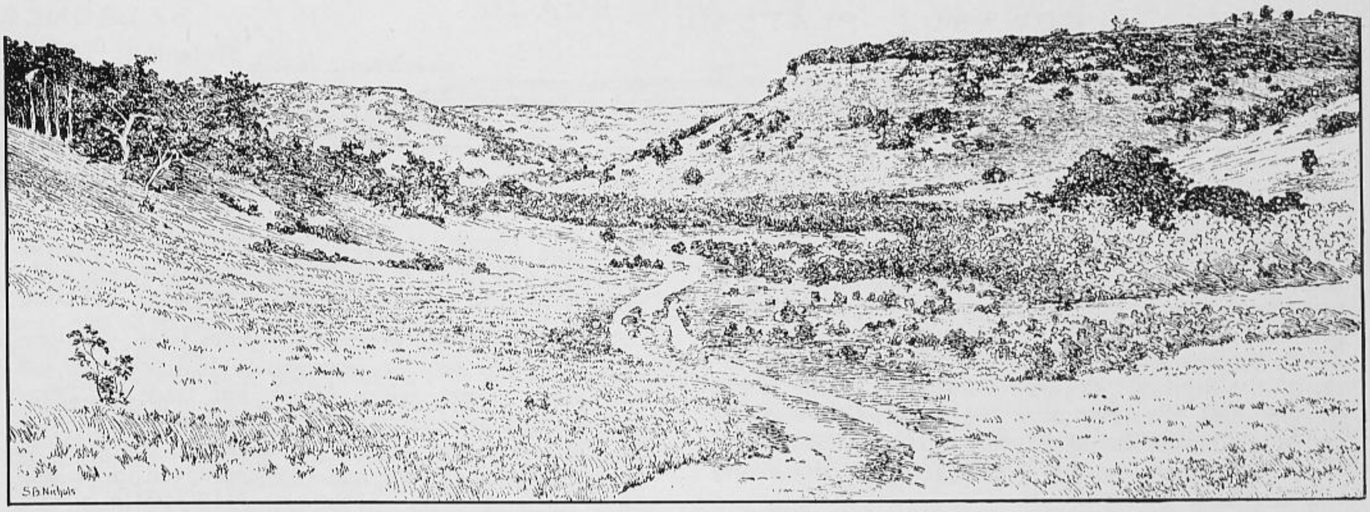


Fig. 16. Lithograph of typical cut plain topography in Lampasas County, Texas. Hill, 1900, p. 5.

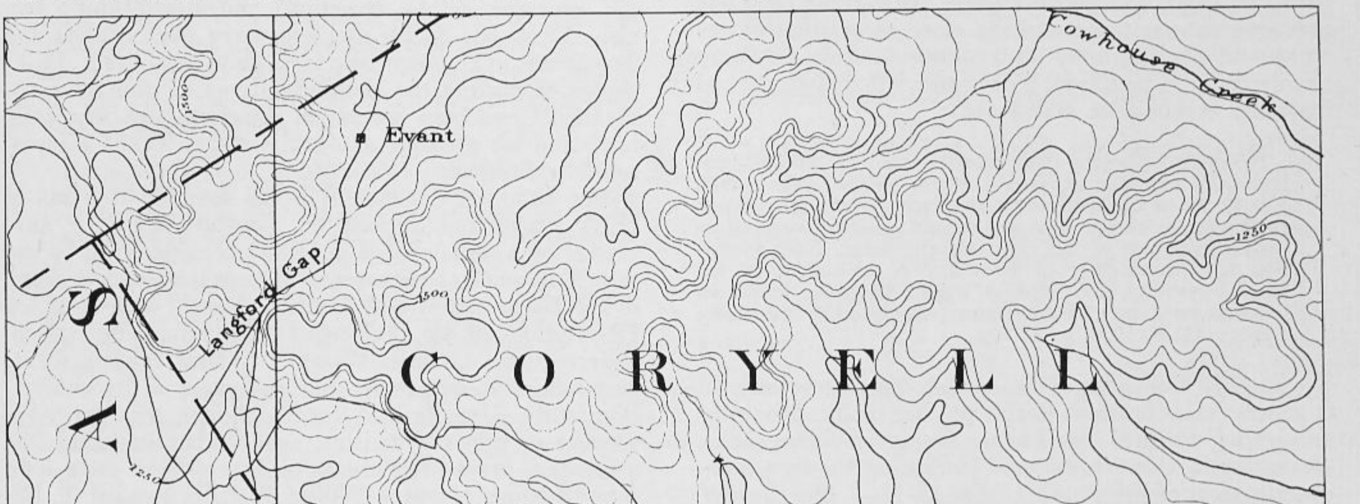


Fig. 17. Map of a portion of the Lampasas cut plain (contour interval 50 feet). Note the attempt to graphically relate this view to that in Figure 16. Hill, 1900, p. vii.

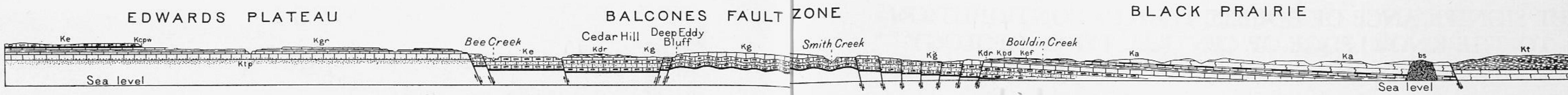


Fig. 18. Continuous segments of Hill's final section along the south side of the Colorado River, showing details of the Balcones fault zone (horizontal and vertical scales, one inch = 3000 feet). Hill, 1902, p. 7.

and social life which Washington then afforded and long glorious trips into the wilderness in close contact with primitive nature" (Hill, 1931b, p. 67). The joyful effort produced his last and most important works on Central Texas geology, two folios for the U.S. Geological Survey's atlas series: "Physical Geography of the Texas Region" and "Description of the Austin Quadrangle," and a monograph included in the Survey's 21st *Annual Report*: "Geography and Geology of the Black and Grand Prairies, Texas."

"Physical Geography of the Texas Region," published in 1900, was above all else Hill's most complete and articulate statement of the close association of geology and physiography on a statewide scale. By way of introduction he stated, with a conviction that marked his most enthusiastic endeavors:

> Nowhere is there a more intimate relation between geologic formation and physiography than in the Texas region. Nearly all topographic conditions which influence human environment, except climate, depend on the composition and arrangement of the various rock sheets. Each formation has peculiarities of stratification, consolidation, cohesion, friability, and porosity which, when the formation is acted upon by climatic factors, result in various relief forms. (Hill, 1900, p. 2)

To amplify this point Hill, within the framework of a genetic classification of the physiographic provinces and relief features of Texas, employed lithographs, photographs, charts and maps (including the first topographic map of the state) (Figs. 15-17). The illustrations condensed his discussion of geology and physiography (including drainage, climatic features, vegetation, soils, mineral resources, and population distribution) into a succinct fifteen pages that were a magnificent example of U. S. Geological Survey publications at their peak of lavishness and excellence.

The Austin Folio, printed two years later, was likewise of this genre. Its compilation had occupied not only Hill's efforts (since 1886), but those of Texas Survey personnel, primarily in more precisely defining the Colorado River section. In addition, the facilities of the National Survey had been employed in making a new topographic map of the area (Hill, 1931c, p. 43). The result was a geologic map of the Austin quadrangle, accompanied by structural and stratigraphic sections (Fig. 18) (with supplementary photographs and engravings of characteristic fossils and localities). Hill's dream of making the Colorado River section the most detailed Cretaceous section in America had been realized, and his geologic study of Central Texas was essentially finished.

But although the Austin Folio signified the last of Hill's major publications on Central Texas, it succeeded by a year what is generally considered to be the crowning work of his career: "Geography and Geology of the Black and Grand Prairies, Texas, with Detailed Descriptions of the Cretaceous Formations and Special Reference to Artesian Waters." Those Survey members who reviewed the manuscript prior to its publication in the 21st *Annual Report,* though they voiced a number of minor criticisms, agreed that it would "be a standard work of reference on that subject for a long time to come" (Bailey Willis, F. L. Ransome, T. W. Stanton to Charles D. Walcott *in* Alexander, 1973, p. 77). Their prophecy has held true, partly because of the immense scope and detail of the work (it contains

Nomenclature of the Texan Cretaceous area and its local sections from Arkansas to the Rio Grande.

Classification of formations.			Mappable lithologic formations in the local sections.						
Series.	Divisions. *a* (Groups.)	Major formations.	Arkansas-Choctaw section.	Denison section.	Fort Worth section.	Waco section.	Austin section.	Guadalupe section.	Uvalde section.
GULF SERIES.	Montana.	Navarro.	Arkadelphia. Washington. Anona (White Cliffs). Roxton.		Navarro.	Navarro.	Webberville.	Bexar.	Eagle Pass.
	Colorado.	Taylor.			Taylor.	Taylor.	Taylor.	Taylor.	Upson. Anacacho. Cline.
		Austin.	Austin.	Austin.	Austin.	Austin.	Austin.	Austin.	Austin.
		Eagle Ford.	Concealed.	Eagle Ford.	Eagle Ford.	Eagle Ford.	Eagle Ford.	Eagle Ford.	Eagle Ford.
	Dakota.	Woodbine.	Concealed. Morris Ferry.	Lewisville. Dexter.	Lewisville. Dexter.				

a Groups of formations. Divisions of series.

Fig. 19. Chart showing Hill's final classification of the Gulf Series of the Texas Cretaceous. Hill, 1901, p. 114.

666 pages, 71 plates, and 80 text figures) (Figs. 19 and 20), but more importantly, because this sum total of Hill's geological investigations in Central Texas was conceived as a guide to both the scientist and the ordinary citizen.

Such a conception was prompted by his confidence in the economic and scientific wealth of the region and perpetuated by a compelling desire to discern and communicate the nature of this wealth. Thus Hill concentrated his studies along the lines of Texas physiography and Cretaceous stratigraphy, as a means of elucidating what he regarded as Central Texas' most vital resource, artesian waters. When his investigations strayed toward what were at the time considered purely scientific ventures, he felt an incumbent need to reassert the inherent utility of the endeavor. Such was the case with his paleontologic studies:

> Paleontology is the most reliable guide in determining the position of any bed in the geologic series with a view to ascertaining the depth, from any particular portion of the surface, of the underground waters in the Cretaceous regions of Texas. If a few species of fossils, such as can be found in any locality, be sent to one familiar with the sequence of the beds, he can predict within a few feet the depth below the surface of any particular water-bearing stratum in the series. It was a labor of years to disentangle the pre-existing confusion concerning the occurrence and succession of these fossils and their bearings upon the determination and definition of the strata. (Hill, 1901, p. 24)

A progression of publications had traced this "labor of years" and determined its final form and extent in the 21st *Annual Report.* Hill, with the sentiment of a true pioneer, saw his work as a stimulus and guide to those that would follow:

> When appreciation of geologic investigation shall have been awakened in Texas and the region under discussion shall have been studied more closely by resident students, in the manner now common in other parts of the United States, the data here presented will be largely increased and refined, and the conclusions will doubtless be correspondingly amended and rectified. (Ibid.)

The U.S. Geological Survey had nurtured and sustained this pioneering effort. But Powell's personal administration was finally superseded by a more "business-like" organization under Charles D. Walcott. "Master Geologists" of "general ability" were replaced by specialists; "the brickmakers pushed the architects aside" (Hill, 1931b, p. 68), and Hill's interests drew him elsewhere.

Nomenclature of the Texan Cretaceous area and its local sections from Arkansas to the Rio Grande—Continued.

Classification of formations.			Mappable lithologic formations in the local sections.						
Series.	Divisions. (Groups.)	Major formations.	Arkansas-Choctaw section.	Denison section.	Fort Worth section.	Waco section.	Austin section.	Guadalupe section.	Uvalde section.
COMANCHE SERIES.	Washita.	Buda. *a*					Buda.	Buda.	Buda.
		Denison.		Grayson. Main Street. Paw Paw. Marietta. Denton.	Grayson. Main Street. Paw Paw. Marietta. Denton.	Del Rio.	Del Rio.	Del Rio.	Del Rio.
		Fort Worth.		Fort Worth.	Fort Worth.	Fort Worth.	Georgetown.	Georgetown.	Georgetown.
		Preston.		Duck Creek. Kiamitia.	Duck Creek. Kiamitia.				
	Fredericksburg.	Edwards.	Goodland.	Goodland.	Goodland.	Edwards.	Edwards.	Edwards.	Edwards.
		Comanche Peak.				Comanche Peak.	Comanche Peak.	Comanche Peak.	Comanche Peak.
		Walnut.		Walnut.	Walnut.	Walnut.	Walnut.		
	Trinity.	Paluxy.	Antlers.	Antlers.	Paluxy.	Paluxy.			
		Glen Rose.			Glen Rose.	Glen Rose.	Glen Rose.	Glen Rose.	Glen Rose.
		Travis Peak.			Basement sands, not named. *b*	Basement sands, not named. *b*	Travis Peak.		Concealed.

a The Buda formation of the southern section may be synchronous with the Grayson and Main Street of the northern section. *b* Not recognizable south of the Colorado Valley.

Fig. 20. Chart showing Hill's final classification of the Comanche Series of the Texas Cretaceous. The nomenclature for Hill's subdivisions of the Comanche and Gulf (Fig. 19) Series has remained essentially unchanged. Hill, 1901, p. 115.

THE SIGNIFICANCE OF ROBERT T. HILL'S CONTRIBUTION TO THE KNOWLEDGE OF CENTRAL TEXAS GEOLOGY

Robert T. Hill contributed to the knowledge of Central Texas geology the first systematic explication of the region's chief geological features. But his contribution is more than a manifestation of his efforts to advance this knowledge in areas of both theoretical and practical value. His contribution illustrates the unique combination of factors that determined not only the nature of his work but also the ultimate success of his endeavor, as measured by the remarkable durability of his observations and conclusions and the generally favorable judgment of his peers and successors. Briefly, these factors may be considered in terms of the man, his methodology, and the region he chose to study.

Hill's work, in its most personal sense, demonstrates his competency—his ability to apply the methodology of his day to the definition and solution of the geological problems of a region. The essence of this ability, the power to observe precisely and reason validly, was developed during Hill's years at Cornell, and was first utilized to review critically the status of geologic knowledge of Texas. Subsequent inculcation of a methodology, through the agency of the U. S. Geological Survey, encouraged the full realization of Hill's aptitudes in a form suitable to that methodology, and in the form expressed in his work.

Previous investigations of Central Texas geology, besides reflecting the physical and individual limitations of Hill's predecessors, provide an illuminating contrast to the factors determining his success, particularly the eminent suitability of his methology. Considered in its most restricted sense, this methodology was a body of conventions, as chiefly prescribed by the U. S. Geological Survey, for the definition of geological phenomena; in addition, it was a formalization of certain qualities essential to the successful utilization of these conventions, as implicitly expressed in Chamberlain's concept of the multiple working hypothesis. In more expansive terms, Hill's methodology incorporated the knowledge, procedures, and objectives of late nineteenth century American geology under the aegis of the U.S. Geological Survey.

The suitability of any methodology, and the investigator's ability to utilize this methodology, is ultimately determined by the nature of the problem it is called upon to solve. In the case of R. T. Hill, the problem was the geological characterization of Central Texas, of which he had this to say:

> The strata of the Cretaceous period in the Texas region are so uniform and simple in their deposition, and the exposures and contacts of the groups so well marked, that they would be easily described had not the publications by early writers involved it in much confusion (Hill, 1887c, p. 290).

Thus Hill's success was determined in part by the region he chose to study. Neither his predecessors nor his successors have exceeded his fundamental conclusions because he was the first competent geologist to examine and describe this region in sufficient detail and with sufficient tools to define its chief geological features.

SPECULATIONS

This paper is notably lacking in bases for comparison. Perhaps the best measure of the uniqueness of the circumstances facilitating Hill's valuable contribution would be a comparison of his work in Central Texas with that in Cuba, California, or the Trans-Pecos region. I suspect that the quality of his geologic investigations in these other regions, in terms of his ability to apply the methodology of his day to the definition and solution of geologic problems, was no less than that in Central Texas. What differed was the circumstance under which his contribution was made. The bulk of the Trans-Pecos work was never published; his work in Cuba, though it earned him the title "Father of Antilean Geology," has been superseded; and his work in California, though of immediate interest and utility to the general public, was marred by biased and unprofessional editing and publishing.

Another aspect of this comparison may include those areas of investigation where Hill may have been guilty of a misapplication of methodology; the most notable instance being his studies of the Nevada gold fields (Camp Alunite, etc.). If he was guilty of such a transgression, a comparison with his work in Central Texas would serve to amplify and perhaps clarify the significance of his contribution to the knowledge of that region.

Another valuable comparison might be made between Hill and a geologist of similar training, working at about the same time in a region of similar geology with about the same degree of previous investigation. While such a task may appear impossible, there seem to have been several other geologists working under circumstances similar to Hill's. The prime question to ask would be the significance of their contributions. Whether the answer to this question could, through comparison, give a truer measure of the significance of Hill's contribution is difficult to say, as it would depend largely upon the extent of parallelism between the circumstances influencing the geologists' work.

APPENDIX

FIELD BOOK EXCERPTS

The following excerpts from notes made by Robert T. Hill on his first field excursion in Central Texas as a member of the U.S. Geological Survey (Hill 1886a), and the accompanying illustrations, exemplify Hill's approach to and solution of geological field problems. Notice that he systematically employs several lines of evidence to develop and test his conclusions. Also, note that these conclusions are based entirely on personal observation; Hill considers the opinions of others only as they are confirmed or denied by his experience.

p. 1 *Fort Worth* August 9, 1886

General Topography

Fort Worth is on the Texas Pacific Railway, 30 miles W of Dallas. It is situated in the midst of a high, nearly level prairie. The Trinity river flows within a short distance north of the city. Railroad cuts and erosion of drainage basins have made exposures of the strata.

Geology

The entire region, excepting river basins, is Cretaceous —the exact age of which will be determined hereafter.

p. 3 Section of south side of Trinity River. [Figs. 21-24]

p. 4 Sections north of Fort Worth. [Figs. 24-28]

p. 5 This section (section 4) represents the formation covering the tops of the high prairies for many miles around this region. [Fig. 29]

p. 7 *Tuesday Aug. 10.*

Fort Worth to Dallas Texas and return. Distance 30 miles.

The limestone prairies are succeeded a mile or two east of Fort Worth by the formation of the Lower Cross Timbers. . . .

p. 9 These begin 3 miles E. of Fort Worth and extend to Arlington 15 m. E. This is a cross section. They consist of a long belt of timber, extending from the Red River to Bremond. . . .

p. 10 Everywhere the surface soil is a dirty sand several inches thick. Beneath this is a *red* subsoil. . . . Beneath this is usually found 10 to 20 feet of "pack sand" which is in itself a pure white sand. . . . [Fig. 30]

p. 12 Thursday Aug. 13

Studied the formation underlying the prairies for many miles on every side of Fort Worth. Found it to consist universally of the decomposing yellow Washita limestone. . . .

I visited hundreds of outcrops and always found same formation and same fossils. The surface of the rocks gave everywhere indication of erosion. [Fig. 29]

p. 13 From these observations I conclude that the Grand Prairie between the Lower and Upper Cross Timbers is formed by the erosion of the upper layers of the Cretaceous down to the hard yellow rock of this group which forms the surface of the country at every point.

This is the Washita limestone of Shumard. I have found always the Blue marl underneath not above as Shumard makes it.

p. 14 Wednesday Aug. 12.

Contniued studies in neighborhood of Fort Worth. Took buggy and traveled East 3 miles to Cross Timbers.

p. 15 It cannot be too often said that these notes must be read *progressively*; the reader should be prepared to find modifications of opinions continually.

p. 16 *Friday Aug. 14.*

Took Fort Worth and Denver City Railway, running northwest from Fort Worth, for in order to find extent of Cretaceous formation that constituted the prairie of this region.

p. 17 The railway track seems to run upon one stratum of yellow Cretaceous limestone, ...

p. 18 The Upper Cross Timbers. These were met with just one mile N of Decatur. . . .

p. 19 At this point the stratigraphy of these Cross Timbers display the following section, which continued diagonally across them 30 miles distant NW to 3 miles beyond Bowie, and directly across them from Bowie to St. Joe, 20 miles E. [Figs. 31-34]

p. 20 This day's work settles a long debated question; viz: *What is the origin of the deep sandy surface soil of the Cross Timbers, and why does timber grow there? When it will not grow elsewhere in this region of Texas?*

Ans(1) Wherever the shallow superficial surface is eroded only a few feet, this pure sand is reached. This, mixed with the red subsoil, gives it its dirty color and the winds blow it everywhere, concealing exposures of mother strata.

p. 21 *What is the red clay subsoil?*

It may be the sediment of the "red rises" of some quaternary stream, and these long cross timbers may have represented their channels. (I disbelieve this theory now. R.T.H. 4,1,'87)

This point remains to be proven.

p. 24 *Monday Aug. 16.*

In the afternoon I continued section of strata due South (of Fort Worth). Hitherto, be it remembered, I had studied the strata on the North, West and East.

Today's work was a most valuable culmination to the whole. It was as follows:

A complete and continuous section was made from the top to the bottom of the exposures (of) Cretaceous strata of this region. It began at the lime kiln near the city of Fort Worth and extended South two miles as follows. [Figs. 35-38]

p. 29 August 18, 1886

Left Fort Worth for Dallas to endeavor to find relations of Cretaceous to the eastward with Tertiary.

p. 30 Mr. Cummings accompanied me upon a long tramp in afternoon. We studied the White rock formation.

This limestone is massive, chalky. Hardness 2. White and bluish in color and fully 300 feet thick on both sides of the Trinity valley at Dallas. [Fig. 39]

This formation is different in every respect from the "Texas" Cretaceous visible at Fort Worth and throws some light on things. At last a differentiation appears.

p. 31 Mr. Cummings says that this White rock formation does not extend west of the cross timbers between here and Fort Worth. My own extended observations show that his statement is true.

Is this above or below the Fort Worth group? that is the question.

I now have five or six distinct groups of the Cretaceous in an east west line across the State, the superposition of which is unknown. They are as follows: [Fig. 40]

It shall now be my aim to correlate these groups.*

*The results of Hill's efforts to correlate these "distinct groups" are contained in Hill (1887b).

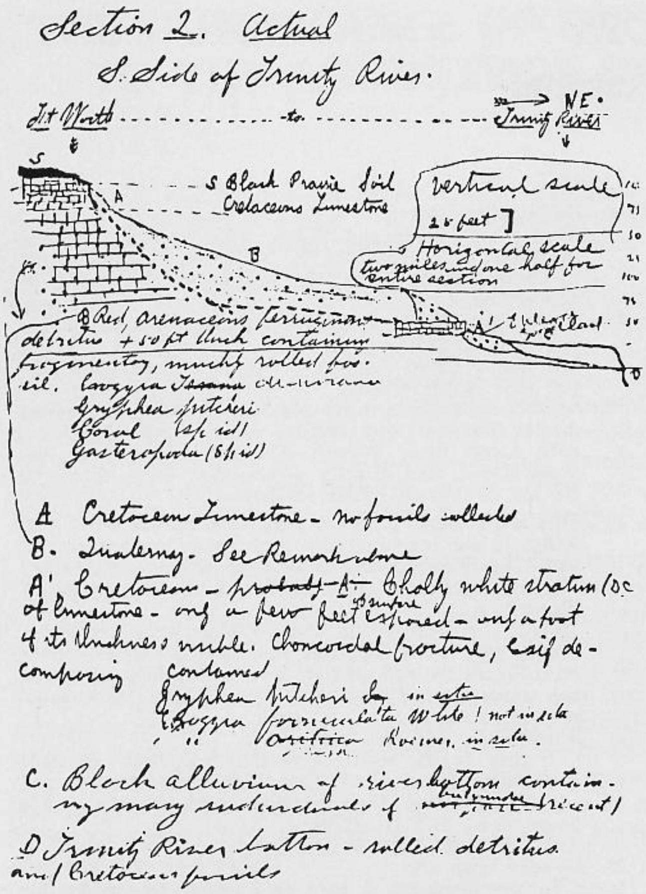
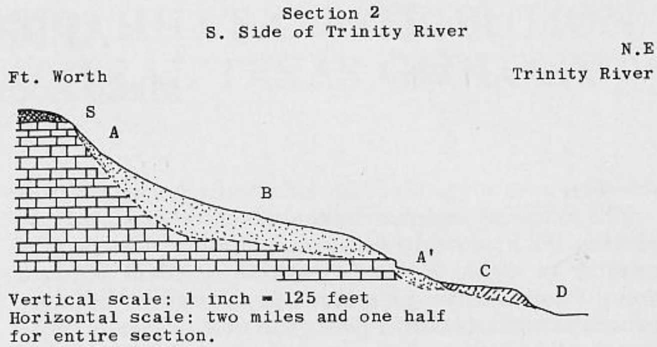


Fig. 21. Hill's cross section of the south side of the Trinity River. Hill, 1886a, p. 3.



S. Black Prairie Soil.

A. Cretaceous Limestone - no fossils collected.

B. Quaternary - Red, arenaceous ferruginous detritus +50 feet thick containing fragmentary, muchly rolled fossil.

A'. Cretaceous -A- Chalky white stratum of limestone - only a few feet of surface exposed - only a foot of its thickness visible, conchoidal fracture, easily decomposing. Contained...(lists fossils).

C. Black alluvium of river bottom containing many individuals of...(recent).

D. Trinity River bottom - rolled detritus and Cretaceous fossils.

Fig. 22. Adaptation of Hill's cross section of the south side of the Trinity River. Hill, 1886a, p. 3.

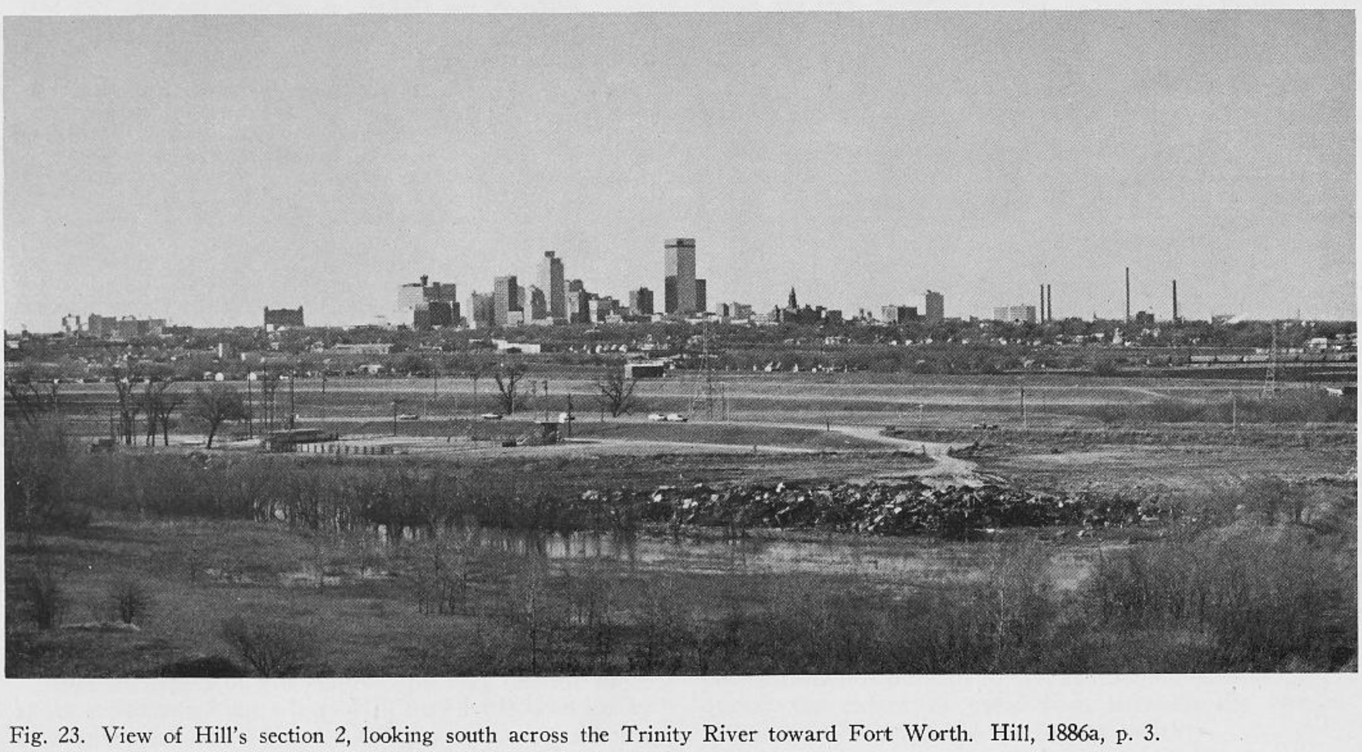


Fig. 23. View of Hill's section 2, looking south across the Trinity River toward Fort Worth. Hill, 1886a, p. 3.

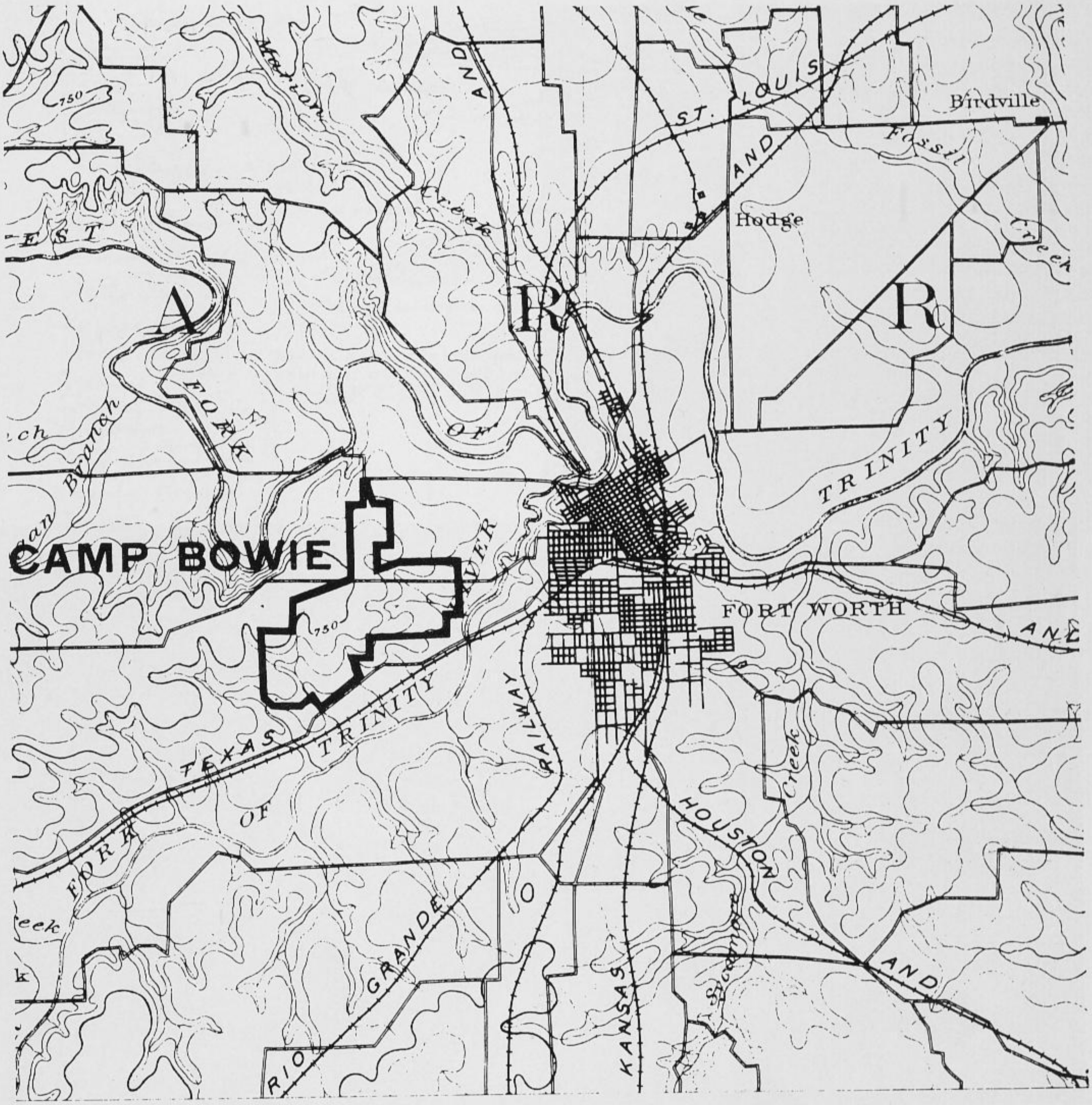


Fig. 24. Hill's sections 2, 3, 4, and 8 on the 1894 U.S. Geological Survey Reconnaissance map showing the Fort Worth region. Scale 1:125,000; Contour interval 50 feet.

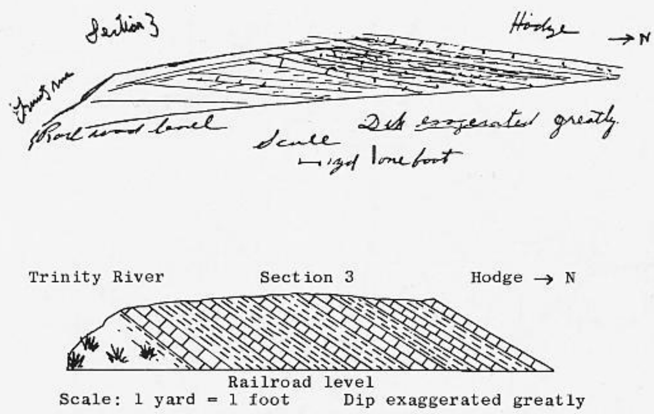


Fig. 25. Hill's drawing and an adaptation of a section exposed in a railroad cut on the Texas and Pacific Railway four miles north of the center of Fort Worth. Hill, 1886a, p. 4.

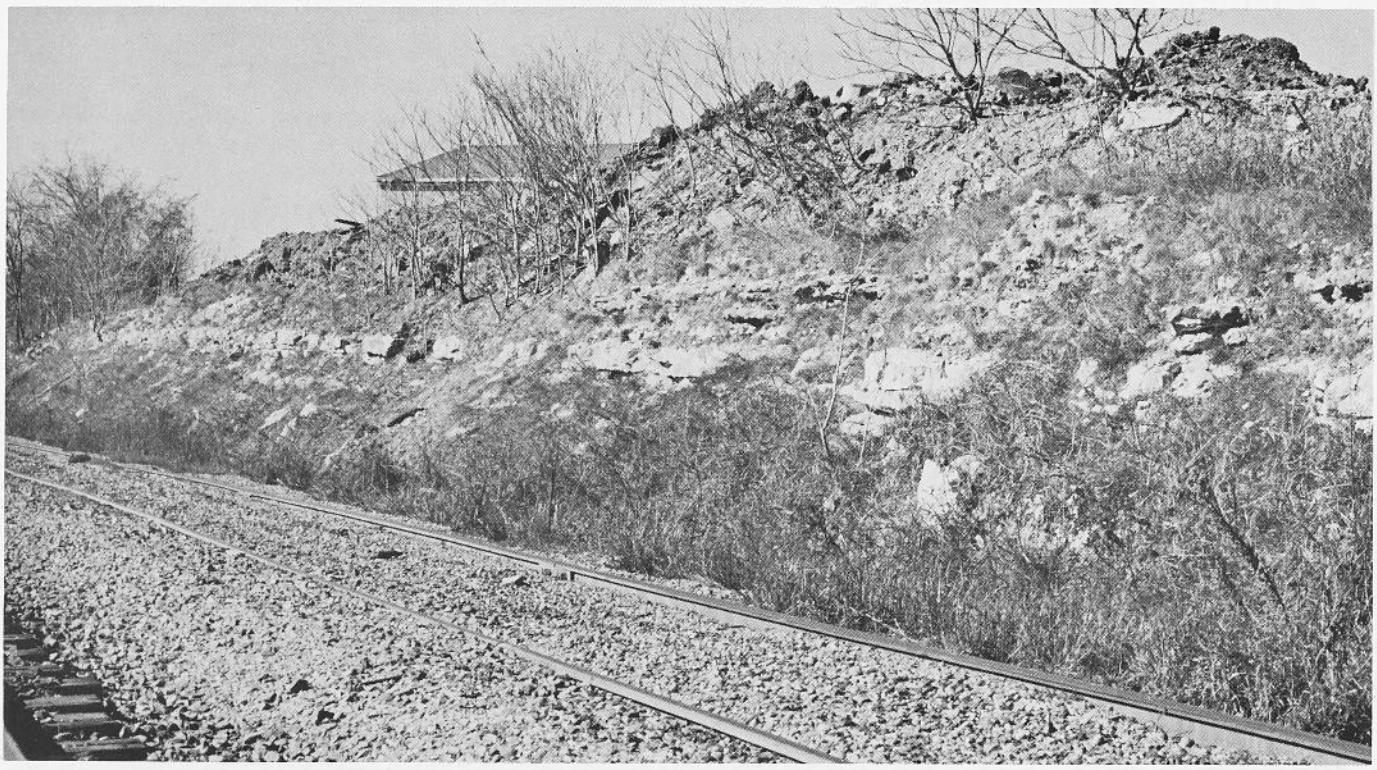
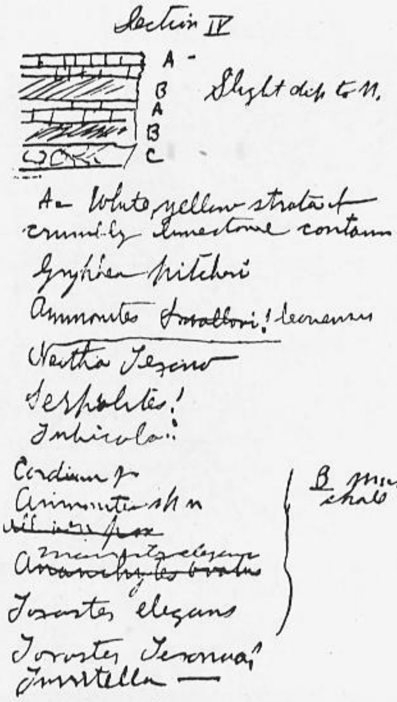
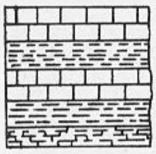


Fig. 26. View of Hill's section 3, looking south along the Texas and Pacific Railway about four miles north of downtown Fort Worth. Note the slight northward dip of the strata as exaggerated in Figure 25.



Section 4



A
B
A Slight dip to N.
B
C

A. White, yellow strata of crumbly limestone containing (lists fossils).

B. Muddy, intervening shale (lists fossils).

C. A softer bluish marl.

Fig. 27. Hill's drawing and an adaptation of the same section shown in Figure 25, delineating the strata exposed. Hill, 1886a, p. 4.

Fig. 28. View of Hill's section 4 showing the "white, yellow strata of crumbly limestone" and the "muddy, intervening shale." Hill, 1886a, p. 4.

Fig. 29. View of the "high prairies" west of Fort Worth. Hill made particular note of the "firm looking limestone" that disintegrates into fine pieces soon after exposure" (A of Hill's section 4) and is shown here in the foreground. Hill, 1886a, p. 5.

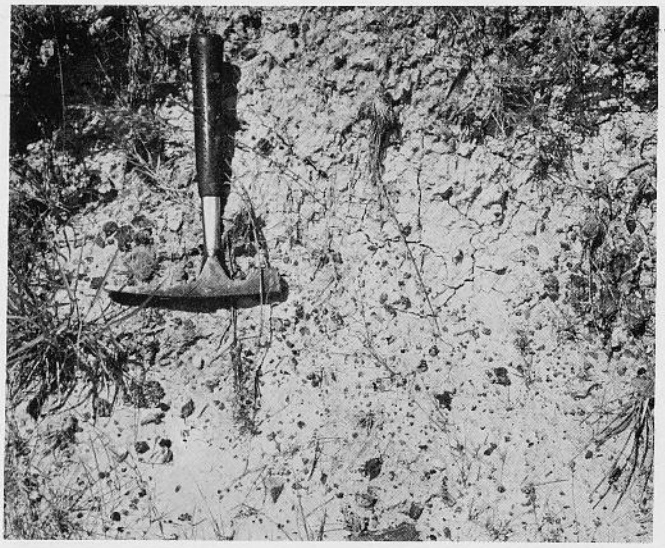


Fig. 30. Weathered "pack sand" containing ironstone concretions. Hill commonly found this "pure white sand" underlying the sandy red soil of the Cross Timbers. Hill, 1886a, p. 10.

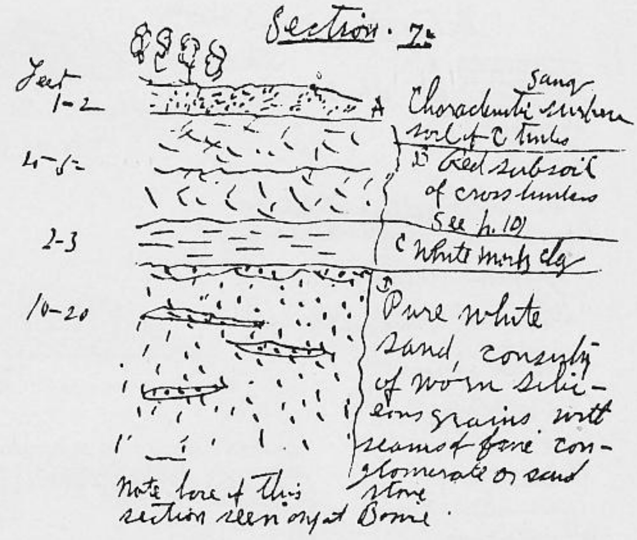


Fig. 31. Hill's generalized section of the Cross Timbers northwest of Fort Worth. Hill, 1886a, p. 19.

Section 7

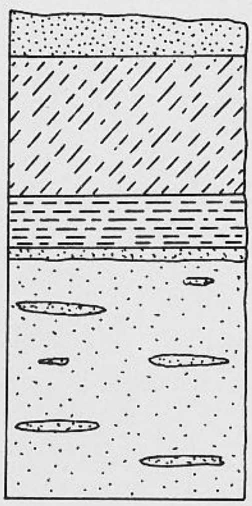
Feet

1-2 A

2-5 B

2-3 C

10-20 D



Note base of this section seen only at Bowie.

A. Characteristic sandy surface soil of cross timbers.

B. Red subsoil of cross timbers.

C. White marly clay.

D. Pure white sand, consisting of worn siliceous grains with seams of fine conglomerate or sandstone.

Fig. 32. Adaptation of Hill's generalized section of the Cross Timbers northwest of Fort Worth. Hill, 1886a, p. 19.

Fig. 33. View of Hill's section 7 approximately ten miles north of Decatur, Texas. The hammer is resting on a "seam of fine conglomerate" (D of section 7). In the distance are A and B of section 7. Hill, 1886a, p. 19.

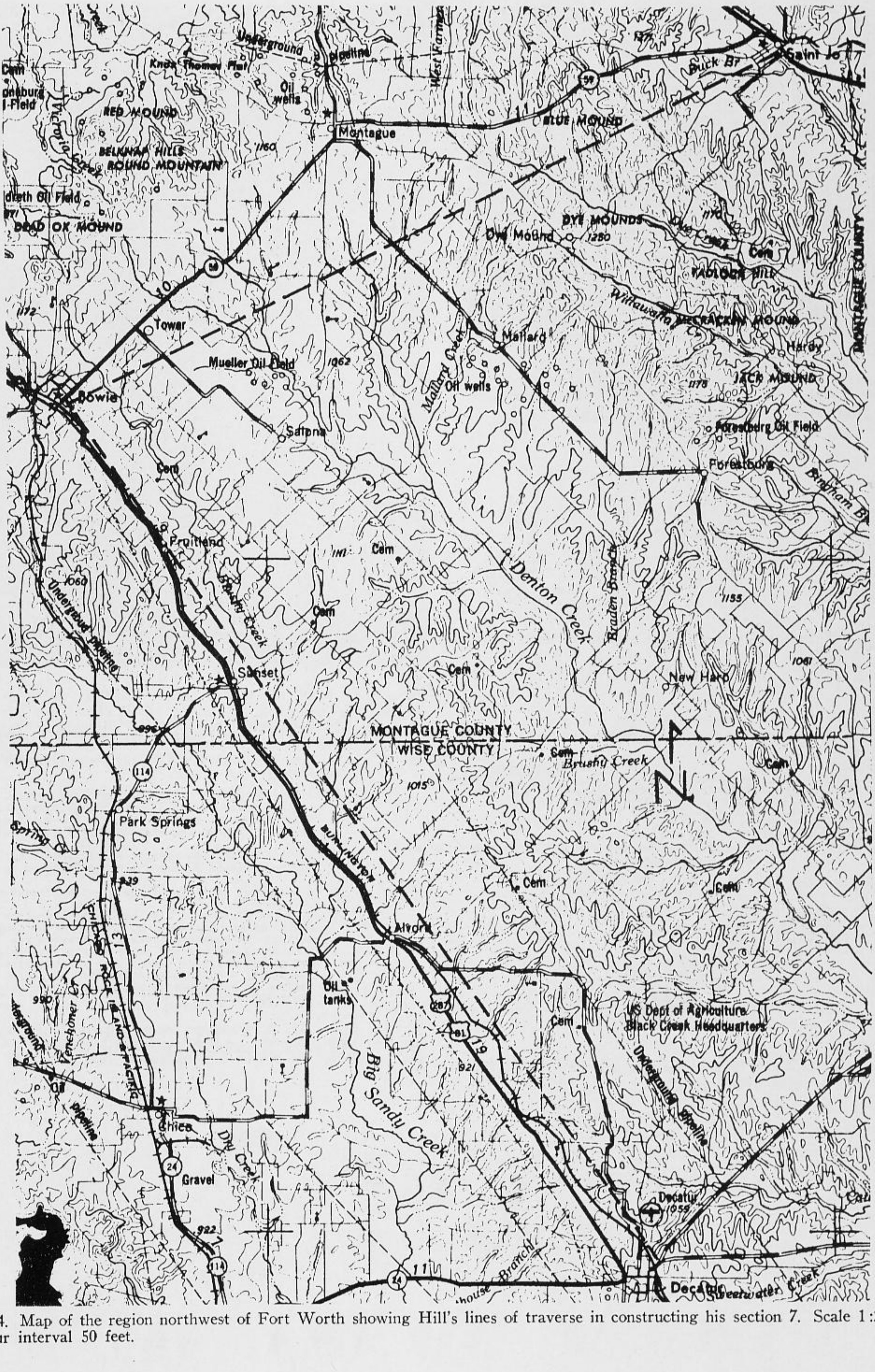


Fig. 34. Map of the region northwest of Fort Worth showing Hill's lines of traverse in constructing his section 7. Scale 1:250,000; Contour interval 50 feet.

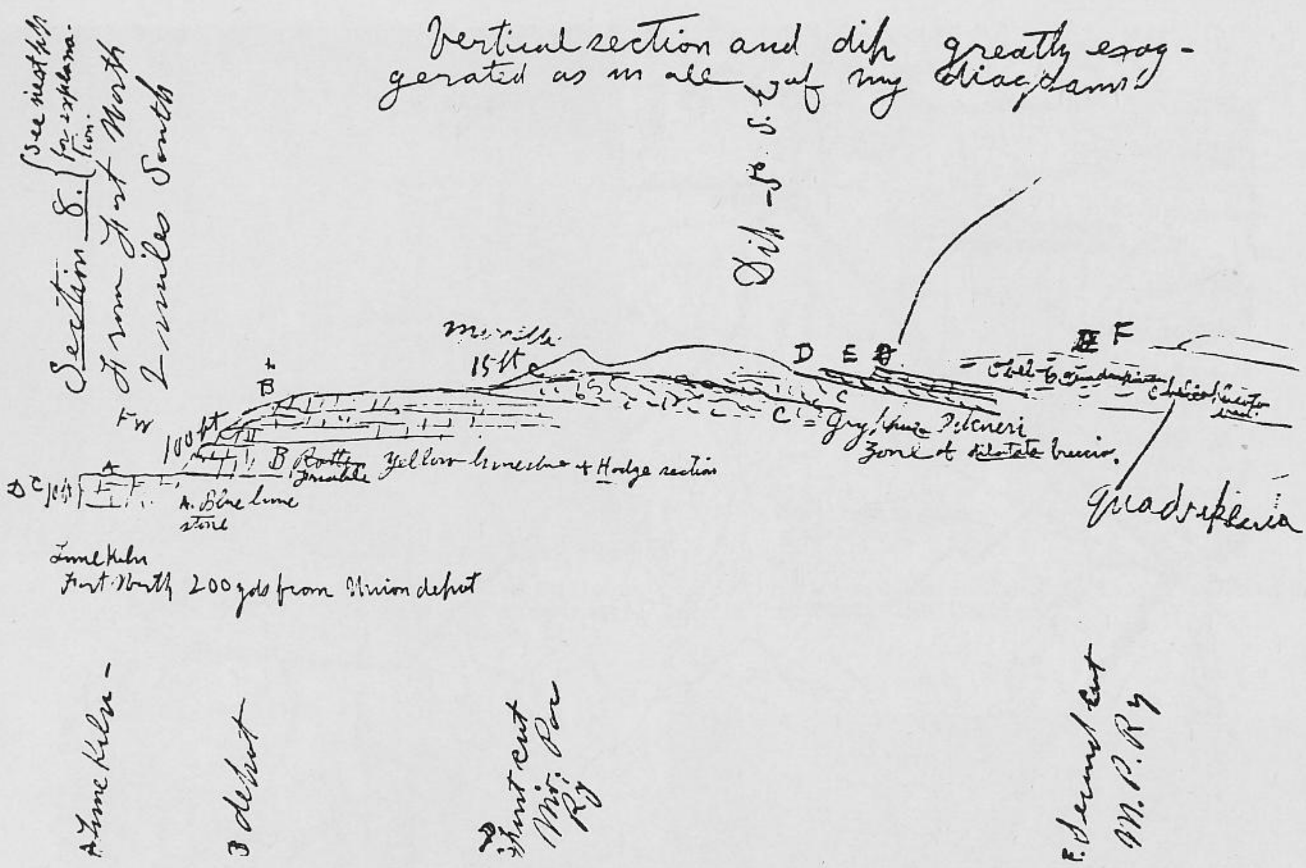


Fig. 35. Hill's drawing of a section extending "from Fort Worth to 2 miles south." Hill, 1886a, p. 25.

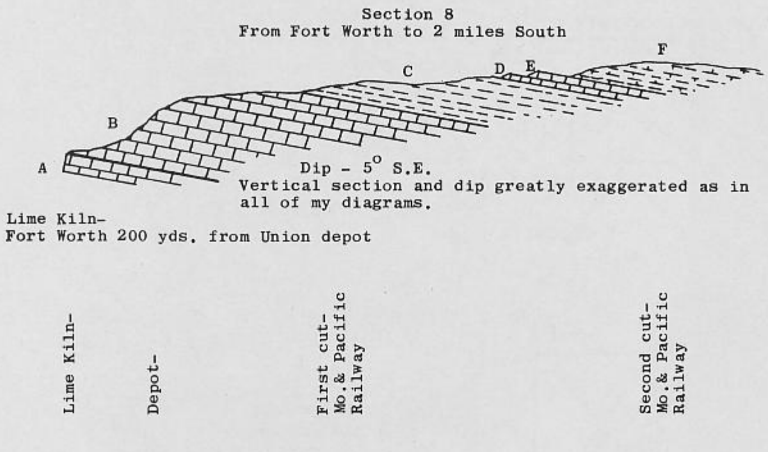


Fig. 36. Adaptation of Hill's section extending two miles south of Fort Worth. Hill, 1886a, p. 25.

A. C of Section 4...10 feet of blue limestone. Same relative position, fossils, and color of strata.

B. Same as A of Section 4...100 feet of friable yellow limestone.

C. A mass of shells of gryphea pitcheri Morton. Sometimes loosely packed; occasionally firmly cemented. This stratum is 15 feet thick in the cut 1 mile South of town on the Missouri Pacific Railway.

D. Above this gryphea breccia was 2 feet of pure unctuous clay. No fossils could be found in it.

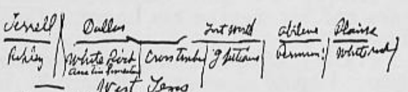
E. A stratum 1 ft. thick of hard yellow limestone.

F. A 10 ft. stratum of clay and small limestone fragments, either much worn by erosion or by chemical action. It seemed a transition between the "rotten" limestone and conglomerate in character, and had it not been capped by a stratum of solid limestone, I would have considered it recent drift. It contained at least one fossil not found below it.... .

Fig. 37. Explanation to accompany Hill's section 8 (Figures 35 and 36). Hill, 1886a, p. 26-28.

Fig. 38. View of Hill's section 8 near his "first cut" on the Missouri and Pacific Railway showing a portion of B and C, *Gryphea* breccia and "friable yellow limestone." This exposure is beneath a bridge over the railroad switching yards in downtown Fort Worth. Hill, 1886a, p. 25.

Fig. 39. View across the Trinity River from east of Dallas showing the bluffs where Hill's "White rock formation" was once visible. Hill, 1886a, p. 30.



West					East
Plains	Abilene	Fort Worth		Dallas	Terrell
White rock	Permian	g. pitcheri	Cross Timbers	White Rock Austin limestone	Ripley

Fig. 40. The "distinct groups of the Cretaceous in an east and west line" that Hill delineated and sought to correlate. Hill, 1886a, p. 31.

REFERENCES

Agassiz, Louis (1886) Geological sketches: Houghton, Mifflin and Co., New York, 311 p.
Alexander, Nancy S. (1973) Robert Thomas Hill (1858-1941) father of Texas geology: an account of his life and an appraisal of his contributions to the geological sciences: Unpub. Ph.D. dissertation, Southern Methodist Univ., Dallas, Texas.
Bishop, Morris (1962) A history of Cornell: Cornell Univ. Press, Ithaca, New York, 651 p.
Boll, Jacob (1879) Texas in its geognostic and agricultural aspect: Am. Naturalist, vol. 13, p. 375-384.
Bradley, W. H. (1963) Geologic laws *in* The fabric of geology (Claude C. Albritton, Jr., *ed.*): Freeman, Cooper and Co., Stanford, Calif., p. 12-23.
Branner, J. C. (1890) The relations of the state and national geological surveys to each other and to the geologists of the country: Am. Geologist, vol. 6, p. 298.
Bruce, Robert V. (1972) A statistical profile of American scientists, 1846-1876 *in* Nineteenth-century American science: a reappraisal (George H. Daniels, *ed.*): Northwestern Univ. Press, Evanston, Ill., p. 63-94.
Chamberlain, Thomas Crowder (1897) The method of multiple working hypotheses: Jour. Geology, vol. 5, p. 837-848.
Cope, Edward D. (1880) On the zoological position of Texas: U. S. Museum of Natural History Bull. 17.
Curti, Merle (1964) The growth of American thought: Harper and Row, New York, 848 p.
Darrah, William Culp (1951) Powell of the Colorado: Princeton Univ. Press, Princeton, N.J., 426 p.
Dumble, Edwin Theodore (1889) First report of progress of the Geological and Mineralogical Survey of Texas: State Printing Office, Austin, Texas.
Dupree, A. Hunter (1957) Science in the federal government: Harvard Univ. Press, Cambridge, Mass., 460 p.
Fairbanks, Helen R. and Berkey, Charles P. (1952) Life and letters of R. A. F. Penrose, Jr.: Geol. Soc. America, New York, 765 p.
Ferguson, Walter Keene (1969) Geology and politics in frontier Texas; 1845-1909: Univ. of Texas Press, Austin, 233 p.
Galveston Daily News, March 26, 1887, p. 5.
Goetzman, William H. (1966) Exploration and empire: the explorer and scientist in the winning of the American west: Alfred A. Knopf, New York, 656 p.
Hartzell, J. C. (1896) The history and principles of geology and its aim: Am. Naturalist, vol. 30, p. 177-183 and 271-279.
Herbst, Juergen (1965) The German historical school in American scholarship: Cornell Univ. Press, Ithaca, New York.
Hewett, Waterman T. (1905) Cornell University: a history (4 vols.): The University Publishing Society, New York.
Hill, Robert Thomas (undated a) Great men whom I met and knew: Unpub. lecture notes, Robert T. Hill Papers, Univ. of Texas Archives, Austin.
__________ (undated b) Appendix: Hill enrages Cummings: Unpub. memoirs, Robert T. Hill Papers, Univ. of Texas Archives, Austin.
__________ (undated c) Autobiographical sketch: Unpub. manuscript, Robert T. Hill Papers, Univ. of Texas Archives, Austin.
__________ (undated d) Washington again: 1891-1903: Unpub. autobiographical notes, Robert T. Hill Papers, Univ. of Texas Archives, Austin.
__________ (1886a) Notes on the Cretaceous strata of Texas; Unpub. field book, Shuler Collection of Hill Materials, Southern Methodist Univ., Dallas, Texas, 91 p.
__________ (1886b) Notes on the Cretaceous strata of Texas; note book no. 2: Field Records File, Index No. RTH—2, U. S. Geol. Survey, Geological Division, Denver, Colo., 94 p.
__________ (1887a) The present condition of knowledge of the geology of Texas: U. S. Geol. Survey Bull., vol. 45, 95 p.
__________ (1887b) The topography and geology of the Cross Timbers and surrounding regions of northern Texas: Am. Jour. Sci., vol. 133, p. 291-303.
__________ (1887c) The Texas section of the American Cretaceous: Am. Jour. Sci., vol. 134, p. 287-309.
__________ (1887d) Artesian wells, from whence they come: their waters and where found: *Fort Worth Gazette,* July 27, 1887.
__________ (1889a) A portion of the geologic story of the Colorado River of Texas: Am. Geologist, vol. 3, no. 5, p. 287-299.
__________ (1889b) A preliminary annotated check list of the Cretaceous invertebrate fossils of Texas, accompanied by a short description of the lithology and stratigraphy of the system: Texas Geol. Survey Bull. no. 4, 57 p.
__________ (1889c) Checklist of the invertebrate fossils from the Cretaceous formation of Texas, accompanied by notes on their geographic and geologic distribution: Univ. of Texas, School of Geology, Austin, vol. 16, 20 p.
__________ (1889d) Events in North American Cretaceous history illustrated in the Arkansas-Texas division of the southwestern region of the United States: Am. Jour. Sci., vol. 137, p. 282-290.
__________ (1890a) A brief description of the Cretaceous rocks of Texas and their economic value: Texas Geol. Survey, Ann. Rept. no. 1, p. 103-141.
__________ (1890b) Classification and origin of the chief geographic features of the Texas region: Am. Geologist, vol. 5, p. 9-29 and 68-80.
__________ (1891) The Comanche series of the Texas-Arkansas region (with discussion by C. A. White and others): Geol. Soc. America Bull. vol. 2, p. 503-528.
__________ (1894) Geology of parts of Texas, Indian Territory and Arkansas adjacent to the Red River region: Geol. Soc. America Bull., vol. 5, p. 297-338.
__________ and Vaughan, T. W. (1898) Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Texas, with reference to the occurrence of underground waters: U. S. Geol. Survey 18th Ann. Rept., pt. 2, p. 193-321.
__________ (1900) Physical geography of the Texas region: U. S. Geol. Survey, Topographic Atlas, folio 3, 12 p.
__________ (1901) Geography and geology of the Black and Grand Prairies, Texas, with detailed descriptions of the Cretaceous formations and special reference to artesian waters: U. S. Geol. Survey 21st Ann. Rpt., 666 p.
__________ and Vaughan, T. W. (1902) Description of the Austin quadrangle, Texas: U. S. Geol. Survey, Geologic Atlas, folio no. 76, 8 p.
__________ (1931a) Dr. Hill recalls memories of pleasant experiences and big men he has known: *Dallas Morning News,* June 9, 1931.
__________ (1931b) Some geological recollections of a young man: Unpub. manuscript, Robert T. Hill Papers, Univ. of Texas Archives, Austin.
__________ (1931c) An annotated bibliography of the writings of Robert T. Hill: 1856-1930: Unpub. manuscript, Robert T. Hill Papers, Univ. of Texas Archives, Austin, 57 p.
__________ (1937) Further recollections of a young man: *Dallas Morning News*, Jan. 24, 1937.
Hofstadter, Richard (1963) Anti-Intellectualism in American life: Alfred A. Knopf, New York, 434 p.
Kitts, David B. (1973) Grove Carl Gilbert and the concept of "hypothesis" in late nineteenth century geology *in* Foundations of scientific method: the nineteenth century (Ronald N. Giere and Richard S. Westfall, *eds.*): Indiana Univ. Press, Bloomington, p. 259-274.
Leighton, Morris M. (1951) Natural resources and geological surveys: Jour. Econ. Geol., vol. 66, p. 563-577.
Manning, Thomas G. (1967) Government in science: the United States Geological Survey, 1867-1894: Univ. of Kentucky Press, Lexington, 257 p.
Marcou, Jules (1854) Notes of a survey of the country comprised between Preston, Red River and El Paso, Rio Grande del Norte *in* Report of exploration of a route for the Pacific railroad near the thirty-second parallel of latitude from the Red River to the Rio Grande (by Bvt. Capt. John Pope): House Doc. 129, chap. 13, p. 25.

———— (1855) Resumé and field notes *in* Reports of explorations and surveys to ascertain the most practical and economic route for a railroad from the Mississippi River to the Pacific Ocean: 32nd Cong., 2nd sess., Sen. Exec. Doc. 78, vol. 2, pt. 4, p. 127.

———— (1862) Notes on the Cretaceous and Carboniferous rocks of Texas: Proc. Boston Soc. Nat. Hist., vol. 8, p. 86-97.

Marcy, Randolph B. (1854) Exploration of the Red River of Louisiana, in the year 1852, by Randolph B. Marcy, Captain Fifth Infantry, U. S. Army, assisted by George B. McClellan, brevet Captain U. S. Engineers; with reports on the natural history of the country and numerous illustrations: Govt. Printing Office, Washington, D.C., p. 158.

Mather, Kirtley F. (1959) Geology, geologists, and the AAAS: Science, vol. 129, p. 1106-1111.

Miller, Howard S. (1964) A bounty for research: the philanthropic support of scientific investigation in America, 1838-1902: Unpub. Ph.D. dissertation, Univ. of Wisconsin.

Moore, Raymond C. (1941) Stratigraphy *in* Geology, 1888-1938: Geol. Soc. America, Fiftieth Anniversary Volume, p. 179-220.

Powell, John Wesley (1889) Eighth annual report of the director of the United States Geological Survey, part 1: Govt. Printing Office, Washington, D.C., 474 p.

Roemer, Ferdinand (1846) A sketch of the geology of Texas: Am. Jour. Sci., vol. 2, p. 358-365.

———— (1848) Contributions to the geology of Texas: Am. Jour. Sci., vol. 6, p. 21-28.

———— (1849) Roemer's Texas: mit besonderer Rücksicht auf deutsche Auswanderung, und die physichen Verhältnisse des Landes nach eigener Beobachtung geschildert von Dr. Ferdinand Roemer mit einem naturwissen schaftlichen Anhange und einer topographisch: Adolph Marcus, Bonn, p. 379.

———— (1852) The Cretaceous formations of Texas and their organic inclusions [in German]: Unpub. translation by Anita Reeves, Baylor Univ., Waco, Texas, 100 p.

Sellards, E. H. and Baker, C. L. (1934) The geology of Texas, volume II: structural and economic geology: Univ. of Texas Bull., no. 3401, Austin, 884 p.

Shumard, Benjamin F. (1859) Observations upon the Cretaceous strata of Texas: Trans. Acad. Sci. St. Louis, no. 1, p. 585.

———— (1861) Descriptions of new Cretaceous fossils from Texas: Proc. Boston Soc. Nat. Hist., no. 8, p. 188-205.

Stanley-Brown, Joseph (1932) Memorial of Richard Alexander Fullerton Penrose, Jr.: Geol. Soc. America Bull., vol. 43, p. 68-108.

Stanton, Timothy William (1897) A comparative study of the Lower Cretaceous formations and faunas of the United States: Jour. Geology, vol. 5, p. 579-624.

Sterling, E. W. (1940) The Powell Irrigation Survey, 1888-1893: Miss. Valley Hist. Review, vol. 27, p. 422.

Vaughan, Thomas Wayland (1944) Memorial to Robert Thomas Hill: Geol. Soc. America Proc., 1943, p. 141-168.

White, Charles A. (1887) On the Cretaceous formations of Texas and their relation to those of other portions of North America: Proc. Acad. Nat. Sci. of Philadelphia, p. 39-47.

Williams, Henry Shaler (1893) Geology as a part of a college curriculum: Jour. Geology, vol. 1, p. 37-46.

Wrather, William Emory (1941) Memorial, Robert Thomas Hill: 1858-1941: Am. Assoc. Petrol. Geol. Bull., vol. 25, p. 2221-2228.

Young, Keith (1965) The Roessler maps: Texas Jour. Sci., vol. 27, p. 28-45.

INDEX

BAYLOR GEOLOGICAL PUBLICATIONS*

Baylor Geological Studies

1. Holloway, Harold D. (1961) The Lower Cretaceous Trinity aquifers, McLennan County, Texas: Baylor Geological Studies Bull. No. 1 (Fall). Out of print.
2. Atlee, William A. (1962) The Lower Cretaceous Paluxy Sand in central Texas: Baylor Geological Studies Bull. No. 2 (Spring). Out of print.
3. Henningsen, E. Robert (1962) Water diagenesis in Lower Cretaceous Trinity aquifers of central Texas: Baylor Geological Studies Bull. No. 3 (Fall). Out of print.
4. Silver, Burr A. (1963) The Bluebonnet Member, Lake Waco Formation (Upper Cretaceous), central Texas—A lagoonal deposit: Baylor Geological Studies Bull. No. 4 (Spring). $1.00 per copy.
5. Brown, Johnnie B. (1963) The role of geology in a unified conservation program, Flat Top Ranch, Bosque County, Texas: Baylor Geological Studies Bull. No. 5 (Fall). Out of print.
6. Beall, Arthur O., Jr. (1964) Stratigraphy of the Taylor Formation (Upper Cretaceous), east-central Texas: Baylor Geological Studies Bull. No. 6 (Spring). $1.00 per copy.
7. Spencer, Jean M. (1964) Geologic factors controlling mutation and evolution—A review: Baylor Geological Studies Bull. No. 7 (Fall). Out of print.

Urban geology of Greater Waco. A series on urban geology in cooperation with Cooper Foundation of Waco.

8. Part I: Geology (1965) Geology and urban development by Peter T. Flawn; Geology of Waco by J. M. Burket: Baylor Geological Studies Bull. No. 8 (Spring). $1.00 per copy.
9. Part II: Soils (1965) Soils and urban development of Waco by W. R. Elder: Baylor Geological Studies Bull. No. 9 (Fall). $1.00 per copy.
10. Part III: Water (1966) Surface waters of Waco by Jean M. Spencer: Baylor Geological Studies Bull. No. 10 (Spring). $1.00 per copy.
11. Part III: Water (1976) Subsurface waters of Waco by Siegfried Rupp: Baylor Geological Studies Bull. No. 11 (Fall). $1.00 per copy.
12. Part IV: Engineering (1967) Geologic factors affecting construction in Waco by R. G. Font and E. F. Williamson: Baylor Geological Studies Bull. No. 12 (Spring). $1.00 per copy.
13. Part V: Socio-Economic Geology (1967) Economic geology of Waco and vicinity by W. T. Huang; Geology and community socio-economics—A symposium coordinated by R. L. Bronaugh: Baylor Geological Studies Bull. No. 13 (Fall). $1.00 per copy.
14. Part VI: Conclusions (1968) Urban geology of greater Waco—Summary and recommendations by Editorial Staff: Baylor Geological Studies Bull. No. 14 (Spring). $1.00 per copy.

15. Boone, Peter A. (1968) Stratigraphy of the basal Trinity (Lower Cretaceous) sands, central Texas: Baylor Geological Studies Bull. No. 15 (Fall). $1.00 per copy.
16. Proctor, Cleo V. (1969) The North Bosque watershed, Inventory of a drainage basin: Baylor Geological Studies Bull. No. 16 (Spring). Out of print.
17. LeWand, Raymond L., Jr. (1969) The geomorphic evolution of the Leon River system: Baylor Geological Studies Bull. No. 17 (Fall). Out of print.
18. Moore, Thomas H. (1970) Water geochemistry, Hog Creek basin, central Texas: Baylor Geological Studies Bull. No. 18 (Spring). $1.00 per copy.
19. Mosteller, Moice A. (1970) Subsurface stratigraphy of the Comanchean Series in east central Texas: Baylor Geological Studies Bull. No. 19 (Fall). $1.00 per copy.
20. Byrd, Clifford Leon (1971) Origin and history of the Uvalde Gravel of central Texas: Baylor Geological Studies Bull. No. 20 (Spring). Out of print.
21. Brown, Thomas E. (1971) Stratigraphy of the Washita Group in central Texas: Baylor Geological Studies Bull. No. 21 (Fall). $1.00 per copy.
22. Thomas, Ronny G. (1972) The geomorphic evolution of the Pecos River system: Baylor Geological Studies Bull. No. 22. (Spring). Out of print.
23. Roberson, Dana Shumard (1972) The paleoecology, distribution and significance of circular bioherms in the Edwards Limestone of central Texas: Baylor Geological Studies Bull. No. 23 (Fall). Out of print.
24. Epps, Lawrence Ward (1973) The geologic history of the Brazos River: Baylor Geological Studies Bull. No. 24 (Spring). Out of print.
25. Bain, James S. (1973) The nature of the Cretaceous-pre Cretaceous contact in north-central Texas: Baylor Geological Studies Bull. No. 25 (Fall). $1.00 per copy.
26. Davis, Keith W. (1974) Stratigraphy and depositional environments of the Glen Rose Formation, north-central Texas: Baylor Geological Studies Bull. No. 26 (Spring). $1.00 per copy.
27. Baldwin, Ellwood E. (1974) Urban geology of the Interstate Highway 35 growth corridor between Belton and Hillsboro, Texas: Baylor Geological Studies Bull. 27 (Fall). $1.00 per copy.
28. Allen, Peter M. (1975) Urban geology of the Interstate Highway 35 growth corridor from Hillsboro to Dallas County, Texas: Baylor Geological Studies Bull. No. 28 (Spring). $1.00 per copy.
29. Belcher, Robert C. (1975) The geomorphic evolution of the Rio Grande: Baylor Geological Studies Bull. No. 29 (Fall). $1.00 per copy.
30. Flatt, Carl Dean (1976) Origin and significance of the oyster banks in the Walnut Clay Formation, central Texas: Baylor Geologocial Studies Bull. No. 30 (Spring). $1.00 per copy.
31. Dolliver, Paul Noble (1976) The significance of Robert Thomas Hill's contribution to the knowledge of central Texas Geology: Baylor Geological Studies Bull. No. 31 (Fall). $1.00 per copy.

Baylor Geological Society

101. Type electric log of McLennan County. 1"-100'; 1"-50'-$2.00.
102. Reptile charts—Comparison of flying and swimming reptiles. $0.10 each. Comparison of the dinosaurs. $0.10 each.

103-114, 116, 118-126, 130-132, 136. Out of print. For titles see earlier Baylor Geological Studies Bulletins.

115. Why teach geology? A discussion of the importance and cost of teaching geology in high schools, junior colleges and smaller 4-year institutions. Free upon request. 27 pp. (1961).
117. Shale environments of the mid-Cretaceous section, central Texas—A field guide. Leaders—Beall, A. O.; Johnson, C. F.; and Silver, B.A.; 1964. $2.00 per copy.
127. Thee Guidebook. Geology of the Trinity Group in the type area. A professional level guide, 1970. $4.00 per copy.
129. Urban Geology, 1972. $6.00 per copy.
133. Whitney Reservoir. Geology of the Whitney Reservoir Area, 1974. $1.50 per copy.
134. The Black and Grand Prairies. A physiographic study of two central Texas Prairies, 1974. $1.50 per copy.
137. Structural geology of central Texas. A professional level guidebook. $6.00 per copy.
138. Tertiary-Cretaceous border. Structural geology southeast of Waco. $1.50 per copy.

*Publications available from Baylor Geological Studies or Baylor Geological Society, Baylor University, Waco, Texas 76703.

Texas residents add five cents per dollar for state tax.

BAYLOR UNIVERSITY

GEOLOGY